Developing Apama Applications

Version 9.10

August 2016

APAMA

This document applies to Apama Version 9.10 and to all subsequent releases.

Specifications contained herein are subject to change and these changes will be reported in subsequent release notes or new editions.

Document ID: PAM-DEV-910-20160810

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About this Guide

Apama provides different technologies for developing applications: EPL, Event Modeler, and Java. You can use one or several of these technologies to develop an Apama application. In addition, there are C++, C, and Java APIs for developing components that plug-in to a correlator. You can use these components from EPL.

Documentation roadmap

Apama provides documentation in the following formats:

- HTML (viewable in a web browser)
- PDF (available from the documentation website)
- Eclipse help (accessible from the Software AG Designer)

You can access the HTML documentation on your machine after Apama has been installed:

- **Windows.** Select **Start > All Programs > Software AG > Tools > Apama *n.n* > Apama Documentation *n.n***. Note that **Software AG** is the default group name that can be changed during the installation.
- **UNIX.** Display the `index.html` file, which is in the `doc` directory of your Apama installation directory.

The following table describes the different guides that are available.

Title	Description
Release Notes	Describes new features and changes since the previous release.
Installing Apama	Instructions for installing Apama.
Introduction to Apama	Introduction to developing Apama applications, discussions of Apama architecture and concepts, and pointers to sources of information outside the documentation set.
Using Apama with Software AG Designer	Instructions for using Apama to create and test Apama projects, develop EPL programs, define Apama queries, develop JMon programs, and store, retrieve and play back data.

Title	Description
Developing Apama Applications	Describes the different technologies for developing applications: EPL monitors, Apama queries, Event Modeler, and Java. You can use one or several of these technologies to implement a single Apama application. In addition, there are C++, C, and Java APIs for developing components that plug in to a correlator. You can use these components from EPL.
Connecting Apama Applications to External Components	Describes how to connect Apama applications to any event data source, database, messaging infrastructure, or application. The general alternatives for doing this are as follows: ■ Implement standard Apama Integration Adapter Framework (IAF) adapters. ■ Create applications that use correlator-integrated messaging for JMS or Software AG's Universal Messaging. ■ Use connectivity plug-ins written in Java or C++. ■ Develop adapters with Apama APIs for Java and C ++. ■ Develop client applications with Apama APIs for Java, .NET, and C++.
Building and Using Dashboards	Describes how to build and use an Apama dashboard, which provides the ability to view and interact with scenarios and DataViews. An Apama project typically uses one or more dashboards, which are created in the Dashboard Builder. The Dashboard Viewer provides the ability to use dashboards created in Dashboard Builder. Dashboards can also be deployed as simple Web pages, applets, or WebStart applications. Deployed dashboards connect to one or more correlators by means of a Dashboard Data Server or Display Server.
Deploying and Managing Apama Applications	Describes how to deploy components with Command Central or with Apama's Enterprise Management and Monitoring (EMM) console. Also provides information for:

Title	Description
	■ Improving Apama application performance by using multiple correlators and saving and reusing a snapshot of a correlator's state. ■ Managing and monitoring over REST (Representational State Transfer). ■ Using correlator utilities.

In addition to the above guides, Apama also provides the following API reference information:

- API Reference for EPL in ApamaDoc format
- API Reference for Java in Javadoc format
- API Reference for C++ in Doxygen format
- API Reference for .NET in HTML format

Online Information

Software AG Documentation Website

You can find documentation on the Software AG Documentation website at http://documentation.softwareag.com. The site requires Empower credentials. If you do not have Empower credentials, you must use the TECHcommunity website.

Software AG Empower Product Support Website

You can find product information on the Software AG Empower Product Support website at https://empower.softwareag.com.

To submit feature/enhancement requests, get information about product availability, and download products, go to Products.

To get information about fixes and to read early warnings, technical papers, and knowledge base articles, go to the Knowledge Center.

Software AG TECHcommunity

You can find documentation and other technical information on the Software AG TECHcommunity website at http://techcommunity.softwareag.com. You can:

- Access product documentation, if you have TECHcommunity credentials. If you do not, you will need to register and specify "Documentation" as an area of interest.
- Access articles, code samples, demos, and tutorials.

- Use the online discussion forums, moderated by Software AG professionals, to ask questions, discuss best practices, and learn how other customers are using Software AG technology.
- Link to external websites that discuss open standards and web technology.

Contacting customer support

If you have an account, you may open Apama Support Incidents online via the eService section of Empower at https://empower.softwareag.com/. If you do not yet have an account, send an email to empower@softwareag.com with your name, company, and company email address and request an account.

If you have any questions, you can find a local or toll-free number for your country in our Global Support Contact Directory at https://empower.softwareag.com/public_directory.asp and give us a call.

I Developing Apama Applications in EPL

The event correlator is Apama's core event processing and correlation engine. The interface to the correlator lets you inject events that the correlator analyzes. You can configure the correlator to watch for particular events or patterns of interest. In addition, you specify the actions to undertake when the correlator identifies such patterns. Identification of events of interest plus what to do when such events are found constitute an Apama application's logic.

To deploy an application on the correlator, you can use either the correlator's native Apama Event Processing Language (EPL) or the Apama in-process API for Java (JMon). Alternatively, you can define application logic in the Event Modeler, which provides a graphic user interface. The information presented here focuses exclusively on EPL.

Developing Apama Applications in EPL teaches you how to write EPL programs. While some programming experience is assumed, no prior knowledge of EPL is assumed.

Software AG Designer provides tutorials that can help you get started with EPL. On the Welcome page of Software AG Designer, click **Tutorials** under the **Apama** heading.

Note: MonitorScript is the old name for EPL. You might still see the old name in the product documentation.

1 Getting Started with Apama EPL

Apama Event Processing Language (EPL) is an event-driven programming language. It lets you write applications that:

- Monitor streams of events to find particular events or patterns of events of interest
- Analyze events (or patterns of events) of interest to determine whether some action is appropriate
- Perform actions based on particular events or patterns of events

This section discusses the main concepts you must understand to write applications in EPL.

Introduction to Apama Event Processing Language

EPL is a flexible and powerful ”curly-brace”, domain-specific language designed for writing programs that process events. In EPL, an event is a data object that contains a notification of something that has happened, such as a customer order was shipped, a shipment was delivered, a sensor state change occurred, a stock trade took place, or myriad other things. Each kind of event has a type name and one or more data elements (called fields) associated with it. External events are received by one or more adapters, which receive events from the event source and translate them from a source-specific format into Apama's internal canonical format. Derived events can be created as needed by EPL programs.

Though it contains many of the familiar constructs and features found in general-purpose programming languages like Python or Java, EPL also has special features to make it easy to aggregate, filter, correlate, transform, act on, and create events in a concise manner. Here is the canonical `"hello world"` example written in EPL:

```
monitor HelloWorld
{
   action onload()
   {
      print "Hello world!";
   }
}
```

The Apama event processor, called the correlator, receives events of various types from external sources. The EPL programs that process these events are monitors or queries.

Monitors have registered event handlers, called listeners, for events of particular types with specific combinations of data values or ranges of values. When a listener detects an event of interest, it triggers a particular action. If there are no listeners for an event, the correlator either discards it or passes it to a listener specifically for events that have no handler. A monitor instance processes events on one correlator and can send events to communicate with other monitors on the same correlator or remote correlators.

Queries are scalable across multiple correlators. An Apama query operates on only the input event types you specify and you can filter which instances of those events should be processed. Apama partitions these incoming events according to a key field that you specify, for example, there might be a partition for each credit card number. The query processes the events in each partition independently of the events in every other partition. As events are added to partitions, the query checks for a set of events that matches the event pattern you specified, which can optionally specify complex conditions for there to be a match. When a match is found the query executes procedural code that you have defined, which can include sending events.

Event handlers in EPL are conceptually similar to methods or functions used for handling user-interface events in other languages, such as Java Swing or SWT applications. In EPL, the correlator executes code only in response to events.

The correlator is capable of looking for hundreds of thousands of different events or different event patterns concurrently. When you write an EPL application, you write a set of monitors and/or one or more queries and then you inject or load them into a running correlator. As streams of events pass into a correlator, the monitors and their listeners and/or the queries watch for the events or patterns of events that you have specified as being of interest. There are a variety of actions that you can specify that you want the correlator to perform when a listener or query detects an event or event pattern of interest. For example, the most common action for a monitor is to generate and dispatch a message to an external receiver.

EPL is case-sensitive.

How EPL applications compare to applications in other languages

EPL is an event-oriented programming language, as opposed to an object-oriented language. Because EPL is part of an event-processing framework, it requires a different approach to decomposing the problem you want to solve.

EPL syntax is similar to other scripting languages. EPL has variables, data structures, conditions, and procedures (called actions in EPL). But EPL supports a paradigm that is different from that supported by other scripting languages:

- A monitor or a query is the basic module in EPL programs.
- All communication is by means of message passing.
- All processing is triggered in response to events.
- Monitors spawn instances of themselves to generate multiple units of execution and/or to initiate parallel processing. A query uses a key to partition incoming events and can share the same data across multiple correlators.

EPL requires a different way of developing applications.

About dynamic compilation in the correlator

EPL is dynamically compiled. You inject (load) EPL source files into a running correlator. The correlator compiles the files into optimized byte-code representations.

The EPL compiler is strict. There is no implicit type conversion. You cannot discard return values. To minimize the chance of runtime errors, your code must be explicit and not make assumptions. The correlator terminates execution of a program at the first runtime error.

The dynamic compilation approach removes the need for a byte code interpreter that supports older versions of byte code. Also, the correlator can apply new optimization techniques during byte code generation.

About the Apama development environment in Software AG Designer

Software AG Designer provides an integrated environment for developing Apama applications. The process of developing an Apama application is centered around an Apama *project*. In Software AG Designer, you create a project and then you use Software AG Designer to:

- Add and manage the component files that make up the application.
- Write the EPL for your application.
- Specify the adapters, dashboards, and scenarios that are necessary for the application.
- Specify the configuration properties necessary for launching the application.
- Run and monitor the application.
- Export the initialization information necessary for deploying the application.
- Export your EPL and scenario files to a Correlator Deployment Package (CDP).

As you add components to your application, Software AG Designer automatically generates the boilerplate EPL code for the application's standard features and launches the appropriate editor where you add the code to implement the component's behavior.

A central Apama feature in the Software AG Designer is the EPL editor. The EPL editor provides the following support for writing EPL:

- Automatic EPL validation
- Content assistance
- Auto-completion
- Hovering over an event declaration displays the event's type definition
- Automatic indenting and bracketing
- A separate panel shows the hierarchy of the EPL that appears in the editor
- Ability to define templates for frequently-used fragments of EPL

In Software AG Designer, you can examine the EPL files that are part of the Apama demo applications. On the Welcome page of Software AG Designer, click **Demos** under the **Apama** heading, select the Process Monitor demo, and then double-click a `.mon` file to view it in the EPL editor. If necessary, click the **Show All Folders** icon to display the monitors.

Terminology

This topic provides a definition of each important EPL term. The definitions are organized into several groups.

Basic modules

EPL Term	Definition
Application	An Apama application consists of one or more collaborating monitors and/or one or more queries.
Package	A mechanism for qualifying monitor, query and event names. Monitors, queries and global events in the same package must each have a unique name within the package.
Context	Contexts allow EPL applications to organize work into threads that the correlator can concurrently execute.
Monitor	A monitor is a basic unit of program execution. Monitors have both data and logic. Monitors communicate by sending and receiving events. A monitor is defined in a `.mon` file. In a monitor, you can create multiple contexts and divide processing among multiple contexts. A monitor cannot contain an Apama query.
Query	An Apama query is a basic unit of program execution. It partitions incoming events according to a key and then independently processes the events in each partition. Processing involves watching for an event pattern and then executing a block of procedural code when that pattern is found. A query is defined in a `.qry` file. In a query, you do not create contexts. Apama automatically uses multiple contexts as needed to process your query. An Apama query cannot contain a monitor.
Channel	A string name that monitor instances and receivers can subscribe to in order to receive particular events. Adapter and client configurations can specify the channel to deliver

EPL Term	Definition
	events to. In EPL, you can send an event to a specified channel. Queries do not subscribe to channels.
Event (*type*)	An event is a data object. All events have an event type and an ordered set of event fields. An event type might also have zero or more defined event actions that operate on the event fields.
Field	A data element of an event.
Method	A method is a pre-defined action. A given EPL type has a given set of methods that it supports.

Data types

EPL Term	Definition
Data type	Usually referred to as simply `type`. EPL supports the following value types: `boolean`, `decimal`, `float`, `integer`, and the following reference types: `action`, `Channel`, `chunk`, `context`, `dictionary`, `event`, `Exception`, `listener`, `location`, `sequence`, `StackTraceElement`, `stream`, `string`. Also, `monitor` is a very limited pseudo-type.
`sequence`	An EPL type used to hold an ordered set of objects (referenced by position).
`dictionary`	An EPL type used to hold a keyed set of objects (referenced by key).
`location`	An EPL type that represents a rectangular area in a two-dimensional unitless Cartesian coordinate plane.
`chunk`	An EPL type that references an opaque data set, the data items of which are manipulated only in a correlator plug-in.
`listener`	You can assign an event listener or a stream listener to a variable of this type and then subsequently call `quit()` on the listener to remove the listener from the correlator.

EPL Term	Definition
`action`	An EPL type that references an action. Actions in EPL are the equivalent of methods in object-oriented languages. Actions are user-defined methods that you can define in monitor and query definitions, event type definitions, and custom aggregate function definitions.
`context`	An EPL type that provides a reference to a context. A context lets the correlator concurrently process events.
`stream`	An EPL type that refers to a stream object. Each stream is a conduit through which items flow. A stream transports items of only one type, which can be any Apama type. Streams are internal to a monitor.
`Channel`	An EPL type that contains a string or a context. A contained string is the name of a channel. A contained context lets you send an event to that context. Defined in the `com.apama` namespace.
`Exception`	Values of `Exception` type are objects that contain information about runtime errors. Defined in the `com.apama` namespace.
`StackTraceElement`	A `StackTraceElement` type value is an object that contains information about one entry in the stack trace.

Monitors

EPL Term	Definition
Monitor name	Each monitor has a name that can be used to delete the monitor from the correlator.
Monitor definition	The set of source statements that define a monitor.
Monitor instance	A monitor instance is created whenever a monitor is loaded into the correlator. Subsequent monitor instances are created whenever a monitor instance spawns. As one time, a monitor instance was referred to as a sub-monitor.
Sub-monitor	A monitor instance was previously referred to as a sub-monitor.

Queries

See also "Query terminology" on page 80.

EPL Term	Definition
Query name	Each Apama query has a name that can be used to delete the query from the correlator.
Query definition	The set of source statements that define an Apama query.
Query instance	A query instance is created whenever a non-parameterized query is loaded into the correlator. When a parameterized query is loaded, no instances are created until parameter values are provided. After specification of parameter values, Apama creates an instance of the query, which is referred to as a parameterization. A query definition supports multiple parameterizations.
Query key	A query key identifies one or more fields in the event types that the query specifies as input event types. Each query input event type must specify the same key.
Query partition	A partition contains a set of events that all have the same key value. One or more windows contain the events added to each partition.

Events

EPL Term	Definition
Event name	Every event must identify its event type. Event types are identified by a unique event name. The event name can also be used to remove the event definition from the correlator.
Event definition	The set of source statements that define an event type.
Event type	All events of a given event type have the same structure. An event type defines the event name, the ordered set of event fields and the set of event actions that can be called on the event fields.
Event field	A data element of an event.

EPL Term	Definition
Event action	An action defined within an event definition. The action can operate only on the fields of the event and any arguments passed into the action call.

Listeners

EPL Term	Definition
Event listener	A construct that monitors the events passed to, or routed within, a correlator context. When the event pattern matches the event pattern specified in an event listener, the correlator invokes the event listener's code block. In monitors, it is up to you to define event listeners. In queries, Apama defines event listeners for you.
`on` statement	EPL statement that defines an event listener. An `on` statement specifies an `event` expression and a listener action.
Stream listener	A construct that continuously watches for items from a stream and invokes the listener code block each time new items are available.
`from` statement	EPL statement that defines a stream listener. A `from` statement specifies a source stream, a variable, and a code block. The `from` statement coassigns each stream output item to the specified variable and executes the statement or block once for each output item.
Listener action	The action, statement or block part of a listener.
Listener handle	It is possible to assign the handle (reference) to a listener to a `listener` variable. This variable can then be used to quit the listener.
Event template	Specifies an event type and the set of (or set of ranges of) event field values to match.
Event operator	Relational, logical, or temporal operator that applies to an event template and that you specify in an event expression.

EPL Term	Definition
Event expression	An expression, constructed using event operators and event templates, that identifies an event or pattern of events to match.

Streams

See also the above definitions for *stream*, *stream listener*, and *from statement*.

EPL Term	Definition
Stream query	A stream query is defined in a monitor. A stream query is a query that the correlator applies continuously to one or two streams. The output of a stream query is one continuous stream of derived items. A stream query is a completely different construct than an Apama query.
Stream source template	An event template preceded by the `all` keyword. It uses no other event operators. A stream source template creates a stream that contains events that match the event template.
Stream network	Network of stream source templates, streams, stream queries, and stream listeners. Upstream elements feed into downstream elements to generate derived, added-value items.
Activation	When the passage of time or the arrival of an item causes a stream network or an element in a stream network to process items.

Defining event types

Conceptually, an event is an occurrence of a particular item of interest at a specific time. Examples of events include:

- A price of $100 for a share of IBM stock at noon on November 7, 2014
- Purchase of 1000 shares of IBM stock at $80 per share at 12:01 PM on December 12, 2014
- RFID tag 123-456-789 was scanned at 10:05 AM at loading dock 3
- Purchase order 55555 for 10,000 widgets sent to Acme Motor Supply
- TCP/IP address 123.4.56.789 just accessed server 5

- Container X was overfilled greater than 0.2 grams more than standard amount

An event usually corresponds to a message of some form. The correlator is designed to take in huge numbers of messages per second, and sift them for the events or patterns of events of interest. When the correlator detects interesting events or patterns it can undertake a variety of actions.

A correlator can receive events in several ways:

- You use Software AG Designer to send events from a file.
- From an adapter that receives an event from an external source. Apama adapters translate events from non-Apama format to Apama format.
- You run the Apama `engine_send` utility to manually send events into the correlator.
- A monitor or query generates an event within the correlator.
- You can write an application in C, C++, Java, or .NET that uses the Apama client API to send events into the correlator.

The correlator propagates information by sending events.

In EPL, each event is of a specific type. An event type has a name and a particular set of fields. Each field has a name and is one of a selection of types. Every event instance of a given event type has the same set and order of fields. For the correlator to process an event of a specific event type, it needs to have the event type definition for that type. Having the definition for an event type, lets the correlator

- Operate on the messages of that event type
- Create optimal indexing structures for finding events of that type that are of interest

An event type definition specifies the event type's name and the name and type of each of its fields.

See also "Specifying named constant values" on page 270.

Allowable event field types

A field in an event can be any Apama type. For more information on these types, see "Types" on page 767.

Certain field types are valid only within a certain scope and you cannot pass events with such field types outside that scope. The details are as follows:

- `context` — When an event contains a `context` type field, you can send the event to other monitors within the same correlator but you cannot send the event outside the correlator. In other words, you can send or route the event. See "Generating events" on page 284.
- `chunk`, `listener` and `stream` — An event that contains one or more of these types of fields is valid only within the monitor that creates it. You cannot send, route, or enqueue an event that contains a field of type `chunk`, `listener` or `stream`.

If an event contains a `chunk`, `listener`, or `stream` field you cannot listen for that event.

Format for defining event types

In EPL, the format for an event type definition is as follows:

```
event event_type {
   [
   [ wildcard] field_type field_name ; |
   constant field_type field_name  := literal ; |
   action_definition
   ] ...
}
```

Syntax description

Syntax Element	Description
`event`	This EPL keyword is required. It indicates an `event` type definition.
`event_type`	Replace *`event_type`* with a name that you choose for this event type. An EPL best practices convention is to specify an initial capital in event type names, and to capitalize subsequent words in the name. For example: `StockTick`.
`{ }`	Enclose the field definitions in curly braces.
`wildcard`	Specify the `wildcard` keyword in front of a field definition when you are certain that you will never specify that field in the match criteria for this event type. In other words, when the correlator watches for certain events of this type, the value of a wildcard field is always irrelevant. For more details, see "Improving performance by ignoring some fields in matching events" on page 174.
`field_type`	Replace *`field_type`* with the name of a type. If you specify `action`, `sequence`, `stream` or `dictionary`, you must also specify the type of the action's argument(s) and return value if there are any, the type of the values in the `sequence` or `stream`, or the type of the dictionary's key as well as the type of the values in the dictionary. For example: `dictionary<integer,string>`. For more

Syntax Element	Description
	details, see "dictionary" on page 791 and "sequence" on page 805.
field_name	Replace *field_name* with a name that you choose for this field. An event can have zero or more fields. You might define an event with no fields in a situation where only detection of the event is needed to start some process. While there is no limit to the number of fields in an event, the correlator can index up to 32 fields per event. This means that the correlator can match on up to 32 fields per event. If an event type has more than 32 fields, you must specify the `wildcard` keyword for the additional fields. Note that if the type of an event field is `location`, that field counts as 2. For example, if you have 28 non-`location` type fields and 2 `location` fields, then you have reached the limit of 32 indexed fields. If you try to inject an event definition that specifies more than 32 fields and you do not specify the `wildcard` keyword for additional fields, the correlator rejects the file. You must add the `wildcard` keywords to be able to inject the file.
`constant`	Specify the `constant` keyword in front of a field definition whose type is `boolean`, `decimal`, `float`, `integer`, or `string` and whose value never changes.
literal	If you specify the `constant` keyword, you must assign a literal to that field. The type of the literal must be the same as the *field_type* you specified for this field.
action_definition	When you specify an action in an event type definition you can call that action on an instance of the event. See "Specifying actions in event definitions" on page 274.

Example event type definition

For example, the EPL definition of an event type for simple financial stock price ticks might include the stock's name and its price:

```
event StockTick {
   string name;
   float price;
}
```

To represent a specific instance of an event, use the following form:

```
event_type (field1_value, field2_value ...)
```

For example, a `StockTick` event describing Acme's new price of `55.20` looks like this:

```
StockTick("ACME", 55.20)
```

The reading order of fields in an event type definition and in instances of that event type must always match and is always left-to-right and then top-to-bottom. That is, `"ACME"` is the value of the `name` field and `55.20` is the value of the `price` field.

Working with events

After you define an event type, there are built-in methods you can call on it, and there are various ways that you can make that event available to monitors and queries.

You can call a number of methods on any `event` type. For an overview of these methods, see "event" on page 796.

Making event type definitions available to monitors and queries

A monitor or query must have information about the type definitions of the events that it processes. You can provide this information as follows:

- Define the event type in a separate file that contains only event definitions. An event type definition file has a `.mon` extension. It is still an EPL file even though it contains only event type declarations.

  You can define any number of event types in a single file. A common practice is to define the event interface to a service in a file that is separate from the implementation of that service. You might have a single event interface file and multiple implementations of services that process those event types.

  An event type definition file is the only way to make event type definitions available to queries.

- Define the event type in the monitor. Only instances of that monitor can process events of that type. Also, events of that type cannot be sent into the correlator from outside. When you define an event type inside a monitor it has a fully qualified name. For example:

  ```
  monitor Test
  {
     event Example{}
  }
  ```

The fully qualified name for the `Example` event type is `Test.Example` and the `toString()` output for the event name is `"Test.Example()"`.

- After the optional `package` specification, define the event type at the beginning of an EPL file that also defines monitors. All event type declarations must be before the monitor declarations. After you inject this file into the correlator, the following monitors can process events of that type:
  - All monitors that you define in the same file
  - All monitors that you inject after you inject the file that contains the event definition.

You might have a need for different event type definitions to have the same event type name. In this situation, define each event type in a different package. Remember that event types to be used by queries must be defined in event type definition files. Then, in your monitor or query, use one of the following ways to make the appropriate event type definition available. In the monitor or query:

- Specify the fully qualified name of the event type, for example:

  ```
  com.apamax.test.Status
  ```

- After any `package` declaration and before any other declarations, specify a `using` declaration. For example:

  ```
  using com.apamax.test.Status;
  ```

  In your code, you can then simply refer to the `Status` event type.

Do not create EPL structures in the `com.apama` namespace. This namespace is reserved for future Apama features. If you inadvertently create an EPL structure in the `com.apama` namespace, the correlator might not flag it as an error in this release, but it might flag it as an error in a future release.

See also "Name Precedence" on page 929.

An event type definition must be injected into the correlator before a monitor that processes events of that type. After you inject an event type definition into the correlator, any monitor that you inject after that can process events of that type.

During development, when you use Software AG Designer to launch a project, it ensures that files are injected in the right order. When more than one project requires the same event definition file, do one of the following:

- In each project, declare an external dependency on the common event definition file:
  1. In Software AG Designer, in the Apama Developer perspective, in the **Developer Project View**, select the project name.
  2. Press **Alt-Enter**.
  3. Select **MonitorScript Build Path**.
  4. Click the **External Dependencies** tab.

5. Click **Add External**.
6. Navigate to the event type definition file, and select it.
7. Click **Open**.

- Create a project that contains the common event definition file. In each project that requires these event definitions, declare a dependency on the project that contains the common event definition file.

  1. Create the project that contains the common event type definition file and keep that project open in Software AG Designer.
  2. In the **Developer Project View**, select the name of a project that needs to use the common event definition file.
  3. Press **Alt-Enter**.
  4. Select **MonitorScript Build Path**.
  5. Select the **Projects** tab.
  6. Click **Add**.
  7. Select the project that contains the event definition file, and click OK.

Channels and input events

Adapters, Apama client applications, and tools such as the `engine_send` correlator utility send events into the correlator. Each incoming event is associated with a channel either explicitly or implicitly. An event that has a channel explicitly set is delivered on the specified channel. An event that does not have a channel explicitly set is delivered on the default channel. The default channel's name is the empty string.

An incoming event that is sent on the default channel goes to each public context. In addition, contexts can subscribe to channels of interest (see "Subscribing to channels" on page 70). An incoming event for which a channel is explicitly set goes to each context that is subscribed to its associated channel. If there are no contexts subscribed to the specified channel the event is discarded.

Any running Apama queries receive events that come in on the default channel. In addition, Apama queries run in contexts that are subscribed to receive events sent on the `com.apama.queries` channel. So queries also receive events sent on that channel.

Events sent into the correlator from, for example, clients and adapters, are not normally delivered to external receivers. However, external receivers can specify the `com.apama.input` channel in their configuration. This is a wildcard for all events coming into the correlator. Also, an external receiver can specify `com.apama.input.`*`channel_name`* to receive correlator input events that are associated with that particular channel.

When two events are sent to different channels there is no ordering guarantee. The only guarantee is that events going from the same source to the same destination on the same channel will be delivered in order. Also, if there is an external connection with, for example, an adapter or client, then the events must use the same connection for them to be delivered in the same order.

All routable event types can be sent to channels, including event types defined in monitors.

An Apama application can use Software AG's Universal Messaging (UM) message bus to deliver events on specified channels. If a correlator is configured to connect to UM then a channel might have a corresponding UM channel.

See *Choosing when to use UM channels and when to use Apama channels* in *Connecting Apama Applications to External Components*.

2 Defining Monitors

A monitor is one of the basic units of EPL program execution.

Note: The other basic unit is a query. A monitor cannot contain a query. A query cannot contain a monitor. For information about writing queries, see "Defining Queries" on page 75. For a comparison of queries and monitors, see "Architectural comparison of queries and monitors" on page 79.

Monitors have both data and logic. Monitors communicate by sending and receiving events. You define a monitor in a `.mon` source file. When you load the `.mon` file into the correlator, the correlator creates an instance of the defined monitor.

A monitor instance can operate like a factory and spawn additional monitor instances. A spawned monitor instance is a duplicate of the monitor instance that spawned it except that the correlator does not clone any active listeners or stream queries. Spawning lets a single monitor instance generate multiple instances of itself. While generally, the spawned monitor instances all listen for the same event type, each one can listen for events that have different values in particular fields.

It is good practice to define monitors and events in separate files. An advantage of doing this is that queries, as well as monitors, can use the same event definitions. When you inject files into the correlator, be sure to load event type definitions before you load the monitors and/or queries that process events of those types.

The topics below provide information and instructions for defining monitors. For reference information, see "Monitors" on page 845. Apama provides several sample monitor applications, which you can find in the `samples\monitorscript` directory of your Apama installation directory.

See also: "Overview of Developing Apama Applications" in *Using Apama with Software AG Designer* and "Overview of Deploying Apama Applications" in *Deploying and Managing Apama Applications*.

About monitor contents

A file that defines a monitor has the following form:

1. An optional `package` declaration
2. Followed by
    a. Zero or more `using` declarations
    b. Zero or more custom aggregate function definitions
    c. Zero or more event type definitions
3. One or more monitor definitions

When you define monitors that are closely related, it is your choice whether to define them in the same file or different files.

A monitor must have information about any event types it processes. Hence, the correlator must receive and parse all of the event types used by the monitor before it is able to correctly parse the monitor itself.

A monitor can contain one or more *global variables*. A global variable declaration appears inside a monitor but outside any actions. The variable is global within the scope of the monitor.

A monitor can also contain a number of *actions*. Actions are similar to procedures. Finding an event, or pattern of events, of interest can trigger an action. You can also trigger an action by invoking it from inside another action.

Any construct that you declare inside a monitor is available only from within that monitor. In other words, its use is restricted to the scope of the monitor.

Below is a minimal monitor:

```
monitor EmptyMonitor {
   action onload() {
   }
}
```

The monitor above does not do anything; it does not register interest in any event or event pattern, it does not have variables, and it does not do anything in its single `action` statement. However, it does show the minimum structure of a monitor:

- It specifies the `monitor` keyword followed by the name of the monitor. In the example, the name of the monitor is `EmptyMonitor`. The name of the monitor and the name of the file that contains the monitor do not need to be the same. A single file can contain multiple monitors.

- It declares the `onload()` action. When you inject a monitor into the correlator, the correlator executes the monitor's `onload()` action. Every monitor must contain an `onload()` action. The `onload()` action is similar to the `main()` function in C/C++.

  If you define two or more monitors in the same file, the correlator executes the `onload()` actions of the monitors in the order in which you define the monitors. If there is an `onload()` action whose execution is dependent on the results of the execution of the `onload()` action of another monitor, but sure you define that other monitor earlier in the same file. If you define that other monitor in a separate file, be sure you inject that file first. Tip: it is better to avoid these dependencies as much as possible by using initialization events. See "Using events to control processing" on page 67.

EPL provides a number of actions, such as `onload()`, `onunload()`, and `ondie()`. You can define additional actions, and assign a name of your choice that is not an EPL keyword. See "List of EPL keywords" on page 920.

Do not create EPL structures in the `com.apama` namespace. This namespace is reserved for future Apama features. If you do inadvertently create an EPL structure in the `com.apama` namespace, the correlator might not flag it as an error in this release, but it might flag it as an error in a future release.

Loading monitors into the correlator

During development, you use Software AG Designer to load your project, including monitors, into the correlator. Software AG Designer ensures that files are loaded in the required order.

At any time, you can use the correlator utility, `engine_inject`, to load EPL files into the correlator. See "Injecting EPL code" in the "Correlator Utilities Reference" section of *Deploying and Managing Apama Applications*.

In a deployment environment, you can load monitors into the correlator in any of the following ways:

- Use the `engine_inject` utility.
- Write a program in C, C++, Java, or .NET and use the corresponding Apama client API.
- Use the Apama Management & Monitoring tool.

If you try to inject a monitor whose name is the same as a monitor that was already injected, the correlator rejects the monitor. You can inject two monitors with the same name into the correlator only if they exist in different packages. To specify the package for a monitor or event type, add a `package` statement as the first line in the EPL file that contains the monitor/event definition. For example:

```
package com.mycompany.mypackage;
monitor Foo {
     …
}
```

Terminating monitors

A monitor instance terminates when one of the following events occurs:

- The monitor instance executes a `die` statement in one of its actions.
- A runtime error condition is raised.
- The monitor is terminated externally (for example, with the `engine_delete` utility). When the correlator deletes a monitor it terminates all instances of that monitor.
- The monitor instance has executed all its code and there are no active event or stream listeners. This will occur rapidly if the monitor's `onload()` action does not create any listeners. See also "Beware of accidental stream leaks" on page 263.

When a monitor instance terminates, the correlator invokes the monitor's `ondie()` action, if it is defined. You cannot spawn in an `ondie()` action.

Unloading monitors from the correlator

The correlator unloads a monitor in the following situations:

- All of the monitor's instances have terminated.

- An external request kills the monitor. This kills any instances of the monitor.

If the monitor defines an `onunload()` statement, the correlator executes it just before it unloads the monitor. You cannot spawn in an `onunload()` action.

Example of a simple monitor

The empty monitor discussed in "About monitor contents" on page 50 does not do anything. To write a useful monitor, add the following:

- An event type definition
- A global variable declaration
- An event expression that indicates the pattern to monitor for
- An action that operates on an event that matches the specified pattern

For example, the EPL below

- Defines the `StockTick` event type, which is the event type that the monitor is interested in.
- Defines the `newTick` global variable, which is accessible by all actions within this monitor. The `newTick` variable can hold a `StockTick` event.
- Registers an interest in all `StockTick` events.
- Invokes the `processTick()` action when it finds a `StockTick` event. The `processTick`() action uses the `log` command to output the name and price of all `StockTick` events received by the correlator.

Lines starting with `//` are comments. EPL also supports the standard C/Java `/* ... */` multi-line comment syntax.

```
// Definition of the event type that the correlator will receive.
// These events represent stock ticks from a market data feed.
event StockTick {
   string name;
   float price;
}

// A simple monitor follows.
monitor SimpleShareSearch {
   // The following is a global variable for storing the latest
   // StockTick event.
   StockTick newTick;
      // The correlator executes the onload() action when you inject the
      // monitor.
      action onload() {
         on all StockTick(*,*):newTick processTick();
      }
      // The processTick() action logs the received StockTick event.
      action processTick() {
         log "StockTick event received" +
            " name = " + newTick.name +
            " Price = " + newTick.price.toString() at INFO;
      }
}
```

About the variable in the example

The single global variable is of the event type `StockTick`. A variable can be of any primitive type — `boolean`, `decimal`, `float`, `integer`, `string`, or any reference type — `action`, `context`, `dictionary`, `event`, `listener`, `location`, `sequence` or `stream`.

About the onload() action

In this example, the `onload()` action contains only one line of code:

```
on all StockTick(*,*):newTick processTick();
```

This line specifies the following:

- `on all StockTick(*,*)` indicates the event to look for.

  The `on` statement begins the definition of an *event listener*. It means, "when the following event (or a pattern of events) is received ..." This event listener is looking for all `StockTick` events. The asterisks indicate that the values of the `StockTick` event fields do not matter.

- `:newTick processTick();` indicates what to do when a `StockTick` event is found.

  If the event listener finds a `StockTick` event, the coassignment `(:)` operator indicates that you want to copy the found event into the `newTick` global variable. The `onload()` action then invokes the `processTick()` action.

About event listeners

The `on` statement must be followed by an event expression. An event expression specifies the pattern you want to match. It can specify multiple events, but this simple example specifies a single event in its event expression. For details, see "About event expressions and event templates" on page 160.

The `all` keyword extends the `on` command to listen for all events that match the specified pattern. Without the `all` keyword, the event listener would listen for only the first matching event. In this example, without the `all` keyword, the event listener would terminate after it finds one `StockTick` event.

In the sample code, the event expression is `StockTick(*,*)`. Each event expression specifies one or more *event templates*. Each event template specifies one event that you want to listen for. The `StockTick(*,*)` event expression contains one event template.

The first part of an event template defines the type of event the event listener is looking for (in this case `StockTick`). The section in parentheses specifies filtering criteria for contents of events of the desired type. In this example, the event template sets both fields to wildcards (`*`). This declares an event listener that is interested in all `StockTick` events, regardless of content.

When an event listener finds a matching event, the listener can use the assignment operator (`:`) to place that event in a *global* or *local* variable. For example:

```
on all StockTick(*,*):newTick processTick();
```

This copies a `StockTick` event into the `newTick` global variable. This is known as a variable coassignment.

Finally, the `on` statement invokes the `processTick()` action. For all received `StockTick` events, regardless of content, the sample monitor copies the matching event into the `newTick` global variable, and then invokes the `processTick()` action. For details, see "Using global variables" on page 266.

About the processTick() action

The `processTick()` action executes the `log` command to output some data on the registered logging device, which by default is standard output. This `log` statement is used to report some of the fields from the received event.For details, see "Logging and printing" on page 295.

Accessing fields in events

EPL uses the `'.'` operator to access the fields of an event. You can see that the `processTick()` action uses the `'.'` operator to retrieve both the `name` (`newTick.name`) and `price` (`newTick.price`) fields of each event.

The `log` command requires strings as fields, so the `processTick()` action specifies the built-in `.toString()` operation on the nonstring value:

```
newTick.price.toString()
```

Spawning monitor instances

It is frequently necessary to enable a single monitor to concurrently listen for multiple kinds of the same event type. For example, you might want one monitor to listen for and process stock ticks that each have a different stock name. You accomplish this is by spawning monitor instances as described in the topics below.

See also "Spawning to contexts" on page 309.

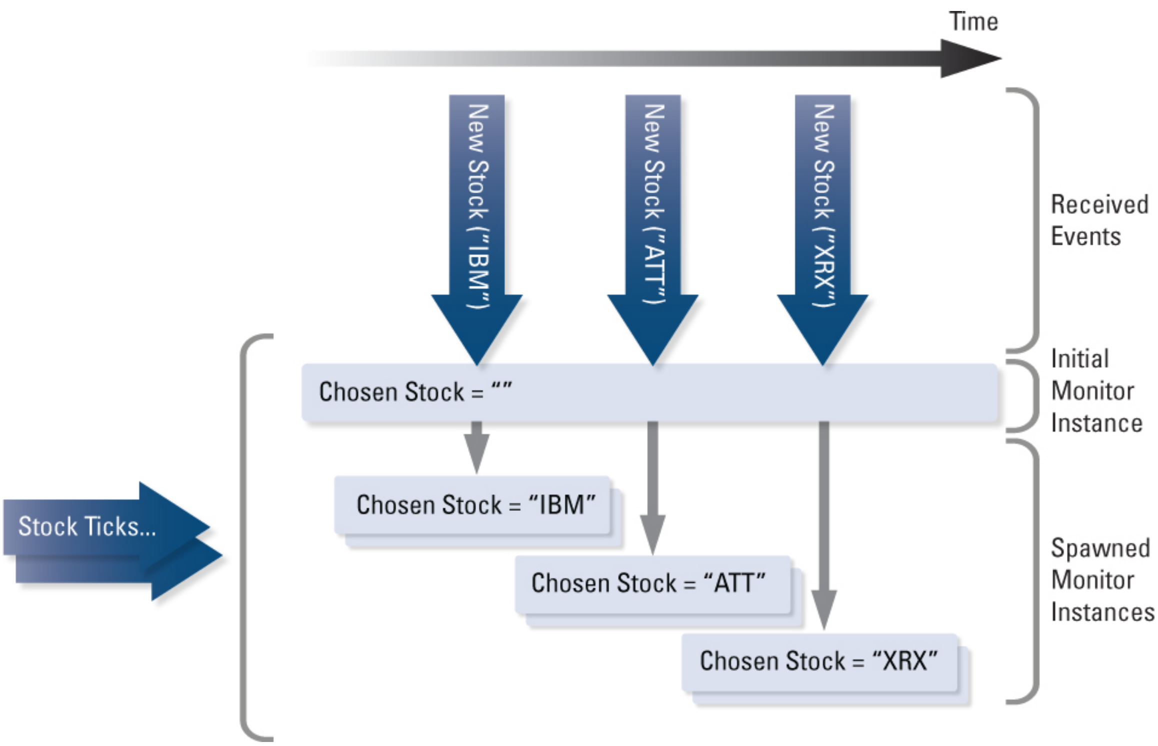
How spawning works

In a monitor, you spawn a monitor instance by specifying the `spawn` keyword followed by an action. When the correlator spawns a monitor instance, it does the following:

1. Creates a new instance of the monitor that is spawning.
2. Copies the following, if there are any, to the new monitor instance:
   - Current values of the spawining monitor instance's global variables
   - Any arguments declared in the action that is specified in the `spawn` statement
   - Anything referred to indirectly by means of the copied variables and arguments
3. Executes the named action with the specified arguments in the new monitor instance.

The new monitor instance does not contain any active event listeners, stream listeners, streams or stream queries that were in the spawning monitor instance. For example, data held in local variables that are bound to a listener are not copied from the spawning monitor instance to the new monitor instance. The figure below illustrates this process:

Spawning process



The figure shows a monitor that spawns when it receives a `NewStock` event. Initially, the monitor has one active event listener. When the event listener finds the first `NewStock` event, the monitor

1. Copies the name `IBM` to the `chosenStock` variable.
2. Spawns a monitor instance.

The spawned monitor instance duplicates the initial monitor instance's state. In this example, this means that the value of the `chosenStock` variable in the spawned monitor instance is `IBM`. When the initial monitor instance receives another `NewStock` event (the value of the `name` field is `ATT`), it again copies the stock's name to the `chosenStock` variable and spawns. The same occurs for the `XRX` event, resulting in three spawned monitor instances.

Each new monitor instance starts with no active event listeners. It then creates a new event listener for `StockTick` events of the chosen stock (see the sample code in the next topic). The initial monitor instance's event listener for `NewTick` events remains active after spawning. However, because the action to create a new `StockTick` event listener is executed only in the spawned monitor instances, the initial monitor instance continues to listen for only `NewTick` events.

Sample code for spawning

EPL that implements the example described in "How spawning works" on page 55 is as follows:

```
// The following event type defines a stock that a user is interested
// in. The event type includes the name of the stock (name) and the
// user's personal name (owner).
//
event NewStock {
   string name;
   string owner;
}

event StockTick {
   string name;
   float price;
}

monitor SimpleShareSearch {
   NewStock chosenStock;
   integer numberTicks;
   StockTick newTick;

   // Listen for all NewStock events. When a NewStock event is found
   // assign it to the chosenStock variable and spawn with a call to
   // the matchTicks() action. This clones the state of the monitor
   // and launches a monitor instance that executes matchTicks().
   action onload() {
      numberTicks := 0;
      on all NewStock (*, *):chosenStock spawn matchTicks();
   }

   // In the spawned monitor instance, listen for only those StockTick
   // events whose name matches the name in the chosenStock variable.
   action matchTicks() {
      on all StockTick(chosenStock.name,*):newTick processTick();
   }

   action processTick() {
      numberTicks := numberTicks + 1;
      log "A StockTick regarding the stock "
         + newTick.name + "has been received "
         + numberTicks + " times. This is relevant for "
         + " Trader name: " + chosenStock.owner
         + " and the price is " + newTick.price.toString() at INFO;
         + ".";
   }
}
```

This example defines a new event type named `NewStock`. Traders dispatch this event when they want to look for a specific kind of stock event. The code example spawns a monitor instance when the monitor finds a `NewStock` event. For example, if three `newStock` events are received by the initial monitor instance, there will be three spawned monitor instances. Other than spawning, the difference between this code sample and the sample in "Example of a simple monitor" on page 53is that this one specifies an owner in each `NewStock` event and the monitor's state now includes a counter.

In this example, after spawning, all processing is within a spawned monitor instance. Processing begins with execution of the `matchTicks` action. This action starts by defining an event listener for `StockTick` events whose `name` field matches the `name` field in the spawned monitor instance's `chosenStock` variable. When there are multiple, spawned monitor instances, each spawned monitor instance listens for only the `StockTick` events that match their `chosenStock` name.

The `numberTicks` counter variable and the `chosenStock` event variable, which contains the stock name and the owner's name, are available in the cloned state of the spawned monitor instance. This lets the `processTick()` action in each spawned monitor instance

- Customize output to include the originating trader's name
- Maintain a counter of how many `StockTicks` for a particular stock have been detected for a trader

The really important aspect that distinguishes spawning is that the entire variable space is cloned at the moment of spawning. In the example, every spawned monitor instance has a copy of the `chosenStock` variable that contains the `NewStock` event that triggered spawning. Also, every spawned monitor instance has a copy of the `numberTicks` variable, which is always set to `0` when the initial monitor instance spawns. This ensures that each spawned monitor instance can maintain an accurate count of how many matching `StockTick` events have been found.

The initial monitor instance listens for `NewStock` events. Remember that spawning does not clone active listeners, so the spawned monitor instances do not have listeners that watch for `NewStock` events. Each spawned monitor instance listens for only those `StockTick` events that contain `name` fields that match that spawned monitor instance's value for the `chosenStock` variable.

Typically, spawning is not an expensive operation. However, its overhead does increase as the size of the monitor being spawned increases. When writing an EPL application avoid repeated spawning of monitors that contain a large number of variables.

Spawned monitor instances contain copies of all global state from the spawning monitor instance. It does not matter whether the spawned monitor instance is going to use that state or not. To avoid wasting memory, a typical practice is to hold state in events that are referred to by local variables, which are not copied during spawning. This ensures that you do not have a lot of state information in global variables when the monitor instance spawns. Alternatively, you can insert code so that the new monitor instance clears unneeded state immediately after it starts running.

For information about spawning to actions that are members of events, see "Spawning" on page 275.

Terminating monitor instances

The example discussed in "Sample code for spawning" on page 57 spawns a monitor instance for each `newStock` event that the initial monitor instance receives. This is not always desirable. For example, if two identical `newStock` events are received, two identical monitor instances are spawned. To prevent this, you can use the `die` statement to delete a monitor instance if a more recent one (with the same spawning properties) has been created. For example:

```
action onload() {
   on all NewStock(*, *):chosenStock spawn matchTicks();
}
action matchTicks() {
   on NewStock (chosenStock.name, chosenStock.owner) die();
   // ...
}
```

In this fragment, the monitor spawns when it receives a `NewStock` event. In the spawned monitor instance, the initial `on` statement activates an event listener for a `NewStock` event that is identical to the one that caused the spawning. In other words, the spawned monitor instance is listening for a `NewStock` event where the fields are the same as that held by the `chosenStock` variable. If such an event arrives, the monitor instance terminates. This structure ensures that only one monitor instance for each stock name and owner exists at any one time. The same `NewStock` event kills the existing monitor instance and causes spawning of a new monitor instance. That is, the same event triggers the concurrent event listeners of the initial monitor and the spawned monitor instance.

In this solution, when a `NewStock` event kills an existing monitor instance and spawns a new monitor instance, the value of the `numberTicks` variable in the new instace is zero. Often, this kind of behavior is required. You want to ignore the state of the old monitor instance and start afresh.

Note that the event that triggers the initial monitor instance's event listener and causes the spawning of a monitor instance does not get processed by the spawned monitor instance's new event listener. An event is available to only those event listeners that are active when the correlator receives the event.

You can also use the `die` statement to kill a monitor instance at will. For example, consider the following fragments:

```
event StopStock {
   string name;
   string owner;
}

action onload() {
   on all newStock(*, *):chosenStock spawn matchTicks();
}

action matchTicks() {
   on StopStock (chosenStock.name, chosenStock.owner) die();
   // . . .
}
```

Traders would send `StopStock` events when they are no longer interested in a particular stock. Receiving a matching `StopStock` event kills the monitor instance that is listening for that stock. You can use this technique to explicitly kill any monitor instance.

About executing ondie() actions

A monitor instance can terminate for any of the following reasons:

- It executes all its code and has no active listeners or streaming elements.

- The `die()` operation is called on it.
- The `engine_delete` utility or an Apama client API removes the monitor from the correlator.
- A run-time error is detected in the monitor's code, which causes that instance of the monitor to die.

In all of these situations, if the monitor defines an `ondie()` action, the correlator invokes it. Like the `onload()` and `onunload()` actions, `ondie()` is a special action because the correlator invokes it automatically in certain situations.

Suppose that a monitor that defines the `ondie()` action spawns ten times, and each monitor instance dies. The correlator invokes `ondie()` eleven times: once for each spawned monitor instance, and once for the initial monitor instance. Then, just before the monitor's EPL is unloaded from the correlator, the correlator invokes the `onunload()`action only once, and it does so in the context of the last remaining monitor instance.

The correlator executes each `ondie()` operation in the context of its monitor instance. Therefore, the `ondie()` operation can access the variables in the monitor instance being terminated.

You cannot spawn in an `ondie()` or an `onunload()` action.

Specifying parameters when spawning

When spawning a monitor instance, you can pass parameters to an action. For example:

```
monitor m {
   action onload() {
      spawn forward("a", "channelA");
      spawn forward("b", "channelB");
  }

   action forward(string arg, string channel) {
      Event e;
      on all Event(arg):e {
         send e to channel;
      }
      on StopForwarding(arg) {
         die();
      }
   }
}
```

The following are equivalent:

```
spawn actionName(); // This is the correct syntax.
spawn actionName;   // This is deprecated. Do not use it.
```

Communication among monitor instances

In EPL applications, everything in a monitor instance is private. There is no direct way for a monitor instance to invoke an action or access the state of another monitor instance.

Instead, messages, in the form of events, are the mechanism for communication among monitor instances. All events are visible to all interested monitor instances.

Consequently, how you divide your application operations into monitors and what events the monitor instances use to communicate are crucial design decisions. An understanding of the order in which the correlator processes events for monitors helps you determine where and when to allocate events.

The topics below provide information for making these decisions.

To use the MemoryStore correlator plug-in to share state between monitors, see "Using the MemoryStore" on page 365. If you are mixing monitors and queries in your application, see "Communication between monitors and queries" on page 157.

Organizing behavior into monitors

Typically, an Apama application consists of several monitors each doing a specific task. For example, a simple algorithmic trading system might consist of the following monitors:

- A monitor that manages order processing by spawning a monitor instance for each order.
- One or more market data monitors. Each monitor listens for a different type of market data (such as tick data, market depth) required to process orders. Each of these monitors typically spawns a monitor instance for each stock you want to observe.

A more complex application might organize its orders into portfolios or split sets of orders into smaller orders for wave trading or some other purpose.

In an Apama application, each monitor can usually be categorized as a core processing monitor or a service monitor. A core processing monitor performs the tasks you want to accomplish. A service monitor provides data needed by the core processing monitors. Typically, the core processing monitors spawn multiple monitor instances. These monitor instances will consume data from the same service monitors. For example, all monitor instances that manage the individual orders for a given stock would obtain tick data from the same instance of a service monitor. The ordinality of the solution elements — for example, `N` order processors that require data from `1` tick data provider — often dictates how the solution code should be organized into separate monitors. See also "About service monitors" on page 67.

The ordinality of the solution elements often dictates how the solution code should be organized into separate monitors. For example, there is an N:1 relationship between the 'N' order processor monitor instances that require market data for a given stock and the '1' market data service monitor instance that supplies it.

Event processing order for monitors

As mentioned earlier, contexts allow EPL applications to organize work into threads that the correlator can execute concurrently. When you start a correlator it has a main context. In a monitor, you can create additional contexts to enable the correlator to concurrently process events.

> **Note:** In a query, you do not create contexts. Instead, Apama automatically creates contexts as needed to process the incoming events.

Each context, including the main context, has its own input queue, which receives

- Events sent specifically to that context from other contexts.
- Events sent to a channel that a monitor in the context is subscribed to. See .

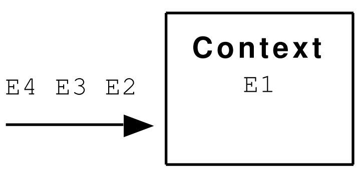
Concurrently, in each context, the correlator

- Processes events in the order in which they arrive on the context's input queue
- Completely processes one event before it moves on to process the next event

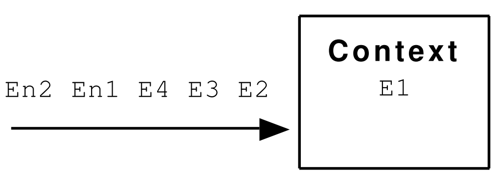
When the correlator processes an event within a given context, it is possible for that processing to route an event. A routed event goes to the front of that context's input queue. The correlator processes the routed event before it processes the other events in that input queue.

If the processing of a routed event routes one or more additional events, those additional routed events go to the front of that context's input queue. The correlator processes them before it processes any events that are already on that context's input queue.

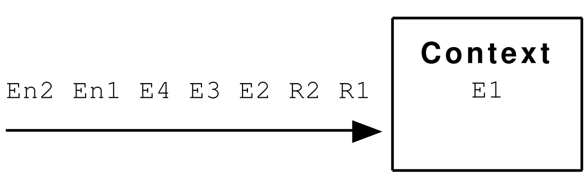
For example, suppose the correlator is processing the `E1` event and events `E2`, `E3`, and `E4` are on the input queue in that order.



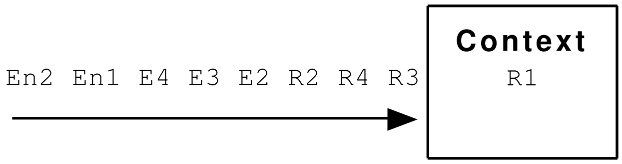
While processing `E1`, suppose that events `En1` and `En2` are created in that order and enqueued. These events go to the special queue for enqueued events. Assuming that there is room on the input queue of each public context, the enqueued events go to the end of the input queue of each public context:



While still processing `E1`, suppose that events `R1` and `R2` are created in that order and routed. These events go to the front of the queue:



When the correlator finishes processing E1, it processes R1. While processing R1, suppose that two event listeners trigger and each event listener action routes an event. This puts event R3 and event R4 at the front of the context's input queue. The input queue now looks like this:



It is important to note that R3 and R4 are on the input queue in front of R2. The correlator processes all routed events, and any events routed from those events, and so on, before it processes the next routed or non-routed event already on that queue.

Now suppose that the correlator is done processing R1 and it begins processing R3. This processing causes R5 to be routed to the front of that context's input queue. The context's queue now looks like the following:

See also "Understanding time in the correlator" on page 194.

Allocating events in monitors

Note: The principles described here apply to variables of any type, not just to any event type or any reference type.

When writing monitors consider when and where to declare and populate event variables. You can declare event variables at the monitor level or inside an action. Event variables that you declare at the monitor level are similar to global variables.

Events are reference types. This means that, for example, a variable of event type Foo is not an instance of Foo. The variable is a reference to an instance of Foo.

You cannot initialize the fields of a monitor-level variable. You can, however, initialize a monitor-level instance of the event that the variable refers to. For example:

```
Foo a := Foo(1, 2.3);
```

This instantiates a Foo event and specifies that a refers to that event. Now suppose you declare the following:

```
Foo b := a;
```

This does not instantiate a new Foo event. It only initializes b as an alias for a.

When you declare an event at the monitor level, the correlator can automatically use default values for the event's fields. You can, but you do not have to, initialize field values. This is because the correlator implicitly transforms a statement such as this:

```
Foo a;
```

into this:

```
Foo a := new Foo;
```

Before you use a locally declared event variable in an action, you must either assign it to an existing event of the same type, or you must specify the `new` operator to create a new event to assign to the variable. Note that each event field of an event created using `new` initially has the default value for that event field type.

The following code illustrates these points:

```
event Foo
{
   integer i,
   float x;
}

monitor Bar
   Foo a; //  Global (monitor-level) declaration.
          //  The correlator creates a Foo event with default
          //  values for fields.

   action onload() {
      a.i := 10;      // Assign non-default value.
      a.x := 20.0;    // Assign non-default value.
      Foo b;          // Local (in an action) declaration.
                      // The correlator does not create an event yet.
      b := new Foo;   // Create a default Foo event and assign
                      // it to local event.
      b.i := 10;      // Assign a non-default value.
      b.x := 20.0;    // Assign a non-default value.
      Foo c := a;     // You can assign a locally declared event to
                      // reference an existing event.
                      // Variables a and c alias the same event.
      c.i := 123      // The value of a.i is now also 123.
      Foo d := Foo(15,30.0);
                      // Create an event and also initialize it.
   }
```

Sending events to other monitors

After you inject a monitor into the correlator, it can communicate with other injected monitors under the following conditions:

- If the source monitor instance and the target monitor instance are in the same context, the source monitor instance can route an event that the target monitor instance is listening for. A routed event goes to the front of the context's input queue. The correlator processes all routed events before it processes the next non-routed event on the context's input queue. If the processing of a routed event routes another event, that event goes to the front of the input queue and the correlator processes it before it processes any other routed events on the queue. See "Event processing order for monitors" on page 61.
- If the source monitor instance and the target monitor instance are in different contexts, the source monitor instance must have a reference to the context that contains the target monitor instance. The source monitor instance can then send an event to the context that contains the target monitor instance. The target monitor instance must be listening for the sent event or the context that contains the target

monitor instance must be subscribed to the channel that the event is sent on. See "Sending an event to a particular context" on page 312 and "Subscribing to channels" on page 70.

Within a context, an application can use routed events and completion event listeners to initiate and complete a service request inline, that is, prior to processing any subsequent events on the input queue. See "Specifying completion event listeners" on page 172.

In the following example, the event listeners trigger in the order in which they are numbered.

```
monitor Client {
...
   listener_1:= on EventA() { route RequestB(…) }
   listener_5:= on ResponseForB () { doWork(); }
   listener_6:= on completed EventA() { doMoreWork(); }
...
}

monitor Service1{
...
   listener_2:= on RequestB(…)
   route RequestC();
   listener_4:= on ResponseForC{
   route ResponseForB ();
   }
...
}

monitor Service1a{
...
   listener_3:= on RequestC (…)
   route ResponseForC();
}
```

Best practices for working with routed events include:

- Keep them small — preferably zero, one, or two fields.
- Specify wildcards wherever appropriate in definitions of events that will be routed.

See also "Generating events with the route command" on page 284.

Defining your application's message exchange protocol

Monitors use events to communicate with each other. Consequently, an EPL application will have a well-defined message exchange protocol. A message exchange protocol defines the following:

- Types and structure of events that function as messages between monitor instances
- Relationships among these events
- Sequence and flow of events — which events are sent in response to receiving particular events
- Which monitors need to be able to handle which events, and conversely, which monitors should not receive which events

- Which channels these events are sent to, or whether they are sent directly between contexts.

When you define your application's message exchange protocol, keep in mind that any event that the correlator processes is potentially available to all loaded monitors. Consequently, you want to follow conventions that prevent the inadvertent matching of events with event listeners. These conventions are:

- Use packages to restrict the scope of event names (for example, `MyPackage`, `YourPackage`).
- Use duplicate event definitions with different event names (for example, `MyStartEvent`, `YourStartEvent`).
- Use discriminating/addressing information in the event (for example, `Request{integer senderId;...}, Response { integer toSender;...}`).

While event definitions provide partial support for a robust message exchange protocol, they lack the ability to specify event patterns, request-response associations, and so on. You should insert structured comments in your event definition files to define this part of the message exchange protocol. The comments that describe the relationships among the events define the contract that the participating monitors must adhere to. It is up to you to document the expected flows and patterns and to ensure that your monitors comply with the contract.

Some common message exchange patterns are:

- Request/response
- Publish/subscribe/unsubscribe
- Start/stop

To identify the event types that a core monitor needs to support, consider the following:

- What actions do you want to perform on the object that the monitor represents? You might want to define an event that is dedicated to each action. For example, for an order processing monitor, you might define an event type for each of the following actions:
  - Place an order
  - Change an order
  - Cancel an order
  - Suspend trading
  - Resume trading
- What initialization and termination events are needed? Keep in mind that a core monitor is typically a factory that creates monitor instances that each represent a single entity. You probably want to define at least one event type for initialization and one event type for termination.

- Do you need other control events? For example, in the order processing example, do you need a control event that suspends all trading and applies to all orders? See "Using events to control processing" on page 67.
- Do you need to add any events to observe what is happening in the monitor? For example, each order processing monitor could support a request/response protocol to inquire of its state or it could simply send an `OrderProcessingState` event each time there is a significant state change.

Using events to control processing

In addition to using events to share data, you can use events to control processing. Control events are like switches. You use them to move a monitor from one state to another. Control events typically contain little or no data; that is, they have one or no fields.

A common use for control events is to initialize or terminate a process. For example, rather than use an `onload()` statement to set things up, it is good practice to use a monitor's `onload()` statement to create an event listener for a start event. This practice defers initialization until the start event is received. Similarly, you can use a stop event to signal to a monitor that it should perform shutdown actions such as deallocating resources before you terminate the correlator.

For example, consider the following action:

```
action initialize() {
   on EndAuction() and not BeginAuction() startNormalProcessing;
   on BeginAuction() and not EndAuction() startAuctionProcessing;
   route RequestAuctionState(); //A service monitor will respond with
                                 //an EndAuction or BeginAuction event
}
```

In this code, `EndAuction` and `BeginAuction` can be viewed as control events. Receipt of one of these events determines whether the monitor executes the logic associated with being in an auction or out of an auction.

About service monitors

Of course, all monitors can be considered to be providing some kind of service. However, as mentioned earlier, it can be helpful to view the monitors that make up your application as either core processing monitors or service monitors. It is common for a single instance of a service monitor to provide data to a set of monitor instances spawned from a core processing monitor instance.

Apama provides a number of service monitors that fit this pattern. These service monitors provide support for the following:

- Dataview service — exposes read-only data to dashboards. This data comes from EPL and Java applications.
- Password service — supports retrieval of passwords from implementation-specific providers.

- Scenario service — provides support for all scenario-based applications.

In addition, there are a number of service monitors for use by adapters:

- ADBC adapter — provides event capture and playback in conjunction with Apama's Data Player in Software AG Designer. Also monitors Java database connectivity (JDBC) and open database connectivity (ODBC).
- IAF status manager — monitors connectivity with an adapter.

Adding predefined annotations

Some EPL language elements can take predefined annotations. They provide the runtime and Software AG Designer with extra information about these language elements. Annotations can appear immediately before the following:

- Monitor declarations
- Event declarations
- Fields of events
- Actions in monitors or event definitions

Annotations have packaged names like events. Thus, either their full name, or (preferably) a `using` declaration should be added to the file to allow the name to be used without having to specify its full name. Annotations are written as an at symbol (@) followed by the name of the annotation, followed by parameters in parentheses. The values used in annotation parameters must be literals. If both annotations and ApamaDoc are specified, the order should be: ApamaDoc, followed by annotations, followed by the language element that they apply to.

The following annotations are available:

Annotation	Parameters	Description
`SideEffectFree`	None	This annotation is part of the `com.apama.epl` package. It tells the EPL compiler that this action has no side effects. When called from a log statement, the compiler is free to not call an action if it has no side effects and the log level is such that the log statement would not print anything to the log file. See "Logging and printing" on page 295.
`OutOfOrder`	None	This annotation is part of the `com.apama.queries` package. It tells the query runtime that these events

Annotation	Parameters	Description
		may occur out of order. See "Out of order events" on page 114.
TimeFrom	string	This annotation is part of the com.apama.queries package. It tells the query runtime the default action name on the event definition to obtain source time from. See "Using source timestamps of events" on page 107.
Heartbeat	string	This annotation is part of the com.apama.queries package. It tells the query runtime the default heartbeat event type to use. See "Using heartbeat events with source timestamps" on page 112.
DefaultWait	string	This annotation is part of the com.apama.queries package. It tells the query editor in Software AG Designer the default time to wait to use. See "Using source timestamps of events" on page 107.
ExtraFieldsDict	string	This annotation is part of the com.softwareag.connectivity package. It names a field of type dictionary<string,string> where the apama.eventMap connectivity host plug-in will place unmapped entries. See "Translating EPL events using the apama.eventMap host plug-in" in *Connecting Apama Applications to External Components*.

Example:

```
using com.apama.epl.SideEffectFree;
monitor SomeMonitor {
    action onload() {
        Event e;
        on all Event():e {
            log prettyPrint(e) at DEBUG;
        }
    }
    @SideEffectFree()
    action prettyPrint(Event e) returns string {
        return e.field1 +" : "+e.field2.toString();
    }
```

```
}
```

Subscribing to channels

Adapters and clients can specify the channel to deliver events to. In EPL, you can send an event to a specified channel. To obtain the events delivered to particular channels, monitor instances and external receivers can subscribe to those channels.

In a monitor instance, to receive events sent to a particular channel, call the `subscribe()` method on the `monitor` pseudo-type by using the following format:

```
monitor.subscribe(channel_name);
```

Replace *`channel_name`* with a string expression that indicates the name of the channel you want to subscribe to. You cannot specify a `com.apama.Channel` object that contains a string.

Call the `subscribe()` method from inside an action. Any monitor instance in any context can call `monitor.subscribe()`.

The `subscribe()` method subscribes the calling context to the specified channel. When a context is subscribed to a channel events delivered to that channel are processed by the context, and can match against any listeners in that context. This includes listeners from monitor instances other than the instance that called `subscribe()`. However, the subscription is owned by the monitor instance that called `monitor.subscribe()`. If that monitor instance terminates, then any subscriptions it owned also terminate.

A subscription ends when the monitor instance that subscribed to the channel terminates or executes `monitor.unsubscribe`.

Whether an event is coming into the correlator or is generated inside the correlator, it is delivered to everything that is subscribed to the channel. If the target channel has no subscriptions from monitor instances nor external receivers then the event is discarded.

For example:

```
monitor pairtrade
{
   action onload()
   {
      on all PairTrade(): pt {
         spawn start_trade(pt.left, pt.right) to context(pt.toString());
      }
   }

   action start_trade(string sym1, string sym2)
   {
      monitor.subscribe("ticks-"+sym1);
      monitor.subscribe("ticks-"+sym2);
      // Next, set up listeners for sym1 and sym2.
      . . .
   }
}
```

This code spawns a monitor for each trade pair. The spawned monitor subscribes to just the ticks for the symbols passed to it. If a symbol in one pair is slow to process, any unrelated pairs of symbols are unaffected. See *Event association with a channel* in *Deploying and Managing Apama Applications*.

In a context, any number of monitor instances can subscribe to the same channel. When multiple monitors in a context require data from a channel the recommendation is for each monitor to subscribe to that channel. This ensures that the termination of one monitor does not affect the events received by other monitors. Subscriptions are reference counted. The result of multiple subscriptions to the same channel from the same context is that each event is delivered once as long as any of the subscriptions are active. An event is not delivered once for each subscription.

Suppose that in one monitor instance you unsubscribe from a channel but another monitor instance in the same context is subscribed to that channel. In the monitor instance that unsubscribed, be sure to terminate any listeners for the events from the unsubscribed channel. Events from the unsubscribed channel continue to come in because of the subscription from the other monitor instance.

To explicitly terminate a subscription, call `monitor.unsubscribe(`*`channel_name`*`)`. In a given context, if you terminate the last subscription to a particular channel then the context no longer receives events from that channel. If events from the previously subscribed channel were delivered but not yet processed (they are waiting on the input queue) those events will be processed. This could include the processing of any listener matches. It is an error to unsubscribe from a channel that the calling monitor instance does not have a subscription to, and this will throw an exception.

If a monitor is going to terminate anyway there is neither requirement nor advantage to calling `unsubscribe()`. Calling `unsubscribe()` can be useful when a monitor listens to configuration data during startup but does not need to listen to it during normal processing.

Note: The `subscribe()` and `unsubscribe()` methods are static methods on the `monitor` type. However, it is not possible to use instances of the `monitor` type. For example, there cannot be variables or event members of type `monitor`.

See also "Channels and contexts" on page 310.

Apama queries cannot subscribe to channels. However, events sent on the default channel as well as events sent on the `com.apama.queries` channel are received by all running Apama queries. See "Defining Queries" on page 75.

If a correlator is configured to connect to UM then a channel might have a corresponding UM channel. If there is a corresponding UM channel the monitor is subscribed to the UM channel. See *Choosing when to use UM channels and when to use Apama channels* in *Connecting Apama Applications to External Components*.

About the default channel

The name of the default channel is the empty string.

Public contexts, including the main context, are always subscribed to the default channel. Contexts that Apama queries run in are also always subscribed to the default channel.

When an adapter or client that is sending events to the correlator does not specify a target channel the event goes to the default channel. There is no need for a public context to subscribe to the default channel.

Events generated by the `enqueue` or `route` statements are not delivered to the default channel.

An adapter that is using Universal Messaging (UM) to send events cannot use the default channel. See *Configuring adapters to use UM* in *Connecting Apama Applications to External Components*.

About wildcard channels

An external receiver can be configured to listen on the `com.apama.input` channel, which is a wildcard channel for all events that come into the correlator. This can be useful for diagnostics, testing, or auditing, but it is not recommended for production. In a production environment, the recommendation is to explicitly specify the channels that the receiver should listen on.

A monitor instance cannot subscribe to `com.apama.input`.

To configure an external receiver to process all events generated in the correlator, specify that the receiver listens on the default channel (`""`). With this specification, a receiver would get all events generated by the `send...to` *`channel`* and `emit` statements regardless of the channel the event was directed to. Events generated by the `enqueue` or `route` statements are not delivered to the default channel.

Adding service monitor bundles to your project

Depending on what your Apama application does, it might require one or more provided service monitors. Apama organizes service monitors into bundles. To use the service, you add the bundle to your Apama project in Software AG Designer.

To add a bundle to your project

1. In the Apama Developer perspective, open the project that you want to add the bundle to.
2. In the **Developer Project View**, right-click the project name and select **Properties** from the menu that appears.
3. In the **Properties** dialog, select **MonitorScript Build Path**.
4. Select the **Bundles** tab.
5. Click **Add** to display a list of Apama bundles.
6. Select the bundle you want to add.

7. Click OK twice.

The bundle now appears in the **Developer Project View** panel. Expand the bundle directory to see the contents. To understand exactly what each service monitor provides, open the service's EPL file in Software AG Designer. The comments in the EPL file explain the purpose of each service monitor and how to use it.

You can also write your own service monitors. Best practices for doing this include:

- Follow good engineering practices for defining message exchange protocols
- Copy the conventions used in the Apama-provided service monitors as these monitors implement common patterns.

Utilities for operating on monitors

Apama provides the following command-line utilities for operating on monitors. For details about using these utilities, see *Deploying and Managing Apama Applications*, "Correlator Utilities Reference".

- `engine_inject` — injects files into the correlator.
- `engine_delete` — removes items from the correlator.
- `engine_send` — sends Apama-format events to the correlator.
- `engine_receive` — lets you connect to a running correlator and receive events from that correlator.
- `engine_watch` — lets you monitor the runtime operational status of a running correlator.
- `engine_inspect` — lets you inspect the state of a running correlator.
- `engine_management` — lets you shut down a running correlator or obtain information about a running correlator. You can also use this utility to manage other types of components, such as adapters, sentinel agent processes, and continuous availability processes.

3 Defining Queries

A query is one of the basic units of EPL program execution.

Note: The other basic unit is a monitor. A monitor cannot contain a query. A query cannot contain a monitor. For information about writing monitors, see "Defining Monitors" on page 49. For a comparison of queries and monitors, see "Architectural comparison of queries and monitors" on page 79.

Apama queries are suitable for applications where the incoming events provide information updates about a very large set of real-world entities. Apama provides several sample query applications, which you can find in the `samples\queries` directory of your Apama installation directory.

The topics below provide information and instructions for defining queries.

For reference information, see "Queries" on page 853.

See also: "Using Query Designer" in *Using Apama with Software AG Designer* and "Deploying and Managing Queries" in *Deploying and Managing Apama Applications*.

Introduction to queries

An Apama query is a self-contained processing element that communicates with other queries, and with its environment, by sending and receiving events. Queries are designed to be multithreaded and to scale across machines.

You use Apama queries to find patterns within, or perform aggregations over, defined sets of events. For each pattern that is found, an associated block of procedural code is executed. Typically this results in one or more events being transmitted to other parts of the system.

Note: If a license file cannot be found while the correlator is running, several restrictions are enforced on queries. See "Running Apama without a license file" in *Introduction to Apama*.

Example of a query

The following code provides an example of a query. This query monitors credit card transactions for a large set of credit card holders. The goal is to identify any fraudulent transactions. While this example illustrates query operation, it is not intended to be a realistic application.

```
query ImprobableWithdrawalLocations {
   parameters {
      float period;
   }
   inputs {
      Withdrawal(value>500) key cardNumber within period;
   }
   find Withdrawal:w1 -> Withdrawal:w2
      where w2.country != w1.country {
      log "Suspicious withdrawal: " + w2.toString() at INFO;
   }
}
```

Each query definition is in a separate file that has a `.qry` file name extension. The example shows several query features:

- Parameters section

  Queries can be parameterized. When a query has no parameters, a single instance of the query is automatically created when the query is loaded into a correlator. If one or more parameters are defined for a query, when the query is loaded into a correlator, no instances are created until you define an instance and specify a set of parameter values for that instance.

- Inputs section

  The `inputs` section identifies the events that the query will operate on, that is, the event inputs. This section contains one or more definitions. Each definition identifies the type of input event (`Withdrawal` in the example) together with details identifying which `Withdrawal` events are input, how those events are distributed, and what state, or event history, is to be held.

  The query key is a fundamental concept. If a key is defined, then the incoming events are partitioned into different sets based on the value of the key. Query processing operates independently for each set/partition. In the example query, events for each `cardNumber` will be independently processed.

  For each event input, the definition identifies the set of events that are current. When looking for pattern matches or evaluating aggregates, only current events are used. For each event input, the set of events that is current is referred to as the event window.

- Find statement

  The `find` statement identifies an event pattern to be matched and defines what event processing actions are taken when a match is found. A `find` statement consists of an event pattern followed by a `find` block.

  The event pattern can specify conditions that determine whether there is a match. A `where` condition specifies a Boolean expression that must evaluate to true for there to be a match. A `within` condition specifies that certain elements within the pattern must occur within a given time period. A `without` condition specifies an event whose presence can prevent a match.

  Statements in a `find` block can send events to communicate with other queries, with monitor instances, and with external system elements in a deployment, such as adapters, correlators, or other deployed processes. Some EPL statements, such as `on`, `spawn`, `from`, and `die` are not allowed in queries.

Use cases for queries

Apama queries are useful when you want to monitor incoming events that provide information updates about a very large set of real-world entities such as credit cards, bank accounts, cell phones. Typically, you want to independently examine the set of events associated with each entity, that is, all events related to a particular credit card account, bank account, or cell phone. A query application operates on a huge number of independent sets with a relatively small number of events in each set.

One use case for Apama queries is to detect subsequent withdrawals from the same bank account but from locations that make it improbable that the withdrawals are legitimate. Very large numbers of withdrawal events would stream into your application. A query can segregate the transactions for each bank account from the transactions of any other bank account. Your query application can then check the transaction events for a particular account to determine if there have been withdrawals within, for example, a two-hour period from locations that are more than two hours apart. You can write a query application so that if it finds this situation the response is to contact the credit card holder.

Another use case is to detect repeated maximum withdrawals from the same automatic teller machine (ATM) within a short period of time. This might be due to a criminal with a stack of copied cards and identification numbers. In this case, a query can segregate events by ATMs. That is, the transactions conducted at a particular ATM would be in their own partition, separate from transactions conducted at any other ATM. Your query application can check the events in each partition to determine if, for example, there are repeated withdrawals of $500 within one hour. If such a situation is found your query can be written to send an alert message to the local police.

Another use case for Apama queries is to offer a better data plan to new smartphone users. Large numbers of events related to cell phone customers would come into the system. Your query application can create sets of events where each set, or partition, contains the events related to one cell phone customer. When your query detects an upgrade from a flip phone to a smart phone, your application can automatically send a message to that customer that outlines a better data plan.

In summary, the characteristics of an Apama query application include:

- You want to monitor a very large number of real-world entities.
- You want to process events on a per-entity basis, for example, all events related to one credit card account.
- The data you need to retain in order to run Apama queries is either too large to fit on to a single machine or there is a requirement to place it in shared, fast-access storage (a cache) to support resilience/availability requirements.

More information about the use cases for queries can be found in "Understanding queries" in *Introduction to Apama*.

Delayed and out of order events

In many of the typical applications envisaged for Apama queries, the input events may be either delayed or out of order. For example, cars and other mobile sources of events such as smart phones and tablet computers might normally send regular streams of events, but when such devices are out of network coverage, these events will have to be batched and sent when back in range. Many older generation factory robots store events and only send periodic batches by design. And in other cases, events may be sent out of order. Television set top boxes, for example, often employ distinct channels for tuning information and diagnostics. This means that a "channel changed" event may be received before a "set top box crashed" event, and so may be thought to have caused it, even though the event in fact happened after it, and was causally unconnected.

Delayed or out of order events can create problems for the query runtime because it assumes that events should be treated as being in the order in which they are processed, and the time of each event is the correlator's time at the point the event is processed. However, provided that the input events contain a timestamp recording the time that the event was created at the source, these problems can be overcome by using the Apama queries source timestamp functionality. This allows the queries runtime to wait for specified periods before processing events, and then to process those events on the basis of their source timestamps rather than the time they were received by the correlator. (For out of order events, the Apama event definitions must have the appropriate annotation; for more information, see "Out of order events" on page 114).

Events can also be supplemented by heartbeat events with timestamps from data sources to inform the query runtime when communication with the data source is working correctly, which avoids long delays waiting for events to occur in case they are delayed.

See "Using source timestamps of events" on page 107 for details on how to configure Apama queries to use source timestamps.

Architectural comparison of queries and monitors

In some ways, an Apama query is similar to an Apama monitor. Each operates as a self-contained event processing agent that communicates with other monitors and queries by sending and receiving events.

Note: While Apama queries and Apama stream queries use similar terminology, they are different constructs. Apama queries can communicate with monitors but Apama queries are not contained in monitors. Whereas Apama stream queries are defined and operate inside monitors.

One difference between a monitor and a query is the programming model for scaling. With monitors, the approach is procedural. A `spawn` statement is used to create new monitor instances. Typically, for each real-world entity, a separate monitor instance is used to handle the events relating to that entity. The developer has full control over what data is held where as well as the design of the solution architecture. With queries, the approach is declarative. A key is defined which is used to identify how the events are partitioned such that events from each real-world entity are handled separately. Also, queries can use a distributed Apama MemoryStore to share historical data between correlators. This allows query deployments to scale across several hosts, make the same data available to multiple correlators and provide availability should a correlator fail or be taken down for maintenance.

Another difference between monitors and queries is the way in which they handle the state, or event history. With monitors, each monitor instance holds the state, or event history, needed for its continuing processing. This state is held in memory, which allows high-performance processing over complex state. With queries, the only state is the event history, which is held separately from the query. The query is effectively stateless, which allows queries to easily scale across correlators.

Typically, a monitor instance operates on events that relate to a particular real world entity. To operate on events related to another entity in the same set, the monitor typically spawns another instance. In contrast, the definition of a query specifies how to partition incoming events so that each set of events that relates to a particular real-world entity is in its own partition. The query operates on the events in each partition independently of every other partition.

The following table compares monitor variables with query parameters:

Monitor variables	Query parameters
Can store any complex state that the monitor requires	Must be one of the following types: `boolean`, `float`, `integer`, `string`.
Can be updated by the monitor.	Can only be read by the query.
Are private to that monitor instance.	Are controlled by Scenario Service clients.

A monitor can subscribe to a channel to receive all events sent on that channel. A query cannot subscribe to a channel. However, running Apama queries automatically receive all events sent on the `com.apama.queries` channel as well as all events sent on the default channel. For example, monitors, adapters, and the `engine_send` utility can send events to the `com.apama.queries` channel.

Both monitors and queries can send events to a channel. In both monitors and queries, the `send` command sends events to only those components that are connected to that correlator. For both monitors and queries, sending events to other correlators in the cluster requires connections created by the `engine_connect` utility or the use of Universal Messaging to connect the correlators to the same set of UM channels.

In general, monitors follow a more imperative pattern while queries have more declarative clauses. For example, a monitor can use conditional `if...then...else` statements to determine whether there is a match that triggers some processing. A query specifies `where`, `within`, and/or `without` clauses to define filters, time constraints, and exclusions, respectively, right in the event pattern. In general, this allows queries to be simpler than monitors.

Query terminology

The following table defines important query terms.

Term	Description
query	A self-contained processing unit. It partitions incoming events according to a key and then independently

Term	Description
	processes the events in each partition. Processing involves watching for an event pattern and then executing a block of procedural code when that pattern is found.
input	An event type that a query operates on. An input definition specifies an event type plus details that indicate how to partition incoming events and what state, or event history, is to be held.
key	A query key identifies one or more fields in the events being operated on. Each input definition must specify the same key.
partition	A partition contains a set of events that all have the same key value. One or more windows contain the events added to each partition.
window	For each input, a window contains the events that are current. The query operates on only current events.
latest event	The latest event is the event that was most recently added to a partition.
set of current events	The events that are in the window(s) of a partition.
pattern	Specification of the event or sequence of events or aggregation that you are interested in. A pattern can include conditions and operators.
match set	A match set is the set of events that matches the specified pattern. A match set always includes the latest event.
parameterization	A query definition that specifies parameters is a parameterized query. An instance of a parameterized query is referred to as a parameterization.
source timestamp	The time an event occurred at its source. This may be before it is processed if there is some delay or disruption in delivering the event from the source to the query runtime. This will be data in one or more fields of an input event. Queries can use the source timestamp if an action is provided to obtain the source timestamp in the correct

Term	Description
	form. See "Using source timestamps of events" on page 107.
heartbeat event	An event that a query uses to determine when communication with a data source is working correctly, and it has not missed any events that are delayed. With heartbeat events, received input events can be processed as they are considered definitive. Without these, the query runtime needs to wait for the input's wait time specified in the query definition to ensure it avoids missing delayed events.
definitive time	The point in time for which the query runtime has been told that it can assume it has received all the events it is going to receive. All events at or before this point in time are considered definitive and can be used to evaluate the query. This applies when using the source timestamp functionality.

Overview of query processing

When Apama executes queries, it does so in parallel, making use of multiple CPU cores as available. This is good for performance, but uses more resources on the hosts running the correlator and can, in edge cases, cause events to be processed in an order that is different from the order in which they were delivered to the correlator. To simplify testing, a serial mode is supported where events are processed in order, no matter how quickly they are sent.

Apama processes queries as follows:

1. Based on the `inputs` section of a query, the query subsystem creates listeners for the required events.
2. Running Apama queries receive events sent on the default channel and on the `com.apama.queries` channel.
3. Events matching those listeners are forwarded to the query subsystem that processes the events.
4. The events are processed in parallel. That is, multiple threads of execution are employed, thereby achieving vertical scaling on machines that have multiple cores.
5. The query subsystem must locate the relevant events for the query partition. That is, the previously encountered events that are still current according to the defined event windows for that query. The information in the incoming event, that is, the key, is all that is required to locate these events.

6. The window contents are updated, adding the new event and discarding any events that are no longer current.
7. The system then checks the updated window contents to determine if there are any new pattern matches.
8. For each new pattern match the associated `find` block statements are executed.

In a single correlator solution, events in a particular partition are held in one or more Apama MemoryStore records. The key from the incoming event is used to locate these records. In a multi-correlator solution, the records are held in a distributed cache, accessed by means of the MemoryStore API. All of this is internal, however, you should consider timing constraints when deciding whether a query-based solution is appropriate for a given problem. See "Understanding queries" in *Introduction to Apama*.

After injecting a query into a correlator, events may be immediately sent to that query. If necessary, Apama stores these events until the query is prepared. That is, the query might be opening local/remote stores. Events are delivered when the query is ready to process them. There is no guarantee that the order in which the events arrived in the correlator is the same order in which the query processes them. See "Event ordering" in "Testing query execution" on page 155.

When testing, either send events at a realistic event rate, with pauses in between each set of events, or use single context mode. To send events with pauses, you can place `BATCH` entries in the `.evt` file. See "Event timing" in *Deploying and Managing Apama Applications*.

By default, the query subsystem determines the size of the machine it is running on (the number of cores) and scales accordingly. If other services are affected by the load on the host machine, or for testing, then send one of the following events to the correlator (for example, by creating an `.evt` file in Software AG Designer and sending it as part of the Run Configuration) to configure how the correlator executes queries:

- `com.apama.queries.SetSingleContext()`
- `com.apama.queries.SetMultiContext()`

Overview of query application components

While queries can make up the central logic of an Apama deployment, deploying an Apama query application also requires event definitions, and connections to event sinks and event sources. Optionally, an Apama query application can make use of correlator plug-ins, EPL actions, and interactions with EPL monitors.

In addition to queries, the following components are required to implement a query application.

- Event definitions. This includes event types used by adapters or mapped from message busses (see below) or used internally within application components. Typically, event types specific to an adapter or to existing messages on a message bus would be written by those creating or configuring the adapter.
- Connections between event sources and queries and also between queries and event sinks. This is typically handled by adapters or by mapping to messages on a message

bus by means of JMS. For testing, it is possible to use Software AG Designer or command line tools to send and receive messages.

- A correlator process. Several queries can share the same correlator process. Queries can be started by Ant scripts, which can be exported from an Apama project. For testing, Software AG Designer can start the queries.
- Optionally, queries can use a library of functions that you provide. These would be written in EPL and can call correlator plug-ins written in C++ or Java. Functions in such a library can be invoked from different points in a query.
- Optionally, a query can interact with monitors. See "Communication between monitors and queries" on page 157.

Additional information about query application architecture is in "Query application architecture" in *Deploying and Managing Apama Applications*.

Writing event definitions

Event definitions are defined in Apama `.mon` files. When writing event type definitions be sure to consider the following:

- An `inputs` block in a query can specify filters on event fields of type `boolean`, `decimal`, `float`, `integer`, `string` or `location`.
- An event field to be specified as a query key must be of type `boolean`, `decimal`, `float`, `integer`, `string` or `location`.
- An event field to be specified in an `inputs` block, whether as a filter or a key, cannot be marked with the `wildcard` modifier in the event type definition.
- A `where` condition in a query can make use of all actions and fields of events, including members of reference types such as `sequence`, `dictionary` and other events.
- Specifying an event filter in an `inputs` block is very efficient because it prevents any part of the query from executing if the filter condition does not match. However, a filter in an `inputs` block can operate on only contiguous ranges and can compare only a single field to a constant or parameter value.

  Specifying an event filter in a `where` condition is more expensive than specifying an event filter in an `inputs` block. However, a filter in a `where` clause can be more powerful because it can specify any EPL expression.
- A query cannot use an event that contains an `action` variable or fields of type `chunk` or `listener`.
- If you want to take advantage of the source timestamp functionality, be sure to add an event field that records the time of the creation of the data encapsulated in the event, and an action that returns this time in the form of a float representing the number of seconds since the epoch (midnight , 1 Jan 1970 UTC). If the time data is not in this format, you can use the TimeFormat Event library to perform the relevant conversions (for further information, see "Using the TimeFormat Event Library" on page 357).

For example, consider the following event definitions:

```
event Slice {
    integer quantity;
    float price;
}
event UsableEvent {
    integer quantity;
    string username;
    wildcard string auxData;
    sequence<Slice> slices;
    action averagePrice() returns float {
        float t:=0;
        Slice s;
        for s in slices {
            t:=t+s.price;
        }
        return t/(slices.length().toFloat());
    }
}
event InternalEvent {
    action<> returns float  averager;
}
```

`UsableEvent.quantity` and `UsableEvent.username` can be used in a query `inputs` block or in a query `where` condition.

`UsableEvent.auxData`, `UsableEvent.slices` and `UsableEvent.averagePrice()` can be used in `where` conditions but not in `inputs` blocks.

`InternalEvent` cannot be an input to a query because it has an `action` variable. However, an instance of `InternalEvent` could be used in a `where` condition or in triggered EPL code in a `find` block.

For example, the `find` statement in a query can be written as follows:

```
find UsableEvent:e1 and UsableEvent:e2
   where e1.averagePrice() > e2.averagePrice()
   and
   e1.slices[0].price < e2.slices[0].price
```

Action definitions can supply helper actions such as the `averagePrice()` action above. This can be useful in both event types used by adapters and in internal event types. For example, some event types may have no members but simply be a named container for useful library actions.

To make use of correlator plug-ins, written in C, C++ or Java, it is recommended to write an EPL event type or set of event types that wrap the plug-in. This provides a more consistent interface and can add type safety to the use of chunks, which are opaquely-typed C, C++ or Java objects. These EPL actions can then be called from queries, as can any EPL action.

Event sinks and sources

A typical deployment includes adapters that connect the Apama system to external sources of data or provide the means to send events out of Apama. This can include:

- Adapters hosted in the Apama IAF. See "Using the IAF" in *Connecting Apama Applications to External Components*.
- Connections to a JMS message bus with mapping of JMS messages to Apama event types. See "Correlator-Integrated Messaging for JMS" in *Connecting Apama Applications to External Components*.
- Connections to a database by means of ADBC. See "Using the Apama Database Connector" in *Connecting Apama Applications to External Components*.
- Connections to other components using the Apama `engine_client` library. See "Developing Custom Clients" in *Connecting Apama Applications to External Components*.

For testing purposes, Software AG Designer can send / receive events from / to files, and command line tools are provided as well.

Correlator process

When developing queries in Software AG Designer, launching a configuration starts a correlator and injects queries into it by default. It is also possible to export the Apama launch configuration to an Ant script, which can be copied onto another machine such as a server to run your project on that machine.

It is possible to run multiple correlators that are configured to use the same distributed cache store. These correlators share query state. In such deployments, the recommendation is to use a JMS Message Queue. Typically, these deployments would use correlators on separate physical machines so a failure of one does not affect others. For testing, it is possible to run several correlators on a single machine provided a separate port number is allocated to each correlator. Take care to use the correct port number when interacting with the correlators.

Format of query definitions

A query searches for an event pattern that you specify. You define a query in a file with the extension `.qry`. Each `.qry` file contains the definition of only one query. The following sample shows the definition of a simple query that will search for a `Withdrawal` event pattern:

```
query ImprobableWithdrawalLocations {
    metadata {
        "author":"Apama",
        "version":"1"
    }
    parameters {
        float period;
    }
    inputs {
        Withdrawal() key cardNumber within (period);
    }
    find
        Withdrawal:w1 -> Withdrawal:w2
        where w2.country != w1.country {
        log "Suspicious withdrawal: " + w2.toString() at INFO;
    }
```

```
}
```

The format for a query definition is as follows:

```
query name {
   [ metadata { metadata_block } ]
   [ parameters { parameters_block } ]
   inputs { inputs_block }
   find pattern block
   [ action_definition ... ]
}
```

Syntax Element	Description
`query name`	Specify the `query` keyword followed by a name for your query. Like monitors and event types, the identifier you specify as the name of a query must be unique within your application.
`metadata`	The `metadata` section is optional. If you specify a `metadata` section, it must be the first section in the query. Metadata are specified as a list of key-value pairs. Both key and value must be `string` literals. For more information, see "Defining metadata in a query" on page 88.
`parameters`	The `parameters` section is optional. If you specify a `parameters` section, it must follow the `metadata` section, if there is one, and precede the `inputs` section. Parameters must be `integer`, `float`, `string` or `boolean` types. Specify one or more *`data_type parameter_name`* pairs. Any parameters you specify are available in the `inputs` section and in the `find` statement. For more information about parameters and how parameters get their values, see "Implementing parameterized queries" on page 146.
`inputs`	The `inputs` section is required and it must follow the `parameters` section, if there is one, and precede the `find` statement. In the `inputs` section, you must define at least one input. If you specify more than one input each input must be a different event type. The `inputs` section specifies the events that the query operates on. An input definition can include the keyword, `key`, followed by one or more fields in the specified event. This is the query key. The correlator uses the key to partition incoming events into separate windows. For example, the `cardNumber` key indicates that there is a separate window for the `Withdrawal` events for each

Syntax Element	Description
	card number. In other words, each window can contain `Withdrawal` events associated with only one account. For details, see "Defining query input" on page 94.
`find` statement	After the `inputs` section, you must specify a `find` statement. A `find` statement specifies the event pattern of interest and a block that contains procedural code. This code can define EPL actions you want to perform when there is a match. For more information, see "Finding and acting on event patterns" on page 120.
`action_definition`	After the `find` statement, you can optionally specify one or more actions in the same form as in EPL monitors. An expression in a `find` statement can reference an action defined in that query. See "Defining actions in queries" on page 145.

Defining metadata in a query

You can record information about a query in the `metadata` section. This can be, for example, the recording author, the version number, or the last modified date of a query. Once defined, metadata information about a query can be viewed in the Scenario Browser. See also "Using the Scenario Browser view" in *Using Apama with Software AG Designer*.

Format for defining query metadata

You define query metadata in the `metadata` section of a query definition. The `metadata` section is optional. If you specify a `metadata` section, it must be the first section in the query. The format for specifying the `metadata` section is as follows:

```
metadata {
key:value
   [ , key:value ]...
}
```

key and *value* must be `string` literals. Both are case-sensitive.

value can be a multi-line string.

key must be a valid EPL identifier (see "Identifiers" on page 919). Therefore, *key* must not include spaces, hyphens, dots or any other characters that are not allowed in EPL identifiers.

All *key* definitions that are contained in a single `metadata` section of a query must be unique.

It is recommended to use lowerCamelCase style for the key. The prefix "apama" should not be used for the key as it is reserved for future use.

Partitioning queries

Based on the values of selected fields in incoming events, the correlator segregates events into many separate partitions. Partitions typically relate to real-world entities that you are monitoring such as bank accounts, cell phones, or subscriptions. For example, you can specify a query that partitions `Withdrawal` events based on their account number. Each partition could contain the `Withdrawal` events for one account. Typically, a query application operates on a huge number of partitions with a relatively small number of events in each partition.

Each partition is identified by a unique key value. You specify a `key` definition in each input definition in the query's `inputs` block. The `key` definition specifies one or more fields in the event type you want to monitor. The number, order and type of the key fields must be the same in each input definition in a query.

A query operates on the events in the windows in each partition independently of the other partitions.

Note: Several restrictions are enforced on queries if a license file cannot be found while the correlator is running. See "Running Apama without a license file" in *Introduction to Apama*.

Defining query keys

At runtime, each partition is identified by a unique key value, which is the value of one or more fields in the events that the query operates on.

Note: Using a key is optional. If you do not specify a key, all events the query operates on are in one partition. Since this is an unusual use case for queries, the documentation assumes that you always choose to specify a key.

An event member that is declared as a constant cannot be used as a query key.

In a query, each input definition in the `inputs` section specifies the query key in the `key` definition. The `key` definition specifies one or more fields in the event that the window will contain. For example:

```
query ImprobableWithdrawalLocations {
   inputs {
      Withdrawal() key cardNumber within (600.0);
   }
   find (Withdrawal:w1 -> Withdrawal:w2)
        where (w1.country != w2.country) {
            getAccountInfo();
            sendEmail();
        }
}
```

In this example, the definition for Withdrawal events specifies that the cardNumber field is the key. When the correlator processes a Withdrawal event, it adds the event to the partition identified by the Withdrawal event's cardNumber value.

Suppose the input definition in this example specifies two key fields:

```
inputs {
   Withdrawal() key cardNumber, cardType within (600.0);
}
```

Each partition is now identified by a combination of the cardNumber value and the cardType value. When you specify two or more key fields, insert a comma after each field except the last one. It is allowable to specify key fields in an order that is different than the order of the fields in the event.

When you specify more than one input in a query, each input definition must specify the same number and data type order of key fields. For example:

```
inputs {
   Withdrawal() key cardNumber within (600.0);
   AddressChange() key cardNumber retain 1;
}
```

For each input in this example, the key is the cardNumber field. The data type of the cardNumber field in the Withdrawal event must be the same as the data type of the cardNumber field in the AddressChange event.

Sometimes, a field in one event contains the same information as a field in another event but the two fields have different names. For example, information about the type of a card could be in the cardType field in Withdrawal events and the typeOfCard field in AddressChange events. In this situation, you must specify an alias for one of the event field names. You do this in the input definition's key definition. In the following example, as cardType in the second input definition specifies the alias:

```
inputs {
   Withdrawal() key cardNumber, cardType within (600.0);
   AddressChange() key cardNumber, typeOfCard as cardType retain 1;
}
```

When you specify more than one input, the key definition in each input definition must specify the same number of fields in the same order. Also, the data type of a field in one key definition must be the same as the data type of its corresponding field in every other key definition in the same inputs block. If the names of corresponding key fields are not the same, you must use the as keyword to specify an alias.

While specification of an alias for a key field name is sometimes required, it is always an option you can choose to use. For example:

```
inputs {
   Withdrawal() key number as cardNumber, cardType within (600.0);
   AddressChange() key number as cardNumber, typeOfCard as cardType retain 1;
}
```

An alias maps a field in an event to a key field. You cannot use an alias as a field of the event. For example, consider the following query:

```
query Q {
   inputs {
      A() key surname as lastName,  dob as dateOfBirth retain 5;
```

```
      B() key lastName, dateOfBirth retain 4;
   }
   find A:a -> B:b  ...
}
```

In the `find` block of this query, you can use the following

- `a.surname, a.dob` - Names of event fields
- `b.lastName, b.dateOfBirth` - Names of event fields
- `lastName, dateOfBirth` - Names of key fields

Query partition example with one input

A key can be one event field. For example:

```
query ImprobableWithdrawalLocations {
   inputs {
      Withdrawal() key cardNumber within (600.0);
   }
   find (Withdrawal:w1 -> Withdrawal:w2)
        where (w1.country != w2.country) {
            getAccountInfo();
            sendEmail();
   }
}
```

In the previous code fragment, the key is the `cardNumber` field in the incoming `Withdrawal` event type. When a `Withdrawal` event arrives the correlator adds it to the window in the partition identified by the value of the `Withdrawal` event's `cardNumber` field. For each partition, each unique card number in this example, the correlator maintains the window and evaluates the pattern separately from every other partition.

Suppose that `cardNumber` is the first field in `Withdrawal` events. The following table shows what happens at runtime.

Incoming Event	Goes Into Window in Partition Identified by This Key Value	Window Contents
`Withdrawal (12345, 50.0, ...)`	`12345`	`Withdrawal (12345, 50.0, ...)`
`Withdrawal (24601, 60.0, ...)`	`24601`	`Withdrawal (24601, 60.0, ...)`
`Withdrawal (12345, 10.0, ...)`	`12345`	`Withdrawal (12345, 50.0, ...),` `Withdrawal (12345, 10.0, ...)`

In the execution of this query, there is no interaction between the `Withdrawal` events for account number `12345` and the `Withdrawal` event for account number `24601`.

Query partition example with multiple inputs

The following query provides an example of partitioning with two inputs. This query operates on `APNR` (Automatic Plate Number Recognition) events and `Accident` events:

```
query DetectSpeedingAccidents {
   inputs {
      APNR() key road within(150.0);
      Accident() key road within(10.0);
   }
   find APNR:checkpointA -> APNR:checkpointB -> Accident:accident
      where checkpointA.plateNumber = checkpointB.plateNumber
      and checkpointB.time - checkPointA.time < 100
      // Which indicates the car was speeding
   {
      emit NotifyPolice(accident.road, checkpointA.plateNumber);
   }
}
```

The `road` field in an `APNR` event must be the same type as the `road` field in an `Accident` event. Assuming that `road` is a string, each partition is identified by a unique value for that string.

Suppose the correlator processes the following events in top to bottom order and that `road` is the first field in each event:

```
Accident("M11")

APNR("A14", "FAB 1", ...)

APNR("A14", "BSG 75", ...)

APNR("M11", "ZC 158", ...)

APNR("A14", "BSG 75", ...)

APNR("M11", "ZC 158", ...)

APNR("A14", "FAB 1", ...)

Accident("A14")
```

The following table shows which events are in which partitions. Note that in each partition, the `APNR` events are in one window and the `Accident` events are in another window. Although the events are in separate windows, the correlator time-orders the events across all windows in a partition.

Events in Partition Identified by "M11"	Events in Partition Identified by "A14"
`Accident("M11")`	`APNR("A14", "FAB 1", ...)`
`APNR("M11", "ZC 158", ...)`	`APNR("A14", "BSG 75", ...)`
`APNR("M11", "ZC 158", ...)`	`APNR("A14", "BSG 75", ...)`

Events in Partition Identified by "M11"	Events in Partition Identified by "A14"
	`APNR("A14", "FAB 1", ...)` `Accident("A14")`

In each partition, the query evaluates the event pattern against the events in the windows in that partition. The query does this for each partition separately from every other partition. In this example, when the correlator adds the `Accident("A14")` event to the partition identified by `"A14"` the event pattern is triggered if the `where` clause in the `find` statement evaluates to true. The event pattern is not triggered in the partition identified by `"M11"`.

About keys that have more than one field

A key can be made up of several event fields. For example, a `Transaction` event might contain a field that indicates the transaction source account and another field that indicates the transaction destination account. You can specify that you want to partition `Transaction` events according to each unique source/destination combination:

```
query TransactionMonitor {
   inputs {
      Transaction() key source, dest within PERIOD;
   }
...
}
```

In this example, there is a partition identified by the value of each `source`/`dest` combination. Each of the following events is added to a window in a different partition:

This Event	Is Added to the Window in the Partition Identified By
`Transaction(1, 100, ...)`	`1, 100`
`Transaction(1, 102, ...)`	`1, 102`
`Transaction(2, 100, ...)`	`2, 100`
`Transaction(2, 102, ...)`	`2, 102`

Regardless of the event pattern in the query, this query monitors the transfer of money from one specific account to another specific account. This query handles each transfer between the same two accounts separately from all other transactions.

Now suppose that there is an `Acknowledgement` event that acknowledges that a transaction has succeeded. It also has account source and account destination fields, but they are inverted when compared to the transaction event fields. That is, the source account for an acknowledgment is the destination account of the transaction. To ensure that the acknowledgments are added to the same partition as the corresponding transactions, the `key` definition specifies the `as` keyword:

```
inputs {
   Transaction() key source as txSource, dest as txDest within PERIOD;
   Acknowledgement() key dest as txSource, source as txDest within PERIOD
}
```

The query partitions events according to the combined values of the fields identified by `txSource` and `txDest`. The following table shows the partition that each event is added to.

This Event	Is Added to a Window in the Partition Identified By
`Transaction(1, 100, ...)`	`1, 100`
`Acknowledgement(100, 1, ...)`	`1, 100`
`Transaction(1, 102, ...)`	`1, 102`
`Transaction(2, 100, ...)`	`2, 100`
`Acknowledgement(100, 2, ...)`	`2, 100`

As you can see, a `Transaction` event and its `Acknowledgement` event are each added to a window in the same partition.

Defining query input

In a query definition, you must specify an `inputs` block that defines at least one input. The input definitions identify the events that you want the query to operate on. An input definition can specify particular content and it can also specify a number of events or a time period. For example:

```
query FraudulentWithdrawalDetection {
    inputs {
        Withdrawal(amount > 10.0)
            key cardNumber, cardType
            within 600.0;
        AddressChange()
            key cardNumber, typeOfCard as cardType
            retain 1;
     }
    find (Withdrawal:w1 -> Withdrawal:w2)
        where (w1.country != w2.country or w1.city != w2.city)
        without AddressChange:ac {
            getAccountInfo();
            if preferredContactType = "Email" then {
                sendEmail();
            }
            if preferredContactType = "SMS" then {
                sendSMS();
```

```
            }
    }
}
```

The previous code defines two inputs. For each input, there is an associated window of events. The first input window contains `Withdrawal` events and the second contains `AddressChange` events.

The input definition for the `Withdrawal` events specifies that each `Withdrawal` event in the window must have a value greater than `10.0` in the `amount` field. The input definition for the `AddressChange` events does not specify an event filter. Therefore, each `AddressChange` event that arrives is eligible to be in the window.

The next element in an input definition is the key definition. The key definition indicates how you want to partition the incoming events. If you define more than one input, the number, type and order of the key fields must be the same for each input. In the previous sample code, assume that the key fields for `Withdrawal` events, `cardNumber` and `cardType` are `integer` and `string`, respectively, and that the key fields for `AddressChange` events, `cardNumber` and `typeOfCard` are also `integer` and `string`, respectively. The two input keys match in number, type and order of key fields.

After the key definition, you can specify a `within` clause, a `retain` clause, or both. If you specify both, the `within` clause must be before the `retain` clause. A `within` clause specifies a period of time. Only events that arrive within that period of time are in the window. In the window that contains `Withdrawal` events, only `Withdrawal` events that have arrived in the last 10 minutes (`600.0` seconds) are in the window. A `retain` clause specifies how many events can be in the window. In the window that contains `AddressChange` events, only the last `AddressChange` event that arrived can be in the window. When an `AddressChange` event arrives, if an `AddressChange` event is already in the window it is ejected.

After the duration, you can optionally specify a `with unique` clause to prevent repeated values appearing in the window. If specified, the `with unique` clause lists one or more fields or actions on the event type (action names should be followed by open and close parentheses). If there is more than one event in the window after the `within` and `retain` specifications, then all but the latest are discarded. See "Matching only the latest event for a given field" on page 119.

The final, optional, element of an input definition is the specification of the event source timestamp and the associated wait period. If you expect that input events from a source will be subject to delays or may be received out of order, then you can specify a `time from` clause with the name of an action that returns a float specifying the number of seconds from the epoch (midnight, 1 Jan 1970 UTC) that the event was created. If you do this, you must also add a `wait` clause which requires a float or time literal specifying the maximum delay expected for these events. This tells the query runtime how long it must wait if it has not received any events before it can continue processing the events it has received. Both of these clauses require that the event definition must have a source timestamp recording the time of creation of the event, and a corresponding action that returns that timestamp in the form of a float representing the number of seconds since the epoch. In the example below, the query is gathering data from cars, which may be delayed if a vehicle goes out of network coverage. Accordingly, the input definitions specify that the source timestamps of the events are to be obtained from the events' getEcuTime actions which simply return the value of the events' ts float field. Further, the input definitions specify that in each case, the runtime should wait for up to 1 hour before continuing to process any events already received to allow for possible delays. For further details, see "Using source timestamps of events" on page 107.

```
event CarRPM {
    string carId;
    float ts;
    float rpm;
    action getEcuTime() returns float {
        return ts;
    }
}
event CarEngineTemp {
    string carId;
    float ts;
    float temp;
    action getEcuTime() returns float {
        return ts;
    }
}
event CarEngineMisfire {
    string carId;
    float ts;
    action getEcuTime() returns float {
        return ts;
    }
}
query DetectEnginePerformanceProblems {
  inputs {
    CarEngineTemp() key carId within 1 hour time from getEcuTime wait 1 hour;
    CarRPM() key carId within 1 hour time from getEcuTime wait 1 hour;
    CarEngineMisfire() key carId within 1 hour time from getEcuTime wait 1 hour;
  }
  find CarEngineTemp:t and CarRPM:r -> wait 1 minute
    where t.temp > T_THRESHOLD
    where r.rpm > R_THRESHOLD
    without CarEngineMisfire:misfire {
    log "Possible engine performance problem" + t.toString() + r.toString();
  }
}
```

Typically, you define one to four inputs. If you define more than one input, each must be a different event type. In other words, two inputs to the same query cannot be the same event type.

Queries can share windows

All query instances that have the same input definitions share the same windows. Two queries have the same input definitions when they specify:

- the same input event types (the order can be different)
- the same keys
- the same (if any) input filters
- the same use of source timestamps - that is, the same action named in time from clauses (wait times may be different)

- the same use of heartbeat events

Any `wait`, `within`, `retain` or `with unique` specifications can be different.

When two query instances have the same input definitions and no parameters are used in any input filters, then all instances of those query definitions can share window data. If parameters are used in input filters, then parameterizations with different parameter values each store data separately. This increases total storage requirements and cost of processing the queries.

If a query is already running and you inject a query that defines the same inputs or create a parameterization that defines the same inputs then the new query instance or new parameterization uses the same windows as the query that was already running. This means that events that were received before the new query was injected or before the parameterization was created can be in a match set for the new query instance or new parameterization. This can happen when an event arrives after the new query is injected or after the parameterization is created and that event completes the pattern that the new instance or parameterization is looking for.

To reduce the amount of memory storage required to run queries, you might want to adjust the input definition for a query so that it is the same as another query. For example, suppose query `Q` is consuming inputs `A`, `B`, and `X`, while query `P` is consuming inputs `A`, `B`, and `Y`. If both queries define both `X` and `Y` as inputs (as well as `A` and `B`) then they can share the same windows. This can be an advantage when there are many `A` and `B` events but comparatively few `X` and `Y` events. If many queries can be written with similar input sections then they can share windows, which can lead to very efficient use of memory.

If the reason for adding an input using source timestamps is simply in order to share window contents, then the wait time for this input can be zero to avoid unnecessary delays.

Format of input definitions

In a query definition, you define one or more inputs in the `inputs` block. The format of the `inputs` block is as follows.

```
inputs {
event_type(event_filter)
   key query_key [within_clause] [retain_clause]
   [with_unique_clause]
   [time_from_clause wait_clause [or_clause]] ;

   [ event_type(event_filter)
   key query_key [within_clause] [retain_clause]
   [with_unique_clause]
   [time_from_clause wait_clause [or_clause]] ; ]...
}
```

Syntax Element	Description
event_type	Name of the event type that you want to operate on. The event type must be parseable. See "Type properties summary" on page 811. Event type names can come from the root namespace, a `using` declaration, or a local package as specified in a `package` declaration.
event_filter	Optionally filter which events of this type you want to be in the window. For example, you might define the window to contain only the events whose `amount` field is greater than `10`. The rules for what you can specify for the event filter are the same as for what you can specify in an event template in EPL. See "Event templates" on page 830.
query_key	Specify one or more event fields. You can specify event fields of type `boolean`, `decimal`, `float`, `integer`, `string` or `location`. The correlator uses the key to partition the events. Each partition is identified by a unique key value. One or two fields in a key is typical. Three fields in a key is unusual and rarely needed. More than three fields is discouraged. When you define more than one input in a query ■ The number, type, and order of the key fields in each input definition must be the same. ■ If the names of the key fields are not the same in each input definition, you must specify aliases so that the names match. For details, see "Partitioning queries" on page 89.
retain_clause	Optionally specify `retain` followed by an EPL `integer` expression that indicates how many events to hold in the window. For example, if you specify `retain 1`, only the last event that arrived that is of the specified type and that has the key value(s) associated with that partition is in the window. You must specify a `retain` clause or a `within` clause or both. While it is possible to retain any number of events, you must ensure that you define an input that allows

Syntax Element	Description

	a match with the event pattern specified in the corresponding `find` statement. For example, the following query never finds a match:
	`query Q {`
	`    inputs {`
	`        A() key k retain 3;`
	`    }`
	`    find A:a1 -> A:a2 -> A:a3 -> A:a4 {`
	`        print a1.toString()+ " - "+a4.toString();`
	`    }`
	`}`

within_clause	Optionally specify `within` followed by a `float` expression or time literal that specifies the length of time that an event remains in the window. You must specify a `retain` clause or a `within` clause or both. See "Specifying event duration in windows" on page 101.
with_unique_clause	Optionally specify a set of secondary keys which constrains the window to only include the latest event for each value for the set of keys. See "Matching only the latest event for a given field" on page 119.
time_from_clause	Optionally specify `time from` followed by the name of an action that specifies how the source timestamp of the event can be obtained. The named action must be an action defined on that input event type. It must take no parameters and must return a float. This is taken to be when the event occurred, specified as seconds since the epoch. **Note:** You are not permitted to use the event's built-in `getTime()` method. This method returns the time when the correlator either processed or created the event, which defeats the purpose of the source timestamp functionality.
wait_clause	If a *time_from_clause* is provided, a *wait_clause* is required, which specifies `wait` followed by a `float` expression or time literal which specifies the maximum delay expected for events. This is how long a query will wait for events if it has not received any events. See also "Using heartbeat events with source timestamps" on page 112 and "Out of order events" on page 114.

Syntax Element	Description
or_clause	Optionally specify a heartbeat event type which informs the query runtime when communication with the data source is not delayed. See "Using heartbeat events with source timestamps" on page 112. This can only be specified if the *time_from_clause* and *wait_clause* are specified.

Behavior when there is more than one input

The correlator orders the events in a window according to the time it processes each event, that is, the time it adds the event to its window. When a query defines more than one input then, for each partition, the correlator maintains a single time-order for all events in all windows.

Suppose the correlator adds an event to a window and within 0.1 seconds the correlator adds a different event to the same window or to another window in the same partition. Outside a query, these two events might have the same timestamp because default correlator behavior is to increment the timestamp only every tenth of a second. In a query, however, if an event is added to a window within 0.1 seconds after another event was added to a window, the correlator assigns the second event a timestamp with enough significant digits to ensure that time order is preserved. The following code fragment shows the result of calling the `getTime()` method on two events that arrive within 0.1 seconds of each other:

```
find E:e -> F:f {
   print e.getTime().toString(); // Yields "1365761429.1"
   print f.getTime().toString(); // Yields "1365761429.100001"
}
```

The order of the events is important when the event pattern in a `find` statement specifies the followed-by operator. Consider this example:

```
query Q {
   inputs {
      A() key k retain 20;
      B() key k retain 10;
   }
   find A:a -> B:b { ... }
}
```

This pattern does not trigger when the correlator adds an `A` event to the `A` window. But if there is already an `A` event in the `A` window then this pattern triggers when a `B` event is added to the `B` window.

In a partition, at any one time, it is possible for the set of windows to contain multiple sets of events that, each taken in isolation, would match the defined event pattern. In this case, the event matching policy determines which of the candidate sets triggers an action. See "Event matching policy" on page 143 for a description of how the query chooses the event set that triggers an action. To illustrate event matching policy, that topic provides an example of query behavior when there is more than one window.

Specifying event duration in windows

In an input definition, you can specify an optional `within` clause that indicates the length of time that an event remains in the window. For example:

```
query FraudulentWithdrawalDetection {
    inputs {
        Withdrawal() key userId within 1 hour;
     }
    find Withdrawal:w1 -> Withdrawal:w2
        where w1.city != w2.city {
        log "Suspicious withdrawal: " + w2.toString() at INFO;
    }
    ...
}
```

In this example, a `Withdrawal` event remains in the window for 1 hour. After 1 hour in the window, an event is ejected. Each time an event is added to one of the windows in a partition, the correlator evaluates the find pattern for that partition. Ejection of an event from a window does not trigger pattern evaluation. There are two formats for specifying a `within` clause:

- `within` *`time_literal`*
- `within` *`float_expression`*

Parentheses in `within` clauses are allowed. The rules for specifying a time literal are:

- Specify one or more `integer` or `float` literal(s) and follow each one with a keyword that indicates a time unit.
- Time unit keywords are:
  - `day`, `days`
  - `hour`, `hours`
  - `min`, `minute`, `minutes`
  - `sec`, `second`, `seconds`
  - `msec`, `millisecond`, `milliseconds`

  Outside a query, you can use these keywords as identifiers. Inside a query, you cannot use these keywords as identifiers unless you prefix them with a hash symbol (#). See "Escaping keywords to use them as identifiers" on page 923.
- A space is required between an `integer` or `float` literal and its time unit. A space is required after a time unit if it is followed by an `integer` or `float` literal. Additional whitespace is allowed.
- If you specify more than one time unit keyword they must be in the order of decreasing size. For example, `days` must be before `minutes`.
- You need not specify all time units.
- Each time unit keyword must represent a different time unit, that is, you cannot, for example, specify both `day` and `days`.

Examples of valid time literals:

- `10 hours`
- `1 days 12 hours`
- `1 day 2 hours 30 minutes 4 sec`
- `2 days 5 minutes`
- `2.5 sec`
- `10 seconds` - This is equivalent to specifying the `float` expression `10.0`.

Note: While it is possible to define time literals using `float` values, for example, `3.5 days 12.5 hours 33.3 min`, it is recommended that you use only `integer` values when the specification includes more than one time unit. For example, rather than specifying `2 days 65.75 minutes`, you should specify `2 days 1 hour 6 min 15 sec`.

If you open and edit a query in Apama's Query Designer in Software AG Designer, it modifies the time literal (if necessary) such that it contains only integers. Also, the allowable range of integers is `0` to `23` for hours, `0` to `59` for minutes, `0` to `59` for seconds, and `0` to `999` for milliseconds. Where necessary, the Query Designer rounds up to a whole number of milliseconds. For example, suppose you specify the following time literal in EPL code:

```
3.5 days 4 hours 27.5 minutes 1002.75 milliseconds
```

The Query Designer converts this to 3 days 16 hours 27 minutes 31 seconds 3 milliseconds. The actual query designer display is: **3d 16h 27m 31s 3ms**.

When you specify a `float` expression it indicates a number of seconds.

Consider the example at the beginning of this topic as the following events are added to their appropriate windows:

Time	Event Added to Window
`10:00`	`Withdrawal("Dan", "London")`
`10:30`	`Withdrawal("Dan", "Dublin")`
`10:45`	`Withdrawal("Dan", "Paris")`
`11:15`	`Withdrawal("Ray", "Honolulu")`
`11:30`	`Withdrawal("Dan", "Rome")`

For the partition identified by a `userId Dan`, the query evaluates the pattern at the following times:

Time	Window Contents	Matching Events
`10:00`	`Withdrawal("Dan", "London")`	
`10:30`	`Withdrawal("Dan", "Dublin")` `Withdrawal("Dan", "London")`	`w1=Withdrawal("Dan", "London")` `w2=Withdrawal("Dan", "Dublin")`

`10:45`	`Withdrawal("Dan", "Paris")`
	`Withdrawal("Dan", "Dublin")`
	`Withdrawal("Dan", "London")`
		`w1=Withdrawal("Dan", "Dublin")`
		`w2=Withdrawal("Dan", "Paris")`

`11:30`	`Withdrawal("Dan", "Rome")` `Withdrawal("Dan", "Paris")`	`w1=Withdrawal("Dan", "Paris")` `w2=Withdrawal("Dan", "Rome")`

An event remains in its window for exactly the specified duration. For example, at 11:00, `Withdrawal("Dan", "London")` is no longer in the window and at 11:30, `Withdrawal("Dan", "Dublin")` is no longer in the window. Although the contents of the window have changed, ejection of an event does not cause evaluation of the event pattern.

At 11:15, there is no evaluation of the event pattern for the partition identified by a user Id of `"Dan"` because an event is added to a window in the partition identified by a user Id of "Ray".

Specifying maximum number of events in windows

In an input definition, you can specify a `retain` clause that indicates how many events can be in the window. For example:

```
query FraudulentWithdrawalDetection2 {
   inputs {
      Withdrawal() key userId retain 3;
   }
   find Withdrawal:w1 -> Withdrawal:w2 where w1.city != w2.city {
      log "Suspicious withdrawal: " + w2.toString() at INFO;
   }
}
```

In this query, only the most recent three `Withdrawal` events can be in the window. In other words, the window cannot contain more than three events. If only zero, one or two `Withdrawal` events with a particular key have arrived since the application was started then there would be only zero, one or two events, respectively, in the window.

The correlator evaluates the event pattern each time an event is added to the window. Suppose that at the indicated times the following events are added to the window in the partition identified by `userIdDan`:

Time	Event Added to Window
10:00	Withdrawal("Dan", "Dublin")
10:10	Withdrawal("Dan", "London")
10:20	Withdrawal("Dan", "London")
10:30	Withdrawal("Dan", "London")
11:30	Withdrawal("Dan", "Paris")

For the partition identified by the `userId Dan`, the query evaluates the pattern at the following times:

Time	Window Contents	Matching Events
10:00	Withdrawal("Dan", "Dublin")	
10:10	Withdrawal("Dan", "Dublin") Withdrawal("Dan", "London")	w1=Withdrawal("Dan","Dublin") w2=Withdrawal("Dan","London")
10:20	Withdrawal("Dan", "Dublin") Withdrawal("Dan", "London") Withdrawal("Dan", "London")	w1=Withdrawal("Dan","Dublin") w2=Withdrawal("Dan","London")
10:30	Withdrawal("Dan", "London")	

Time	Window Contents	Matching Events
	Withdrawal("Dan", "London") Withdrawal("Dan", "London")	
11:30	Withdrawal("Dan", "London") Withdrawal("Dan", "London") Withdrawal("Dan", "Paris")	w1=Withdrawal("Dan","London") w2=Withdrawal("Dan","Paris")

It is important to note that at 10:30, the Withdrawal("Dan", "Dublin") event that arrived at 10:00 is no longer in the window because the window retains three events at most and there are three Withdrawal events that have been added to the window more recently.

Specifying event duration and maximum number of events

In an input definition, you can specify a within clause that indicates how long an event can remain in the window and a retain clause that indicates how many events can be in the window. When you specify both a within clause and a retain clause the within clause must be before the retain clause. For example:

```
query FraudulentWithdrawalDetection3 {
   inputs {
      Withdrawal() key userId within 1 hour retain 3;
   }
   find Withdrawal:w1 -> Withdrawal:w2 where w1.city != w2.city {
      log "Suspicious withdrawal: " + w2.toString() at INFO;
   }
}
```

In this query, a Withdrawal event can be in the window for up to one hour and only the three most recent Withdrawal events, if each one arrived during the previous hour, can be in the window. In other words, the window cannot contain an event that arrived more than an hour ago and it cannot contain more than three events. If only two Withdrawal events arrived in the previous hour then there would be only two events in the window.

Suppose that at the indicated times the following events are added to the window in the partition identified by a userIdDan:

Time	Event Added to Window
10:00	Withdrawal("Dan", "Dublin")

Time	Event Added to Window
10:10	`Withdrawal("Dan", "London")`
10:20	`Withdrawal("Dan", "London")`
10:30	`Withdrawal("Dan", "London")`
11:30	`Withdrawal("Dan", "Paris")`

For the partition identified by `userId Dan`, the query evaluates the pattern at the following times:

Time	Window Contents	Matching Events
10:00	`Withdrawal("Dan", "Dublin")`	`w1=Withdrawal("Dan","Dublin")` `w2=Withdrawal("Dan","London")`
10:10	`Withdrawal("Dan", "Dublin")` `Withdrawal("Dan", "London")`	`w1=Withdrawal("Dan","Dublin")` `w2=Withdrawal("Dan","London")`

10:20	`Withdrawal("Dan", "Dublin")`
	`Withdrawal("Dan", "London")`
	`Withdrawal("Dan", "London")`	

10:30	`Withdrawal("Dan", "London")` `Withdrawal("Dan", "London")` `Withdrawal("Dan", "London")`	
11:30	`Withdrawal("Dan", "Paris")`	

It is important to note that at `10:30` the `Withdrawal("Dan", "Dublin")` event that arrived at `10:00` is no longer in the window because the window retains three events at most and there are three `Withdrawal` events that have been added to the window more recently. Also, at `11:30` there are no `Withdrawal("Dan","London")` events in the window as they have been ejected because more than one hour has elapsed since each one was added to the window.

Using source timestamps of events

By default, the query runtime assumes that events should be treated to be in the order in which they are processed, and the time of each event is the correlator's time at the point the event is processed. This is suitable if events are delivered reliably to the Apama correlator in a short amount of time and in order. However, if the events are delayed, accumulated into batches before being sent or delivered over unreliable networks, then it may be necessary to use the time at which an event happened at the event source, which would have to be available in the event in order for queries to use the source timestamp. For example, a car may measure the engine's temperature, RPM and other important statistics along with a timestamp, and record these in a small computer in the car. Periodically, when the car is connected to a wireless network, the car will send this data as a batch of events. For the correct behavior of queries that make use of the time or ordering of events, the query will need to be configured to use the source timestamp.

Note: Source timestamps are not intended to be a replacement for Xclock. They can, however, be used in conjunction with Xclock for testing purposes. Xclock is controlling the correlator's time (see "Disabling the correlator's internal clock" on page 197). Source timestamps indicate the time at which an event occurred.

In order to use the source timestamp:

- Every event which may be delayed should contain the source timestamp in some form.
- An action must be defined on the event definition, which takes no parameters and returns a float. This should calculate the source time of the event - typically the time the event occurred - based on the fields of the event. The return value of the action should specify the time in seconds since the epoch (midnight, 1 Jan 1970 UTC). If the event contains the time in seconds since the epoch (in this example, stored in a field named `sourceTime`), this can be as simple as the following:

  ```
  action getSourceTime() returns float { return sourceTime; }
  ```

  Otherwise, the TimeFormat event library can be used to help convert from time of day and date, and perform timezone conversions as necessary. For example, if the source timestamps in your events are not already in the UTC timezone, then one way to do this is to include a timezone field and then use the `TimeFormat` event's `parseWithTimeZone` action to obtain the source time in the correct form as shown in the following event definition:

  ```
  using com.apama.correlator.timeformat.TimeFormat;
  using com.apama.queries.TimeFrom;
  @TimeFrom("getSourceTime")
  event E {
    integer k;
    string sourceTime;
  ```

```
  string timeZone;
  action getSourceTime() returns float {
      TimeFormat timeFormat := TimeFormat();
      return timeFormat.parseWithTimeZone("HH:MM:SS", sourceTime, timeZone);
  }
}
```

See also "Using the TimeFormat Event Library" on page 357.

- The event definition should have a `@TimeFrom` annotation (as in the above example) or queries that use the event as an input must specify a `time from` clause that names the action that provides the source time. In either case, queries must always specify a maximum time to wait for the events (see below). If both are specified, the `time from` clause in the query takes precedence.

  See also "Adding predefined annotations" on page 68.

Note: You are not permitted to use the event's built-in `getTime()` method. This method returns the time when the correlator either processed or created the event, which defeats the purpose of the source timestamp functionality.

Waiting for delayed events

If using source timestamps, we assume events may be delayed between the source time at which they occur and being processed by the Apama correlator. If no events are received by the correlator, it needs to distinguish between no events having occurred and events being delayed. If events are delayed, the query runtime will wait before evaluating the query, as it does not have a definitive view of all of the events. A query that uses source timestamps must specify the maximum wait time that a query will wait before it will process events. This is the maximum delay that the query will tolerate and the maximum delay between an event having occurred and the query processing that event. The wait time is inclusive - that is, an event delayed by exactly the value specified in the `wait` clause will be considered valid.

The maximum wait time must be specified and must be set to a reasonable value, as it can increase the number of events stored by the query runtime, and processing of the query may be delayed by up to that duration. The maximum wait time for an input may be less than or more than the within duration, but should not represent a large number of events for typical event rate for that input.

The wait time must be specified in a query using the `wait` clause in an input declaration. The `wait` clause can specify a time as a time literal (using `days`, `hours`, `minutes` and `seconds`) or as a `float` expression. Both the `time from` and `wait` clauses must be specified (or neither).

It is possible to mix inputs that have source times and events that do not have source times in a single query. Event inputs without a source time are equivalent to using `currentTime` (that is, the correlator's current time, see "currentTime" on page 912) as the source time, and a `wait` time of 0.

Event definitions may have an annotation defined `@DefaultMaxDelay` which specifies the default value to use for the wait time. This is only informational and used by the **Design** tab in Software AG Designer when editing query files as a means of setting the default wait time. The query must always specify the wait time, even if it is using the default value. Note that the editor will copy the value from the annotation, so changing the annotation will not affect existing query definitions.

Definitive time of a query event source

Given that input events may be delayed or out of order, how does the query runtime know when it is safe to process events? To answer this question, we introduce the concept of definitive time. The point in time for which the query runtime is entitled to think that it has received all the events it is going to receive is called the "definitive time". All events at or before this point in time are considered definitive and can be used to evaluate the query. Events after the definitive time will not be processed until they become definitive (that is, the definitive time has changed so that the events are now at or before the definitive time). The query runtime will assume that no further events will be received with a time before the definitive time, and will only evaluate events that have occurred before the definitive time.

In the case of an individual query input, the definitive time of that input is the latest of:

- The timestamp of the latest event received (unless the event definition is marked as occurring out of order, see "Out of order events" on page 114).
- The timestamp of the latest heartbeat event, if specified (see "Using heartbeat events with source timestamps" on page 112).
- The correlator's current time less the maximum wait time of a query.

The query's overall definitive time is then determined as the minimum or earliest of the definitive times for each input.

If no events (either input or heartbeat events) are received, then a query may need to wait in order to evaluate the events it has received (particularly if using the `wait` operator in the pattern, or more than one input, where some inputs have no events received).

The concept of definitive time is best explained using worked examples. Consider, first, a query with a single input event type.

```
using com.apama.queries.TimeFrom;
@TimeFrom("getSourceTime")
event E {
    integer k;
    float sourceTime;
    action getSourceTime() returns float {
        return sourceTime;
    }
}
query SingleInput {
    inputs {
        E() key k within 1 hour wait 2 hours;
    }
    find E:e1 -> E:e2 where e2.getSourceTime() - e1.getSourceTime() > 600.0  {
        log "Time gap " + (e2.getSourceTime() - e1.getSourceTime()).toString();
    }
}
```

In this case, where there is only a single input type, the definitive time will be the latest or most recent of either: the source timestamp of the last event, or the current time minus the wait time (2 hours in this example). The following table shows how the query runtime keeps track of the definitive time as it receives input events.

Wall Time	E event source timestamp	Query definitive time	Result	Explanation
10:00	07:00	08:00		
10:05	07:30	08:05		Nothing - events are too old.
10:10	08:30	08:30		
10:24	08:32	08:32		Nothing - event timestamps were only 2 minutes apart.
10:26	08:50	08:50	Time gap 18 minutes	
10:30	10:30	10:30		Nothing - only 1 event in the "within 1 hour" window.

Now consider a more complex case where the query has two input event types. Events of type E are defined as above, but we add another definition for events of type X.

```
@TimeFrom("getSourceTime")
event X {
    integer k;
    float sourceTime;
    action getSourceTime() returns float {
        return sourceTime;
    }
}
query MultipleInputs {
    inputs {
        E() key k within 1 hour wait 1 hour;
        X() key k within 1 hour wait 1 hour;
    }
    find E:e1 -> E:e2 without X:x {
```

```
        log "Got (" + e1.sourceTime.toString() + ", "
             + e2.sourceTime.toString() + ")";
    }
}
```

Once again the table below shows how the definitive time of the query is determined. In this case, the runtime must take the definitive time as being the earliest of the definitive times of the input types because, as the pattern depends on all input types, it is only up until that point that it has a definitive view of all the query inputs.

For example, at wall time 09:22, even though the runtime has got E events with source timestamps 08:32 and 08:40, it is not entitled to conclude that we have a match for the query pattern because the most recent X event has a timestamp of only 08:25, so we do not yet know if there was an X event between 08:32 and 08:40 that would prevent a match. The wait time of 1 hour has not yet elapsed, so the definitive time of the query remains at 08:25, which is the source time of the most recent X event.

It is not until wall time 09:23 that we receive another X event with a source timestamp of 08:50. At this point, given that in this example we know that events are being delivered in order, it is safe for the runtime to assume that there were no other X events between 08:25 and 08:50 and so it can proceed to execute the query and match for the two pairs of E events ("08:30, 08:32" and "08:32, 08:40"). Further, at this time (wall time 09:23) the receipt of the X event with source timestamp 08:50 allows the runtime to update the definitive time of the overall query to 08:40, which has become the earliest of the definitive times of the query inputs.

Wall Time	E event source timestamp	X event source timestamp	Query definitive time	Result	Explanation
09:20	08:30	08:25	08:25		
09:21	08:32		08:25		Nothing yet. Still waiting for an X.
09:22	08:40		08:25		
09:23		08:50	08:40	Got (08:30, 08:32) Got (08:32, 08:40)	
09:24	08:55		08:50		No 08:40 - 08:55 match,

Wall Time	E event source timestamp	X event source timestamp	Query definitive time	Result	Explanation
					there is an X at 08:50.
09:25	09:00		08:50		Nothing yet - still waiting for X after 08:50.
09:26		08:57	08:57		No 08:55 - 09:00 match, there is an X.
09:27	09:10		08:57		Nothing yet - still waiting for X after 08:57.
10:10			09:10	Got (09:00, 09:10)	We waited for 1 hour for an X.

Using heartbeat events with source timestamps

When using source timestamps, if a query's input has no events for a period of time, then the query will wait for the specified wait time for that query before evaluating events. This can cause unacceptable delays in processing events from other inputs. Some data sources may provide *heartbeat* events with timestamps which signal that communication from the data source to the queries system is working correctly. If these events occur but no input events have been received, then the query can infer that no input events, or only the input events received, have occurred, and thus the query's input is definitive upon receiving a heartbeat, without having to wait any further. If communication is disrupted or delayed, then the heartbeat events will similarly be delayed, and the query will wait, as it has to in order to process delayed events.

Heartbeat events are specified on the input event type's definition or per input of the query. They are only used if a query input is using source timestamps, that is, it has a `wait` clause specified. The heartbeat can be specified as a `@Heartbeat` annotation on the event definition, which should name the fully qualified event type to use as heartbeat events.

If a query input contains a `time from` clause, then the heartbeat must be explicitly named with an `or heartbeat-type` clause after the `wait` clause. For example, these two are equivalent:

```
@TimeFrom("getEcuTime")
@Heartbeat("CarHeartbeat")
event CarEngineTemp { .. }
...
query ... {
    inputs {
        CarEngineTemp() key carId within 1 hour wait 6 hours;
    }
    ...
```

or:

```
query ... {
    inputs {
        CarEngineTemp() key carId within 1 hour time from getEcuTime
           wait 6 hours or CarHeartbeat;
    }
    ...
```

The following rules apply for the heartbeat event:

- The heartbeat event cannot be filtered.
- The heartbeat event must share the same key fields and the same types as the input event type. In the above example, both `CarEngineTemp` and `CarHeartbeat` must have a field named `carId` which is of the same type in each event type.
- The heartbeat event must have a matching action for obtaining the source time. In the above example, both `CarEngineTemp` and `CarHeartbeat` must have an action of the signature `action getEcuTime() returns float`. Typically, these would have the same implementation, as the heartbeat would have source timestamps in the same form as the input events; but the implementation of these methods may be different for heartbeat events (see "Out of order events" on page 114.)
- The heartbeat event cannot be used as an input in the pattern, unless it is also listed as an input event in its own right.
- The same heartbeat event type may be used for different inputs of the same query (this is typical, as a query may use a number of different types of events from the same data source, such as a car in the above example).

When a heartbeat event is received and processed, it will step forward the definitive time for all inputs that specify that heartbeat event. Thus, if all inputs use the same heartbeat event, then that heartbeat can step forward the definitive time, allowing the query to evaluate events received on some inputs without having to wait for the input wait time on other inputs where no input events were received.

Typically, heartbeat events will be delivered regularly. The rate at which heartbeat events are sent is dependent on the data source, but the queries system must be able to handle all of the heartbeat events from all data sources as well as the input events. Some devices may only send the heartbeats under certain conditions, for example, a car may only send heartbeats if the engine is running or the car is occupied. If no heartbeat events are received, then queries will use the wait time specified in the input before evaluating any events received, as needed.

Note that queries assume that the heartbeat events are delivered in the same order as input events. If an input event arrives with a timestamp before a previous heartbeat event, it will be discarded.

Typically, heartbeat events will be events that come from the same data source as the input events they are used with. Thus, any communications disruption affecting the input events will affect the heartbeat events in the same way. This is not a requirement; if some other system has knowledge of when a data source is connected or disconnected, the heartbeat events could be sent from that system - but if the system incorrectly sends heartbeat events and input events are delayed, then input events may be discarded.

Out of order events

When using source timestamps (see also "Using source timestamps of events" on page 107), the query runtime by default expects events to arrive in order. If an event arrives with an earlier source timestamp than a previous event for that same partition, it will be discarded. However, there are two cases where this behavior does not occur (see below), and queries will store events which arrive out of order and re-order them so that when they are processed, they are processed in order according to the source time.

Note: In both cases described below (with the `@OutOfOrder()` annotation and delayed events), heartbeat events (if specified) are always considered definitive, even if they are delayed. You cannot use an event definition with an `@OutOfOrder()` annotation as a heartbeat event. Note that as soon as a heartbeat event is processed, the query will ignore any events with earlier timestamps.

Case 1: Using the `@OutOfOrder()` annotation on the event definition

If the event definition (in an EPL file) has the `@OutOfOrder()` annotation which is available in the package `com.apama.queries` (see also "Adding predefined annotations" on page 68), then the queries runtime will treat it as not occurring in order.

This means that definitive time is not affected by the timestamp on the events. Thus, events will not be processed until the specified wait time has elapsed since their source time, or a heartbeat event (if specified) with a later timestamp has been processed (and all inputs have had their definitive time moved forward).

It is recommended to use heartbeats when using `@OutOfOrder()` events. They are not required, but if not used, the query execution will be delayed by the longest input wait specified in the query.

The following example compares the behavior if `@OutOfOrder()` is or is not specified on the input:

```
query FindAdjacentAEvents {
    inputs {
        A() within 30.0 wait 20 seconds;
    }
    find A:a1 -> A:a2 {
        print "a1 = "+a1.toString()+"; a2 = "+a2.toString();
    }
}
```

In the following tables, the events are listed in the order in which they are processed, but they occur in the order A(1), A(2), A(3), A(4). Note that A(2) is delayed by more than the wait time of the query (the actual events would have a source timestamp, but we show that as a separate column for clarity).

The following table applies if the event definition does have `@OutOfOrder()`:

Input event	Input event timestamp	Correlator time	Notes	Query definitive time	Query output
A(1)	10:00:10	10:00:20		10:00:00	
A(4)	10:00:20	10:00:30		10:00:10	
A(3)	10:00:15	10:00:32		10:00:12	
		10:00:35	20 seconds after A(3)'s source time (10:00:15)	10:00:15	a1=A(1); a2=A(3)
A(2)	10:00:12	10:00:37	discarded - more than 20 seconds old	10:00:17	
		10:00:40	20 seconds after A(4)'s source	10:00:20	a1=A(3); a2=A(4)

Input event	Input event timestamp	Correlator time	Notes	Query definitive time	Query output
			time (10:00:20)		

The following table applies if the event definition does *not* have `@OutOfOrder()`:

Input event	Input event timestamp	Correlator time	Notes	Query definitive time	Query output
A(1)	10:00:10	10:00:20		10:00:10	
A(4)	10:00:20	10:00:30		10:00:20	a1=A(1); a2=A(4)
A(3)	10:00:15	10:00:32		10:00:20	(nothing - event is discarded as it is out of order)
A(2)	10:00:12	10:00:37	discarded - more than 20 seconds old	10:00:20	

Case 2: Events are delayed

Even in the case where events are normally delivered in order from the data source, if there is a delay which is then resolved, a number of delayed events may all be processed in a very short space of time. Even if they are delivered to Apama correlators in the correct order, the query runtime runs in parallel within the correlator, so events processed close together in time may be processed out of order, even if they do not have an `@OutOfOrder()` annotation on the event definition. If an event is delayed, then the query runtime will wait before considering the event's time as definitive for that input.

By default, the query runtime considers an event as delayed if its source time is more than 10 seconds before the correlator's time at the point it is processed, and it will wait for 10 seconds before considering the event's time as definitive for that input. These settings can be modified by sending in a `SetDelayedEventsLeeway(`*`delayLeeway`*`,` *`reorderBuffer`*`)` event:

```
com.apama.queries.SetDelayedEventsLeeway(5, 20.0)
```

The above example would set the query runtime to consider events older than 5 seconds as delayed, and would not consider them definitive until 20 seconds after they were received.

To consider all events in order regardless of delay, send an event with the first value set to `infinity` (as all actual delays must be less than infinity):

```
com.apama.queries.SetDelayedEventsLeeway(infinity, 0.0)
```

These events should be sent to all correlators in a cluster, typically as part of the initialization of the correlator along with injecting the query definitions.

The following example compares the behavior with different configurations and some delayed events:

```
query FindAdjacentAEvents {
    inputs {
        A() within 30 minutes wait 10 minutes;
    }
    find A:a1 -> A:a2 {
        print "a1 = "+a1.toString()+"; a2 = "+a2.toString();
    }
}
```

The following table lists the events where the A event does not have `@OutOfOrder()`. The last three columns give the behavior with different configurations:

- **Default config. A.** Matches with the default values: 10 seconds delay threshold and 10 seconds reorder buffer.
- **Config. B.** Matches if `SetDelayedEventsLeeway(300, 10)` is sent: 5 minutes (300 seconds) delay threshold and 10 seconds reorder buffer.
- **Config. C.** Matches if `SetDelayedEventsLeeway(10, 60)` is sent: 10 seconds delay threshold and 1 minute reorder buffer.

Input event	Input event timestamp	Correlator time	Definitive time of the query for default leeway values	Default config. A	Config. B	Config. C
A(1)	10:06:10	10:10:30	10:00:30 (10 minutes ago)			
A(4)	10:06:20	10:10:31	10:00:31 (10 minutes ago)		a1=A(1); a2=A(4)	

Input event	Input event timestamp	Correlator time	Definitive time of the query for default leeway values	Default config. A	Config. B	Config. C
A(3)	10:06:15	10:10:32	10:00:32 (10 minutes ago)		(A(3) out of order and discarded)	
A(2)	10:06:13	10:10:33	10:00:33 (10 minutes ago)		(A(2) out of order and discarded)	
		10:10:43	10:06:20 (latest A event received)	a1=A(1); a2=A(2) a1=A(2); a2=A(3) a1=A(3); a2=A(4)		
		10:11:33				a1=A(1); a2=A(2) a1=A(2); a2=A(3) a1=A(3); a2=A(4)
A(6)	10:12:05	10:12:10	10:12:05 (latest A event received)	a1=A(4); a2=A(6)	a1=A(4); a2=A(6)	a1=A(4); a2=A(6)
A(5)	10:12:04	10:12:11	10:12:05 (latest A	(none - event A(5) is discarded)	(none - event A(5) is discarded)	(none - event A(5) is discarded)

Input event	Input event timestamp	Correlator time	Definitive time of the query for default leeway values	Default config. A	Config. B	Config. C
			event received)			

Note that A(6) is treated as occurring in order, as it is delayed by less than the *delayLeeway* value. Thus A(5) is discarded, as it has occurred out of order.

Matching only the latest event for a given field

A query input can optionally limit the window to only contain the most recent item for each value of a given field or action of the event. This is performed by the `with unique` operator, which is followed by one or more fields or actions of the input event type.

For example, consider a query looking at sensor data from a number of sensors on the same production line, with events that specify the `productionLine` and `sensorId`. The query compares sensor values between different machines and sensors on the same production line, so the query can be keyed on the `productionLine` field of events, but not on the `sensorId` field. However, only the latest event for each sensor is required. By specifying a `with unique sensorId` clause, only the latest value of each sensor is used.

If you add a `with unique` clause, if there is more than one item in the window that has the same value for all the fields or actions listed in the `with unique` clause, then only the most recent event is considered to be in the window and can match the pattern. The suppression of duplicates occurs after the `within` and/or `retain` clauses apply. For example:

```
inputs {
    Sensor() key productionLine retain 3 with unique sensorId;
}
```

Given the following events, the window contains only those marked in the third column of the following table (assuming all are for the same `productionLine`):

Event	`sensorId`	Window contains	Notes
1	A	1(A)	
2	B	1(A), 2(B)	
3	C	1(A), 2(B), 3(C)	

Event	sensorId	Window contains	Notes
4	B	3(C), 4(B)	Event 1 is discarded due to `retain 3`. Event 2 is discarded as event 4 has the same `sensorId`.
5	D	3(C), 4(B), 5(D)	
6	C	4(B), 5(D), 6(C)	Event 3 is discarded due to `retain 3`.
7	D	6(C), 7(D)	Event 4 is discarded due to `retain 3`. Event 5 is discarded as event 7 has the same `sensorId`.

Note that the `with unique` is applied after the `retain` expression. Any `with unique` expression does not affect window sharing (see also "Queries can share windows" on page 96) nor how much data is stored.

The `with unique` clause comes after the sizing of the window (`within`, `retain`) and before, if present, the `time from`, `wait` or `or` clauses used for specifying source time.

`with unique` can list a number of comma-separated members or calls to actions, where the action name is followed by parentheses. Actions used in a `with unique` clause must take no parameters and return a value. The ordering is unimportant.

For example, using `with unique upperName()` for an event definition such as the following would only keep one event for each value of the name field, ignoring case:

```
event E {
    string name;
    action upperName() returns string { returns name.toUpper(); }
}
```

Finding and acting on event patterns

In a query, the `find` statement specifies the event pattern you are interested in. At runtime, for each event that the correlator adds to a window, the query checks for a match. Depending on the definition of the event pattern, the set of events that matches the pattern contains one or more events. This is the match set. A match set

- Always contains the latest event, which is the event that was most recently added to a window.
- Satisfies the event pattern.
- Is always the most recent set that matches the event pattern. This is important when there is more than one set that is a candidate for the match set.

The format of a `find` statement is as follows:

```
find pattern block
```

Syntax Element	Description
pattern	The event pattern that you want to find. See "Defining event patterns" on page 121.
block	The procedural code to execute when a match is found. See "Acting on pattern matches" on page 145.

Defining event patterns

In a query definition, you specify a `find` statement when you want to detect a particular event pattern. The `find` statement specifies the event pattern of interest followed by a procedural block that specifies what you want to happen when a match is found. For example:

```
query ImprobableWithdrawalLocations
{
    inputs {
        Withdrawal() key cardNumber within 24 hours;
    }
    find
        Withdrawal:w1 -> Withdrawal:w2 where w2.country != w1.country {
          log "Suspicious withdrawal: " + w2.toString() at INFO;
        }
}
```

In this example, the window that the query operates on contains any `Withdrawal` events that have arrived in the last 24 hours. The key is the card number so each partition contains only `Withdrawal` events that have the same value in their `cardNumber` field. In other words, each partition contains the `Withdrawal` events for one particular account. For more information about input definitions, see "Defining query input" on page 94.

The `find` statement specifies that the event pattern of interest is a `Withdrawal` event followed by another `Withdrawal` event.

In each partition, the `where` clause filters the `Withdrawal` events so that there is a match only when the values of their `country` fields are different. The two event templates in the `find` statement coassign matching `Withdrawal` events to `w1` and `w2`, respectively.

In this example, the two matching `Withdrawal` events might or might not have arrived in the partition consecutively. For details, see "Query followed-by operator" on page 124.

When there is a match the query executes the action in the `find` block.

The format for defining a `find` statement is as follows:

```
find
   [every] [wait duration:identifier]
event_type:identifier [find_operator event_type:identifier]...
   [wait duration:identifier]
   [where_clause] [within_clause] [without_clause]
```

```
   [select_clause] [having_clause] {
block
   }
```

Syntax Element	Description
event_type	Name of the event type you are interested in. You must have specified this event type in the `inputs` section.
`every`	Specify the optional `every` modifier in conjunction with the `select` and `having` clauses. This lets you specify a pattern that aggregates event field values in order to find data based on many sets of events. See "Aggregating event field values" on page 139.
`wait`	Specify the optional `wait` modifier followed by a time literal or a `float` expression. A `wait` modifier indicates a period of elapsed time at the beginning of the event pattern and/or at the end of the event pattern. A `float` expression always indicates a number of seconds, See "Query wait operator" on page 129.
identifier	Coassign the matching event to this identifier. A coassignment variable specified in an event pattern is within the scope of the `find` block and it is a private copy in that block. The exception to this is in an aggregating find statement, only the projection expression can use the coassignments from the pattern. The procedural block of code can use projection coassignments and any parameters, but it cannot use coassignments from the pattern. Changes to the content that the variable points to do not affect any values outside the query. Unlike EPL event expressions, you need not declare this identifier before you coassign a value to it. In an event pattern in a `find` statement, each coassignment variable identifier must be unique. You must ensure that an identifier in an event pattern does not conflict with an identifier in the `parameters` section, or `inputs` section.

Syntax Element	Description
find_operator	Optionally specify `and` or `->` and then specify an *`event_type`* and coassignment variable. Parentheses are allowed in the pattern specification and you can specify multiple operators, each followed by an *`event_type`* and coassignment variable. For example, the following is a valid `find` statement: `find (A:a1 -> ((A:a2)) -> (A:a3) -> (A:a4 -> A:a5 -> A:a6) -> (((A:a7) -> A:a8) -> A:a9) -> A:a10) { print "query with 10: "+a1.toString()+ " - "+a10.toString(); }`
where_clause	To filter which events match, specify `where` followed by a Boolean expression that refers to the events you are interested in. The Boolean expression must evaluate to true for the events to match. The `where` clause is optional. Coassignment variables specified in the `find` or `select` statements are in scope in the `where` clause. Also available in a `where` clause are any parameter values and key values. This `where` clause applies to the event pattern and is referred to as a find `where` clause to distinguish it from a `where` clause that is part of a `without` cause, which is referred to as a without `where` clause. See "Query conditions" on page 130.
within_clause	A `within` clause sets the time period during which events in the match set must have been added to their windows. A pattern can specify zero, one, or more `within` clauses. See "Query conditions" on page 130.
without_clause	A `without` clause specifies event types whose presence prevents a match. See "Query conditions" on page 130.
select_clause	A `select` clause indicates that aggregate values are to be computed. See "Aggregating event field values" on page 139.
having_clause	A `having` clause restricts when the procedural code is invoked for a pattern that aggregates

Syntax Element	Description
	values. See "Aggregating event field values" on page 139.
block	Specify one or more statements that operate on the matching event(s). For details about code that is permissible in the `find` block, see "Acting on pattern matches" on page 145. Items available in a `find` block can include: ■ Any parameters defined in the `parameters` section ■ Coassignment variables specified in the event pattern (or projection coassignments in the case of aggregating `find` statements). ■ Key values

Query followed-by operator

You can specify the -> (followed-by) operator in the `find` statement. The -> operator matches events that come after each other. The event on the left of the operator always arrives in the correlator before the event on the right. In other words, the -> operator is always between two distinct events. For example, `A:a1 -> A:a2` requires the arrival of two instances of an `A` event for the query to find a match. Also, any `where` clauses in the `find` statement must evaluate to true for an event pattern to match. Finally, the match set always includes the latest event.

Thus, the rules for when there is a match for an event pattern that specifies one or more followed-by operators are as follows. All of these requirements must be met for there to be a match.

- There are events in the partition that match the subpatterns on both sides of the followed-by operator(s).
- There is a match for the subpattern on the left of a followed-by operator before there is a match for the subpattern on the right of a followed-by operator. One event cannot match more than one subpattern in an event pattern.
- If a subpattern contains a `where` clause then the `where` clause must evaluate to true for the subpattern to match.
- The match set contains the latest event.
- If there is more than one candidate event set for the match set then it is the most recent candidate event set that is the match set. See "Event matching policy" on page 143.

The following sections provide examples that illustrate these rules.

Two coassignments

Consider the following code in which the `Withdrawal` event contains only one field of interest, which is the country. Assume that the query partitions arriving `Withdrawal` events into windows according to the account number field.

```
find Withdrawal:w1 -> Withdrawal:w2
   where w1.country = "UK" and w2.country = "Narnia" {
      // Recent card fraud in Narnia against UK customers
      emit SuspiciousWithdrawal(w2);
}
```

To make it easier to understand the behavior of the `->` operator in more populated windows, the following example events omit the account number field but include a unique identifier field. Suppose the window for this query contains the following events, in arrival order top to bottom:

```
Withdrawal("Belgium", 1)
Withdrawal("UK", 2)
```

Although there is a `Withdrawal` event followed by another `Withdrawal` event, the `where` clause does not evaluate to true so there is no match. Now suppose the window contains these events:

```
Withdrawal("UK", 3)
Withdrawal("Narnia", 4)
```

Now the query finds a match. There is a `Withdrawal` event followed by another `Withdrawal` event, and the `where` clause evaluates to true. `Withdrawal("UK, 3")` is coassigned to `w1` and `Withdrawal("Narnia", 4)` is coassigned to `w2`. The query executes the statements in its `find` block, which in this example is to emit the event that triggered the match.

In this example, the `Withdrawal` events in the match set arrived consecutively. However, this is not a requirement. Consider a window that contains the following events:

```
Withdrawal("UK", 5)
Withdrawal("Belgium", 6)
Withdrawal("Belgium", 7)
Withdrawal("Narnia", 8)
```

When `Withdrawal("Narnia", 8)` is added to its window, the query finds a match because the `Withdrawal("UK", 5)` event is followed by the `Withdrawal("Narnia", 8)` event and the `where` clause evaluates to true for those two events. The effective behavior is that all combinations of events in the window are inspected to find a combination that matches. The `Withdrawal("UK, 5")` event is coassigned to `w1` and `Withdrawal("Narnia, 8")` is coassigned to `w2`. The query executes the statements in its `find` block.

A match must include the event that arrived most recently in the window (the latest event). This ensures that a query does not detect more than one match for the same combination of events. In the previous example, the query found a match when the `Withdrawal("Narnia", 8)` event arrived.

Imagine that another `Withdrawal` event arrives and the window now contains the following events:

```
Withdrawal("UK", 5)
```

```
Withdrawal("Belgium", 6)
Withdrawal("Belgium", 7)
Withdrawal("Narnia", 8)
Withdrawal("Belgium", 9)
```

While the window still contains the `Withdrawal("UK", 5)` event followed by the `Withdrawal("Narnia", 8)` event, the arrival of the `Withdrawal("Belgium", 9)` event does not trigger a new match because it is not part of that combination. However, suppose the `Withdrawal("Narnia", 10)` event arrives. The window now contains the following events:

```
Withdrawal("UK", 5)
Withdrawal("Belgium", 6)
Withdrawal("Belgium", 7)
Withdrawal("Narnia", 8)
Withdrawal("Belgium", 9)
Withdrawal("Narnia", 10)
```

Now the query finds a new match. The `Withdrawal("UK", 5)` event is followed by the just arrived `Withdrawal("Narnia", 10)` event and the `where` clause evaluates to true for these two events. This match set contains `Withdrawal("UK", 5)` and `Withdrawal("Narnia", 10)`. While this match set contains the same `Withdrawal("UK", 5)` event that was in the previous match set, it is a new match set because it contains the event that arrived most recently, which is the `Withrawal("Narnia", 10)` event.

Suppose that the `Withdrawal("Narnia", 14)` event has just arrived in the following window:

```
Withdrawal("Belgium", 11)
Withdrawal("UK", 12)
Withdrawal("UK", 13)
Withdrawal("Narnia", 14)
```

In this situation, there is a match set that contains the two most recently arrived events, that is, `Withdrawal("UK", 13)` and `Withdrawal("Narnia", 14)`. The `Withdrawal("UK", 12)` event is not part of the match set because it is not the most recently arrived `Withdrawal` event whose country field is `"UK"`.

Three coassignments

The code example below shows three coassignments in the `find` statement. This query partitions the arriving events into windows according to their Automated Transaction Machine identifier numbers (`atmId`).

```
query RepeatedMaxWithdrawals {
    inputs {
        Withdrawal() key atmId within 4 minutes;
    }
    find Withdrawal:w1 -> Withdrawal:w2 -> Withdrawal:w3
        where w1.amount = 500 and w2.amount = 500 and w3.amount = 500  {
      log "Suspicious withdrawal: " + w3.toString() at INFO;
    }
}
```

Each window contains the `Withdrawal` events that occurred in the last four minutes at a particular ATM. For simplicity, the following examples show only the `amount` and `transactionId` event fields. Suppose the following events are in the window and that they arrived in order from top to bottom:

```
Withdrawal(500, 101)   w1
Withdrawal(500, 102)   w2
Withdrawal(500, 103)   w3
```

After the third event arrives, the event pattern is matched, the `where` clause evaluates to true, and the events are coassigned to `w1`, `w2`, and `w3` as shown above.

Another event arrives in the window:

```
Withdrawal(500, 101)
Withdrawal(500, 102)   w1
Withdrawal(500, 103)   w2
Withdrawal(500, 104)   w3
```

When the fourth event arrives there is a new match and the events are coassigned as shown above. The `Withdrawal(500, 101)` event is not part of the new match set. A match set always includes the most recent events that satisfy the event pattern and that allow the `where` clause to evaluate to true.

Another event arrives and the window now contains these events:

```
Withdrawal(500, 101)
Withdrawal(500, 102)
Withdrawal(500, 103)
Withdrawal(500, 104)
Withdrawal(100, 105)
```

The latest event, `Withdrawal(100, 105)`, does not have `500` in its `amount` field. Consequently, its arrival in the window does not trigger a new match because a match set must always include the latest event. While the window still contains three events that satisfy the event pattern, the actions in the `find` block are not executed as a result of the arrival of `Withdrawal(100, 105)` because it did not trigger a new match.

Another event arrives and the window now contains these events:

```
Withdrawal(500, 101)
Withdrawal(500, 102)
Withdrawal(500, 103)  w1
Withdrawal(500, 104)  w2
Withdrawal(100, 105)
Withdrawal(500, 106)  w3
```

With the arrival of the `Withdrawal(500, 106)` event, there is a new match and the events are coassigned as shown above. The coassigned events are the three most recently arrived events that satisfy the event pattern. It does not matter that `Withdrawal(100, 105)` arrived after some events that are in the match set. That event does not satisfy the event pattern and so it is not included in the match set.

Finally, suppose all of the following events have arrived in the window within the specified four minutes:

```
Withdrawal(500, 101)
Withdrawal(500, 102)
Withdrawal(500, 103)
Withdrawal(500, 104)
Withdrawal(100, 105)
Withdrawal(500, 106)   w1
Withdrawal(500, 107)   w2
```

```
Withdrawal(100, 108)
Withdrawal(100, 109)
Withdrawal(500, 110)   w3
```

As you can see, the latest event causes a new match. This match set does not include the two events that arrived just before the latest event. Those two events do not satisfy the event pattern.

Query and operator

In a `find` statement, you can specify the `and` operator in the event pattern. The conditions on both sides of the `and` operator must evaluate to true for the query to find a match. The condition on each side of an `and` operator can be a single event template or a more complex expression.

In the next example, assuming that an `X` event and a `Y` event have already been added to their respective windows, adding an `A` event to its window causes a match.

```
(X:x -> A:a1) and (Y:y -> A:a2)
```

In the second example, suppose events were added to their windows in this order: `X(1)`, `A(1)`, `Y(1)`, `A(2)`. The `A(1)` event is not included in the match set. Only `A(2)` is in the match set because it is the most recent `A` event to follow `X(1)` as well as the most recent `A` event to follow `Y(1)`.

When a single event is used in more than one coassignment you must coassign the event, `A` in these examples, to distinct identifiers, `a1` and `a2` in these examples.

Specification of an `and` operator implies that there are no requirements regarding the order in which the events specified in the event pattern are added to the window. For example, events specified in the right-side condition can be added to their windows before events specified in the left-side condition. When conditions specify multiple events the events that cause one side of the `and` operator to evaluate to true

- Can all be added to their windows before the events that cause the other side to evaluate to true
- Can all be added to their windows after the events that cause the other side to evaluate to true
- Can arrive in their windows at times interleaved with the arrival of the events that cause the other side to evaluate to true
- Can contain the events that cause the other side to evaluate to true
- Can be contained by the events that cause the other side to evaluate to true

When there is an order requirement or when you require multiple instances of the same event type specify the followed-by (->) operator.

The `and` operator has a higher precedence that the followed-by operator. For clarity, use brackets in expressions that specify both types of operators.

Query wait operator

You can specify the `wait` operator in an event pattern. The `wait` operator indicates that there must be a time interval either at the beginning of the matching pattern or at the end of the matching pattern. The format for specifying the `wait` operator is as follows:

```
wait ( durationExpression ) : coassignmentId
```

Syntax Element	Description
durationExpression	A time literal (such as `2 min 3 seconds`) or a `float` expression. A `float` expression can use constants and parameters. It indicates a number of seconds.
coassignmentId	An identifier. You can specify this identifier only in a `between` clause. See "Query condition ranges" on page 136.

Typically, you specify the `wait` operator in conjunction with an event pattern condition. For example:

```
find A:a -> B:b -> wait(10):t
   without X:x between ( b t )
```

There is a match for this pattern when these things happen in this order:

1. An `A` event is added to a window in a partition.
2. A `B` event is added to a window in the same partition.
3. Ten seconds go by without an `X` event being added to a window in that partition.

The `wait` operator can be unambiguously at the beginning of a pattern that uses the followed-by operator or unambiguously at the end of a pattern that uses the followed-by operator. For example:

```
X:x -> wait(1.0) -> Y:y              // Not allowed
X:x and wait(1.0) and Y:y            // Not allowed
X:x and Y:y and wait(1.0)            // Not allowed
wait(1.0) -> (X:x and Y:y)           // Allowed
wait(1.0) -> X:x -> Y:y -> wait(1.0) // Allowed
```

The following code fragment detects the opening of a door without security authorization:

```
find wait( 5 seconds ):p -> DoorOpened:e
   without SecurityAuthorization:s where s.doorId = e.doorId {
   emit UnautorizedAccess(e.doorId);
   }
```

Suppose the following events were received:

Time	Event
00	`SecurityAuthorization("door1")`
02	`DoorOpened("door1")`
07	`DoorOpened("door1")`
15	`DoorOpened("door2")`

The first `DoorOpened` event for `door1` does not generate an alert because a `SecurityAuthorization` event was received within the 5 seconds that preceded the first `DoorOpened` event and the `doorId` field is the same for both events. That is, because the Boolean expression in the `where` clause of the `without` clause evaluates to true, a match is prevented and so an alert is not sent.

The second `DoorOpened` event for `door1` causes an `UnautorizedAccess` alert because the `SecurityAuthorization` event was received more than 5 seconds before the second `DoorOpened` event for `door1`.

The `DoorOpened` event for `door2` causes an `UnauthorizedAccess` alert because a `SecurityAuthorization` event was not received within the 5 seconds that preceded that `DoorOpened` event. Since there was no `SecurityAuthorization` event, the Boolean expression in the `where` clause that is in the `without` clause evaluates to false, which allows a match.

Query conditions

A `find` statement can specify conditions that determine whether there is a match for the specified event pattern. The following table provides an overview of the conditions you can specify.

Condition:	**`where`**	**`within`**	**`without`**
Specifies:	Boolean expression	Time period	Event type coassigned to an identifier
Latest event can cause a match when:	The Boolean expression evaluates to true.	Events in the pattern (or, if specified, the `between` range) must have been received within the time specified. That is, the elapsed time	An event of a specified type was not added to a window after the addition of the oldest event in the potential match set nor before the

Condition:	where	within	without
		from when the first event was received to when the last event was received must be less than the within time period.	addition of the latest event.
Number allowed:	Zero or more	Zero or more	Zero or more
Order when all conditions are specified:	1st	2nd	3rd
Format:	where *boolean_expression*	within *time_literal*	without *typeId* : *coassignmentID*
Notes:	where x where y is equivalent to where x and y A where clause that precedes any within or without clauses is referred to as a find where clause.	Alternatively, you can specify within *expression*. The expression must evaluate to a float. Optionally, after each within clause, you can specify a between clause. See "Query condition ranges" on page 136.	Optionally, after each without clause you can specify one where clause, which is referred to as a without where clause to distinguish it from a find where clause. Optionally, after each without clause, you can specify a between clause. See "Query condition ranges" on page 136.

Query where clause

A where clause filters which events match. A where clause consists of the where keyword followed by a Boolean expression that refers to the events you are interested in.

In a find `where` clause, the Boolean expression must evaluate to true for the events to match.

The `where` clause is optional. You can specify zero, one or more `where` clauses.

Note: You can specify a find `where` clause that applies to the event pattern and you can also specify a without `where` clause that is part of a `without` clause. Any `where` clauses that you want to apply to the event pattern must precede any `within` or `without` clauses.

Coassignment variables specified in the `find` or `select` statements are in scope in a find `where` clause. Also available in a find `where` clause are any parameter values and key values.

Query within clause

A `within` clause sets the time period during which events in the match set must have been added to their windows. A pattern can specify zero, one, or more `within` clauses. These must appear after any find `where` clauses and before any `without` clauses. The format of a `within` clause is as follows. The `between` clause is optional.

```
within durationExpression [ between ( identifer1 identifier2 ... ) ]
```

The *`durationExpression`* must be a time literal (such as `2 min 3 seconds`) or it must evaluate to a `float` value. A `float` expression can use constants and parameters. It indicates a number of seconds.

For example, consider the following `find` statement:

```
find LoggedIn:lc -> OneTimePass:otp
   where lc.user = otp.user
   within 30.0 {
      emit AccessGranted(lc.user);
   }
```

If specified, the `between` clause lists two or more items. Each item can be a coassigned event in the pattern. A `wait` coassignment can also be specified. These items define a range. See "Query condition ranges" on page 136. For example:

```
find wait(1.): w -> A:a {
...
 within (5.0) between w a
```

Now assume that the following events arrive:

Time	Event	Access Granted?
`10`	`LoggedIn("Andy")`	
`15`	`OneTimePass("Andy")`	Yes. Both events received within 30 seconds.
`20`	`LoggedIn("Mike")`	

Time	Event	Access Granted?
60	OneTimePass("Mike")	No. OneTimePass event received more than 30 seconds after corresponding LoggedIn event.
60	LoggedIn("Sam")	
90	OneTimePass("Sam")	No. OneTimePass event received exactly 30 seconds after corresponding LoggedIn event. For there to be a match, the OneTimePass event must be received less than 30 seconds after its corresponding LoggedIn event.

As mentioned earlier, a `find` statement can specify multiple `within` clauses. This is useful when the pattern of interest refers to multiple events and you specify a `between` range as part of each `within` clause. When you specify multiple `within` clauses they must all be satisfied for there to be a match.

Query without clause

A `without` clause specifies event types, which must be specified in the `inputs` block of the query, whose presence prevents a match. For example, if a potential match set contains 3 events, it can be a match only if a type specified in a `without` clause was not added to a window neither after the first event nor before the third event. Any event type that can be used in the `find` pattern can be used in the `without` clause.

Optionally, after each `without` clause, you can specify one `where` clause, which is referred to as a without `where` clause to distinguish it from a find `where` clause. The following table compares find `where` clauses and without `where` clauses.

Find `where` clause	Without `where` clause
True allows a match. Think of this as a positive `where` clause.	False allows a match. Think of this as a negative `where` clause.
Can only be before any `within` or `without` clauses	Can only be part of a `without` clause
Applies to the event pattern	Applies to the event specified in its `without` clause
Cannot refer to event specified in `without` clause	Can refer to event specified in `without` clause

The absence of an event of a type specified in a `without` clause has the same effect as the presence of an event for which the without `where` clause evaluates to false.

In addition to being able to refer to parameters and coassignment identifiers in the event pattern, a without `where` clause can refer to the one event mentioned in its `without` clause. When a without `where` clause evaluates to true the presence of the `without` event prevents a match. If a without `where` clause is false, then that `without` event instance is ignored; that is, a match is possible.

A `without` clause cannot use the `->` or `and` pattern operators. However, you can specify multiple `without` clauses. If there are multiple `without` clauses each one can refer to only its own coassignment and not coassignments in other `without` clauses. However, all `without` clauses can make use of the pattern's standard coassignments, such as `od.user` in the example at the end of this topic.

If there are multiple `without` clauses a matching event for any one of them prevents a pattern match. Multiple `without` clauses can use the same type and the same coassignment, which is useful only when their `where` conditions are different.

Typically, a without `where` clause references the event in its `without` clause, but this is not a requirement.

Optionally, after each `without` clause, you can specify a `between` clause, which lists two or more coassigned events. It can also list a `wait` coassignment. For an event to cause a match, the type specified in the `without` clause cannot be added to the window between the points specified in the `between` clause. See "Query condition ranges" on page 136.

Any `without` clauses must be after any find `where` clauses and `within` clauses. If you specify both optional clauses, the without `where` clause must be before the `between` clause.

When a `without` clause includes both optional clauses, `where` and `between`, the format looks like this:

```
without typeId : coassignmentId
   where boolean_expression
   between ( identifier1  identifier2 ... )
```

As mentioned previously, a find `where` clause applies to the event pattern while a without `where` clause applies to the event specified in its `without` clause. The following table shows the resulting behavior according to the type of the `where` clause and the value of its Boolean expression:

Type of where clause	Boolean expression evaluates to true	Boolean expression evaluates to false
Find `where` clause applies to event pattern	Allows match	Prevents match
Without `where` clause applies to its `without` event	Prevents match	Allows match

Example

Consider the following `find` statement:

```
find OuterDoorOpened:od -> InnerDoorOpened:id
   where od.user = id.user
   without SecurityCodeEntered:sce where od.user = sce.user {
      emit Alert("Intruder "+id.user);
}
```

Now suppose the following events arrive:

Event Received	Result
`OuterDoorOpened("Andrew")`	
`SecurityCodeEntered("Andrew")`	Causes the without `where` clause to evaluate to true, which prevents a match.
`InnerDoorOpened("Andrew")`	No alert is set.
`OuterDoorOpened("Brian")`	
`InnerDoorOpened("Brian")`	Because there is no intermediate `SecurityCodeEntered` event, there is a match and the query sends an alert. This is an example of how the absence of an event of a type specified in a `without` clause has the same effect as the presence of an event for which the without `where` clause evaluates to false.
`OuterDoorOpened("Chris")`	
`SecurityCodeEntered("Charlie")`	Causes the without `where` clause to evaluate to false, which allows a match.
`InnerDoorOpened("Chris")`	Causes a match and the query sends an alert.
`OuterDoorOpened("Dan")`	
`SecurityCodeEntered("David")`	Causes the without `where` clause to evaluate to false, which allows a match.

Event Received	Result
`SecurityCodeEntered("Dan")`	Causes the without `where` clause to evaluate to true, which prevents a match.
`SecurityCodeEntered("Densel")`	Causes the without `where` clause to evaluate to false, which allows a match.
`InnerDoorOpened("Dan")`	There is no match because one of the `SecurityCodeEntered` events caused the without `where` clause to evaluate to true, which prevents a match.

Query condition ranges

The `within` and `without` clauses (See "Query conditions" on page 130) can each have an optional `between` clause that restricts which part of the pattern the `within` or `without` clause applies to. The format for specifying a range is as follows:

```
between ( identifer1 identifier2 ... )
```

At least two identifiers that are specified in the event pattern are required. The identifiers specify a period of time that starts when one of the specified events is received and ends when one of the other specified events is received. A `between` clause is the only place in which you can specify a coassignment identifier that was assigned in a `wait` clause. You cannot specify identifiers used in a `without` clause. Also, the same event cannot match both the coassignment identifier in the `without` clause and an identifier in a `between` clause.

The condition that the `between` clause is part of must occur in the range of identifiers specified in the `between` clause. For example, consider the following `find` pattern:

```
find A:a and B:b and C:c without X:x between ( a b )
```

For there to be a match set for this pattern, no `X` event can be added to its window between the arrivals of the `a` and `b` events. If events are received in the order `B A X C`, then there is a match set because the `X` event is not between the `a` and `b` events. If the events are received in the order `B C X A`, then there is no match set because an `X` event occurred between the `a` and `b` events.

Here is another example:

```
find A:a -> B:b -> (C:c and D:d)
   within 10.0 between (a b)
   within 10.0 between (c d)
```

Range	Description
`(a b)`	This duration starts when an `A` event is received because the pattern is looking for an `A` event followed by a `B` event. For there to

Range	Description
	be a match, the B event must arrive less than 10 seconds after the A event.
(c d)	After an A event followed by a B event has been received, this duration starts when either a C event or a D event is received. Since the pattern is looking for a C and a D, it does not matter which event is received first. For there to be a match, the event that is not received first must be received less than 10 seconds after the first event.

The following table provides examples of match sets.

Time	Event Received	Match Set
10	A(1)	
15	B(1)	
20	D(1)	
25	C(1)	A(1),B(1),D(1),C(1)
37	D(2)	No match. More than 10 seconds elapsed between C(1) and D(2).
40	C(2)	A(1),B(1),D(2),C(2)

The range is exclusive. That is, the range applies only after the first event is received and before the last event is received. For example, consider this pattern:

```
find A:a1 -> A:a2 without A:repeated  between ( a1 a2 )
```

A match set for this pattern is two consecutive A events. If three consecutive A events are added to the window, the first and third do not constitute a match set event though the first A was followed by the third A. This is because the second A was added between the first and the third A events. In other words, the events that match a1 and a2 are excluded from the range in which the repeated event can match. The following table provides examples of match sets for this pattern. It assumes that A(1) is still in the window when A(4) is added.

Event Added to Window	Match Set	Not a Match Set
A(1)		

Event Added to Window	Match Set	Not a Match Set
`A(2)`	`A(1), A(2)`	
`A(3)`	`A(2), A(3)`	`A(1), A(3)`
`A(4)`	`A(3), A(4)`	`A(1), A(4)` and `A(2), A(4)`

The query below is a real world example of the pattern just discussed. It emits the average price change in the last minute.

```
query FindAveragePriceMove {
   inputs {
      Trade() key symbol within 1 minute;
   }
   find every Trade:t1 -> Trade:t2
      without Trade:mid between (t1 t2)
      select avg(t2.price - t1.price):avgPriceChange {
         emit AveragePriceChange(symbol, avgPriceChange);
   }
}
```

It is illegal to have two `within` clauses with identical `between` ranges. This would be redundant, as only the shortest `within` duration would have any effect. It is, however, legal to have more than one `without` clause with the same `between` range. Typically, these would refer to different event types or `where` conditions.

Special behavior of the `and` operator

To optimize performance when evaluating a query `where` clause, the correlator evaluates each side of an `and` operator as early as possible even if evaluation is not in left to right order. This behavior is different from the behavior outside a query. That is, outside a query, the left side of an `and` operator is guaranteed to be evaluated first. See "Logical intersection (and)" on page 895.

For example, suppose you specify the following event pattern:

```
A:a -> B:b where a.x = 1 and b.y = 2
```

Consider what happens when the following events are added to their windows:

```
A(1), A(2), A(3), B(5), B(4), B(3)
```

The correlator can identify that

- Only the `a` coassignment target is needed to evaluate the `a.x = 1` condition.
- Only the `b` coassignment target is needed to evaluate the `b.y = 2` condition.

Because none of the `B` events cause the `b.y = 2` condition to evaluate to true, the correlator does not evaluate the `a.x = 1` condition.

In a `where` clause, because the right side of an `and` operator might be evaluated first, you should not specify conditions that have side effects. Side effects include, but are not limited to:

- `print` or `log` statements
- `route`, `emit`, `enqueue...to` statements
- Modifying events, sequences, dictionaries, etc
- Causing a runtime error
- Calling an action that has a side effect statement in it
- Calling plug-ins that have side effects

If a `where` clause calls an action that has a side effect, you should not rely on when or whether the action is executed.

Whether the correlator can optimize evaluation of the `where` clause depends on how you specify the `where` clause conditions. For example, consider the following event definition:

```
event Util {
    action myWhereClause(A a, B b) returns boolean {
         return a.x = 1 and b.y = 2;
    }
}
```

Suppose you specify the following event pattern:

```
A:a -> B:b where (new Util).myWhereClause(a, b)
```

If the same `A` and `B` events listed above are added to their windows, the result is the same as the result of evaluating

```
A:a -> B:b where a.x = 1 and b.y = 2
```

However, evaluation might take longer because the correlator cannot separate evaluation of `b.y = 2` from evaluation of `a.x = 1`. The `myWhereClause()` action returns `a.x = 1 and b.y = 2` as a single expression. Consequently, the correlator evaluates `(new Util).myWhereClause(a, b)` for each combination of `a` and `b`. Given the `A` and `B` events listed above, this is a total of 9 times.

While the correlator might evaluate some `where` clause conditions in a right-to-left order, the correlator always evaluates each `where` clause condition as soon as it is ready to be evaluated. When multiple conditions become ready to be evaluated at the same time then the correlator evaluates those conditions in the order they are written. For example, the typical pattern of checking whether a dictionary contains a key before operating on the value with that key continues to work reliably:

```
E:e -> F:f where e.dict.hasKey("k") and e.dict["k"] = f.x and f.y = 1
```

In this example, `f.y = 1` might be evaluated before the other two conditions, but `e.dict.hasKey("k")` is always evaluated before `e.dict["k"] = f.x`, and the latter is not evaluated if the `hasKey()` method returns false.

Aggregating event field values

A `find` statement can specify a pattern that aggregates event field values in order to find data based on many sets of events. A pattern that aggregates values specifies the `every` modifier in conjunction with `select` and `having` clauses.

Based on a series of values, an aggregate function computes a single value, such as the average of a series of numbers. For an overview of all built-in aggregate functions, see "Built-in aggregate functions" on page 870.

> **Note:** If a built-in aggregate function does not meet your needs, you can use EPL to write a custom aggregate function. A custom aggregate function that you want to use in a query must either be a bounded function or it must support both bounded and unbounded operation. See "Defining custom aggregate functions" on page 241.

For example, the following query watches for a withdrawal amount that is greater than some threshold multiplied by the average withdrawal amount of the `ATMWithdrawal` events in the window, which might be as many as 20 events. This query uses the `last()` aggregate function to identify the event added to the window most recently and uses the `avg()` aggregate function to find the average withdrawal amount of the events in the window. The `having` clause must evaluate to true for the query to send the `SuspiciousTransaction` event, passing the transaction Id of the suspicious withdrawal.

```
using com.apama.aggregates.avg;
using com.apama.aggregates.last;
query FindSuspiciouslyLargeATMWithdrawals {
   parameters {
      float THRESHOLD;
   }
   inputs {
      ATMWithdrawal() key accountId retain 20;
   }
   find every ATMWithdrawal:w
      select last(w.transactionId):tid
      having last(w.amount) > THRESHOLD * avg(w.amount){
      send SuspiciousTransaction(tid) to SuspiciousTxHandler;
   }
}
```

To use an aggregate function in a `find` statement, specify the `every` modifier and specify one or more `select` or `having` clauses. A `select` clause indicates that aggregate values are to be computed. Each `select` clause specifies a projection expression and a projection coassignment. The projection expression can use coassignments from the pattern if the coassignments are within a single aggregate function call. For example, the following pattern computes the average value of the `x` member of event type `A` in the query's input and coassigns that average value to `aax`.

```
find every A:a select avg(a.x):aax
```

A `select` clause can use parameter values. For example the following two `select` clauses are both valid if there is a parameter `param`:

```
find every A:a
   select avg(param * a.x):apax
   select param * avg(a.x):paax
```

You can specify multiple `select` clauses to produce multiple aggregate values.

In an aggregating `find` statement, only the projection expression can use the coassignments from the pattern. The procedural block of code can use projection coassignments and any parameters, but it cannot use coassignments from the pattern.

The `first()` and `last()` built-in aggregate functions are useful if you want to refer to the coassignment value of the oldest or newest event, respectively, in the window.

The following example determines the average price of trades other than your own:

```
find every Trade:t
   where t.buyer != myId and t.seller != myId
   select wavg(t.price, t.amount):avgprice
```

Match sets used in aggregations

In `find` statements without the `every` modifier, only the most recent set of events that match the pattern are used to invoke the procedural code block. With the `every` modifier, every set of events that matches the pattern is available for use by the aggregate function, provided that the latest event is present in one of the sets of events. Any events or combinations of events that do not match the pattern or do not match the `where` clause, or are invalidated due to a `within` or `without` clause, are ignored; their values are not used in the aggregate calculation.

For example, consider the following `find` statement:

```
find every A:a -> B:b
   where b.x >= 2
   select avg(a.x + b.x):aabx {
   print aabx.toString();
}
```

The following table shows what happens as events are added to the window.

Event Added to Window	Match Sets	Average Of	Value of aabx
`A(1)`	None		
`A(2)`	None		
`B(2)`	`A(1), B(2)` `A(2), B(2)`	`3` and `4`	`3.5`
`B(1)`	None because `B(1)` causes the `where` clause to be false.		
`B(3)`	`A(1), B(2)` `A(2), B(2)`	`3`, `4`, `4`, and `5`	`4`

Event Added to Window	Match Sets	Average Of	Value of aabx
	A(1), B(3) A(2), B(3)		

Using aggregates in namespaces

As with event types, an aggregate function is typically defined in a namespace. To use an aggregate function, specify its fully-qualified name or a `using` statement. The built-in aggregate functions are in the `com.apama.aggregates` namespace. For example, to use the `avg()` aggregate function you would specify the following in the query:

```
using com.apama.aggregates.avg;
```

Filtering unwanted invocation of procedural code

Each `select` clause defines an aggregate value to be produced. You can also specify one or more `having` clauses to restrict when the procedural code is invoked. For example, consider the following `find` statement:

```
find every A:a
   select avg(a.x):aax
   having avg(a.x) > 10.0 {
   print aax.toString();
}
```

This example calculates the average value of `a.x` for the set of `A` events in the window. However, it executes the procedural block only when the average value of `a.x` is greater than `10.0`.

Multiple having clauses

You can specify multiple `having` clauses and you can use parameter values in `having` clauses. For example,

```
find every A:a
   select avg(a.x):aax
   select sum(a.y):aay
   having avg(a.x) > 10.0
   having sum(a.y) > param1
   having max(a.z) < param2
   {
   print aax.toString(), + " : " + aay.toString();
}
```

When you specify more than one `having` clause it is equivalent to specifying the `and` operator, for example:

```
   ...
   having avg(a.x) > 10.0 or sum(a.y) > param1
   having max(a.z) < param2
   ...
```

is equivalent to

```
   ...
   having ( avg(a.x) > 10.0 or sum(a.y) > param1 ) and  ( max(a.z) < param2 )
   ...
```

Using a select coassignment in a having clause

Rather than specifying an aggregate expression twice, once in a `select` clause and then subsequently in a `having` clause, it is possible to refer to the aggregate value by using the `select` coassignment name. For example:

```
find every A:a
   select avg(a.x):aax
   having avg(a.x) > 10.0 {
   print aax.toString();
}
```

You can rewrite that as follows:

```
find every A:a
   select avg(a.x):aax
   having aax > 10.0 {
   print aax.toString();
}
```

Using a having clause without a select clause

When you want to test for an aggregate condition but you do not want to use the aggregate value, you can specify a `having` clause without specifying a `select` clause. For example,

```
find every A:a
   having avg(a.x) > 10.0 {
   print "Average value is greater than ten!";
}
```

Event matching policy

It is possible for the windows for a given key to contain multiple sets of events that, each taken in isolation, would match the defined event pattern. In this case, the matching policy determines which of the candidate event sets is the match set that triggers the query. There are two event matching policies:

- Recent — This is the only policy followed for queries that to not specify the `every` keyword, that is, they do not specify aggregate functions.
- Every — This is the only policy followed for queries that specify the `every` keyword. That is, they specify aggregate functions.

For both policies, the match set must include the latest event. The latest event is the event that was most recently added to the set of windows identified by a particular key.

For the recent matching policy, to identify which candidate match set triggers the query, the correlator compares the times of the second-most-recent events in the candidate event sets. If one of these events is more recent than its corresponding event(s) then the candidate event set it is in is the match set. However, if two or more candidate event sets share the second-most-recent event, then the correlator compares the times of the third-most-recent events in those candidate event sets. The correlator continues this until it finds an event that is more recent than its corresponding event(s) in other candidate event set(s). The candidate event set that becomes the match set is referred to as the most recent set that matches the event pattern.

Once the correlator determines which candidate event set is the match set, it ignores the order of any earlier events in any event sets. This means that it is possible for the most recent set of events to contain an event that was added earlier than an event in a set that is not the most recent set. The following event definitions and sample query illustrate this.

```
event APNR {
   // Automatic Plate Number Recognition
   string road;
   string plateNumber;
   integer time; // Represents time order for illustration purposes
}
event Accident {
   string road;
}
event NotifyPolice {
   string road;
   string plateNumber;
}
```

The following query uses these events:

```
query DetectSpeedingAccidents {
   inputs {
      APNR() key road within(150.0);
      Accident() key road within(10.0);
   }
   find APNR:checkpointA -> APNR:checkpointB -> Accident:accident
      where checkpointA.plateNumber = checkpointB.plateNumber
      and checkpointB.time - checkPointA.time < 100
      // Which indicates the car was speeding
   {
      emit NotifyPolice(accident.road, checkpointA.plateNumber);
   }
}
```

Suppose the following events are in the query windows:

```
APNR("MyRoad", "2N2R4", 1000)
APNR("MyRoad","FAB 1", 1010)
APNR("MyRoad","FAB 1", 1080)
APNR("MyRoad","2N2R4", 1090)
Accident("MyRoad")
```

There are two candidate event sets:

Coassignment identifier	A candidate event set	Another candidate event set
checkpointA	APNR("MyRoad", "2N2R4", 1000)	APNR("MyRoad","FAB 1", 1010)
checkpointB	APNR("MyRoad", "2N2R4", 1090)	APNR("MyRoad","FAB 1", 1080)
accident		

Coassignment identifier	A candidate event set	Another candidate event set
	`Accident("MyRoad")`	`Accident("MyRoad")`

Both sets match against the single `Accident` event. The next most recent events are `APNR("MyRoad","2N2R4", 1090)` and `APNR("MyRoad","FAB 1", 1080)`. The `APNR("MyRoad", "2N2R4", 1090)` event is more recent. Consequently, after the `Accident` event is added to its window, there is a match and the match set includes the `Accident` event and the `2N2R4 APNR` events. This is the most recent set of events.

In this example, in the most recent set of events, the earliest event, `APNR("MyRoad", "2N2R4", 1000)` is earlier than the earliest event, `APNR("MyRoad", "FAB 1", 1010)`, in the other set of events.

Acting on pattern matches

When a query finds a set of events that matches the specified pattern it executes the statements in its `find` block. The `find` block specifies one or more statements that operate on the matching event(s). The items available in a `find` block include:

- Any parameters defined in the `parameters` section.
- Coassignment variables specified in the event pattern.

  In the case of an aggregating `find` statement, only the projection expression can use the coassignments from the pattern. The `find` block can use projection coassignments, but it cannot use coassignments from the pattern.
- Key values.
- Actions that are defined in the same query after the `find` block. Any expression in the `find` statement pattern or block can reference an action defined after the `find` block.
- EPL constructs and statements that are allowed in queries. See "Restrictions in queries" on page 151.

Defining actions in queries

In a query, after a `find` statement, you can define one or more actions in the same form as in EPL monitors. See "Defining actions" on page 271.

In a given query, an action that you define can be referenced from any expression in that query's `find` statement, including any statements in its `find` block. For example:

```
query CallingQueryActions {
   parameters {
      float distanceThreshold;
      float period;
   }
   inputs {
      Withdrawal() key account within period;
   }
```

```
   find Withdrawal: w1 -> Withdrawal: w2
      where distance(w1.coords, w2.coords ) > distanceThreshold
      {
      logIncident( w1, w2 );
      sendSmsAlertToCustomer(
         getTelephoneNumber(w1), getAlertText(w1,w2) );
   }
   action distance( Coords a, Coords b) returns float {
      integer x := a.x - b.x;
      integer y := a.y - b.y;
      return ( x*x + y*y ).sqrt();
   }
   action logIncident ( Withdrawal w, Withrawal w2 ) { ... }
   action getTelephoneNumber(Withdrawal w ) returns string { ... }
   action getAlertText ( Withdrawal w1, Withrawal w2 ) returns string { ... }
   action sendSmsAlertToCustomer( string telephoneNumber, string text ) { ... }
}
```

Note: In a query, do not define an action whose name is `onload`, `ondie`, `onunload`, `onBeginRecovery`, or `onConcludeRecovery`. In EPL monitors, actions with these names have special meaning. For more information, see "Monitor actions" on page 849.

Implementing parameterized queries

An Apama query can define parameters and then refer to those parameters throughout the query definition. This enables a query definition to function as a template for multiple query instances.

A query that defines parameters is referred to as a parameterized query. An instance of a parameterized query is referred to as a parameterization.

A parameterized query offers the following benefits:

- Patterns of interest (`find` patterns) may be customized from a single generic query. This can significantly reduce the amount of code that needs to be written and maintained.
- Parameterizations exist only at runtime. There is no need to maintain a file for each instance.
- Parameters can be used throughout the query in which they are defined. For example, you can use them in the definition of inputs, in `find` actions, and in user-defined actions. Values do not need to be hardcoded.

See also: "Query lifetime" on page 854.

Format for defining query parameters

You define query parameters in the `parameters` section of a query definition. The `parameters` section is optional. If you specify a `parameters` section, it must follow the `metadata` section, if defined, and it must precede the `inputs` section.

The format for specifying the `parameters` section is as follows:

```
parameters {
```

```
data_type parameter_name;
   [ data_type parameter_name; ]...
}
```

Parameters must be `integer`, `float`, `string` or `boolean` types. Specify one or more *`data_type parameter_name`* pairs. The parameter name can use any of the characters allowed for EPL "Identifiers" on page 919. Any parameters you specify are available throughout the rest of the query.

In the following example, the `parameters` section is in bold as are the references to the parameters.

```
query FaultyProduct {
parameters {
          string product;
          float thresholdCost;
          float warrantyPeriod;
        }
        inputs {
          Sale() key customerId within warrantyPeriod;
          Repair() key customerId retain 1;
        }
        find Sale():s1 -> Repair():r1
          where s1.product = product
          and r1.product = product
          and r1.cost >= thresholdCost
        {
          log "Cost of warranty covered repair for product \"" + product +
             "! above threshold $" + thresholdCost.toString() + " by $
             " + (r1.cost - thresholdCost).toString() at INFO;
        }
     }
```

Parameterized queries as templates

When a parameterized query is injected into a correlator no instances of the query are created until a request to create a parameterization is sent using the Scenario Service (that is, the `com.apama.services.scenario` client API). This request must include valid values for the query's parameters. For example, if the query in the previous topic is injected, the request to create a parameterization must include valid values for the `product`, `thresholdCost`, and `warrantyPeriod` parameters. Only then does the query become active.

A parameterized query lets you define a generic query `find` pattern that operates on a particular group of input types and that can be customized for particular criteria. The query in the previous topic could be created for any product with the threshold cost and warranty period specified as required. To achieve the same result with a non-parameterized query, you would have to define a query such as the following:

```
query FaultyProduct {
   inputs {
      Sale() key customerId within 1 week; //warrantyPeriod
      Repair() key customerId retain 1;
   }
   find Sale():s1 w-> Repair():r1
      where s1.productId = "Mobile device A" // productId
      and r1.productId = "Mobile device A" // productId
      and r1.cost >= 50.00 // thresholdCost
   {
```

```
      log "Cost of warranty covered repair for product \"Mobile device A\
      " above threshold $50.00 by $" + (r1.cost - 50.00).toString() at INFO;
   }
}
```

While this query is valid it has the drawback that whenever you want to perform a similar query for a product that differs by type, warranty coverage period or threshold repair cost then a new query will need to be written (or most likely copied and pasted) with the new set of values and then injected into the correlator. The benefit of a parameterized query is that only one query definition needs to be injected into the correlator and you can then manually or programatically create as many different instances for the different product-value combinations as required.

Using the Scenario Service to manage parameterized queries

There are several ways to manage (create/edit/remove) parameterizations:

- Use the `ScenarioService` API in Java or .NET client libraries. See "Developing Custom Clients" in *Connecting Apama Applications to External Components".*
- Use Apama's Scenario Browser view in Software AG Designer. See "Scenario Browser view" in *Using Apama with Software AG Designer*.
- Write dashboards that control the instances of a parameterized query. See "Building Dashboard Clients" in *Building and Using Dashboards*.

The Scenario Service is also used to read and manage instances of scenarios, DataViews and MemoryStore.

To these tools, a query will appear with the fully qualified name declared in the `.qry` file prefixed with `QRY_` to highlight that the entity being viewed is a query. For parameterized queries, instances can be created, edited or deleted. For unparameterized queries, a single instance will appear as soon as the query is injected. This instance cannot be edited nor deleted, nor new instances created.

When there is a request to create a parameterization the Scenario Service tries to validate the supplied parameter values. If the values are valid the result is as if a query with those values had just been injected.

The parameter setting capabilities provided for queries are similar to that for scenarios. For example, end users have the ability to define conditions on parameter values when setting them in dashboards. Parameter values can be modified only by the Scenario Service. Updates by the Scenario Service do not occur atomically across all contexts if the query is running in multiple contexts. Consequently, it is possible to observe the effects of the old parameter values interleaved with the effects of the new parameter values. For example, consider a query that has a pattern such as the following:

```
find A:a -> wait(paramValue):t
```

The wait period will be based on the value the parameter had when the wait period started. If the parameter value is edited after the `A` event enters the partition the `wait` still fires according to the old value. Such transitions are typically short. The actual time required depends on various factors such as machine load and memory.

Some important differences between parameterized queries and scenarios include:

- Parameterized queries have input variables but not output variables. Scenarios, DataViews and MemoryStore have both input variables and output variables. All queries have an empty list of output variables.
- Requests to create or update a parameterization with values that are invalid will be denied. Invalid values are values that would cause `wait`, `within` or `retain` clauses to evaluate to less than or equal to zero, or would cause them to fail to evaluate, for example, by causing a runtime exception to be thrown.

For example, consider the following query:

```
query ParameterizationExample {
   parameters {
      integer intParam;
      integer floatParam;
   }

   inputs {
      A() key id retain (10/intParam);
      B() key id within (5.0 - floatParam);
   }

   find A:a -> B:b -> wait(-1.0 * floatParam)
      where (a.intField/intParam > 0) {
      log "Found match" at INFO;
   }
```

Suppose that there is a request to create a parameterization of this query. The request indicates that `intParam` is equal to `0` and `floatParam` is equal to `10.0`. If the parameterization were created then every expression that contains a parameter value would immediately throw an exception or be invalid. In the `inputs` block, evaluation of the `retain` expression would result in a divide-by-zero exception. The `within` expression would evaluate to `-5.0`, which is not valid. Similarly, upon evaluating the elements in the `find` block the `wait` expression would be a negative value and the `where` clause would also result in a divide-by-zero exception. Since a parameterization such as this would lead to either invalid expressions or exceptions being thrown, these values are not allowed. If you try to pass disallowed values to the Scenario Service `createInstance()` method then the Scenario Service returns `null`. Similarly, if you try to pass invalid values to the Scenario Service `editInstance()` method then the Scenario Service returns false, which indicates an error.

Referring to parameters in queries

You can refer to parameters throughout a query definition.

You cannot change parameter values in the query code itself. Parameter values can be modified only by the Scenario Service.

Caution: Apama recommends that you do not change parameter values used in input filters because it is possible to miss events that would cause a match. In a given parameterization, when an input filter refers to a parameter and you change the value of that parameter, it causes the parameterization to stop and restart. Events sent during the changeover are ignored. Also, there might have been earlier events that match the new parameter value but that did not make it into the window because they did not match the previous parameter value. An alternative is to use a parameter in a `where` clause in the `find` statement instead. This can be more efficient when the parameter value needs to be changed frequently. Using parameter values in input filters can also increase memory usage, see "Queries can share windows" on page 96.

Examples of using parameters in queries:

- In `retain` and `within` expressions that are in the `inputs` block:

```
parameters {
   integer maxRetention;
   float maxDuration;
}
inputs {
   A() key id retain maxRetention;
   B() key id with maxDuration;
}
```

- In the filter of the event template in the `inputs` block:

```
parameters {
   float threshold;
}
inputs {
   Withdrawal(amount > threshold) key k;
}
```

- In `where` and `within` clauses that are in the `find` pattern:

```
parameters {
   float maxDuration;
   float maxDifference;
}
inputs {
   A() key id retain 2;
}
find A:a1 -> A:a2 where (a2.cost - a1.cost) >
   maxDifference within maxDuration {
   ...
}
```

- In `wait` expression(s) that are in the `find` pattern:

```
parameters {
   float interval;
}
inputs {
   A() key id retain 2;
}
find A:a1 -> wait(interval):w1 -> A:a2 {
   ...
}
```

- In an aggregate expression that is in the `find` pattern:

```
parameters {
   float avg;
}
inputs {
   A() key id within 1 day;
}
find every A:a
   select avg(a.cost - avg):avgDeviation {
```

```
    ...
}
```

- In an action that is in the `find` block:

```
parameters {
   float avg;
}
inputs {
   A() key id retain 1;
}
find A:a {
   log "Deviation from mean = " + (a.value - avg).toString();
}
```

- In a user-defined action block:

```
parameters {
   float avg;
}
inputs {
   A() key id retain 1;
}
find A:a {
   log "Deviation from mean = " + getDeviation(a).toString();
}
action getDeviation(A a) returns float {
   return (a.value - avg);
}
```

While parameter values can be used anywhere within the query it is illegal to mutate the parameter values. They can be modified only by the Scenario Service.

Scaling and performance of parameterized queries

Depending on the machine architecture a user can expect to be able to create several hundred parameterizations, which all concurrently process events.

As a result of the time required to process a parameterization edit request, the recommendation is to avoid multiple simultaneous edit requests for the same parameterization. There is no guarantee that all of the threads executing the parameterization will hold the same parameter values during the update period. During the update period, there might be a mix of results based on old parameter values and results based on new parameter values. Any requests to the same parameterization should be spaced approximately 1 second apart to allow time for requests to be executed throughout the parameterization. This applies to create, edit and delete requests.

In a cluster of correlators, the correlators share the same set of parameter values across the cluster. While a Scenario Service client can connect to any correlator in the cluster, it is not recommended to edit the same parameterization from multiple Scenario Service clients concurrently, as the results will be undefined.

Restrictions in queries

There are some EPL elements that are appropriate for monitors but not queries, for example `spawn` and `die`. This is because queries scale automatically, with multiple threads of execution processing the events for different partitions as and when they arrive. Hence, within query code, the `spawn` and `die` operations are meaningless. Queries operate on the events in their windows and do not need to set up event listeners, stream queries, or stream listeners. Also, queries cannot subscribe to receive events sent to particular channels.

The following EPL features cannot be used in queries:

- Event listeners, that is, `on` statements
- Stream queries and stream listeners
- `spawn` and `spawn...to` statements
- `die` statements
- `monitor.subscribe()` and `monitor.unsubscribe()`
- `route` statements
- An identifier cannot start with two consecutive underscore characters. For example, `__MyEvent` is an invalid event type name in a query (it is valid in a monitor). A single underscore at the beginning of an identifier is valid.
- Predefined `self` variable

Of course, you cannot call an action on an event when that action uses a restricted feature listed here.

The recommended means to send events from queries to monitors is by sending to a channel. See "Generating events with the send command" on page 285.

The debugger does not support debugging query execution - it is not possible to set breakpoints in a query file. Use of the debugger can also affect how quickly queries are ready to respond to events, and should not be used in a production system (where it would cause significant pauses of the correlator).

Note: Several restrictions are enforced on queries if a license file cannot be found while the correlator is running. See "Running Apama without a license file" in *Introduction to Apama*.

Best practices for defining queries

Use values for the length of the window that will not store too much data in the window.

Given the expected incoming event rate, set the `within` and/ or `retain` window lengths so that typically less than a hundred events per partition will be within the window. With more than that the cost of executing queries can become excessive and the system will not perform efficiently. There is no limit on the number of events within any partition - if a very small proportion of exceptional partitions has many more, then that is not a problem. The important factor is that if the average number is large, this can affect the performance of executing queries.

Use parameters instead of creating many similar queries.

(See also "Parameterized queries as templates " on page 147). Rather than write many separate queries which are very similar in structure and differ only in values, it may be easier to write a template query and create multiple parameterizations of it. Note that it is not possible to select which fields are keys using parameters - queries that use different keys must be written as separate query files.

Use within in input durations if the partition values change over time

In some queries, the key used by the query may correspond to a transient object - that is, any given value for the partition is not permanent. For example, if tracking parcels being delivered, then each consignment ID will be short lived - once a parcel is delivered, there would in most cases be no more events for that consignment ID (and future deliveries may never re-use the same consignment ID). In these cases, over long periods, the number of different key values processed will only increase, as new IDs are generated. Such queries should include a 'within' specification in the inputs for all event types. Otherwise, if inputs only have a retain specification, then the events will be held forever, and more and more storage will be required by the Queries system. This is not typically necessary if the key corresponds to more permanent objects - such as ATMs or distribution depots.

Use input within that is larger than the value of all waits, withins in the pattern

If your inputs specify a `within` and there are `wait` or `withins` in the pattern, then the input within should be larger than the longest `wait` and `within` in the pattern. If not, the pattern will not have the intended effect, as events will be expired from the input window while a wait or within in the pattern is still active.

Use same set of inputs to allow sharing of data

If you have many queries of different types and they are using a lot of memory or are running slowly, then check if they are using the same inputs definitions (see also "Queries can share windows" on page 96). Memory usage can be reduced and performance increased by making multiple queries use the same set of input definitions, even if some queries have some event types in their inputs that they are not using.

Understand the difference between filters and where clauses

Filters in the input section filter events before they are stored in the distributed cache. By contrast, the where clause filters events (or combinations of events) after they have been stored in the distributed cache. The where clause is more powerful, but also more expensive, especially if most events do not match the where clause.

- A filter applies before the event window. Thus:
  - Events not matching the filter are ignored and do not need to be stored anywhere. This makes filtering a very cheap way of reducing the number of events that need to be processed. The retain count only applies to the events that match the filter. For example, this query input:

    ```
    query Q1 {
    ```

```
    inputs {
        Event( value = 5) key k retain 2;
    }
    find Event:e1 -> Event:e2 {
    }
}
```

Will match events where there have been two events with value = 5; it will match if another event for the same k has occured between them with value not equal to 5. Compare with:

```
query Q2 {
    inputs {
        Event() key k retain 2;
    }
    find Event:e1 -> Event:e2 where e1.value = 5 and e2.value = 5 {
    }
}
```

This only matches if the last two events for a given value of k both have the value 5 - as we only retain 2 events and after retaining 2 events, check that they have value = 5.

- A filter applies to all events - note that in query Q2 above we had to repeat the value = 5 check.
- A where clause does not affect the definition of the inputs; query Q2 could share window contents with other queries that are concerned with different values of 'value', or don't filter at all.
- A filter is restricted to range or equality matches per field of the incoming events. Where clauses can be more complex (e.g. `where e1.field1 + e2.field2 = 10` is valid, as is `e1.isTypeA or e1.isTypeB` - but neither could be expressed in a filter)

Avoid changing parameter values used in filters

If using parameters in filters, avoid changing the values of those parameters. As this changes which events should be being stored in the window, this is similar in effect to stopping a query instance and creating a new query instance - it involves creating new tables in the distributed cache and events that are delivered to correlators while a new table is opened will be dropped. It may be more desirable to use a where clause to restrict which events match a pattern.

Use custom aggregates to get data from multiple match sets

As well as the built-in aggregates, it is possible to define new aggregates in EPL to collate information about all events that matched a pattern. For example, it may be desirable to have a list of all events that matched a pattern. This can be achieved by writing a new custom aggregate. For example:

```
// file MyAggregates.mon:
aggregate CollateEvents(Event e) returns sequence<Event> {
    sequence<Event> allEvts;
    action add(Event e) {
        allEvts.append(e);
    }
    action value() returns sequence<Event> {
        return allEvts;
```

```
    }
}
// file PrintAllEvents.qry:
query PrintAllEvents {
    inputs {
        Event() within 2 hours;
    }
    find every Event:e1 select CollateEvents(e1):c1 {
        Event e;
        for e in c1 {
            print e.toString();
        }
    }
}
```

Testing query execution

When writing queries, as with any programming, it is important to test that the query is behaving as expected. Testing can be as simple as a small Apama project with the event definitions, the queries, and an `evt` file of events to send to the query. You can use this project to check whether the query sends out the correct events. In Software AG Designer, use the **Engine Receive** view to observe the output of the query. Whether or not a query is written to send output events, you can add `log` statements to the query file to verify whether it has or has not triggered.

Be sure to test queries in an environment that is separate from your production environment. Of course, preventing problems is the best way to avoid the need to troubleshoot so ensure that queries are sufficiently tested before deploying them.

The following background information and troubleshooting tips provide some guidance. See also: "Overview of query processing" on page 82.

Exceptions in queries

In a query, exceptions can occur in the following places:

- Procedural code in a `find` statement block
- `having` clause
- `retain` clause
- `select` clause
- `wait` clause
- All `where` clauses
- All `within` clauses

An exception in the `inputs` block (`retain` or `within` clause) or the `find` block's `wait` or `within` clause causes the query to terminate. If there is an exception elsewhere, the query continues to process incoming events. An exception that occurs in a `where` or `having` clause causes the Boolean expression to evaluate to false.

Event ordering in queries

Unlike EPL monitors, the order in which queries process events is not necessarily the order in which they were sent into the correlator. In particular, if two events that will be processed by the same query with the same key value are sent very close together in time (both events received less than about .1 seconds of each other) then they may be processed as if they had been sent in a different order. For example, consider a query that is looking for an `A` event followed by an `A` event. If two `A` events with the same key arrive 1 millisecond apart then the events might not be processed in the order in which they were sent.

Queries use multiple threads to process events and to scale across multiple correlators on multiple machines. To do this efficiently, there is no enforcement that the events are processed in order. However, when events that have the same key arrive roughly about .5 seconds apart or more then out-of-order processing is typically avoided provided the system can keep up with the load. Therefore, you want to specify a query so that it operates on partitions in which the arrival of consecutive events is spaced far enough apart. For example, consider a query that operates on credit card transaction events, which could mean thousands of events per second. You want to partition this query on the credit card number so that there is one event or less per partition per second. By following this recommendation, it becomes possible to process events that are generated at rates of up to 10,000 events per second.

When creating an `evt` file for testing purposes the recommendation is to begin the file with a `&FLUSHING(1)` line to cause more predictable and reliable event-processing behaviour. See "Event timing" in the "Correlator Utilities Reference" section of *Deploying and Managing Apama Applications*. For example, consider the following `evt` file:

Query diagnostics

To help you monitor queries that are running on a given correlator, Apama provides data about active queries in DataViews. See "Monitoring running queries" in *Deploying and Managing Apama Applications*.

When deploying Apama queries it is possible to enable generation of diagnostic information. These are `log` statements that explain some of the internal workings of the query evaluation. In particular, events coming into the query and the contents of the windows before the pattern is evaluated are both logged. This can aid understanding of how the query evaluation occurs. If a query is misbehaving then providing this diagnostics logging to Apama support can help in understanding the issue.

Note: Diagnostic logs contain the event data. You may want to consider using fake data rather than real data if the real data is sensitive.

Logging in *where* statements

It can be useful to modify a query so that rather than including the expression that needs to be evaluated in a `where` clause, the query calls an action on the query to execute the expression used by the `where` clause. This allows logging of inputs and the result of the expression. For example, instead of a query that contains the following:

```
find A:a -> B:b where a.x >= b.x { ...
```

Write the query this way:

```
action compareAB(A a, B b) returns boolean {
    log "compareAB; inputs:  A:a = "+a.toString()+ ", B:b = "+b.toString();
    boolean r:= (a.x >= b.x);
    log "compareAB; result is "+r.toString();
    return r;
}

find A:a -> B:b where compareAB(a, b) { ...
```

You can then use these `log` statements to check if the query is behaving as expected.

Divide and conquer

One of the advantages of testing a query with a known set of input events is that it is possible to see how changing the query affects the results. For example, if a query is not matching any events and has many `within` and `without` clauses, try removing all of them. One way to do this is to place them onto separate lines and use `//` as a comment at the beginning of the lines in the source view. If the query still does not fire, use query diagnostics to check that events are being evaluated. If the query is firing, then add `within` and `without` clauses one at a time until the query stops firing. The problem is at the condition that stops it from firing when it should.

Query performance

A critical factor that affects the performance of queries is the size of the windows specified in the `inputs` block of the query. Aim for windows that contain no more than 100 events. Depending on the distributed cache used to store data, it may also be necessary to change the number of parallel contexts per correlator. Experiment with different values for the number of worker contexts. See also: "Overview of query processing" on page 82.

Using external clocking when testing

When testing queries, as well as switching into single context execution, it is often useful to use external clocking. This allows `&TIME` events to be sent into the correlator to simulate the passage of time, which allows queries involving long durations (for example, multiple days) to be tested easily. To ensure the correct ordering of processing between events and `&TIME` events, you should also include `&FLUSHING(1)` at the beginning of the event file, before any events. See "Externally generating events that keep time (&TIME events)" on page 197 in this document and "Event timing" in the "Event file format" section of the correlator utilities reference in *Deploying and Managing Apama Applications*.

Communication between monitors and queries

Queries can be used with or without monitors written in EPL. If you use monitors in your query application, there are several ways to send data from a monitor to a query:

- To send an event to all Apama queries running on that correlator, send it to the `com.apama.queries` channel.
- Queries receive events sent to the default channel, which is useful for testing.

Note: The order in which events are processed is not guaranteed for queries. See "Event ordering" in "Testing query execution" on page 155.

Queries can send events to EPL monitors by using the `send...to` statement and specifying a channel on which the monitor is listening. The monitor author should make it clear which channel they are expecting events on. The channel name can be a single name for a given monitor or a name constructed from data in the event, so that different values are processed in parallel.

If you are using multiple correlators, be aware that communication between queries and monitors normally takes place within a single correlator. However, it is possible to use `engine_connect` or Universal Messaging to connect correlators. This allows an event sent on a channel on one correlator to be processed by a monitor subscribed to that channel on another correlator.

Unlike a query's history window, any state stored in EPL monitors, including in the listeners, is independent in each correlator, and is not automatically moved or shared between correlators.

4 Defining Event Listeners

In an EPL monitor, an `on` statement specifies an event expression and a listener action.

Note: Queries do not need to set up event listeners so you cannot specify an `on` statement in a query. The information about defining event listeners applies only to monitors.

When the correlator executes an `on` statement it creates an event listener. An event listener observes each event processed by the context until an event or a pattern of events matches the pattern specified in the event listener's event expression. When this happens the event listener triggers, causing the correlator to execute the listener action. At this point, depending on the form of the event expression, the event listener either terminates or continues listening for additional matching event patterns.

An event listener analyzes the event stream until one of the following happens:

- The event listener finds the pattern defined in its event expression.
- The `quit()` method is called on the event listener to kill it.
- The monitor that defines the event listener dies.
- The correlator determines that the event listener can never trigger.

The correlator can support large numbers of concurrent event listeners each watching for an individual pattern.

About event expressions and event templates

To create an event listener, you must specify an event expression. An event expression

- Identifies an event or event pattern that you want to match
- Contains zero or more event templates
- Contains zero or more event operators

An event template specifies an event type and encloses in parentheses the set of, or set of ranges of, event field values to match. An event template can specify wildcards for event fields or can specify that certain event fields must have particular values or ranges of values.

An event expression can specify a temporal operator and zero event templates.

Following are event expressions that are each made up of one event template:

Event Expression	Description
`StockTick(*,*)`	The event listener that uses this event expression is interested in all `StockTick` events regardless of the event's field values.

Event Expression	Description
`NewsItem("ACME",*)`	The event listener that uses this event expression is interested in `NewsItem` events that have a value of `ACME` in their first field. Any value can be in the second field.
`ChainedResponse(reqId="req1")`	The event listener that uses this event expression is interested in `ChainedResponse` events whose `reqId` field has a value of `req1`. If a `ChainedResponse` event has any other fields, their values are irrelevant.

You can specify more than one event template in an event expression by adding event operators. The following table describes the operators that you can use in an event expression.

Category	Operator	Operation
Followed by	`->`	The event listener detects a match when it finds an event that matches the event template specified before the followed-by operator and later finds an event that matches the event template that comes after the followed-by operator.
Repeat matching	`all`	The event listener detects a match for each event that matches the specified event template. The event listener does not terminate after the first match.
Logical operators	`and`	Logical intersection. The event listener detects a match after it finds events that match the event templates on both sides of the `and` operator. The order in which the listener detects the matching events does not matter.
	`not`	Logical negation. The event listener detects a match only if an event that matches the event template that follows the `not` operator has not occurred.
	`or`	Logical union. The event listener detects a match as soon as it finds an event that matches

Category	Operator	Operation
		one of the event templates on either side of the `or` operator.
	`xor`	Logical exclusive or. The event listener detects a match if it finds an event that matches exactly one of the event templates on either side of the `xor` operator. For example, consider this event: `A(1,1)`. This event does not trigger the following listener because it matches the event templates on both sides of the `xor` operator: `on A(1,*) xor A(*,1).`
Temporal operators	`at`	The event listener triggers at specific times or repeatedly at a specified interval.
	`wait`	Limits the amount of time that an event listener can detect a match.
	`within`	The event listener can find a match only within the specified timeframe.

Consider the following example:

```
event Test
{
   float f;
}

monitor RangeExample
{
   action onload()
   {
      on Test (f >= 9.0 ) and Test (f <= 10.0) processTest();
   }

   action processTest();
   {
      do something    }
}
```

The event expression is:

```
Test (f >= 9.0 ) and Test (f <= 10.0)
```

This event expression specifies the `and` operator so the event listener must detect an event that matches both of the event expression's event templates or two events, where one matched the first template and another matched the second. It does not have to be a single event that matches both event templates. The order in which the templates are matched does not matter.

Consider this event expression:

```
A(a = "foo") xor A(b > 9)
```

An event listener that defines this event expression triggers for `A("foo", 9)` but not `A("foo", 10)`. On `A("foo", 10)`, the `A` templates would trigger simultaneously, so the `xor` would remain false.

The correlator can match on up to 32 fields per event. If you specify an event template for an event that has more than 32 fields, you must ensure that the correlator maintains indexes for the particular fields for which you specify values that you want to match.

In other words, when the event definition was loaded into the correlator, the fields that did not have the `wildcard` keyword formed the set of fields that you can match on. An event template can try to match on only those fields. If an event template specifies any of the `wildcard` fields, it must be with an asterisk.

If you try to load a monitor that defines an event template that specifies more than 32 fields without an asterisk or a `wildcard` field without an asterisk, the correlator rejects the monitor. You must correct the template in order to load the monitor.

Specifying the on statement

You specify an `on` statement to define an event listener. The format of an `on` statement is as follows:

```
[listener identifier := ] on event_expr [ coassignment ] listener_action;
```

Syntax description

Syntax Element	Description
identifier	Optionally, you can specify a variable of type `listener` and assign the new event listener to that variable. This gives you a handle to the event listener — if you want to terminate it you can call the `quit()` method on the listener.
event_expr	The event expression identifies the event or pattern of events that you want to match. An event expression is made up of one or more event templates and zero or more event operators.
coassignment	Optionally, you can coassign the matching event to a variable of the same event type. Coassignments are part of event templates. Each event template can have a coassignment, so there can be multiple coassignments in a listener.

Syntax Element	Description
listener_action	The statement or block that you want the correlator to perform when the event listener triggers.

Examples

For example:

```
on StockTick(*,*) processTick();
```

In this example, the event expression contains one event template: `StockTick(*,*)`. The asterisks indicate that the values of the `StockTick` event's two fields are not relevant when matching. When this event listener detects a `StockTick` event, the listener triggers and causes the correlator to execute the `processTick()` listener action.

Following is an example that coassigns the matching event to the `newTick` variable. The `newTick` variable must be a `StockTick` event type variable. Coassignment simply assigns the event to the variable.

```
on StockTick(*,*):newTick processTick();
```

The next example begins with the declaration of a `listener` variable. The statement assigns the event listener to the `l` variable.

```
listener l := on StockTick(*,*):newTick processTick();
```

Suppose that after finding a matching event, the listener action includes specification of an `on` statement. For example:

```
listener l := on StockTick(*,*):newTick {
   on StockTick(newTick.symbol, > newTick.value):risingTick {
      processRisingTick();
   }
}
```

The correlator creates an entirely new event listener to handle the nested `on` statement. This new event listener is completely independent of the enclosing event listener. For example, the enclosing event listener does not wait for the nested event listener to find a matching event.

Using a stream source template to find events of interest

In addition to event listeners, EPL provides stream source templates for finding events of interest. A stream source template is an event template prefixed with the `all` keyword. The result of a stream source template is a stream.

Use streams on a continuous flow of incoming items when you want to aggregate, join to other streams, and/or narrow the scope of the matching items based on content, arrival time, or the most recent particular number of items.

Use an event listener for discrete events or discrete patterns of events for which you want to independently trigger the listener action.

For information about using stream source templates, see "Working with Streams and Stream Queries" on page 205.

Defining event expressions with one event template

This section provides examples of specifying event expressions that contain just one event template. It is important to understand the various ways that you can specify a single event template. When you are familiar with this, it is easier to start applying operators and combining multiple event templates in an event expression.

Listening for one event

Consider the following `on` statement:

```
on StockTick() processTick();
```

This event listener is watching for one `StockTick` event. The values of the `StockTick` event's fields are irrelevent, as indicated by the empty parentheses. When this event listener finds a `StockTick` event, it triggers and terminates. When the event listener triggers, it causes the correlator to execute the `processTick()` action.

Listening for all events of a particular type

Consider the straightforward case where an event expression consists of a single event template. When the event listener finds an event that matches its event template, the event listener triggers, and the correlator executes the listener action. Since the event listener has found the event it was looking for, it terminates.

In some situations, you might want the event listener to continue watching for the same event so that you can act on each one. You do not want the event listener to terminate after it finds one event. In this situation, specify the `all` keyword before the event template, as in the following example:

```
on all StockTick() processTick();
```

When the `all` operator appears before an event template, when that event template finds a match, it continues to watch for subsequent events that also match the template.

Listening for events with particular content

The sample monitor is very simple. It just logs all `StockTick` events. The content of the `StockTick` event is not relevant when matching. See "Example of a simple monitor" on page 53. However, you can filter events according to their content. To alter the example so that the monitor logs only `StockTick` events for a given stock, you must specify a filter on the first field in the event template. For example, suppose you want to log only `ACME` stock ticks. You need to change the following line:

```
on all StockTick(*,*):newTick processTick();
```

to this:

```
on all StockTick("ACME",*):newTick processTick();
```

Now the event listener triggers on only `StockTick` events whose `name` field matches `ACME`.

To filter `StockTick` events based on their price, you might specify the event template shown below. This event template specifies that you are interested in all `StockTick` events whose price is `50.5` or greater.

```
on all StockTick(*, >=50.5):newTick processTick();
```

Using positional syntax to listen for events with particular content

You can specify that you want to listen for `StockTick` events that have a particular name and a particular price. In the `on` statement below, the event listener is looking for `StockTick` events in which the name is `ACME` and the price is `50.5` or less.

```
on all StockTick("ACME", <=50.5):newTick processTick();
```

When you specify this syntax, called positional syntax, the event template must define a value (or a wildcard) to match against for every field of that event's type. You must specify these values in the same order as the fields in the event type definition. Consider the following event type:

```
event MobileUser {
   integer userID;
   location position;
   string hairColour;
   string starsign;
   integer gender;
   integer incomeBracket;
   string preferredHairColour;
   string preferredStarsign;
   integer preferredGender;
}
```

Following is an event listener definition for this event type:

```
on MobileUser(*,*, "red", "Capricorn", *, *, *, *, 1) some_action();
```

Using name/value syntax to listen for events with particular content

Specification of every field in an event can get unwieldy when you are working with event types with a large number of fields and you are specifying values for only a few of them. In this case, you can use the name/value syntax in which you specify only the fields of interest. In the name/value syntax, it is as if you had specified a wildcard (`*`) for each field for which you do not specify a value. For example:

```
on MobileUser(hairColour="red", starsign="Capricorn",
    preferredGender=1) some_action();
```

The table below shows equivalent event expressions that demonstrate how to specify each syntax. The table uses these event types:

```
event A {
   integer a;
   string b;
}

event B {
   integer a;
```

```
}

event C {
   integer a;
   integer b;
   integer c;
}
```

Comparison Criterion	Positional Syntax	Equivalent Name/Value Syntax
Equality	`on A(3,"string")`	`on A(a=3,b="string")`
	`on A(=3,="string")`	`on A(b="string",a=3)`
Relational comparisons	`on B(>3)`	`on B(a>3)`
Ranges	`on B([2:3])`	`on B(a in [2:3])`
Wildcards	`on C(*,4,*)`	`on C(b=4)`
	`on C(*,*,*)`	`on C(a=*,b=4,c=*)`
		`on C()`

For details about the operators and expressions that you can specify in event templates, see "Expressions" on page 891.

It is possible to mix the two syntax styles as long as you specify all positional fields before named fields. For example:

- Correct event template: `on D(3,>4,i in [2:4])`
- Incorrect event template: `on D(k=9,"error")`

Listening for events of different types

A monitor is not limited to listening for events of only one type. A single monitor can listen for any number of event types. The following sample monitor uses the `StockTick` event type and the `StockChoice` event type, which specifies a stock name. When the event listener finds a `StockChoice` event, a second event listener then looks for only stocks that match the name in the `StockChoice` event.

```
// Definition of a type of event that the correlator will receive.
// These events represent stock ticks from a market data feed.
event StockTick {
   string name;
   float price;
}

// Definition of a type of event that describes the stock to process.
// These events come from a second live data feed.
event StockChoice {
   string name;
}
// The following simple monitor listens for two different event types.
```

```
monitor SimpleShareSearch {

   // A global variable to store the matching StockTick event:
   StockTick newTick;

   // A global variable to store the StockChoice event:
   StockChoice currentStock;

   // Wait for a StockChoice event and use its name field to
   // filter for StockTick events.
   action onload() {
      on StockChoice(*):currentStock {
         on all StockTick(currentStock.name, *):newTick processTick();
      }
   }

   action processTick() {
      log "StockTick event received" +
         " name =  " + newTick.name +
         " Price = " + newTick.price.toString() at INFO;
   }
}
```

The differences between the sample in "Example of a simple monitor" on page 53 and this monitor are the following:

- Definition of an additional event type (`StockChoice`)
- Definition of a new global variable (`currentStock`)
- A more complex `onload()` action

While the first two changes are straightforward, the new `onload()` action introduces new behavior. The first line in the `onload()` action is similar to that in the earlier example. In the new example, the monitor creates an event listener for a `StockChoice` event. The content of the `StockChoice` event is not relevant when matching. When the event listener finds an event of this type, it stores the value of the `StockChoicename` field in the `currentStock` variable and triggers the creation of a second event listener.

In this example, the first event listener defines the action of creating the second event listener in-line. The first event listener looks for a `StockChoice` event. The second event listener looks for all `StockTick` events whose `name` field corresponds to the value of `currentStock.name`.

Terminating and changing event listeners

After the correlator creates an event listener, you cannot change it. Instead of changing an event listener, you terminate it and create a new one.

The example in "Listening for events of different types" on page 167 looks for only one `StockChoice` event. The monitor would be more useful if it continued looking for subsequent `StockChoice` events, and on every new `StockChoice` event it changed the second event listener to look for stock ticks for the new company.

When the correlator creates an event listener, it copies from the action the value of any local variables. However, if the variable is of a reference type, changes to the object referred to by the value are seen by other listeners.

The steps and example below shows how to terminate an event listener with the `quit()` operation. See also, "Specifying and not logic to terminate event listeners" on page 179.

When you want to change an event listener, do the following:

1. Obtain a handle to the event listener you want to change.
2. Terminate that event listener with the `quit()` operation.
3. Create a new event listener to take its place.

The following sample monitor does just this.

```
// Definition of a type of event that the correlator will receive.
// These events represent stock ticks from a market data feed.
event StockTick {
   string name;
   float price;
}

// Definition of a type of event that describes the stock to process.
// These events come from a second live data feed.
event StockChoice {
   string name;
}

// The following simple monitor listens for two different event types.

monitor SimpleShareSearch {
   // A global variable to store the matching StockTick event:
   StockTick newTick;

   // A global variable to store the StockChoice event:
   StockChoice currentStock;

   // A handle to the second listener:
   listener l;

   // Record the latest StockChoice event and use its name field
   // to filter the StockTick events.
   action onload() {
      on all StockChoice(*):currentStock {
         l.quit();
         l := on all StockTick(currentStock.name, *):newTick processTick();
      }
   }

   action processTick() {
      log "StockTick event received" +
         " name =  " + newTick.name +
         " Price = " + newTick.price.toString() at INFO;
    }
}
```

The differences between the example in "Listening for events of different types" on page 167 and this example are as follows:

- The monitor in this example declares an additional global variable, `l`, whose type is `listener`.
- The initial `on` statement now specifies the `all` operator. After this event listener finds a `StockChoice` event, it watches for the next `StockChoice` event.
- The `onload()` action specifies a new listener action. Each time the first event listener finds a `StockChoice` event, the listener action:
  - Terminates the second event listener by calling the `l.quit()` method. Of course, upon finding the first `StockChoice` event there is no second event listener to terminate. This is not a problem as in this case the `l.quit()` method does not do anything.
  - Creates a new event listener to seek `StockTick` events for the company named in the `StockChoice` event just detected.
  - Stores a handle to the new event listener in the `l` global variable. The first event listener uses this handle when it needs to terminate the second event listener.

Specifying multiple event listeners

When the correlator encounters an `on` statement, it creates an event listener to watch for events that match the event expression specified in the `on` statement. When the event listener finds a matching event, the event listener triggers and the correlator executes the listener action. Ordinarily the event listener then dies. That is, the event listener processes only a single matching event.

When you require multiple matching events specify the `all` operator before the template for the event for which you want multiple matches. This prevents termination of the event listener upon an event match.

Another way to match multiple events is to define two (or more) event listeners for the same event type. If you specify two `on` commands that require the same event, they both trigger when they find that event. The order in which they trigger is not defined. For example:

```
on all StockTick(*,*):newTick1 { print newTick1.name; }
on all StockTick(*,*):newTick2 { print newTick2.name; }
```

When the correlator receives a single `StockTick` event, the correlator populates both the `newTick1` variable and the `newTick2` variable with the event value. The correlator then prints the value of the `name` field in each variable. This means that an event of the format `StockTick("ACME", 50.10)` causes this output:

```
ACME
ACME
```

Adding further `on` statements to those above would increase the number of times the `string` ACME is printed. This is true regardless of where (that is, in which action) the `on` statements are defined. For example:

```
action action1() {
   on all StockChoice("ACME"):currentStock processTick();
}
```

```
action action2() {
   on all StockChoice("ACME"):currentStock processTick();
}
```

If both the `action1()` and `action2()` actions have been invoked, both will invoke the `processTick()` action when an "ACME" `StockChoice` event is received.

Now consider the following example:

```
on all StockTick("ACME", *) action1();
on all StockTick(*,50.0) action1();
```

The event `StockTick("ACME", 50.0)` will trigger both event listeners. It is not possible to determine which one will execute the action first but the actions will be executed atomically. That is, the correlator will start executing `action1()`, finish it, and only then will the correlator execute `action1()` again. The correlator processes only one listener action at a time.

See "Spawning monitor instances" on page 55 for another way to have multiple event listeners.

Listening for events that do not match

Sometimes it is useful to catch events that do not match other event templates. To do this, specify the `unmatched` keyword in an event template. An `unmatched` event template matches against events for which both of the following are true:

- Except for `completed` and `unmatched` event templates, the event does not cause any other event expression in the same context as the `unmatched` event template to match. For information about `completed` event templates, see the next topic.
- The event matches the `unmatched` event template.

The correlator processes an event as follows:

1. The correlator tests the event against all normal event templates. Normal event templates do not specify the `completed` or `unmatched` keyword.
2. If the correlator does not find a match, the correlator tests the event against all event templates that specify the `unmatched` keyword. If the correlator finds one or more matches, the matching event templates now evaluate to true. That is, if there are multiple `unmatched` event templates that match the event, they all evaluate to true.

The scope of an `unmatched` event template is the context that contains it. Suppose an event goes to two contexts. In one context, there is a matching event listener and in the other context there is a match against an `unmatched` event template. Both matches trigger the listener actions.

Specify the `unmatched` keyword with care. Be sure to communicate with other developers. If your code relies on an `unmatched` event template, and someone else injects a monitor that happens to match some events that you expected to match your `unmatched` event template, you will not get the results you expect.

A typical use of the `unmatched` keyword is to spawn a monitor instance to process a particular subset of events. For example:

```
event Tick{ string stock; ... }
monitor TiickProcessor {
   Tick tick;
   ...
   action onload() {
      on all unmatched Tick():tick spawn processTick();
   }
   action processTick() {
      on all Tick( stock=tick.stock ) ...;
   }
   ...
}
```

See also:

- "Example using unmatched and completed" on page 173.
- "Writing echo monitors for debugging" on page 353

Specifying completion event listeners

In some situations, you want to ensure that the correlator completes all work related to a particular event before your application performs some other work. In your event template, specify the `completed` keyword to accomplish this. For example:

```
on all completed A(f < 10.0) {}
```

Suppose an `A` event whose `f` field value is less than `10` arrives in the correlator. What happens is as follows:

1. If there are normal or `unmatched` event listeners whose event expression matches this `A` event, those event listeners trigger.
2. The correlator executes listener actions and then processes any routed events that result from those actions, and any routed events that result from processing the routed events, and so on until all routed events have been processed.
3. The `completed` event listener triggers.

A common situation in which the `completed` keyword is useful is when a piece of data comes into the system and that piece of data causes a cascade of event listeners to trigger. Each listener action updates some data. When all listener actions have been executed, you want to take a survey of the new state of things and do something in response.

For example, consider a pricing engine made up of many individual pricing engines. When a new piece of market data arrives all pricing engines update their prices and then the controller uses some metric to pick the best price, which it publishes. The controller should publish the new price only after all individual engines have updated their output. The controller achieves this by listening for all the updates but only publishing when the market data event causes the `completed` event listener to trigger. The EPL for this scenario follows.

```
// Request/return best price from *all* markets
event RequestSmartBestPrice{ string stock; integer id; }
event BestSmartPriceReply{ integer id; float price; }

//Request/return best price from individual market(s)
```

```
event RequestBestPrice{ string stock; integer id; }
event BestPriceReply{ integer id; float price; }

// Simple example: Assume 'best' is 'lowest' and no account
// is taken of 'side'.
monitor SmartPriceGetter {
   RequestSmartBestPrice request;
   BestPriceReply reply;
   sequence< float > prices;

   action onload() {
      on all RequestSmartBestPrice(*,*):request spawn getPrices();
   }

   action getPrices() {
      on all BestPriceReply( request.id, * ):reply
         prices.append(reply.price);
      on completed RequestSmartBestPrice( request.stock, request.id ) {
         prices.sort();
         route BestSmartPriceReply( request.id, prices[0]);
         die();
      }
      route RequestBestPrice( request.stock, request.id );
   }
}
```

Example using unmatched and completed

The followiing example shows the use of both the `unmatched` and `completed` keywords. After the example, there is a discussion of the processing order.

```
on all A("foo",  < 10) : a {
   print "Match: " + a.toString();
   a.count := a.count+1; // count is second field of A
   route A;
}

on all completed A("foo", < 10) : a {
   print "Completed: " + a.toString();
}

on all unmatched A(*,*): a {
   print "Unmatched: " + a.toString();
}
```

The incoming events are as follows:

```
A("foo", 8);
A("bar", 7);
```

The output is as follows.

```
Match: A("foo", 8)
Match: A("foo", 9)
Unmatched: A("foo", 10)
Completed: A("foo", 9)
Completed: A("foo", 8)
Unmatched: A("bar", 7)
```

`A("foo", 8)` is the first item on the queue. The correlator processes all matches for this event except for any matching `on completed` expressions. The correlator processes those after it has processed all routed events originating from `A("foo", 8)`, which includes the processing of all routed events produced from all routed events produced from A(“foo”, 8), and so on.

Correlator processing goes like this:

1. Processing of A("foo", 8) routes A("foo", 9) to the front of the queue.
2. Processing of A("foo", 9) routes A("foo", 10) to the front of the queue.
3. Processing of A("foo", 10) finds a match with the unmatched event expression.
4. All routed events that resulted from A("foo", 9) have now been processed. The completed A("foo", 9) event template now matches so the correlator executes its listener action.
5. All routed events that resulted from A("foo", 8) have now been processed. The completed A("foo", 8) event template now matches so the correlator executes its listener action.
6. Processing of A("bar", 7) matches the unmatched A(*,*)event template and the correlator executes its listener action.

For another example of the use of unmatched and completed, see "Writing echo monitors for debugging" on page 353.

Improving performance by ignoring some fields in matching events

In applications where a particular field of an event type will never participate in the match criteria for that event type, the performance of Apama can be improved (at times drastically) by marking that field as a wildcard field in the event type definition.

For example, consider a version of the StockTick event type that has four fields: name, volume, price, and source. If in our application volume and source are never going to be used for matching on within event templates, that is, they will always be marked as * (wildcard), they could be tagged so explicitly in the event type:

```
event StockTick {
   string name;
   wildcard float volume;
   float price;
   wildcard string source;
}
```

The wildcard keyword tells Apama not to include this field in its internal indexing, as it will never be required in a match operation. This not only saves memory, but can significantly improve performance, particularly when there are many such fields which never occur in match conditions. Note that removing fields from an event type altogether is even more efficient than using wildcard, but this is not always possible. For example, the field might not be relevant in match conditions but it might be input to calculations within an action block, or it might need to be included in an event specified in a send...to statement.

When a field has been declared as a wildcard then any subsequent attempt to define a match condition using that field will result in a parser error, and the offending monitor will not be injected.

Therefore, given the above event type definition, the following will result in a parser error:

```
action someAction() {
   on StockTick("ACME", >125.0,*,"NASDAQ") doSomething();
}
```

while the following is correct:

```
action someAction() {
   on StockTick("ACME", *, 50.0, *) doSomething();
}
```

Defining event listeners for patterns of events

One way to search for an event pattern in EPL is to define an event listener to search for the first event, and then, in that listener action, define a second event listener to search for the second event in the pattern, and so on.

However, the `on` statement takes an event expression, and this can be more than just a single event template.

Consider the following very simple example: locate a news event about ACME followed by a stock price update for ACME.

With the EPL explored so far, one would write this as

```
event StockTick {
   string name;
   float price;
}

event NewsItem {
   string subject;
   string newsHeading;
}

monitor NewsSharePriceSequence_ACME {
   // Look for a news item about ACME, if successful execute the
   // findStockChange() action
   //
   action onload() {
      on NewsItem("ACME",*) findStockChange();
   }

   // Look for a StockTick about ACME, if successful execute the
   // notifyUser() action
   //
   action findStockChange() {
      on StockTick("ACME",*) notifyUser();
   }

   // Print a message, event sequence detected
   //
   action notifyUser() {
      log "Event sequence detected.";
   }
}
```

If, as in this example, you do not intend to express any custom actions after finding an event other than searching for another event, the whole pattern of events to look for can be encoded in a single event expression within a single `on` statement.

An event expression can define a pattern of events to match against. Each event of interest is represented by its own event template. You can apply several constraints on the temporal order that the events have to occur in to match the event expression.

In the more declarative syntax of an event expression, the above monitor would be written as follows:

```
event StockTick {
   string name;
   float price;
}

event NewsItem {
   string subject;
   string newsHeading;
}

monitor NewsSharePriceSequence_ACME {
   // Look for a NewsItem followed by a StockTick
   action onload() {
      on NewsItem("ACME",*) -> StockTick("ACME",*)
      notifyUser();
}

   // Print a message, event sequence detected
   //
   action notifyUser() {
      log "Event sequence detected.";
   }
}
```

Here, instead of just one event template, the `on` keyword is now followed by an event expression that contains two event templates.

The primary operator in event expressions is `->`. This is known as the followed-by operator. It allows you to express a pattern of events to match against in a single `on` statement, with a single action to be executed at the end once the whole pattern is encountered.

In EPL, an event pattern does not imply that the events have to occur right after each other, or that no other events are allowed to occur in the meantime.

Let `A, B, C` and `D` represent event templates, and `A'`, `B'`, `C'` and `D'` be individual events that match those templates, respectively. If a monitor is written to seek `(A > B)`, the event feed `{A',C',B',D'}` would result in a match once the `B'` is received by Apama.

Followed-by operators can be chained to express longer patterns. Therefore one could write,

```
on A -> B -> C -> D executeAction();
```

Notes:

- An event template is in fact the simplest form of an event expression. All event expression operators, including `->`, actually take event expressions as operands. So in the above representation, A, B, C, D could in fact be entire nested event expressions rather than simple event templates.

- It is useful to think of event expressions as being Boolean expressions. Each clause in an event expression can be true or false, and the whole event expression must evaluate to true before the event listener triggers and the action is executed.

  Consider the above event expression: `A -> B -> C -> D`

  The expression starts off as `false`. When an event that satisfies the `A` event template occurs, the `A` clause becomes `true`. Once `B` is satisfied, `A -> B` becomes `true` in turn, and evaluation progresses in a similar manner until eventually all of `A -> B -> C -> D` evaluates to `true`. Only then does the event listener trigger and cause execution of the listener action. Of course, this event expression might never become `true` in its entirety (as the events required might never occur) since no time constraint (see "Defining event listeners with temporal constraints" on page 189) has been applied to any part of the event expression.

Specifying and/or/not logic in event listeners

When the correlator creates an event listener each event template in the event expression is initially false. For an event listener to trigger on an event pattern, the event expression defining what to match against must evaluate to true. Consequently, in an event expression, you can specify logical operators.

Specifying the 'or' operator in event expressions

The `or` operator lets you specify event expressions where a variety of event patterns could lead to a successful match. It effectively evaluates two event templates (or entire nested event expressions) simultaneously and returns true when either of them becomes true.

For example,

```
on A() or B() executeAction();
```

means that either `A` or `B` need to be detected to match. That is, the occurrence of one of the operand expressions (an `A` or a `B`) is enough for the event listener to trigger.

Specifying the 'and' operator in event expressions

The `and` operator specifies an event pattern that might occur in any temporal order. It evaluates two event templates (or nested event expressions) simultaneously but only returns true when they are both true.

```
on A() and B() executeAction();
```

This will seek ‘an `A` followed by a `B`' or ‘a `B` followed by an `A`'. Both are valid matching patterns, and the event listener will seek both concurrently. However, the first to occur will terminate all monitoring and cause the event listener to trigger.

Example event expressions using 'and/or' logic in event listeners

The following example event expressions indicate a few patterns that can be expressed by using and/or logic in event listeners.

Event Expression	Description
`A -> (B or C)`	Match on an `A` followed by either a `B` or a `C`.
`(A -> B) or C`	Match on either the pattern `A` followed by a `B`, or just a `C` on its own.
`A -> ((B -> C) or (C -> D))`	Find an `A` first, and then seek for either the pattern `B` followed by a `C` or `C` followed by a `D`. The latter patterns will be looked for concurrently, but the monitor will match upon the first complete pattern that occurs. This is because the `or` operator treats its operands atomically, that is, in this case it is looking for the patterns themselves rather than their constituent events.
`(A -> B) and (C -> D)`	Find the pattern `A` followed by a `B` (that is, `A -> B`) followed by the pattern `C -> D`, or else the pattern `C -> D` followed by the pattern `A -> B`. The `and` operator treats its operands atomically. That is, in this case it is looking for the patterns themselves and the order of their occurrence, rather than their constituent events. It does not matter when a pattern starts but it occurs when the last event in it is matched. Therefore {`A',C',B',D'`} would match the specification, because it contains an `A -> B` followed by a `C -> D`. In fact, the specification would match against either of the following patterns of event instances; {`A',C',B',D'`}, {`C',A',B',D'`}, {`A',B',C',D'`}, {`C',A',D',B'`}, {`A',C',D',B'`} and {`C',D',A',B'`}

Specifying the 'not' operator in event expressions

The `not` operator is unary and acts to invert the truth value of the event expression it is applied to.

```
on ((A() -> B()) and not C()) executeAction();
```

therefore means that the event listener will trigger `executeAction` only if it encounters an `A` followed by a `B` without a `C` occurring at any time before the `B` is encountered.

The `not` operator can cause an event expression to reach a state where it can never evaluate to true. That is, it becomes permanently false.

Consider the above event listener event pattern: `on (A() -> B()) and not C()`

The event listener starts by seeking both `A -> B` and `not C` concurrently. If an event matching `C` is received before one matching `B`, the `C` clause evaluates to true, and hence `not C` becomes false. This means that `(A -> B) and not C` can never evaluate to true, and hence this event listener will never trigger. The correlator terminates these zombie event listeners periodically.

It is possible to specify the `not` operator in an event expression in such a way that the expression always evaluates to true immediately. Since this triggers the specified action without any events occurring, you want to avoid doing this. See "Avoiding event listeners that trigger upon instantiation" on page 183.

Specifying 'and not' logic to terminate event listeners

A typical situation is that you want to listen for a pattern only until a particular condition occurs. When the condition occurs you want to terminate the event listener. In pseudocode, you want to specify something like this:

```
on all event_expression until stop_condition
```

To define an event listener that behaves this way, you specify `and not`:

```
on all event_expression and not stop_condition
```

The following example listens for a price increase for a particular stock while the market is open.

```
event Price {
   string stock;
   float price;
}
Price p;
on all Price("IBM",>targetPrice):p and not MarketClosed() {
...do something }
```

When you inject a monitor that contains this code, the correlator sets up an event template to listen for `Price` events and another event template to listen for `MarketClosed` events. As long as the correlator does not receive a `MarketClosed` event, `not MarketClosed()` evaluates to true. While `not MarketClosed()` evaluates to true, each time the correlator receives a `Price` event for IBM stock at a price that is greater than `targetPrice`, this event expression evaluates to true and triggers its listener action. When the correlator receives a `MarketClosed` event, `MarketClosed()` evaluates to true and so `not MarketClosed()` evaluates to false. At that point, the event expression can no longer evaluate to true. When the correlator recognizes an event listener that can never trigger, it terminates it. In other words, after the market is closed the event listener terminates.

Typically, the stop condition is a condition that applies to multiple entities. In the previous example, the condition applies to only IBM stock, but it could easily be rewritten to apply to all stocks.

Pausing event listeners

You can also specify `and not` when you want to listen for a pattern, pause when a particular condition occurs, and resume listening for that pattern when some other condition occurs. Consider the example that terminates the event listener after the market closes. Suppose instead that you want to listen for increases in stock prices only when there is no auction. When the correlator receives an `InAuction` event, you want to pause the event listener and when the correlator receives an `AuctionClosed` event you want the event listener to become active again. To do this, you can write something like the following:

```
action initialize() {
   on EndAuction() and not BeginAuction() notInAuctionLogic();
   on BeginAuction() and not EndAuction() inAuctionLogic();
   route RequestAuctionPhase();
}

action inAuctionLogic() {
   on EndAuction() notInAuctionLogic();
}

action notInAuctionLogic() {
   on all Price("IBM",>targetPrice):p and not BeginAuction()
      sellStock();
   on BeginAuction() inAuctionLogic();
}
```

The `initialize()` action sets up two event listeners that determine whether to start with the `inAuctionLogic()` action or the `notInAuctionLogic()` action. The response to the routed `RequestAuctionPhase` event is an `EndAuction` event or a `BeginAuction` event. As soon as one of these events arrive, both event listeners terminate. For example, if an `EndAuction` event arrives, the first event listener terminates because its `EndAuction()` event template evaluates to true and its `not BeginAuction()` event template also evaluates to true. The second event listener terminates because its `not EndAuction()` event template evaluates to false and so the event expression can never evaluate to true.

Choosing which action to execute

Another situation in which `and not` logic can help terminate event listeners is when you want to specify a choice of one or more actions and terminate the event listeners after one is chosen. An example of this appears below. This is the CEP equivalent of a case statement.

```
on Pattern_1() and not PatternMatched() processCase1();
on Pattern_2() and not PatternMatched() processCase2();
on Pattern_3() and not PatternMatched() processCase3();
on Pattern_1() or Pattern_2() or Pattern_3()
{
   route PatternMatched();
}
```

When you inject a monitor that contains this type of code the correlator immediately sets up multiple event listeners. For the example in "Pausing event listeners" on page 180, the event listeners would be watching for these events:

- `Pattern_1`
- `PatternMatched`
- `Pattern_2`
- `Pattern_3`

Initially, all `and not` event templates evaluate to true. Suppose `Pattern_2` arrives. This causes these two event listeners to trigger:

```
on Pattern_2() and not PatternMatched() processCase2();
on Pattern_1() or Pattern_2() or Pattern_3()
```

It is unknown which event listener action the correlator executes first, but the order does not matter. The correlator does all of the following:

- The correlator executes the `processCase2()` action.
- The correlator terminates the event listener that specifies `processCase2()` because it has found its match and it does not specify `all`.
- The correlator routes a `PatternMatched` event to the front of the context's input queue.

When the correlator processes the `PatternMatched()` event, the two event templates that are still watching for `and not PatternMatched` become false. Consequently, those event listeners will never trigger and the correlator terminates them.

Following is another example of specifying `and not` to make a choice:

```
on Ack() and not Nack()
{
   processAck();
}
on Nack() and not Ack()
{
   processNack();
}
```

Specifying 'and not' logic to detect when events are missing

Using `and not` logic with a time-based listener is useful for detecting the absence of an event that is expected.

For example, consider an application that monitors the processing of customer orders. The application listens for `OrderCreate` events, which indicate that a customer has placed an order. After an `OrderCreate` event is found, the application listens for an `OrderStepComplete` event that has an `instanceid` value that matches the `instanceid` value in the `OrderCreate` event and that has a `step` field value of `Order Shipped`. If the application does not find a matching `OrderStepComplete` event within an hour (3600 seconds), the listener triggers and the application generates an alert to indicate that the order was not shipped.

Following is code that shows the listener definition.

```
on all OrderCreate(): oc {
   on wait(3600.00) and not OrderStepComplete(
      instanceid=oc.instanceid,step="Order Shipped"): os {
      // Raise an alert.
   }
}
```

This listener triggers when the event templates on both sides of the `and` operator evaluate to true. The event template before `and` evaluates to true after an hour has elapsed. The event template after `and` evaluates to true in the absence of a matching `OrderStepComplete` event. If the application finds a matching `OrderStepComplete` event within an hour then the second event template evaluates to false and the correlator terminates the listener because it can never trigger.

In the following example, when a `FileReceived` event is found, the application starts to listen for a `FileProcessed` event. If a `FileProcessed` event is not found within 30 seconds of receiving the `FileReceived` event, the application generates an alert.

```
monitor SimpleFileSearch {
   action onload() {
      FileReceived f;
      on all FileReceived():f {
         on wait(30.0) and not FileProcessed(id=f.id) {
         // Send alert that file was not processed.
         }
      on FileProcessed(id=f.id) within(30.0) {
         // Send confirmation that the file was processed.
         }
      }
   }
}
```

How the correlator executes event listeners

An understanding of how the correlator executes event listeners can help you correctly define event listeners. The topics below provide the needed background.

How the correlator evaluates event expressions

When the correlator processes an injection request, it executes the monitor's `onload()` statement, which typically defines an event listener. To understand how the correlator evaluates the event expression in the event listener, consider the following on statement:

```
on A()->B() and C()->D() processOrder();
```

The event expression consists of four templates and three operators. The operators are:

```
->
and
->
```

The correlator does not evaluate the right operand of a followed by operator until after its left operand has evaluated to true. Hence, `B` and `D` are not evaluated initially but will only be evaluated after `A` and `C`, respectively, have become true. Initially, the correlator evaluates the `A` and `C` event templates.

Suppose a C event arrives first. The C part of the event expression is now true and the correlator now evaluates the A and D event templates. Now suppose an A event arrives next. The correlator evaluates the B and D event templates. When a B event arrives the first term, A()->B(), of the event expression becomes true. Finally a D event arrives and the second term, B()->D() becomes true and so the expression as a whole evaluates to true. The event listener triggers.

As mentioned before, when the correlator instantiates an event listener each event template in the event listener is initially false. An event template changes to true when the correlator finds a matching event. In a given context, the correlator cannot find a matching event while it is setting up an event listener because the correlator processes only one thing at a time in each context. Everything happens in order and no two things happen simultaneously in a given context.

Of course, events are always coming into the correlator. These events go on the input queue of each public context to wait their turn for processing. So while a matching event might arrive while the correlator is setting up an event listener, as far as correlator processing is concerned, the event arrives later. See "Understanding time in the correlator" on page 194.

Avoiding event listeners that trigger upon instantiation

Because all event templates are initially false, it is important to think carefully before specifying not in an event expression. It is easy to inadvertently specify the not operator in such a way that the expression evaluates to true immediately upon instantiation. Since this triggers the specified action without any events occurring, it is unlikely to be what you intended and you want to avoid doing this. Consider the following example:

```
on ( A() -> B() ) or not C() myAction();
```

Assuming that A, B and C represent event templates, the value of each starts as being false. This means that not C is immediately true, and hence the whole expression is immediately true, which triggers the specified action. If any of A, B or C is a nested event expression the same logic applies for its evaluation. Typically, the not operator is used in conjunction with the and operator. See "Choosing which action to execute" on page 180.

When an event listener triggers the correlator sends a request to the front of the context's input queue to execute the event listener action. For example:

```
route D();
on not E() {
   print "not E";
}
route F();
```

The route keyword sends the specified event to the front of the context's input queue. The correlator processes this code in the following order:

1. The correlator processes event D.
2. The correlator prints "not E".
3. The correlator processes event F.

When the correlator terminates event listeners

The correlator terminates event listeners in the following situations:

- The event listener's event expression evaluates to true, and does not specify the `all` keyword. The correlator executes the specified action. Since the single defined match was found, the correlator terminates the event listener.
- The correlator recognizes that an event listener's event expression can never evaluate to true. For example:

  ```
  on ( A() -> B() ) and not C()
  ```

  The event listener starts by seeking both `A() -> B()` and `not C()` concurrently. If an event matching `C` is received before one matching `B`, the `C` clause evaluates to true, and hence `not C` becomes false. This means that `(A() -> B()) and not C()` can never evaluate to true, and hence this event listener will never trigger its action. The correlator terminates these zombie event listeners periodically.
- You obtain a handle to an event listener and call the `quit()` method on that event listener. See "Terminating and changing event listeners " on page 168.

How the correlator evaluates event listeners for a series of events

Suppose there are seven event templates defined, which are represented as `A`, `B`, `C`, `D`, `E`, `F` and `G`. Now, consider a series of incoming events, where *`Xn`* indicates an event instance that matches the event template *`X`*. Likewise, *`Xn`*`+1` indicates another event instance that matches against *`X`*, but which need not necessarily be identical to *`Xn`*.

Consider the following pattern of incoming events:

```
C1 A1 F1 A2 C2 B1 D1 E1 B2 A3 G1 B3
```

Given the above event pattern, what should the event expression `A() -> B()` match upon?

In theory the combinations of events that correspond to "an `A` followed by a `B`" are {`A1`, `B1`}, {`A1`, `B2`}, {`A1`, `B3`}, {`A2`, `B1`}, {`A2`, `B2`}, {`A2`, `B3`} and {`A3`, `B3`}. In practice it is unlikely that you want your event listener to match seven times on the above example pattern, and it is uncommon for all the combinations to be useful.

In fact, within EPL, `on A() -> B()` will only match on the first instance that matched the template. Given the above event pattern the event listener will trigger only on {`A1`, `B1`}, execute the associated action and then terminate.

Evaluating event listeners for all A-events followed by B-events

You might want to alter the behavior described in the previous topic, and have the event listener match on more of the combinations. To do this, specify the `all` operator in the event expression.

If the event listener's specification was rewritten to read:

```
on all A() -> B() success();
```

the event listener would match on every `A` and the first `B` that follows it.

The way this works is that upon encountering an `A`, the correlator creates a second event listener to seek the next `A`. Both event listeners would be active concurrently; one looking for a `B` to successfully match the pattern specified, the other initially looking for an `A`. If more `A`s are encountered the procedure is repeated; this behavior continues until either the monitor or the event listener are explicitly killed.

Therefore `on all A() -> B()` would return {`A1`, `B1`}, {`A2`, `B1`} and {`A3`, `B3`}.

Note that `all` is a unary operator and has higher precedence than `->`, `or` and `and`. Therefore

```
on all A() -> B()
```

is the same as both of the following:

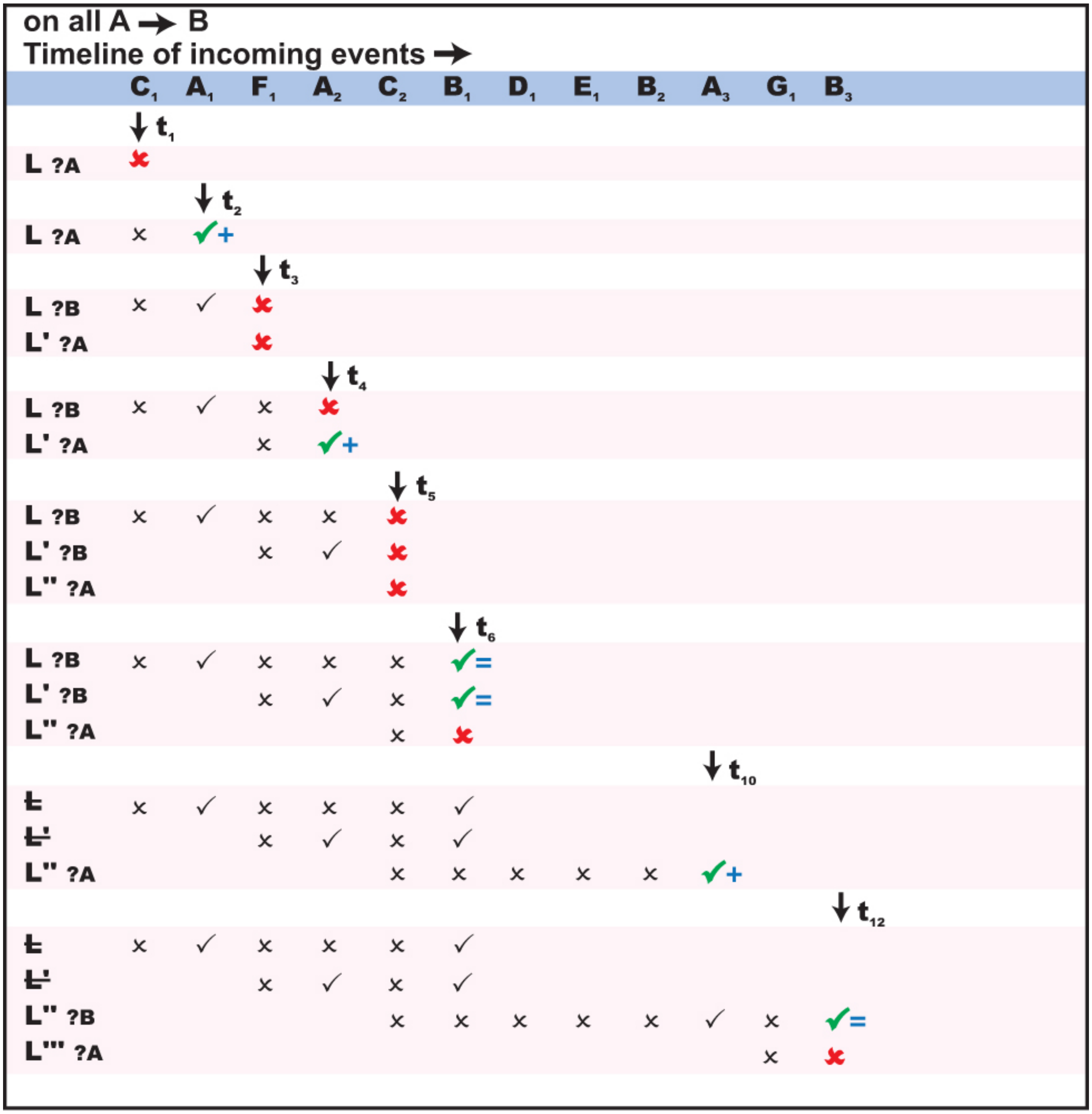
```
on (all A()) -> B()
on ( ( all A() ) -> B() )
```

The following table illustrates how the execution of `on all A() -> B()` proceeds over time as the pattern of input events is processed by the correlator. The timeline is from left to right, and each stage is labeled with a time `tn`, where `tn+1` occurs after `tn`. To the left are listed the event listeners, and next to each one (after the `?`) is shown what event template that event listener is looking for at that point in time. In the example, assuming `L` was the initial event listener, `L'`, `L''` and `L'''` are other sub-event-listeners that are created as a result of the `all` operator.

Guide to the symbols used:

- indicates a specific point in time when a particular event is received
- indicates that at that time no match was found
- indicates that the listener has successfully located an event that matches its current active template
- is used to indicate that a listener has successfully triggered
- indicates that a new listener is going to be created.

The master event listener denoted by `on all A() -> B()` will never terminate as there will always be a sub-event-listener active that is looking for an `A`.



Evaluating event listeners for an A-event followed by all B-events

Consider an event listener defined as follows:

```
on A() -> all B() success();
```

The monitor would now match on all the patterns consisting of the first `A` and each possible following `B`.

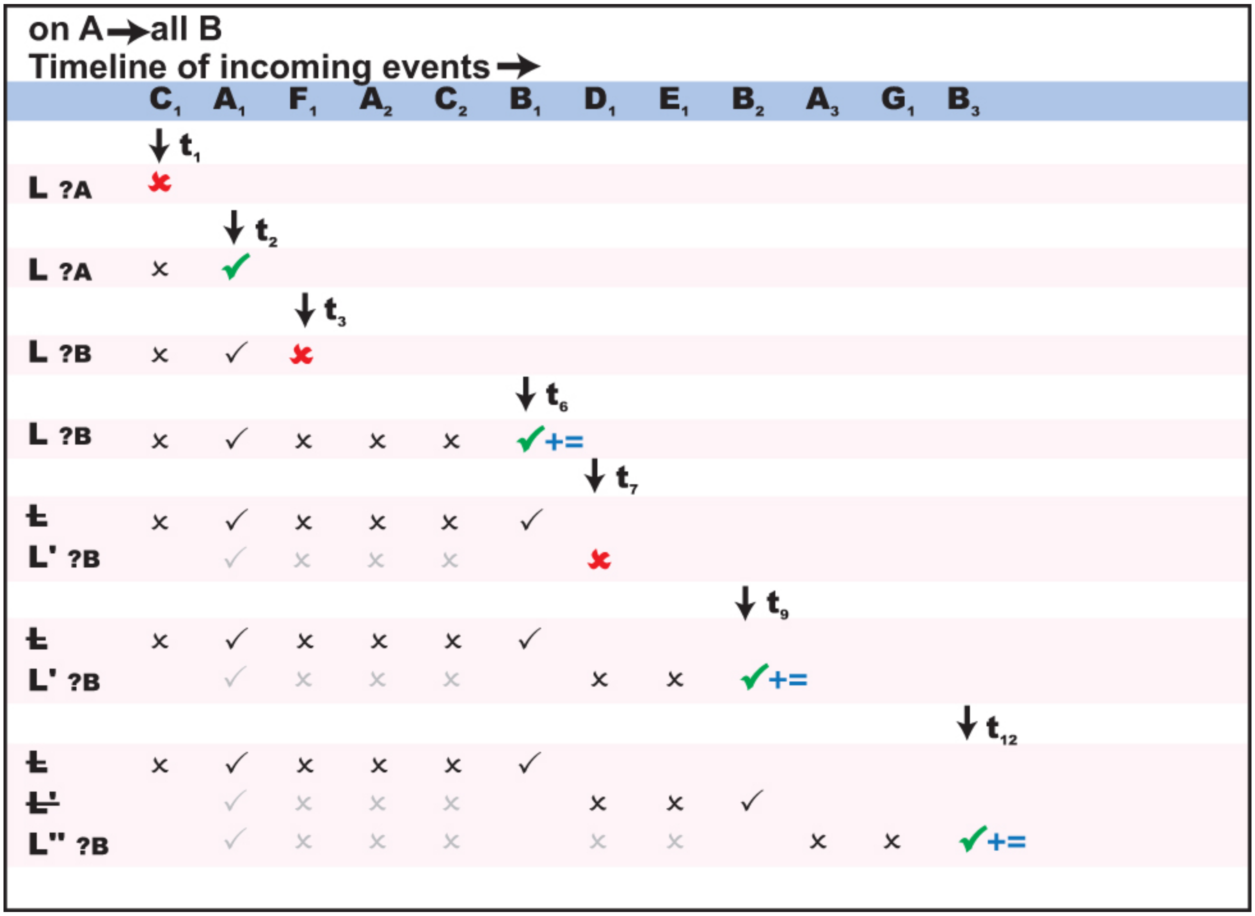
For clarity this is the same as:

```
on ( A() ->  ( all B() ) ) success();
```

The way this works is that the correlator creates a second event listener after finding a matching `B`. The second event listener watches for the next `B`, and so on repeatedly until the monitor is explicitly killed.

Therefore `on A() -> all B()` would match {`A1, B1`}, {`A1, B2`} and {`A1, B3`}.

Graphically this would now look as follows:



The table shows the early states of `L'` and `L''` in light color because those event listeners actually never really went through those states themselves. However, since they were created as a clone of another event listener, it is as though they were.

The master event listener denoted by `on (A() -> all B())` will never terminate as there will always be a sub-event-listener looking for a `B`.

Evaluating event listeners for all A-events followed by all B-events

Consider the following event listener definition:

```
on all A() -> all B() success();
```

or

```
on ( ( all A() ) -> ( all B() ) ) success();
```

Now the monitor would match on an `A` and create another event listener to look for further `A`s. Each of these event listeners will go on to search for a `B` after it encounters an `A`. However, in this instance all event listeners are duplicated once more after matching against a `B`.

The effect of this would be that `on all A -> all B` would match {`A1`, `B1`}, {`A1`, `B2`}, {`A1`, `B3`}, {`A2`, `B1`}, {`A2`, `B2`}, {`A2`, `B3`} and {`A3`, `B3`}. That is, all the possible permutations. This could cause a very large number of sub-event-listeners to be created.

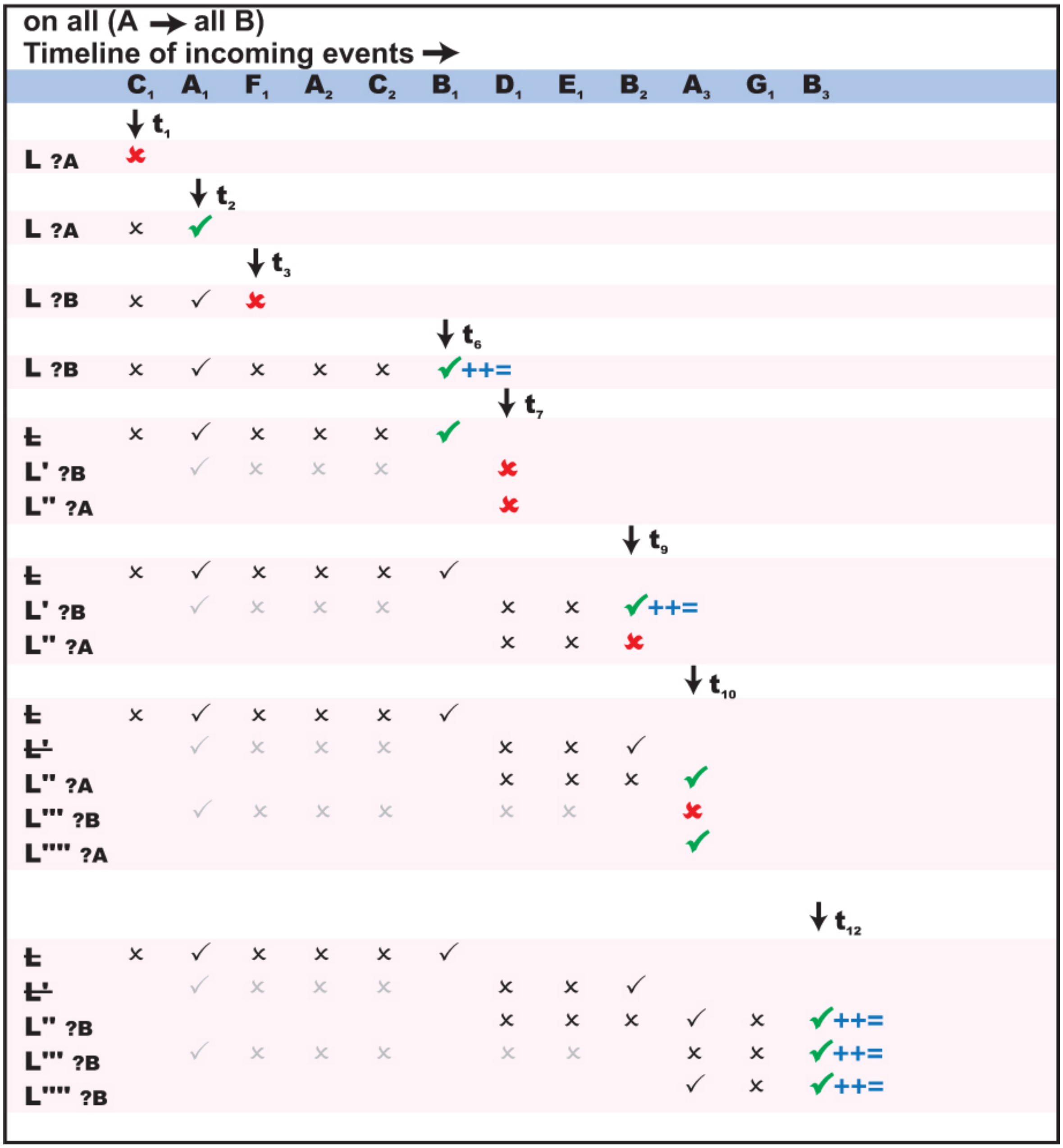
Note: The `all` operator must be used with caution as it can create a very large number of sub-event-listeners, all looking for concurrent patterns. This is particularly applicable if multiple `all` operators are nested within each other. This can have an adverse impact on performance.

Now consider the example,

```
on all ( A() -> all B() ) success();
```

This will match the first `A` followed by all subsequent `B`s. However, as on every match of an `A` followed by `B`, `( A() -> all B() )` becomes true, then a new search for the "next" `A` followed by all subsequent `B`s will start. This will repeat itself recursively, and eventually there could be several concurrent sub-event-listeners that might match on the same patterns, thus causing duplicate triggering.

Give the same event pattern as described in "Evaluating event listeners for all A-events followed by B-events" on page 184, this would be evaluated as follows:



Thus matching against {A1, B1}, {A1, B2}, {A1, B3}, and twice against {A3, B3}. Notice how the number of active event listeners is progressively increasing, until after t12 there would actually be six active event listeners, three looking for a B and three looking for an A.

Defining event listeners with temporal constraints

So far this section has shown how to use event expressions to define interesting patterns of events to look for, where the events of interest depend not only on their type and content, but also on their temporal relationship to (whether they occur before or after) other events.

Being able to define temporal relationships can be useful, but typically it also needs to be constrained over some temporal interval.

Listening for event patterns within a set time

Consider this earlier example:

```
event StockTick {
   string name;
   float price;
}

event NewsItem {
   string subject;
   string newsHeading;
}

monitor NewsSharePriceSequence_ACME {
   // Look for a NewsItem followed by a StockTick
   //
   action onload() {
      on NewsItem("ACME",*) -> StockTick("ACME",*)
         notifyUser();
   }

   // Print a message, event sequence detected
   //
   action notifyUser() {
      log "Event sequence detected.";
  }
}
```

This will look for the event pattern of a news item about a company followed by a stock price tick about that company. Once improved this could be used to detect the beginning of a rise (or fall) in the value of shares of a company following the release of a relevant news headline.

However, unless a temporal constraint is put in place, the monitor is not going to be that pertinent, as it might trigger on an event pattern where the price change occurs weeks after the news item. That would clearly not be so useful to a trader, as the two events were most likely unrelated and hence not indicative of a possible trend.

If the event listener above is rewritten as follows,

```
on NewsItem("ACME",*) -> StockTick("ACME",*) within(30.0)
   notifyUser();
```

the `StockTick` event would now need to occur within 30 seconds of `NewsItem` for the event listener to trigger.

The `within(`*`float`*`)` operator is a postfix unary operator that can be applied to an event template (the `StockTick` event template in the above example). Think of it like a stopwatch. The clock starts ticking as soon as the event listener starts looking for the event template that the `within` operator is attached to. If the stopwatch reaches the specified figure before the event template evaluates to true then the event template becomes permanently false.

In the above code, the timer is only activated once a suitable `NewsItem` is encountered. Unless an adequate `StockTick` then occurs within 30 seconds and makes the expression evaluate to true, the timer will fire and fail the whole event listener.

You can apply the `within` operator to any event template. For example:

```
on A() within(10.0) listenerAction();
```

After the correlator sets up this event listener, the event listener must detect an `A` event within 10 seconds. If no `A` event is detected within 10 seconds, the event expression becomes permanently false and the correlator subsequently terminates the event listener.

Waiting within an event listener

The second timer operator available for use within event expressions is `wait(`*`float`*`)`.

The `wait` operator lets you insert a ‘temporal pause' within an event expression. Once activated, a `wait` expression becomes true automatically once the specified amount of time passes. For example:

```
on A() -> wait(10.0) -> C() success();
```

Execution of this event listener proceeds as follows:

1. Set up an event template to watch for an `A` event.
2. After detecting an `A` event, wait 10 seconds.Set up an event template to watch for a `C` event.

In addition to being part of an event expression, `wait` can also be used on its own.

```
on wait(20.0) success();
```

When the correlator instaniates this event listener the event listener just waits for the number of seconds specified (here being `20`), then it evaluates to true, triggers, and causes the correlator to execute the `success()` action.

Therefore a `wait` clause starts off being false, and then turns to true once its time period expires. This behavior can be inverted through use of `not`. The expression `not wait (20.0)` would start off being true, and stay true for 20 seconds before becoming false.

Consider the following example:

```
on B() and not wait(20.0) success();
```

This event listener triggers only if a `B` event is detected within 20 seconds after the correlator sets up the event template that watches for B events. After 20 seconds, the `not wait(20.0)` clause would become false and prevent the event listener from ever triggering. This would therefore be the same as

```
on B within(20.0) success();
```

By using `all` with `wait`, you can easily implement a periodic repeating timer,

```
on all wait(5.0) success();
```

This event listener triggers every 5 seconds and causes the correlator to execute the `success()` action each time.

See also "Specifying 'and not' logic to detect when events are missing" on page 181.

Triggering event listeners at specific times

The `at` temporal operator lets you express temporal activity with regards to absolute time. The `at` operator allows triggering of a timer:

- **at a specific time**, for example, 12:30pm on the 5th April
- **repeatedly** with regards to the calendar when used in conjunction with the `all` operator, across seconds, minutes, hours, days of the week, days of the month, and months, for example, on every hour, or on the first day of the month, or every 10 minutes past the hour and every 40 minutes past the hour

The syntax of the `at` operator is as follows:

```
at(minutes , hours , days_of_month , months , days_of_week  [ ,seconds ])
```

where the last operand, *seconds*, is optional.

Valid values for each operand are as follows:

Operand	Values
minutes	0 to 59, indicating minutes past the hour.
hours	0 to 23, indicating the hours of the day.
days_of_month	1 to 31, indicating days of the month. For some months only 1 to 28, 1 to 29 or 1 to 30 are valid ranges.
months	1 to 12, indicating months of the year, with 1 corresponding to January
days_of_week	0 to 6, indicating days of the week, where 0 corresponds to Sunday.
seconds	0 to 59, indicating seconds past the minute.

The `at` operator can be embedded within an event expression in a manner similar to the `wait` operator. If used outside the scope of an `all` operator it will trigger only once, at the next valid time as expressed within its elements. In conjunction with an `all` operator, it will trigger at every valid time.

The wildcard symbol (`*`) can be specified to indicate that all values are valid, for example:

```
on at(5, *, *, *, *) success();
```

would trigger at the next “five minutes past the hour”, while

```
on all at(5, *, *, *, *) success();
```

would trigger at five minutes past each hour (that is, every day, every month).

Whereas,

```
on all at(5, 9, *, *, *) success();
```

would trigger at 9:05am every day. However,

```
on all at(5, 9, *, *, 1) success();
```

would trigger at 9:05am only on Mondays, and never on any other week day.
This is because the effect of the wildcard operator is different when applied to the *days_of_week* and the *days_of_month* operands. This is due to the fact that both specify the same entity. The rule is therefore as follows:

- As long as both elements are set to wildcard, then each day is valid.
- If either of the *days_of_week* or the *days_of_month* operand is not a wildcard, then only the days that match that element will be valid. The wildcard in the other element is effectively ignored.
- If both the *days_of_week* and the *days_of_month* operands are not wildcards, then the days valid will be the days which match either. That is, the two criteria are ‘or' 'ed, not ‘and' 'ed.

A range operator (`:`) can be used with each element to define a range of valid values. For example:

```
on all at(5:15, *, *, *, *) success();
```

would trigger every minute from 5 minutes past the hour till 15 minutes past the hour.

A divisor operator (`/`*integer*`,` *x*) can be used to specify that every *x*'th value is valid. Therefore

```
on all at(*/10, *, *, *, *) success();
```

would trigger every ten minutes, that is, at 0, 10, 20, 30, 40 and 50 minutes past every hour.

If you wish to specify a combination of the above operators you must enclose the element in square braces (`[ ]`), and separate the value definitions with a comma (`,`). For example

```
on all at([*/10,30:35,22], *, *, *, *) success();
```

indicates the following values for minutes to trigger on; 0,10, 20, 30, 40 and 50, from 30 to 35, and specifically the value 22.

A further example,

```
on all at(*/30,9:17,[*/2,1],*,*) success();
```

would trigger every 30 minutes from 9am to 5pm on even numbered days of the month as well as specifically the first day of the month.

Using variables to specify times

If you wish to programmatically parameterize usage of the `at` operator, you have to use variables in conjunction with it. You can replace any of the parameters to the `at` operator with a `string` variable or with a `sequence` of `integer` variables.

The first alternative, using a `string` variable, allows you to define the matching criteria within a `string` variable and then specify the variable within the `at` call.

For example,

```
string minutes = "*/30";
on all at(minutes,9:17,[*/2,1],*,*) success();
```

shows how this can be done. Each of the parameters can be replaced with a `string` variable in this way.

The other alternative is to use a `sequence` of `integer` variable. This is only useful when you want to specify a selection of valid values for the parameter.

```
sequence<integer> days = new sequence<integer>;
days.append(1); // Monday is ok
days.append(3); // and so is Wednesday
on all at(*,*,*,*,days) success;
```

Sequences are described in "sequence" on page 805.

Understanding time in the correlator

An understanding of how the correlator handles time is essential to writing Apama applications. The topics below discuss time in the correlator.

Correlator timestamps and real time

When the correlator receives an event, it gives the event a timestamp that indicates the time that the correlator received the event. The correlator then places the event on the input queue of each public context. The correlator processes events in the order in which they appear on input queues.

An input queue can grow considerably. In extreme cases, this might mean that a few seconds pass between the time an event arrives and the time the correlator processes it. As you can imagine, this has implications for whether the correlator triggers listeners. However, the correlator uses event timestamps, and not real time, to determine when to trigger listeners.

As an extreme example, suppose a monitor is looking for `A -> B within(2.0)`. The correlator receives event `A`. However, the queue has grown to a huge size and the correlator processes event `A` three seconds after event `A` arrives. The correlator receives event `B` one second after it receives event `A`. Some events in the queue before event `B` cause a lot of computation in the correlator. The result is that the correlator processes event `B` five seconds after event `B` arrives. In short, event `B` arrives one second after event `A`, but the correlator processes event `B` three seconds after it processes event `A`.

If the correlator used real time, `A -> B within(2.0)` would not be triggered by this pattern. This is because the correlator processes event `B` more than two seconds after processing event `A`. However, the correlator uses the timestamp to determine whether to trigger actions. Consequently, `A -> B within(2.0)` does trigger, because the correlator received event `B` one second after event `A`, and so their timestamps are within 2 seconds of each other.

As you can see, the number of events on an input queue never affects temporal comparisons.

Event arrival time

As mentioned before, when an event arrives, the correlator assigns a timestamp to the event. The timestamp indicates the time that the event arrived at the correlator. If you coassign an event to a variable, the correlator sets the timestamp of the event to the current time in the context in which the coassignment occurs. For JMon applications, this is always the current time in the main context.

The correlator uses clock ticks to specify the value of each timestamp. The correlator generates a clock tick every tenth of a second. The value of an event's timestamp is the value of the last clock tick before the event arrived.

When you start the correlator, you can specify the `--frequency` *`hz`* option if you want the correlator to generate clock ticks at an interval other than every tenth of a second. Instead, the correlator generates clock ticks at a frequency of *`hz`* per second. Be aware that there is no value in increasing *`hz`* above the rate at which your operating system can generate its own clock ticks internally. On UNIX and some Windows machines, this is 100 Hz and on other Windows machines it is 64 Hz.

When you start the correlator, you can specify the `-Xclock` option to disable the correlator's internal clock and replace it with externally generated time events. See "Externally generating events that keep time (&TIME events)" on page 197.

About timers and their trigger times

In an event expression, when you specify the `within`, `wait`, or `at` operator you are specifying a timer. Every timer has a trigger time. The trigger time is when you want the timer to fire.

- When you use the `within` operator, the trigger time is when the specified length of time elapses. If a `within` timer fires, the event listener fails. In the following event listener, the trigger time is 30 seconds after `A` becomes true.

  ```
  on A -> B within(30.0) notifyUser();
  ```

  If `B` becomes true within 30 seconds after the event listener detects an `A`, the trigger time is not reached, the timer does not fire, and the monitor calls the `notifyUser()` action. If `B` does not become true within 30 seconds after the event listener detects an `A`, the trigger time is reached, the timer fires, and the event listener fails. The monitor does not call `notifyUser()`. The correlator subsequently terminates the event listener since it can never trigger.

- When you use the `wait` operator, the trigger time is when the specified pause during processing of the event expression has elapsed. When a `wait` timer fires, processing continues. In the following expression, the trigger time is 20 seconds after `A` becomes true. When the trigger time is reached, the timer fires. The event listener then starts watching for `B`. When `B` is true, the monitor calls the `success` action.

  ```
  on A -> wait(20.0) -> B success();
  ```

- When you use the `at` operator, the trigger time is one or more specific times. An `at` timer fires at the specified times. In the following expression, the trigger time is five minutes past each hour every day. This timer fires 24 times each day. When the timer fires, the monitor calls the `success` action.

  ```
  on all at(5, *, *, *, *) success();
  ```

At each clock tick, the correlator evaluates each timer to determine whether that timer's trigger time has been reached. If a timer's trigger time has been reached, the correlator fires that timer. When a timer's trigger time is exactly at the same time as a clock tick, the timer fires at its exact trigger time. When a timer's trigger time is not exacty at the same time as a clock tick, the timer fires at the next clock tick. This means that if a timer's trigger time is .01 seconds after a clock tick, that timer does not fire until .09 seconds later.

When a timer fires, the current time is always the trigger time of the timer. This is regardless of whether the timer fired at its trigger time or at the first clock tick after its trigger time. In other words, the current time is equal to the value of the `currentTime` variable when the timer was started plus the elapsed wait time. For example:

```
float listenerSetupTime := currentTime;
on wait(1.23) {
   //When the timer fires, currentTime = (listenerSetupTime + 1.23)
  }
```

A single clock tick can make a repeating timer fire multiple times. For example, if you specify `on all wait(0.01)`, this timer fires 10 times every tenth of a second.

Because of rounding constraints,

- A timer such as `on all wait(0.1)` drifts away from firing every tenth of a second. The drift is of the order of milliseconds per century, but you can notice the drift if you convert the value of the `currentTime` variable to a string.

- Two timers that you might expect to fire at the same instant might fire at different, though very close, times.

  The rounding constraint is that you cannot accurately express `0.1` seconds as a float because you cannot represent it in binary notation. For example, the `on wait(0.1)` event listener waits for `0.10000000000000000555` seconds.

To specify a timer that fires exactly 10 times per second, calculate the length of time to wait by using a method that does not accumulate rounding errors. For example, calculate a whole part and a fractional part:

```
monitor TenTimesPerSecondMonitor {
   // Use integers to keep track of the next timer fire time.
   // This ensures that the value of the currentTime variable increases
   // by exactly 1.0 after every 10 tenths of a second.
```

```
   integer nextFireTimeInteger;
   integer nextFireTimeFraction;
   action onload() {
      nextFireTimeInteger := currentTime.ceil();
      nextFireTimeFraction := (10.0 *
         (currentTime-nextFireTimeInteger.toFloat() ) ).ceil();
      setupTimeListener();
   }

   action setupTimeListener() {
      nextFireTimeFraction := nextFireTimeFraction + 1;
      if(nextFireTimeFraction = 10) then {
         nextFireTimeFraction := 0;
         nextFireTimeInteger := nextFireTimeInteger+1;
      }
      on wait( (nextFireTimeInteger.toFloat() +
        (nextFireTimeFraction.toFloat()/10.0) ) - currentTime )
      {
         setupTimeListener();
         doWork();
      }
   }

   action doWork()
   {
      // This is called 10 times every second.
      log currentTime.toString();
      // ...
   }
}
```

When a timer fires, the correlator processes items in the following order. The correlator:

1. Triggers all event listeners that trigger at the same time.
2. Routes any events, and routes any events that those events route, and so on.
3. Fires any timers at the next trigger time.

Disabling the correlator's internal clock

By default, the correlator keeps time by generating clock ticks every tenth of a second. If you specify the `-Xclock` option when you start a correlator, the correlator disables its internal clock. This means the correlator does not generate clock ticks and does not assign timestamps based on clock ticks to incoming events.

Instead, it is up to you to send `&TIME` events into the correlator to externally keep time. This gives you the ability to artificially control how the correlator keeps time.

Time flows in all contexts, including private contexts. Also, different contexts can have different internal times. This happens when one context is still processing events that arrived at an earlier time while another is processing more recent events. The "currentTime" is always the time of the events being processed. (As opposed to wall-clock time, which can be obtained from the Time Manager correlator plug-in.)

Externally generating events that keep time (&TIME events)

A `&TIME` event can have one of the following formats:

- It can contain a number of seconds:

  ```
  &TIME(float seconds)
  ```

  The *seconds* parameter represents the number of seconds since the epoch, 1st January 1970. The maximum value for *seconds* that the correlator can accept is 10^{12}, which equates to roughly 33658 AD, and should be enough for anyone. However, most time formatting libraries cannot produce a date for numbers anywhere near that large.

- Or it can contain a time string:

  ```
  &TIME(string time)
  ```

  The *time* is a string in extended ISO8601 form, with fractional seconds. For example:

  ```
  &TIME("2015-04-20T23:32:41.032+01:00")
  &TIME("2015-04-20T22:32:41.032+00:00")
  &TIME("2015-04-20T22:32:41.032Z")
  &TIME("2015-04-20T22:32:41.032")
  ```

  These all refer to the same time. Note that the first example shows the time in a different timezone with an offset of 1 hour.

When the correlator processes an `&TIME` event by taking it off an input queue, the correlator sets its internal time (the current time) in that context to the value encoded in the event. Every event that the correlator processes after an `&TIME` event and before the next `&TIME` event has the same timestamp. That is, they have the timestamp indicated by the value of the previous `&TIME` event. For example:

```
&TIME(1)
A()
B()
&TIME(2)
C()
```

Events `A` and `B` each have a timestamp of `1`. Event `C` has a timestamp of `2`.

If you specify the `-Xclock` option, and you do not send `&TIME` events to the correlator, it is as if time has stopped in the correlator. Every event receives the exact same timestamp. While not sending time events is not strictly incorrect, it does mean that time stands still.

You must use great care when implementing this facility. There are EPL operations that rely on correct time-keeping. For example, all timer operations rely on time progressing forwards. Timers will fail to fire if time remains at a standstill, or worse, moves backwards. There is a warning message in the correlator log if you send a time event that moves time backwards.

When sending `&TIME` events into a multi-context application, the time ticks are delivered directly to all contexts. This can be different than the way in which events in the `.evt` file are sent in to the correlator and then sent between contexts in an application. This difference can result in processing events at an incorrect simulated time. In these cases, sending `&FLUSHING(1)`, for example, before sending time ticks and events can result in more predictable and reliable behavior.

For more information, see "Event timing" in the correlator utilities section of *Deploying and Managing Apama Applications*.

About repeating timers and &TIME events

You are not required to send `&TIME` events every tenth of a second. You can send them at larger intervals and timers will behave as they would when the correlator generates clock ticks. For a repeating timer, a single `&TIME` event can make it fire multiple times. Consequently, sending an `&TIME` event can have a lot of overhead if it is a large time jump and there are repeating timers. For example, consider the following pattern:

1. You start the correlator and specify the `-Xclock` option, which sets the time to 0.
2. You inject a timer into the correlator, for example, `on all wait(0.1)`.
3. You send an `&TIME` event to the correlator and this event has a relatively large value, for example, `1185898806`.

The result of this pattern is that the timer fires many times because the `&TIME` event causes each intermediate, repeating timer to fire. (Intermediate timers are timers that are set to fire between the last-received time and the next-received time.) For the example given, the timer fires 10^{10} times, which can take a while to process. You can avoid this problem by doing any one of the following:

- Send the correlator an `&TIME` event and specify a sensible time before you set up any timers. This is likely to be your best alternative.
- Send the correlator an `&TIME` event and specify a sensible time before you inject any monitors.
- Send the correlator an `&SETTIME` event before you send the `&TIME` event. See "Setting the time in the correlator (&SETTIME event)" on page 199.

Setting the time in the correlator (&SETTIME event)

A `&SETTIME` event can have one of the following formats:

- It can contain a number of seconds:

  ```
  &SETTIME(float seconds)
  ```

  The *`seconds`* parameter represents the number of seconds since the epoch, 1st January 1970. For example:

  `&SETTIME(0)` sets the time to "Thu Jan 1 00:00:00.0 BST 1970".

  `&SETTIME(1185874846.3)` sets the time to "Tue Jul 31 09:40:46.3 BST 2007".

- Or it can contain a time string:

  ```
  &SETTIME(string time)
  ```

  The *`time`* is a string in extended ISO8601 form, with fractional seconds. For example:

```
&SETTIME("2015-04-20T23:32:41.032+01:00")
&SETTIME("2015-04-20T22:32:41.032+00:00")
&SETTIME("2015-04-20T22:32:41.032Z")
&SETTIME("2015-04-20T22:32:41.032")
```

These all refer to the same time. Note that the first example shows the time in a different timezone with an offset of 1 hour.

Normally, you do not need to send `&SETTIME` events. You would just send `&TIME` events. An `&SETTIME` event is useful only to avoid the problem pattern described above. The only difference between an `&SETTIME` event and an `&TIME` event is that the `&SETTIME` event causes an intermediate, repeating timer to fire only once while the `&TIME` event causes intermediate, repeating timers to fire repeatedly. For example, `on all wait(0.1)` fires ten times for every second in the difference between consecutive `&TIME` events. However, it fires only once when the correlator receives an `&SETTIME` event.

If you decide to send an `&SETTIME` event before an `&TIME` event, you typically want to send the `&SETTIME` event only before the first `&TIME` event. You should not send an `&SETTIME` event before subsequent `&TIME` events. Doing so causes a jumpy quality in the behavior of time. There is a warning message in the correlator log if you set a time that moves time backwards.

For information about when you might want to use external time events, see *Deploying and Managing Apama*, "Correlator Utilities Reference", "Starting the correlator", "Determining whether to disconnect slow receivers".

Out of band connection notifications

Apama applications running in the correlator can make use of Apama *out of band notifications*. Out of band notifications are events that are automatically sent to all public contexts in a correlator whenever any component (an IAF adapter, dashboard, another correlator, or a client built using the Apama SDKs) connects or disconnects from the correlator.

For example, consider an environment where correlator A and correlator B both have out of band notifications enabled and are connected so that events from correlator A are sent to correlator B. In this case, correlator A will receive a `ReceiverConnected` event and correlator B will receive a `SenderConnected` event. The Apama application running in correlator A and B can listen for those events and execute some application logic. Note that clients such as dashboards and IAF adapters typically connect as both receiver and a sender together and, therefore, two events would be sent in quick succession.

Out of band events are defined in the `com.apama.oob` package and consist of:

- `ReceiverConnected`
- `SenderConnected`
- `ReceiverDisconnected`

- SenderDisconnected

The ReceiverConnected and SenderConnected events contain the name of the component that is connecting. When correlators and IAF adapters send a notification event, the format of the string that contains the component name is as follows:

"*name* (on port *port_number*)"

The *name* is the name that was specified when the component was started. For correlators and IAF adapters, you can specify a name with the --name option when you start the component. The name defaults to correlator or iaf according to the type of component. The *port_number* is the port that the connecting receiver or sender is running on.

Out of band events make it possible for developers of Apama components to add appropriate actions for the component to take when it receives notice that another component of interest has connected or disconnected. For example, an adapter can cancel outstanding orders or send a notification to an external system.

Out of band notification events

The out of band events are defined as follows:

```
package com.apama.oob;
// Note that while the logicalId and physicalId are integers, they are
// unsigned 64-bit values. Using EPL integer types would result in some
// IDs being negative, and thus not matching the values given in log files.
/** Notification that a sender has connected */
event SenderConnected {
  /**
  * Component name, as supplied with the -N command line argument
  * to iaf/correlator or engineInit method
  */
  string componentName;
  /**
  * Representation of the address component is connecting from
  */
  string address;
  /**
  * Opaque representation of IDs; these are unique per
  * instance of a process.
  */
  string logicalId;
  /**
  * Opaque representation of IDs; these are unique per
  * instance of a process.
  */
  string physicalId;
  }
/** Notification that a sender has disconnected */
event SenderDisconnected {
  /**
  * Opaque representation of IDs; these are unique per
  * instance of a process.
  */
  string logicalId;
  /**
  * Opaque representation of IDs; these are unique per
  * instance of a process.
```

```
  */
  string physicalId;
  }
/** Notification that a receiver has connected */
event ReceiverConnected {
  /**
  * Component name, as supplied with the -N command line argument
  * to iaf/correlator or engineInit method
  */
  string componentName;
  /**
  * Representation of the address component is connecting from
  */
  string address;
  /**
  * Opaque representation of IDs; these are unique per
  * instance of a process.
  */
  string logicalId;
  /**
  * Opaque representation of IDs; these are unique per
  * instance of a process.
  */
  string physicalId;
  }
/** Notification that a receiver has disconnected */
event ReceiverDisconnected {
  /**
  * Opaque representation of IDs; these are unique per
  * instance of a process.
  */
  string logicalId;
  /**
  * Opaque representation of IDs; these are unique per
  * instance of a process.
  */
  string physicalId;
  }
```

Enabling out of band notifications

To enable out of band notifications in your Apama applications, you add the **Out of band event notifications** bundle to your project in Software AG Designer.

Note: You can also enable out of band notifications for a correlator with the `engine_management` utility using the `engine_management -r setOOB on` command. Be sure to inject the event definitions before running that command. For more information about using the `engine_management` utility, see "Shutting down and managing components" in *Deploying and Managing Apama Applications*.

To enable out of band notifications

1. In the **Project Explorer**, right-click on the project and select **Apama > Add Bundle**.
2. From the Add Bundle dialog, select the **Out of band event notifications** bundle and click **OK** to add the bundle to your Apama project.

The **Out of band event notifications bundle** contains the event definitions and the monitor that enables the notifications.

3. In your Apama application, create a listener for out of band events specific to the components you are interested in.

5 Working with Streams and Stream Queries

EPL lets you create two kinds of queries:

- Self-contained queries are processing elements that communicate with other self-contained queries, and with their environment, by receiving and sending events. Self-contained queries are designed to be multithreaded and to scale across machines. A self-contained query is sometimes referred to as an Apama query. This kind of query is defined in a `.qry` file, which cannot contain a monitor. See "Defining Queries" on page 75.
- Stream queries operate on streams of items to generate more valuable streams that contain derived items. Stream queries are defined in monitors. The following topics provide information about stream queries.

In stream queries, derived items can be events, `location` types or simple types (`boolean`, `decimal`, `float`, `integer`, `string`). You can use standard relational operations, such as filters, joins, aggregation, and projection, to generate items. For example, you can define a query that converts a stream of raw tick data into a stream of volume-weighted average price (VWAP) items.

Stream-based language elements allow operations that refine events to be expressed more clearly and concisely than when using procedural language constructs such as event listeners. In particular, applications that need to calculate one value based on multiple items from an input stream are simpler and more efficient when written with stream queries.

Apama provides sample code that uses streams and stream queries in the `samples\monitorscript` directory of your Apama installation directory. See also: "EPL Streams: A Quick Tour" on page 977.

Introduction to streams and stream networks

A stream query is part of a *stream network*. A stream network starts with one or more *stream source templates* (see "Creating streams from event templates" on page 208). A stream source template collects matching events received by the monitor instance and places them as items in a stream. Stream queries (see "Defining stream queries" on page 211) take existing streams (a stream created by a stream source template or by another stream query) and generate added-value streams that contain derived items. Finally, *stream listeners* (see "Using output from streams" on page 208) bring items out of the stream network and into procedural code. In a given stream network, upstream elements feed into downstream elements to generate derived items.

When a monitor instance receives an event that matches a stream source template the correlator activates the stream network. The passage of time can also cause the correlator to activate a stream network. If, for example, a stream query operates on the items received within the last 5.0 seconds, then 5.0 seconds after an item arrives the correlator will again activate the stream network (see "Adding window definitions to from and join clauses" on page 218).

In a given stream network activation, not all stream queries and not all stream listeners necessarily receive items. Which queries and stream listeners receive items depends on the definitions of the stream queries and stream listeners. However, in a given stream network activation, the correlator passes items through all queries and stream listeners in the network that receive items. A query or stream listener that receives an item is considered to be activated. Only when processing of all activated queries and stream listeners is complete does the correlator process the next event on the context's input queue.

In a given stream network activation, various queries can produce multiple items on their output streams. The items in a particular stream during a particular stream network activation are called a *lot*. If a stream query or stream listener receives a lot that contains multiple items, it processes all items as part of a single stream network activation (see "Working with lots that contain multiple items" on page 245, and "Coassigning to sequences in stream listeners" on page 211).

The items in a lot are always ordered, and the lots themselves are always ordered.

Defining streams

You can use a `stream` variable to reference a stream. A `stream` variable declaration has the following form:

```
stream<type> name
```

Replace *`type`* with the type of the items in the stream. This can be any Apama type.

Replace *`name`* with an identifier for the stream. For example:

```
stream<Tick> ticks;
```

A `stream` variable can be a field in an event. However, you cannot route, enqueue, or send an event that contains a `stream` variable field.

There are two ways to create a stream:

- From an event template. See "Creating streams from event templates" on page 208.
- From the result of a stream query on some other stream. See "Defining stream queries" on page 211.

To obtain a reference to an existing stream, you must assign from or clone another stream value.

An inert stream never generates any output. There are a number of ways to create an inert stream including, but not limited to, the following:

- Calling `new` on a `stream` type or a type that contains a stream
- Declaring a global variable of `stream` type, or a type that contains a stream
- Spawning a monitor instance that contains a stream value

Note: It is permissible to define a `stream` variable that references a stream of `stream` type items. In such a definition, be sure to insert a space between the consecutive right-angle brackets. For example: `stream<stream<float> >`.

You must insert this extra space in all stream definitions that contain a type that encloses another type. For example: `stream<sequence<integer> >`.

Creating streams from event templates

A stream can be created from an event template using the `all` keyword. This is referred to as a stream source template. For example:

```
stream<Tick> ticks := all Tick(symbol="APMA");
```

This creates a stream that contains all subsequent `Tick` events that have the symbol `APMA`. You can use any single event template this way, however, you must specify the `all` keyword and you cannot use any operators such as `and` or followed-by to combine several event templates. See also "Stream network lifetime" on page 250.

Terminating streams

If a stream goes out of scope it continues to exist until the monitor instance terminates or the stream is explicitly terminated in some fashion. Streams are not garbage-collected. This means it is possible to leak streams, thereby consuming memory and potentially performing unnecessary computation, if you do not explicitly terminate steams.

To terminate a stream, call the `quit()` method on a `stream` variable that refers to the stream you want to terminate. For example:

```
stream<integer> foo := all A();
...
foo.quit();
```

This might also terminate connected streams. See "Stream network lifetime" on page 250. It is also possible to terminate connected streams by quitting a stream listener.

Using output from streams

A stream listener passes output items from a stream to procedural code. You use a `from` statement to create a stream listener. The `from` statement has two forms.

The first form of the `from` statement creates a stream listener that takes items from an existing stream. For example:

```
from sA: a {
   /* Code here executes whenever an item is available from sA. */
}
```

The second form of the `from` statement contains a stream query definition, which creates a new stream query. The stream listener takes items from the output stream of the query. For example:

```
from a in sA select a : a {
   /* Code here executes whenever the query produces output. */
}
```

The syntax for the first form is as follows:

```
[listener := ] from streamExpr : variable statement
```

Syntax Element	Description
listener	Optional. You can specify a `listener` variable to refer to the stream listener that the `from` statement creates. You can declare a new `listener` variable or a use an existing `listener` variable.
streamExpr	Specifies any expression of type `stream` except a stream query. This can be, for example, a `stream` variable or a stream source template. If you want to specify a stream query, use the other form of the `from` statement.
variable	Specifies a variable that you want to use to hold the stream output. You must have already declared the variable and the type of the variable must be the same type as the stream output. The `from` statement coassigns the stream output to this variable. For details about the characters you can specify, see "Identifiers" on page 919. The output from a stream is referred to as a *lot*. Like an auction lot, a stream output lot can contain one or more items. If the stream output is a lot that contains more than one item, the `from` statement coassigns each item, in turn, to the variable. See "Working with lots that contain multiple items" on page 245. A `from` statement cannot specify multiple coassignments.
statement	Specifies an EPL statement. Specify a single statement or enclose multiple statements in braces. The `from` statement coassigns each stream output item to the specified variable and executes the statement or block once for each output item. If the steam output is a lot that contains more than one item, and you want to execute the statement or block just once for the lot rather than once for each item in the lot, coassign the result to a `sequence`. See "Coassigning to sequences in stream listeners" on page 211.

The syntax for the second form of the `from` statement is as follows:

```
[listener :=] StreamQueryDefinition : variable statement
```

Syntax Element	Description
listener	Optional. You can specify a `listener` variable to refer to the stream listener that the `from` statement creates. You can declare a new `listener` variable or a use an existing `listener` variable.
StreamQueryDefinition	Specifies a stream query. See "Defining stream queries" on page 211.
variable	Specifies a variable that you want to use to hold the query results. You must have already declared the variable and the type of the variable must be the same type as the query results. The `from` statement coassigns the query result to this variable. For details about the characters you can specify, see "Identifiers" on page 919. If the query outputs lots that contain more than one item, the `from` statement coassigns each item in the lot, in turn, to the variable. See "Working with lots that contain multiple items" on page 245. A `from` statement cannot specify multiple coassignments.
statement	Specifies an EPL statement. You can specify a single statement or you can enclose multiple statements in braces. The `from` statement coassigns each stream output item to the specified variable and executes the statement or block once for each output item. If you want the statement to be executed once per lot rather than once per item coassign the results to a `sequence`. See "Coassigning to sequences in stream listeners" on page 211.

Listener variables and streams

Like event listeners, you can assign a stream listener to a `listener` variable. A stream listener exists until one of the following happens:

- The monitor instance that contains the stream listener is terminated
- The stream or streams the listener refers to are terminated

If you do not want to wait for one of the above to occur, you can stop a stream listener by calling the `quit()` method on a `listener` variable that refers to it. Note that in many cases this will also terminate the stream that is feeding the stream listener. See "Stream network lifetime" on page 250.

Coassigning to sequences in stream listeners

Unlike event listeners, a stream query might generate multiple items for each external or routed event. This is usually due to a batched window (a window that is updated after every *p* seconds or after every *m* items arrive) or to a join operation on two streams. In this case, the correlator executes a stream listener action multiple times, once for each generated item.

In a stream query definition, a window defines the set of items from the input stream that the query operates on. See "Adding window definitions to from and join clauses" on page 218.

To execute the stream listener action only once, and coassign all generated items at once, specify a stream listener that coassigns to a `sequence` variable. The sequence must contain items of the same type as the stream. For example:

```
sequence<A> seqA;
from batchedEvents: seqA {
   /* seqA contains all events that arrive in this batch */
}
```

Defining stream queries

A stream query operates on one or two streams to transform their contents into a single output stream. A stream query definition declares an identifier for the items in the stream so that the item can be referred to by the operators in the stream query. Here is a simple stream query definition:

```
stream<integer> ints := from a in sA select a.i;
```

When the correlator executes a statement that contains a stream query definition the correlator creates a new stream query. Each stream query has an output stream (the type of which might differ from that of the input stream).

A stream query definition is an expression that evaluates to a stream value. The value is a reference to the output stream of the generated query.

Following is an example of a simple stream query in a stream listener:

```
from a in sA select a.b : b {
```

```
    doSomethingWith(b);
}
```

The following table describes the user-defined parts of this stream listener. It is important to understand the distinctive role each one serves.

Syntax Element	Description
`a`	This is an identifier that represents the current item in the stream being queried. See "Specifying input streams in from clauses" on page 216.
`sA`	This variable represents the stream being queried.
`a.b`	This expression describes what each query result looks like. In this example, the query produces outputs from the `b` field of the events in the stream.
`b`	This is the variable that you coassign the query results to so that the correlator can use the query result in the stream listener's code block.

Linking stream queries together

A stream query definition is an expression and its result is a stream. Consequently, with one exception described below, you can use a stream query definition anywhere that you can use a stream value. For example, you can assign the resulting value to a `stream` variable:

```
stream <float> values := from a in sA select a.value;
```

Alternatively, you can use a stream query definition as the return value from an action, for example:

```
action createPriceStream (stream<Tick> ticks) returns stream<float> {
    return from t in ticks select t.price;
}
```

Another option is to embed a stream query within another stream query, for example:

```
float vwap;
from p in (from t in ticks where t.price > threshold select t.price)
within period
select wavg(t.price,t.volume): vwap {
    processVwap(vwap);
}
```

You can use stream variables to link stream queries together, as detailed in the next section.

The exception is that you cannot use a stream query immediately after the `from` keyword in the first form of the `from` statement. For example, the following is not a valid statement:

```
from from t in ticks select t.price : tickPrice {
```

```
   print tickPrice.toString();
}
```

Instead, use the second form of the from statement and specify a stream variable or a stream source template. The following example specifies a stream variable:

```
from t in ticks select t.price : tickPrice{
   print tick.price.toString();
}
```

Simple example of a stream network

Sometimes a single from statement is all that is required to achieve your goal. For example, to obtain a VWAP (Volume-Weighted Average Price) for a stock you can add the following from statement to a monitor:

```
float vwap;
from t in all Tick(symbol="APMA")
   within period
   select wavg(t.price,t.volume) : vwap {
      processNewVwap(vwap); }
```

Often, however, you want to use the output from one query as the input to another query. For example, here is an extract from the statistical arbitrage sample application, which you can find in the samples\monitorscript\statarb directory of your Apama installation directory:

```
action newStatArbOrder(StatArbOrder o) {
   integer BUY:=1, HOLD:=0, SELL:=-1, instruction;

   stream<float> spreads:=
      from a in all Price(symbol=o.primary.symbol) retain 1
      from b in all Price(symbol=o.secondary.symbol) retain 1
      select (a.price - b.price);

   stream<MeanSd> meanSds := from s in spreads within 20.0
      select MeansSd(mean(s), stddev(s) );

   stream<integer> comparison := from s in spreads from m in meanSd
      select compareSpreadAndBands(s, m.mean, m.sd, o.factor);

   stream<integer> prevComparison := from c in comparison
      retain 1
      select rstream c;

   from c in comparison from p in prevComparison
      where c!=HOLD and c!=p select c: instruction {
         if instruction = BUY {
            buyPrimarySellSecondary();
         } else {
            sellPrimaryBuySecondary();
         }
      }
}
```

When queries are connected like this, the set of connected queries is referred to as a stream network.

A stream network is strictly within a monitor instance. Routing an event takes that event entirely out of the stream network since the event would not be received in the same network activation even if it is received by the same monitor. Spawning a monitor makes any stream variables point to inert streams so it is not possible to refer to a stream network from a different monitor instance.

Stream query definition syntax

A stream query definition contains several elements, some of which are optional and some of which are required. These elements, and their constituent parts, are described in the following sections. The elements appear in a stream query in this order:

```
FromClause  [ FromClause  | JoinClause  ] [ WhereClause  ] ProjectionDefinition
```

Element	Required or Optional	Description
FromClause	Required	Specifies the input stream for the query. See "Specifying input streams in from clauses" on page 216. A `from` clause can also specify which items from the input stream the query should operate on. See "Adding window definitions to from and join clauses" on page 218. If a second `from` clause appears the correlator performs a cross-join to combine items from the two streams. See "Defining cross-joins with two from clauses" on page 231.
JoinClause	Optional	Specifies a second stream for the query to operate on. The correlator performs an equi-join to combine items from the two streams. See "Defining equi-joins with the join clause" on page 233. A `join` clause can also specify which items from the input stream the query should operate on. See "Adding window definitions to from and join clauses" on page 218.
WhereClause	Optional	Applies a filtering criterion to the items in the window or the items produced by the join operation. See

Element	Required or Optional	Description
		"Filtering items before projection" on page 235.
ProjectionDefinition	Required	Defines how the query generates output items. See "Generating query results" on page 236.

Identifier scope in stream queries

Consider the following code fragment:

```
integer a;
stream<float> prices := from a in ticks select a.price;
```

In this example, the `a` in the query refers to the current `Tick` item in the stream and not to the `a` integer variable. In a stream query, you can use an identifier that you have not previously declared. If there is a variable in a containing scope that has the same name as an identifier in the query, then for expressions in the query the identifier in the query hides the variable in the containing scope.

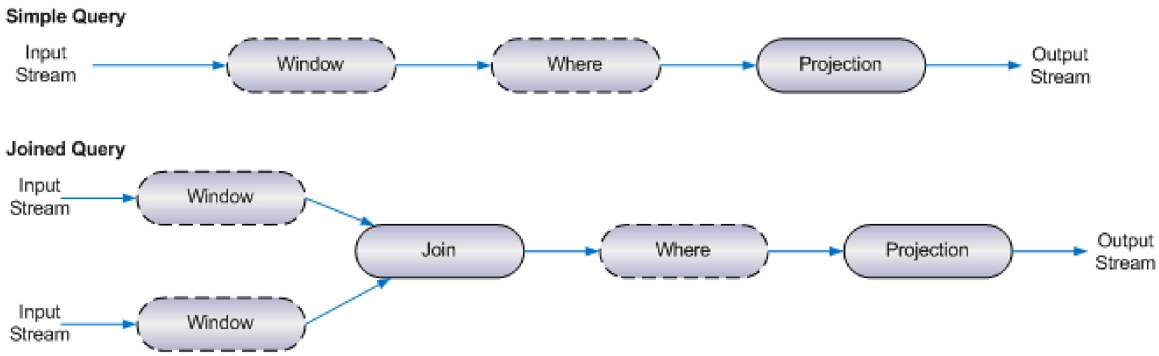
Following is another example of how scope works with steam queries:

```
integer a := 42;
float p;
from a in ticks select a.price:p {
   print a.toString(); // Prints "42" rather than one of the ticks. }
```

The previous code fragment illustrates that identifiers in the listener action can have the same name as identifiers in the stream query. While this is not good practice, it is important to recognize that the listener action is not part of the stream query. Consequently, an identifier in a stream query is out-of-scope in the stream query's listener action.

Stream query processing flow

Each element of the stream query operates on the output of the previous part. To correctly define stream queries, it can be helpful to understand that items flow through the query and the correlator processes the parts of the query in the order shown in the following figure. In the figure, the dashed outlines indicate optional elements.



As items arrive on the input stream(s) and time elapses, the window definition for each stream identifies which items from that stream the query should be processing at any given moment. This includes partitioning, if it is specified. See "Adding window definitions to from and join clauses" on page 218

In queries with two input streams, the correlator combines items from the two streams by means of a cross-join operation (a second `from` clause) or an equi-join operation (a `join` clause). See "Joining two streams" on page 231

The `where` clause, if there is one, filters items. See "Filtering items before projection" on page 235.

The projection definition defines how the query generates output items. This includes the `select` clause, which has appeared in examples such as "Simple example of a stream network" on page 213. See "Generating query results" on page 236.

Specifying input streams in from clauses

In a stream query, each `from` clause specifies a stream that the query is operating on. The syntax of the `from` clause is as follows:

```
from itemIdentifier in streamExpr [WindowDefinition]
```

Syntax description

Syntax Element	Description
itemIdentifier	Specify an identifier that you want to use to represent the current item in the stream you are querying. You use this identifier in subsequent clauses in the query. For details about the characters you can specify, see "Identifiers" on page 919. The type of the identifier is the same as the type of the items that are in the stream you are querying. There is no link between an item identifier in a query and a variable that you might define

Syntax Element	Description
	elsewhere in your code. In other words, it is okay for an in-scope variable to have the same name as an item identifier in a query. Inside the query, the item identifier hides that variable. See the second example below.
streamExpr	Specify an expression that returns a `stream` type. This is the stream that you want to query.
WindowDefinition	Define which portion of the stream to query. See "Adding window definitions to from and join clauses" on page 218.

Examples

The query below generates a stream of `float` items. The item identifier is `a`. The stream variable, `ticks`, refers to a stream of `Tick` events. The `select` clause specifies that each query result item contains only the `price` value from the `Tick` event. Details about the `select` clause are in "Generating query results" on page 236.

```
stream<float> prices := from a in ticks select a.price;
```

The `all` keyword followed by an event template is an expression of type `stream` referred to as a stream source template. Consequently, you can use this in a `from` clause. For example, you can modify the previous example to use the stream source template directly within the stream query:

```
stream<float> prices :=
   from a in all Tick(symbol="APMA") select a.price;
```

Notes

A stream query is an expression of type `stream` and so anywhere that you can specify a `stream` expression you can use a stream query in its place. (There is one exception to this. See "Linking stream queries together" on page 212.) This means you can nest stream queries to create a compound stream query. For example, consider the following non-nested stream queries:

```
stream<A> sA := all A();

stream<integer> derived :=
   from a in sA retain 2 select mean(a.x);

stream<B> sB :=
   from a in derived within 10.0 select B(stddev(a));
```

An equivalent way to write this is as follows:

```
stream<B> sB :=
   from b in
      from a in all A() retain 2 select mean(a.x)
   within 10.0
   select B(stddev(b));
```

The compiler generates the same stream network in both cases so the performance is exactly the same. However, nesting stream queries beyond one level can make the compound stream query hard to understand.

To define a query that operates on two streams, specify two consecutive `from` clauses or specify a `from` clause followed by a `join` clause. See "Joining two streams" on page 231.

Adding window definitions to from and join clauses

The items flowing through a stream are ordered. In any given activation, there are zero or more items that are current. By default, the stream query operates on those current items.

Alternatively, a window may be defined. Window definitions specify which items the query should operate on in each activation, based on (but not limited to) the following:

- The items within a given time period
- A maximum number of items
- The content of the items

As the window contents change, the items in the query projection will also change: new items will be inserted and old ones removed. The output from a query is a stream of items.

If the projection is an aggregate projection then the query output is the result of evaluation of the `select` clause when the window contents change. See "Aggregating items in projections" on page 238.

If the projection is a simple, non-aggregate projection, the default output is the insertion stream or *istream* for short, of new projected items. Alternatively, if the `restream` keyword is specified in the `select` clause, the output is the remove stream (or *rstream*) of items that have become obsolete.

Window definition syntax

There are a number of different formats and keywords that you can use to define a window on a stream. Following are the alternatives you can choose from. See the subsequent topics for details.

```
[partition by partitionByExpr[, partitionByExpr]...]

(
within windowDurationExpr[every batchPeriodExpr]
   [retain windowSizeExpr] [with unique keyExpr]

| retain windowSizeExpr  [every batchSizeExpr] [with unique keyExpr]
)

| retain all
```

Every window definition specifies `retain`, `within` or both.

Syntax description

Syntax Element	Description
partitionByExpr	Optionally specifies an EPL expression that should involve the input item in some way and that returns a comparable type. A `partition by` clause effectively creates a separate window for each encountered distinct value of *partitionByExpr*.
windowDurationExpr	Specifies a `float` expression that indicates a duration of a number of seconds. The window contains the items received within the last *windowDurationExpr* seconds. See "Defining time-based windows" on page 220.
batchPeriodExpr	Specifies a `float` expression that indicates an interval period of a number of seconds. The window updates its contents every *batchPeriodExpr* seconds. See "Defining batched windows" on page 224.
windowSizeExpr	Specifies an `integer` expression that indicates the number of items you want to retain in the window. The window contains the most recent *windowSizeExpr* items. See "Defining size-based windows" on page 222.
keyExpr	Specifies an EPL expression that must contain at least one reference to the input item and must return a comparable type. See "Comparable types" on page 817. If you add a `with unique` clause, if there is more than one item in the window that has the same value for the key identified by *keyExpr*, only the most recently received item is considered to be in the window. See "Defining content-dependent windows" on page 229.
batchSizeExpr	Specifies an `integer` expression that indicates a number of items. The window updates its contents after every *batchSizeExpr* items

Syntax Element	Description
	that match the query are found. See "Defining batched windows" on page 224.

Omitting the window definition

The window definition is optional in a stream query. If you do not specify any window then, for any given activation of the stream query, the stream query operates on only the items that are current for that activation. Typically this is a single event. However, if the source for this query is, for example, a stream query with a batched window then the items in each batch will be processed together as in the following example:

```
stream<A> sA := from a in all A() retain 4 every 4 select a;
from a in sA select count(): c { ... }
```

The second query receives batches of four `A` events and will generate a single aggregate value for each batch. For more details see "Stream queries that generate lots" on page 246.

Retaining all items

The simplest window is one that contains all items that have ever been in the stream. The corresponding window definition is `retain all`. Conceptually, once an item enters a `retain all` window, it remains in the window indefinitely (or until the stream query is terminated). The following query evaluates the running mean of all items that have ever been in the `values` stream:

```
stream <decimal> means := from v in values retain all select mean(v);
```

The `retain all` clause specifies an unbounded window. Unbounded windows have restrictions on their use:

- You cannot have a partitioned or batched unbounded window.
- You cannot perform a join operation on an unbounded window.
- You cannot specify an unbounded window when you use `rstream` in the `select` clause of a query.

When you use a custom (user-defined) aggregate function in a query that contains an unbounded window, you cannot also use a bounded aggregate function. You should also be aware that, if you use a badly implemented custom aggregate function in a query that contains an unbounded window, then this can result in uncontrolled memory usage. See "Defining custom aggregate functions" on page 241.

Defining time-based windows

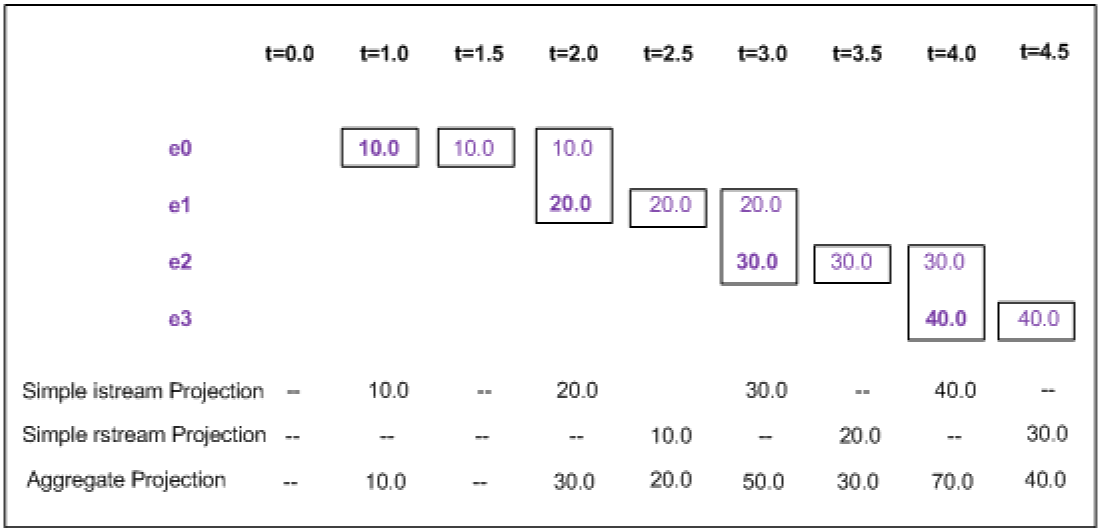
In a time-based window, the items are held in the window for a specific duration. The syntax for defining a time-based window is:

```
within windowDurationExpr
```

Replace *`windowDurationExpr`* with an expression that returns the number of seconds that items should remain in the window as a `float` value. For example, the following query calculates the sum of all items that arrived in a stream of `float` values during the last 1.5 seconds:

```
stream<float> sums := from v in values within 1.5 select sum(v);
```

The following diagram illustrates how this works in practice.



Each column represents a time when the query window contents change whereas each row represents the arrival and lifetime of each event. As an event arrives in the window it appears in bold purple. At each given time, the current window contents is indicated by the items enclosed by boxes — bold purple items are new and lighter purple items are old items still in the window. The numbers at the bottom give the contents of the stream of insertions to and removals from the window in the case where each value is being selected independently, or when the aggregate sum of the values in the set of items in the window is being calculated. The query before the diagram corresponds to the aggregate projection line. The queries shown here are:

Simple istream Projection	`from v in values within 1.5 select v`
Simple rstream Projection	`from v in values within 1.5 select rstream v`
Aggregate Projection	`from v in values within 1.5 select sum(v)`

In a simple, non-aggregate projection, when an event arrives in the window it appears in the istream of the projection. It remains for 1.5 seconds, at which point it appears on the rstream of the projection. The aggregate projection behaves differently. Whenever an item arrives in or is removed from the window, a new sum appears on the istream of the aggregate projection.

Defining size-based windows

As well as time, you can specify windows that contain only a certain number of items. In a size-based window, as each new item arrives, it is added to the window. After the number of items in the window reaches the window size limit specified in the query, the arrival of a new item causes the removal of the oldest item from the window.

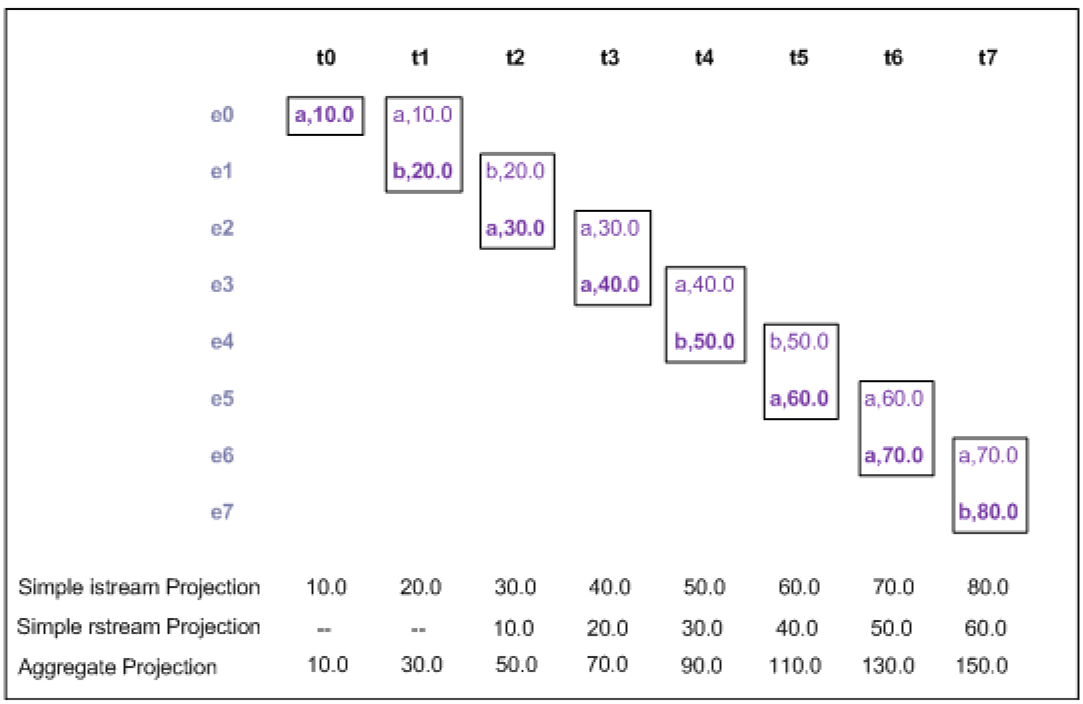
The syntax for defining a size-based window is as follows:

```
retain windowSizeExpr
```

Replace *windowSizeExpr* with an expression that returns how many items you want to retain in the window as an `integer` value. For example, the following query calculates the sum of the last 2 items in a stream of floats:

```
stream <float> sums := from v in values retain 2 select sum(v.number);
```

The following diagram, which uses the same notation as the previous section, illustrates how this works in practice.



The query before the diagram corresponds to the aggregate projection. The three queries shown here are:

Simple istream Projection	`from v in values retain 2 select v.number`

Simple rstream Projection	`from v in values retain 2 select rstream v.number`
Aggregate Projection	`from v in values retain 2 select sum(v.number)`

When an event arrives in the window it appears in the istream of a simple, non-aggregate projection. The first item remains in the window when a second item arrives. When a third item arrives, the first item is no longer in the window and it appears on the rstream of the simple, non-aggregate projection. Likewise, when the fourth item arrives in the window it appears in the istream and the second item appears on the rstream of the simple projection, and so on. The behavior of the aggregate projection is that whenever an item arrives in or is removed from the window, a new sum appears on the istream of the aggregate projection.

Combining time-based and size-based windows

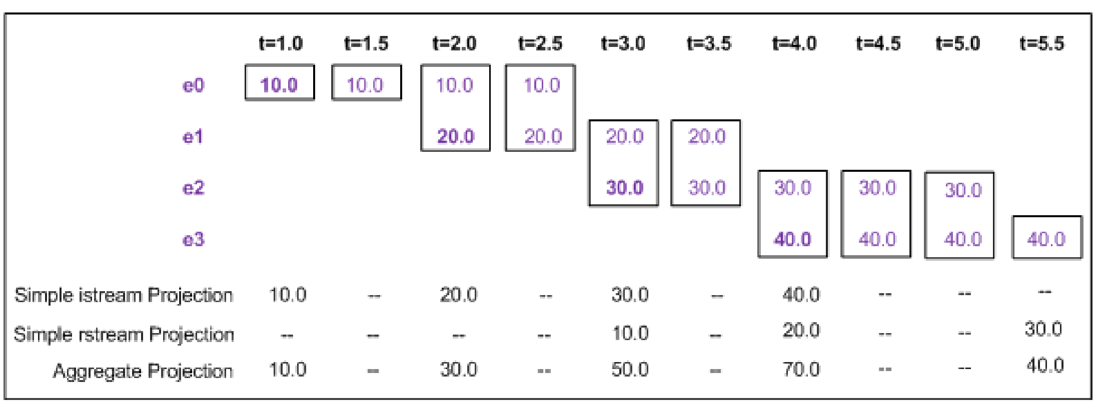
Sometimes you might want to focus on the last *n* items received in the last *d* seconds. To define a window that retains items based on both time and size, use the following format in the `from` clause:

```
within windowDurationExpr retain windowSizeExpr
```

The `within` keyword and expression must be first and the `retain` keyword and expression must be second. As with separate size-based and time-based windows, replace *`windowDurationExpr`* with an expression that returns a number of seconds, *d*, as a `float` value. Replace *`windowSizeExpr`* with an expression that indicates how many items you want to retain in the window, *n*, as an integer value. The window contains the last *n* items received in the last *d* seconds. If no items were received in the last *d* seconds, the window is empty. For example:

```
from v in values within 2.5 retain 2 select sum(v);
```

The following diagram, which uses the same notation as the previous section, illustrates how this works in practice.



The query before the diagram corresponds to the aggregate projection. The three queries shown here are:

Simple istream Projection	`from v in values within 2.5 retain 2 select v`
Simple rstream Projection	`from v in values within 2.5 retain 2 select rstream v`
Aggregate Projection	`from v in values within 2.5 retain 2 select sum(v);`

The important point to note in this example is that some items drop out of the window before the 2.5 second period is passed. When `e2` arrives, `e0` and `e1` are already in the window. Even though `e0` has been there for only 2 seconds, it is removed because `e1` and `e2` are now the two most recent items received in the last 2.5 seconds.

Defining batched windows

The default behavior is that the contents of a window change upon the arrival of each item. The `every` keyword can be used to control when the contents of the window change: it causes the items to be added to the window in batches. Time-based windows can be controlled to update only every *p* seconds and size-based windows can be controlled to update only after every *m* events.

The syntax for a batched window is one of the following:

```
within windowDurationExpr every batchPeriodExpr
| retain windowSizeExpr every batchSizeExpr
| within windowDurationExpr every batchPeriodExpr retain windowSizeExpr
```

Here, *windowDurationExpr* and *windowSizeExpr* retain their meaning from the previous sections. The *batchPeriodExpr* is an expression that returns the time, *p*, between updates as a `float` value. The *batchSizeExpr* is an expression that returns the number of events between updates, *m*, as an `integer` value.

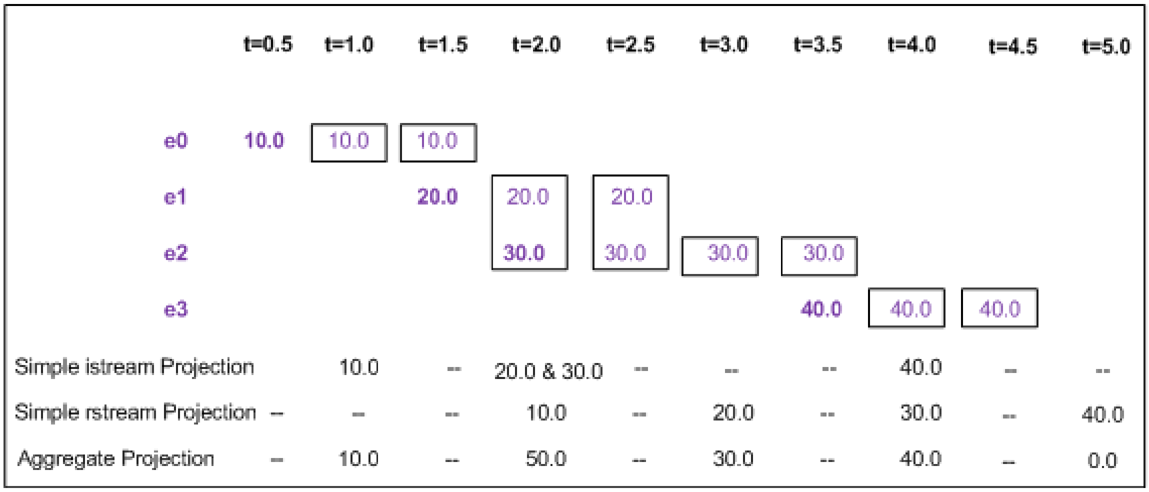
When you specify `within` followed by `every` followed by `retain`, the `every` keyword always indicates a number of seconds. That is, the window updates its content every *p* seconds.

If no items have arrived or expired since the previous window update, the window content is unchanged and consequently the query does not execute. The correlator executes the query only when the window content changes.

Here is an example of a stream query that defines a batched, time-based window. The correlator creates the query at `t=0.0`.

```
from v in values within 1.5 every 1.0 select sum(v)
```

The following diagram illustrates how this works in practice.



The query before the diagram corresponds to the aggregate projection. The three queries shown here are:

Simple istream Projection	`from v in values within 1.5 every 1.0 select v`
Simple rstream Projection	`from v in values within 1.5 every 1.0 select rstream v`
Aggregate Projection	`from v in values within 1.5 every 1.0 select sum(v)`

The important things to note about the behavior of these queries is that the window content changes only every second. Nothing appears on any insert or remove stream between those points. This means that the items `10.0`, `20.0` and `40.0` are not in the window at the moment they arrive, but are kept until the next multiple of 1.0 second. Item lifetimes are calculated from the item arrival time, not the point at which the batching allows the item into the window. Consequently, the lifetime of the items in the window is also affected by the batching. In these examples, you can see that the items that were delayed entering the window are only in the window for one second because they were already 0.5 seconds old at the point they entered the window. For contrast, the item with the value `30.0` remains in the window for 2.0 seconds because after 1.5 seconds the batching has not occurred, and so the window cannot change until the next multiple of 1.0 second.

In the examples given here the batch period is smaller than the duration of the window. If the batch period is larger than the duration of the window then some items can never enter the window, if they would have already expired by the time the next batch arrives in the window.

Batched size-based windows behave similarly to batched time-based windows, except that the batch criteria is waiting for a number of items to arrive. In that case, items always arrive in the window as a multiple of the batch size.

Batched windows produce multiple items at one time. A single group of items flowing between queries together is called a lot. A lot can contain one item or several items. A batched window is one way of producing a lot that contains several items.

Partitioning streams

The `partition by` clause splits a stream into partitions, based on one or more key values. The subsequent window operators are applied to the partitioned stream; the behavior is as if the window operators had been applied separately to each partition. The result of using `partition by` followed by a window operator is referred to as a partitioned window. You use a query with a partitioned window to retain particular items for each partition specified by the `partition by` clause.

Partitioning is introduced with the following syntax:

```
partition by partitionByExpr [, partitionByExpr ]...
```

The `partition by` clause precedes other window operators, so a complete query would be:

```
from a in sA partition by a.x retain 2 select sum(a.y);
```

Each *`partitionByExpr`* is an expression that should contain at least one reference to the input item and must return a comparable type. See "Comparable types" on page 817. Some examples are in the following table. Assume that each `partition by` clause in the table starts with the following:

```
from a in all A() ...
```

Definition	Description
`partition by a.x`	Partition on a single primitive type field of the input event. This is likely to be the most common case.

`partition by a`	Partition on an event's field values. The events that have identical values for all fields are in the same partition. For example:
	`from a in all A()`
	`   partition by a retain 2 select a;`
	Given the following input events:
	`A(1,1)`
	`A(1,2)`
	`A(1,1)`
	The first and third events are in the same partition, the second is not. In this case, the event type `A` must itself be a comparable type.

`partition by 1`	This is a valid partition expression, but it is not recommended. A partition expression should reference the input item in some way.

Definition	Description
`partition by f(a)`	This is a valid partition expression if `f()` is a function that returns an appropriate type.
`partition by a.x*globaldict[a.y]`	Another valid partition expression.

Example

```
from t in all Tick()
   partition by t.symbol retain 1
   select rstream t;
```

This query creates a separate partition for each new stock symbol it finds. Each partition contains the most recent `Tick` event for that symbol. The query output, for each encountered symbol, is the previous `Tick` event for that symbol. Note that it is possible for this query to consume a large quantity of memory.

Partitions and aggregate functions

The `partition by` clause creates several partitions within the window. However, a stream query has other parts in addition to the window. The other parts include the projection and optional join or where elements. These other parts of the query operate on a single window that contains all items from all partitions.

Likewise, when you partition a stream any specified aggregate functions aggregate over all partitions. If you want to generate separate aggregate values for different groups of events then you must specify a `group by` clause. See "Grouping output items" on page 238 . A common use case is to specify matching `partition by` and `group by` clauses.

Consider the following stream query:

```
from a in all A() partition by a.x retain 2 select sum(a.y);
```

The window definition is `retain 2`, and this is partitioned by `a.x`, where `x` is the first field in `A`. There is one `retain 2` partition for each value of `x`. Suppose this stream query receives the following input events:

```
A(1,1)
A(1,2)
A(2,1)
A(2,2)
A(1,3)
A(2,3)
```

After these events have all arrived, one partition contains `A(1,2)` and `A(1,3)` while a second partition contains `A(2,2)` and `A(2,3)`. However, the parts of the query following the window definition operate on the collection of all items in all partitions. In this example, the `sum()` aggregate function generates `10`. It does not generate a lot that contains two values of `5`. Now consider the following query:

```
from t in all Tick()
   partition by t.symbol retain 10
   group by t.symbol
   select mean(t.price)
```

This query returns one mean value per symbol, which is the mean of the last 10 ticks for that symbol. If you do not want all means for all symbols in one lot, you might prefer to spawn monitors so that you have an instance of the following query for each symbol:

```
from t in all Tick(symbol=X)
   retain 10
   select mean(t.price)
```

If you do want the averages for all the symbols in the same stream, then you can specify the group key in the `select` clause in order to later differentiate between the output events, as in the following example:

```
from t in all Tick()
   partition by t.symbol retain 10
   group by t.symbol
   select Output(t.symbol, mean(t.price))
```

As you can see, the `partition by` clause is often used in conjunction with the `group by` clause.

Tip: In EPL, it is common to use `spawn` in a monitor to create separate monitor instances. For example, each monitor instance might process a separate stock symbol. Spawning separate monitor instances might be preferable to using a single monitor instance that specifies `partition by` in a stream query so that it, for example, processes all stock symbols. Spawning separate monitor instances can be more efficient because your application processes only the subset of symbols that are of interest. Also, the subset of symbols of interest can change through the day. Appropriate monitor instances and queries can be created as required.

See also "IEEE special values in stream query expressions" on page 241.

Using multiple partition by expressions

To partition a window according to multiple criteria, you can insert multiple, comma-separated expressions. For example, you can refine a previous query to produce values for different volume bands, as follows:

```
from t in all Tick()
   partition by t.symbol, t.volume.floor()/100 retain 1
   select rstream t;
```

In this example, the correlator applies `retain 1` to each set of ticks that share both the same symbol and the same volume (to within 100). As a result, an item is output only when a replacement tick arrives for an existing symbol in an existing volume band.

Partitioning time-based windows

If a window is purely time-based then there is no benefit to partitioning the window. For example, consider the following two queries:

```
from t in all Tick() within 1.0 ...
from t in all Tick() partition by t.symbol within 1.0 ...
```

The first query outputs every `Tick` received in the last second. The second query organizes the stream of `Tick` events by their symbols, then gives you each one that arrived in the last second. This is still every `Tick` received in the last second. The correlator ignores a `partition by` statement if it is used only with a `within` window.

If your window includes a `retain` clause as well as a `within` clause then it can be helpful to use `partition by`, likewise if there is a `with` clause. See "Defining content-dependent windows" on page 229. For example:

```
from t in all Tick() partition by t.symbol within 10.0 retain 5 ...
```

This window will contain at most 5 `Tick` events for each different symbol received within the last 10 seconds.

Defining content-dependent windows

The contents of the window can also depend on the content of individual items in the stream. Currently the only content-dependent window operator is the `with unique` clause, which limits the window to containing only the most recent item for each key value. The `with unique` clause can be added to a `within` or a `retain` window by following it with:

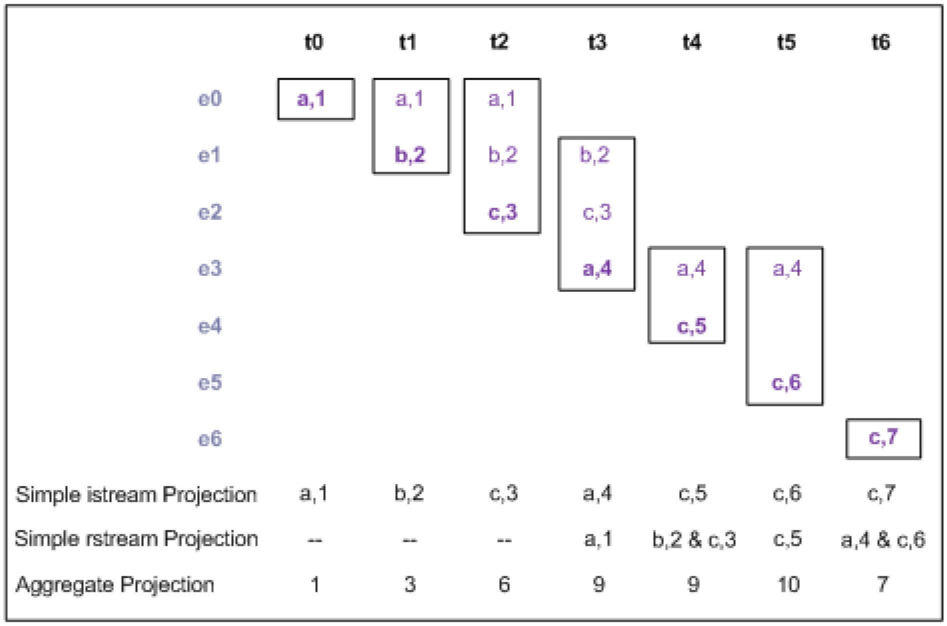
```
with unique keyExpr
```

The *`keyExpr`* follows the same rules as a partition key expression. That is, it is an expression that should contain at least one reference to the input item and must return a comparable type. See "Comparable types" on page 817. Some examples are in the following table.

If you add a `with unique` clause, if there is more than one item in the window that has the same value for the key identified by *`keyExpr`*, only the most recently received item is considered to be in the window. It is important to note that the `with unique` clause processing happens after the rest of the window processing. Consider the following query:

```
from p in pairs retain 3 with unique p.letter select sum(p.number)
```

If the most recent two events have the same letter, there will be only two events over which the sum is calculated. This is illustrated in the following diagram:



The query before the diagram corresponds to the aggregate projection. The three queries shown here are:

Simple istream Projection	`from p in pairs retain 3 with unique p.letter select p`
Simple rstream Projection	`from p in pairs retain 3 with unique p.letter select rstream p`
Aggregate Projection	`from p in pairs retain 3 with unique p.letter select sum(p.number)`

As you can see, when the last three items received all have a unique letter, the query behaves like a `retain 3` window. When the last three items received do not all have a unique letter, the duplicate that arrived first is removed from the window. In this example, the arrival of `c,5` causes the removal of `c,3` even though it was one of the last 3 items received. In other words, the `with unique` clause can cause an item to be removed from the window and the sum earlier than it would otherwise be removed.

The difference between a partitioned window and a window that is using a `with unique` clause can be described as “using `partition by` gives you the last 3 values for each key” and “using `with unique` gives you one value of each key, from the last 3”. You can combine both `partition by` and `with unique` if you are using different key expressions in each clause.

Note that you cannot specify `within` followed by `retain` followed by `with unique`.

See also "IEEE special values in stream query expressions" on page 241.

Joining two streams

When a stream query operates over two input streams it is referred to as a join operation. There are two forms of join operation available in EPL. Each form takes two input streams and produces a single output stream of combined items. A cross-join joins every event from one stream's window with every event in the other stream's window. An equi-join joins events only when they have matching keys.

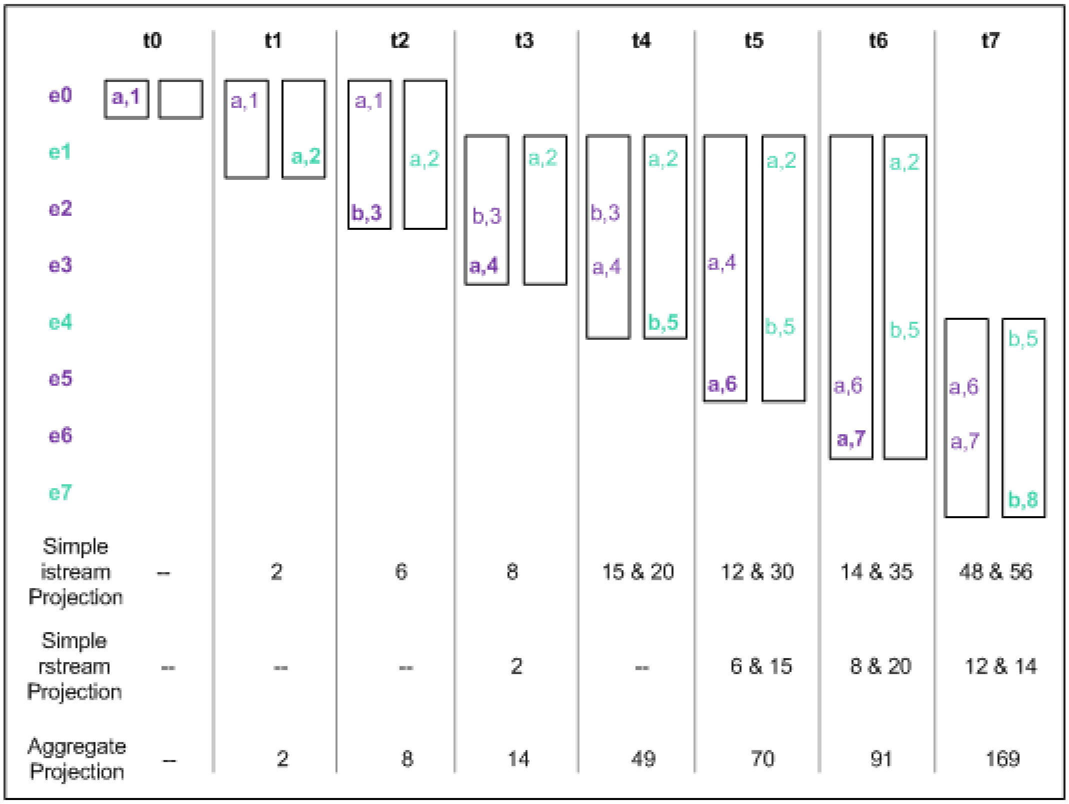
Join operations, particularly cross-joins, can create many more output events than input events, not just the same or fewer.

Defining cross-joins with two from clauses

A cross-join is defined with two `from` clauses, one for each stream, optionally including window definitions. A simple example of this is:

```
from p1 in leftPairs retain 2
   from p2 in rightPairs retain 2
   select sum(p1.num * p2.num);
```

This is illustrated in the following diagram, whose notation differs from the previous diagrams. Here, for each time point there are two columns, one for each side of the join. The first column, with purple events, represents the items from the first `from` clause and the second column, with cyan events represents the items from the second `from` clause. Events in bold arrived during this activation of the stream query and the boxes enclose the windows for each side. As in the previous diagrams, the output is given for each of the three kinds of projections.



The query before the diagram corresponds to the aggregate projection. The three queries shown here are:

Simple istream Projection	`from p1 in leftPairs retain 2`
	`from p2 in rightPairs retain 2`
	`select p1.num * p2.num`

Simple rstream Projection	`from p1 in leftPairs retain 2`
	`from p2 in rightPairs retain 2`
	`select rstream p1.num * p2.num`

Aggregate Projection	`from p1 in leftPairs retain 2`
	`from p2 in rightPairs retain 2`
	`select sum(p1.num * p2.num);`

As shown in the diagram, in a cross-join whenever an item arrives in a window, it is joined to every item in the other window to produce a separate output item for each combination.

Because the number of output items is the product of the size of the two windows, cross-joins are normally used for joins between at least one of:

- A window of size 1
- A stream where you have omitted the window definition

If both sides of the join omit the window definition then for output to occur an item must arrive on each stream during the same activation of the query.

A more concrete example can be seen in the statistical arbitrage sample application (see the `samples/monitorscript/statarb` directory of your Apama installation directory), which includes the following statement:

```
stream <decimal> spreads :=
   from a in all Price(symbol=symbolA) retain 1
   from b in all Price(symbol=symbolB) retain 1
   select (a.price - b.price);
```

This query generates the spread between the latest prices for the two identified stocks. In each `from` clause, the window contains one item. Whenever a new item arrives in one window the query executes the calculation defined in the `select` clause and outputs the result.

To generate a running mean and a standard deviation for this spread value you can define the following query:

```
stream<MeanSD> averages := from s in spreads within 20.0
   select MeansSD(mean(s),stddev(s));
```

Then, to obtain all three current values for the spread, the mean and the standard deviation you can perform a join between the `spreads` stream and the `averages` stream:

```
stream<SpreadMeanSD> all := from s in spreads
   from a in averages
   select SpreadMeansSD(s, a.mean, a.stddev);
```

This query outputs a result only when there is an item currently in both `spreads` and `averages`.

In a cross-join, you cannot specify more than two `from` clauses.

Caution: Be aware that cross-joins have the potential to generate a great quantity of output. It is preferable to use cross-joins only where the window size/duration of any window involved in the cross-join is small. For example, putting 8000 events through a 100x100 cross-join produces 1.6 million output events. You cannot specify a cross-join in a query that contains an unbounded window.

Defining equi-joins with the join clause

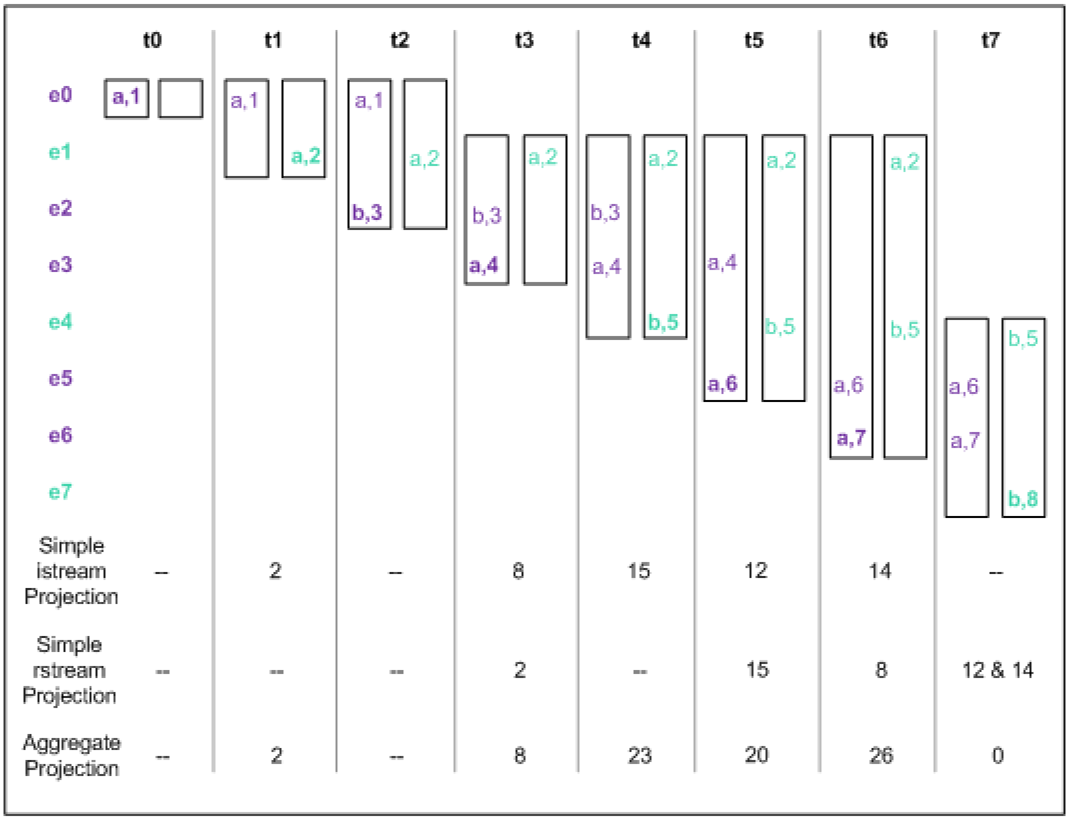
An equi-join has a key expression for each of the two streams that are being joined. Two items are joined into an output item only if the values of their key expressions are equal. The full syntax for an equi-join, consisting of a `from` clause followed by a `join` clause, is:

```
from itemIdentifier1 in streamExpr1 [windowDefinition1]
   join itemIdentifier2 in streamExpr2 [windowDefinition2]
   on joinKeyExpr1 equals joinKeyExpr2
```

As with the partition and unique key expressions, each join key expression must return a "comparable type" on page 817. Also, *`joinKeyExpr1`* must include a reference to *`itemIdentifier1`* and *`joinKeyExpr2`* must include a reference to *`itemIdentifier2`*. Each join key may not refer to the item from the other stream. An example of an equi-join is:

```
from p1 in leftPairs retain 2
   join p2 in rightPairs retain 2
   on p1.letter equals p2.letter
   select sum(p1.num * p2.num);
```

This is illustrated in the following diagram:



The query before the diagram corresponds to the aggregate projection. The three queries shown here are:

Simple istream Projection	`from p1 in leftPairs retain 2`
	`   join p2 in rightPairs retain 2`
	`   on p1.letter equals p2.letter`
	`   select p1.num * p2.num`

Simple rstream Projection	`from p1 in leftPairs retain 2`
	`   join p2 in rightPairs retain 2`
	`   on p1.letter equals p2.letter`
	`   select rstream p1.num * p2.num`

Aggregate Projection	`from p1 in leftPairs retain 2`
	`   join p2 in rightPairs retain 2`
	`   on p1.letter equals p2.letter`
	`   select sum(p1.num * p2.num);`

This diagram shows the input that was used in the cross-join example, but with the join changed to be an equi-join. As you can see, only the items with matching letters appear in the output. The first event on the right side of the join has the same letter as the event on the left, so an output is produced as before. When the second event arrives on the left, however, no output is produced, because the letter does not match the other side. When a `b` event arrives on the right side of the join, that is joined with the `b` event on the left.

Finally, at the end of the table you can see that the join is empty because none of the events on the left match any of the events on the right.

Here is a more concrete example of an equi-join:

```
from r in priceRequest
   join p in prices partition by p.symbol retain 1
   on r.symbol equals p.symbol
   select p.price
```

For each new stock price request, this query generates the latest price for that stock/symbol. In an equi-join, whenever an item enters a window on one side, the correlator evaluates the join condition to determine if the item matches any of the items in the window on the other side. The correlator joins and outputs each matching pair when it finds one.

Typically, you want to create a derived event that is a function of the events on both sides of the join operation. Here is another example:

```
from latest in latestSensorReadings
   join average in averageSensorReadings
   on latest.sensorId equals average.sensorId
   select SensorAlert(latest.sensorId, latest.value, average.mean): alert{
      send alert to "output";
}
```

This query joins a stream of the most recent readings from all the sensors with a stream of averages of the same readings over some period. When a new reading appears it causes an event on the stream of averages at the same time. This causes them to be joined to create an alert that contains both the latest value and the latest average, which is then sent.

See also "IEEE special values in stream query expressions" on page 241.

Filtering items before projection

In a stream query, after the window definition and any `join` clause, you can optionally specify a `where` clause to filter the items produced by the window or join. The `where` clause specifies an arbitrary EPL expression and can filter items based on any criteria available to EPL.

Format

```
where booleanExpr
```

Replace *`booleanExpr`* with a Boolean expression. This expression is referred to as the `where` predicate. Only those items for which the `where` predicate evaluates to true are passed by the filter. For example:

```
from t in ticks retain 100
   where t.price*t.volume>threshold
   select mean(t.price)
```

To calculate the mean price, this query operates on only the items whose value (`t.price` * `t.volume`) is greater than the specified threshold.

Performance

The filtering performed by the `where` clause happens after any window, `with` or `join` operations. In some cases, it is possible to rephrase the query to improve operational efficiency. For example:

```
from t in ticks within 60.0
   where t.price*t.volume>threshold
   select mean(t.price)
```

This query maintains a window of `Tick` items. Now consider this revision:

```
from p in
   (from t in ticks where t.price*t.volume>threshold select t.price)
   within 60.0
   select mean(p)
```

In the first example, the `within` window contains all `Tick` events received in the last minute. In the second example, the `where` clause is before the window definition so the filtering happens before items enter the window. Consequently, the window contains only `float` items for which the `where` predicate is true. These types of optimization are of particular benefit in queries that include both a `where` clause and a `join` operation (equi-join or cross-join). However, care must be taken when refactoring queries, particularly when size-based windows are involved. For example, consider the two queries below:

```
from t in ticks retain 100 where t.price*t.volume>threshold
   select mean(t.price)

from p in
   (from t in ticks where t.price*t.volume>threshold select t.price)
   retain 100 select mean(p)
```

These queries are not equivalent. The first query generates the mean of a subset of the last 100 items. The `where` predicate evaluated to true for only the items in the subset. The second query generates the mean of the last 100 items for which the `where` predicate evaluated to true.

Generating query results

The last component of a stream is the required projection definition, which specifies how to generate items for the query's output stream. A projection definition has the following syntax:

```
[group by groupByExpr[, groupByExpr]...] [having havingExpr]
  select [rstream] selectExpr
```

Each *`groupByExpr`* is an expression that returns a value of a comparable type. These expressions form the group key, which determines which group each output item is a part of. Any aggregate functions in the `having` or `select` expression operate over each group separately. See "Grouping output items" on page 238.

The *`havingExpr`* expression filters output items. See "Filtering items in projections" on page 239.

The value you specify for `selectExpr` defines the items that are the result of the query. The correlator evaluates `selectExpr` to generate each item that appears in the query's output stream. The type of `selectExpr` identifies the type of the query's output stream.

A projection can be one of the following kinds:

- A *simple* projection does not specify any aggregate functions, nor does it specify a `group by` or `having` clause. A simple projection can be a simple istream projection or a simple rstream projection.
- An *aggregate* projection specifies at least one aggregate function across the `having` and `select` expressions.

  You can specify a `group by` clause as part of an aggregate projection. If there is a `group by` clause, the group key must be one or more expressions that take the input event and return a value of a comparable type.

  You cannot specify `rstream` in an aggregate projection.

The following table describes the kinds of expressions that can appear in the `select` expression for each type of projection. In more complex expressions, the rules apply similarly to each sub-expression within that expression.

Kind of Expression	Valid in Projections	Description	Example
Non-item expression	Simple and aggregate	An external variable, constant, or method call, It does not refer to any of the input items.	`select currentTime;`
Item expression	Simple	A reference to the input item or a non-aggregate expression that contains at least one reference to the input item.	`select a.i;` `select sqrt(a.x)*5.0/a.y`
Group key expression	Aggregate	An expression that returns one of the group keys can also occur in the projection.	`group by a.i/10 select (a.i/10)*mean(a.x);`

Kind of Expression	Valid in Projections	Description	Example
Aggregate function expression	Aggregate	An expression that contains at least one aggregate function. Arguments to the aggregate function can include item expressions.	`select mean(a.i);`

Note: An expression might not be syntactically equivalent to a `group by` expression even though it might appear to be equivalent. For example, if the `group by` expression is `a.i*10`, you cannot specify `10*a.i` as an equivalent expression. An equivalent `group by` expression must contain the exact sub-expression specified in the `group by` clause.

Aggregating items in projections

An aggregate function calculates a single value over a window. If a `select` expression contains any aggregate functions, then references to the input item can appear only in the arguments to those aggregate functions. Any EPL expression can appear in the arguments to the function, but other aggregate functions may not. EPL provides several built-in aggregate functions and you can define additional ones. See "Defining custom aggregate functions" on page 241 and "Built-in aggregate functions" on page 870.

Grouping output items

In a `select` clause, when you do not specify a `group by` clause any aggregate functions in the projection operate on all values in the window. This is true even if you partitioned the window. To group the items in the window into one or more separate groups and to calculate an aggregate value for each group of items, use the `group by` clause. The syntax of the `group by` clause is as follows:

```
group by groupByExpr [, groupByExpr ]...
```

Each *`groupByExpr`* is an expression that returns a value of a comparable type. See "Comparable types" on page 817.

These expressions form the group key, which determines which group each output item is a part of. Any aggregate functions in the `select` expression operate over each group separately.

In an aggregate projection, you can refer to any group key expressions anywhere in the `select` expression. However, you can refer to a query input item only in an aggregate function argument. For example:

```
from t in all Tick() within 30.0
   group by t.symbol select TickAverage(t.symbol, mean(t.price));
```

Whenever a lot arrives, this query updates one or more groups. Every group that is updated outputs a `TickAverage` event, and all `TickAverage` events are in the same lot. Each `TickAverage` event contains the symbol and the average price for that symbol over the last thirty seconds. If a group is not updated, it does not output a `TickAverage` event.

You typically use a `group by` clause in a stream query in conjunction with a `partition by` clause. In the following example, the window contains up to 10 events for each stock symbol. The aggregate projection calculates the average price separately for each symbol and each average is based on up to 10 events:

```
from t in ticks partition by t.symbol retain 10
   group by t.symbol select mean(t.price);
```

Obtaining the query's remove stream

For each query, there are items that have been added to the window in a given query activation and items that have been removed (they were previously in the window, but are no longer in the window). By default, a simple, non-aggregate projection returns the items that have been added to the window. This is the istream. To obtain the items that have been removed from the window, add the `rstream` keyword to the `select` clause.

For aggregate projections, obtaining the rstream is not meaningful and therefore the `rstream` keyword is not allowed in aggregate projections.

For examples of specifying `rstream`, see "Defining time-based windows" on page 220, "Defining size-based windows" on page 222, "Defining cross-joins with two from clauses" on page 231 and "Defining equi-joins with the join clause" on page 233.

When you specify `retain all`, you cannot specify `rstream`.

Filtering items in projections

In a stream query, as part of an aggregate projection definition, you can optionally specify a `having` clause to filter the items produced by the projection. The `having` clause specifies an arbitrary EPL expression and can filter items based on any criteria available to EPL.

Format

```
having booleanExpr
```

Replace *`booleanExpr`* with a Boolean expression. This expression is referred to as the `having` predicate. The `having` predicate is evaluated for each lot that arrives. When the `having` predicate evaluates to false the projection does not generate output.

Unlike the `where` clause, the `having` clause

- Is part of the projection
- Filters the output of the projection rather than what comes into the projection
- Cannot refer to individual items
- Can refer only to the group key or aggregates

A `having` clause can only be in an aggregate projection; it cannot be in a simple projection. Each aggregate projection must contain at least one aggregate in a `having` clause or in the `select` clause.Values for aggregates, whether in `having` expressions or `select` expressions, are always calculated over the same window(s). See "Grouping output items" on page 238.

For example:

```
from t in all Temperature() within 60.0
   having count() > 10
   select mean(t.value)
```

This query calculates a rolling average of temperatures over the last minute. In this stream query, the `having` clause permits the average to be ouput only when it is a reliable measure.. The `count()` aggregate function ensures that there are sufficient measurements (at least 10) in the previous 60 seconds to compensate for any noise or one-off errors in the readings.

Because the filtering occurs after the `select` exrpression has been processed, the average is still being calculated invisibly in the background, and can be output the very moment the measurement passes the reliability criterion. In the previous example, this means that after ten items have arrived, the average of all values in the last minute is output.

Filtering grouped aggregate projections

If you specify the `group by` clause, the `having` clause operates separately on each group, just as the `select` clause operates separately on each group. For example, the following code changes the previous code so that it outputs a reliable rolling average for each zone:

```
from t in all Temperature() within 60.0
   group by t.zone
   having count() > 10
   select ZoneAverage(t.zone, mean(t.value))
```

Just as a distinct mean is output for each group (each zone), the criterion for the `having` expression are applied separately to each group. A rolling average for a zone is output only when `count() > 10` is true for that zone.

Performance

It is possible for the stream network to avoid some calculations in a `select` clause when the `having` clause evaluates to false. Since maintaining aggregates can be expensive, this can be a useful optimization. When you know that a `having` clause can often evaluate to false, you can obtain better performance by specifying a `having` clause in the stream query as opposed to specifying a query like this:

```
from t in all Ticks(symbol="APMA") within 60.0 * 10.0
    select MeanStddev(mean(t.value), stddev(t.value)) : avg_sd {
        if(shouldOutput()) then {
            send avg_sd to "output";
       }
    }
```

This query computes a rolling average and standard deviation over the last ten minutes of a stock, and sends them to a dashboard or similar. Optionally, the output feed that sends out the rolling average and standard deviation can be turned off, and this is indicated by the return value of the `shouldOutput()` action. However, even when the output is turned off, `Tick` events still come in and the stream network still calculates the rolling average and standard deviation.

You can rewrite the code such that turning off the output terminates the query and turning on the output restarts the query. This option loses the state of the window and introduces a 10-minute lag before accurate output is available. A better option is to add a `having` clause so that turning off the output removes the performance penalty without losing state. For example:

```
from t in all Ticks(symbols="APMA") within 60.0 * 10.0
    having shouldOutput()
    select AvgStddev(mean(t.value), stddev(t.value)) : avg_sd {
        send avg_sd to "output";
    }
```

The `mean()` and `stddev()` aggregates continue to accumulate state when `shouldOutput()` returns false, but they do not fully calculate the rolling average and standard deviation for each incoming item.

IEEE special values in stream query expressions

The following information about IEEE special values applies to the following expressions:

- The key expression in a `with unique` clause
- A `partition by` expression
- The expressions that define the conditions in a `join` clause
- A `group by` expression

If one of these expressions is a `decimal` or `float` value, or a container that involves a `decimal` or `float` value, and the `decimal` or `float` value is an IEEE special value then the following applies:

- NaN — This value is illegal as all or part of an expression and terminates the monitor instance.
- Positive/negative infinity — These values are legal and all positive infinities are treated as equal as are all negative infinities.

Defining custom aggregate functions

EPL provides a number of commonly used aggregate functions that you can specify in the `select` clause of a query. See "Aggregating items in projections" on page 238.
If none of these functions perform the operation you need, you can define a custom aggregate function. The format for defining a custom aggregate function is as follows:

```
aggregate [bounded|unbounded] aggregateName ([arglist])
   returns retType { aggregateBody }
```

Element	Description
`bounded | unbounded`	Specify `bounded` when you are defining a custom aggregate function that will work with only a bounded window. That is, the query cannot specify `retain all`. Specify `unbounded` when you are defining a custom aggregate function that will work with only an unbounded window. That is, the query must specify `retain all`. Do not specify either `bounded` or `unbounded` when you are defining a custom aggregate function that will work with either a bounded or an unbounded window. If you do not specify `bounded`, you must define the custom aggregate function so that it can handle a window that never removes items. The function should not consume memory per item in the window.
aggregateName	Specify a name for your aggregate function. This is the name you will specify when you call the function in a `select` clause. For details about the characters you can specify, see "Identifiers" on page 919.
arglist	Optionally, specify one or more comma-separated type/name pairs. Each pair indicates the type and the name of an argument that you are passing to the function. For example, `(float price, integer quantity)`.
retType	Specify any EPL type. This is the type of the value that your function returns.
aggregateBody	The body of a custom aggregate function is similar to an event body. It can contain fields that are specific to one instance of the custom aggregate function and actions to operate on the state. The `init()`, `add()`, `remove()` and `value()` actions are special. They define how stream queries interact with custom aggregate functions.

You define custom aggregate functions outside of an event or a monitor and the function's scope is the package in which you declare it. To use custom aggregate functions in other packages, specify the function's fully-qualified name, for example:

```
from a in all A() select com.myCorporation.custom.myCustomAggregate(a)
```

Alternatively, you can specify a `using` statement. For example, suppose you define the `myCustomAggregate()` function in the `com.myCorporation.custom` package. To use that function inside another package, insert a statement such as the following in the file that contains the monitor in which you want to use the function:

```
using com.myCorporation.custom.myCustomAggregate;
```

Insert the `using` statement after the optional `package` declaration but before any other declarations. You can then simply specify the function name. For example:

```
from a in all A() select myCustomAggregate(a)
```

Be sure to inject the file that contains the function definition before you inject the files that contain monitors that use the function.

See also "Names" on page 929.

Example of defining a custom aggregate function

The following example shows the definition of a custom aggregate function that returns the weighted standard deviation of the input values.

```
aggregate bounded wstddev( float x, float w ) returns float {
   // 1st argument is the value, 2nd is the weight.
   float s0;
   float s1;
   float s2;
   action add( float x, float w ) {
      if (w != 0.0) then {
         s0 := s0 + w;
         s1 := s1 + w*x;
         s2 := s2 + w*x*x;
      }
   }
   action remove( float x, float w ) {
      if (w != 0.0) then {
         s0 := s0 - w;
         s1 := s1 - w*x;
         s2 := s2 - w*x*x;
      }
   }
   action value() returns float {
      if (s0 != 0.0) then { return ((s2 - s1*s1/s0)/s0).sqrt(); }
      else { return float.NAN; }
   }
}
```

Defining actions in custom aggregate functions

Certain actions in a custom aggregate function have special meanings and you must define them as follows:

- `init()` — The `init()` action is optional. If a custom aggregate function defines an `init()` action it must take no arguments and must not return a value. The correlator executes the `init()` action once for each new aggregate function instance it creates in a stream query.
- `add()` — A custom aggregate function must define an `add()` action. The `add()` action must take the same ordered set of arguments that are specified in the custom aggregate function signature. That is, the names, types, and order of the arguments must all be the same. The correlator executes the `add()` action once for each item added to the set of items that the aggregate function is operating on.
- `remove()` — A bounded aggregate function must define a `remove()` action. An unbounded aggregate function must not define a `remove()` action. If you do not specify either `bounded` or `unbounded`, the `remove()` action is optional. The `remove()` action must take the same ordered set of arguments as the `add()` action and must not return a value. The correlator executes the `remove()` action once for each item that leaves the set of items that the aggregate function is operating on.The value that `remove()` is called with is the same value that `add()` was called with.
- `value()` — All custom aggregate functions must define a `value()` action. The `value()` action must take no arguments and its return type must match the return type in the aggregate function signature. The correlator executes the `value()` action once per lot per aggregate function instance and returns the current aggregate value to the query.

Custom aggregate functions can declare other actions, including actions that are executed by the above named actions. A custom aggregate function cannot contain a field whose name is `onBeginRecovery`, `onConcludeRecovery`, `init`, `add`, `value`, or `remove`, even if, for example, the custom aggregate function does not define a `remove()` action.

Overloading in custom aggregate functions

As with event types, the names of custom aggregate functions must be unique. Unlike the built-in aggregate functions, there is no overloading, so it is not possible to declare two aggregate functions with the same name and different parameters or two aggregate functions with different bounded and unbounded specifiers and the same name. For example:

```
aggregate unbounded max( float value) returns float {...}
aggregate bounded max( float value) returns float {...}
   // Error! You cannot use the same function name.

aggregate unbounded maxu( float value) returns float {...}
aggregate bounded maxb( float value) returns float {...}
   // Both of these queries are correct. They have different names.
```

In contrast, the built-in bounded and unbounded aggregate functions are overloaded.

Distinguishing duplicate values in custom aggregate functions

Each item in a stream is considered to be unique. However, when duplicate values appear in the set of items that a custom aggregate function operates on, it is not possible for the function to identify the particular instance of the value. If your implementation requires being able to distinguish between instances of duplicate values, you can accomplish this by extending the signatures of the function's `add()` and `remove()` actions.

For example, you might see the following set of `float` values in a stream:

```
1.0   2.0   3.0   4.0   3.0   2.0   1.0
```

Each occurrence of a particular value in the stream represents an individual value, separate from any other occurrences of that value. But when a query presents these values to a custom aggregate function (by means of the `add()` and `remove()` actions) the value alone is not enough to identify the particular occurrence that this value represents.

To distinguish one occurrence from another, extend the action signatures as follows:

- The `add()` action can return a value, which can be of any type.
- If the `add()` action does return a value, then the `remove()` action must accept, as its last argument in addition to its standard arguments, an argument of the same type as that returned by the `add()` action.

When an item is added to the aggregate the value returned by the `add()` action is stored with the item. When that item is removed from the aggregate the same value will be passed to the `remove()` action. Thus, it is possible to distinguish between items with duplicate values by comparing the additional data that is passed to the `remove()` action.

The following example shows an aggregate function that returns the entire window contents, in order, as a sequence:

```
aggregate windowOf(float f) returns sequence<float> {
    dictionary<integer,float> d;
    integer i;
    action init() { d.clear(); i := 0; }
    action add(float f) returns integer {
        i := i+1;
        d[i] := f;
        return i;
    }
    action remove(float f, integer k) { d.remove(k); }
    action value() returns sequence<float> { return d.values(); }
}
```

Working with lots that contain multiple items

Each time a stream query or stream listener is activated it might be processing more than one item at a time. Each simultaneously processed group of items is referred to as a *lot*. Like an auction lot, a lot can contain just one item or it can contain a number of items. Stream listeners can be activated once per item or once per lot. Stream queries try to process each item in a lot as if it arrived separately. See "Behavior of stream queries with lots" on page 246 for a discussion of cases where this is not possible.

When a lot contains multiple items all items in the lot appear in the output stream at the same time. However, the correlator preserves the order in which the stream query generated the items in the lot. When that output stream is the input stream for another stream query, the subsequent query uses the preserved order, if necessary, to determine how to process the items.

Stream queries that generate lots

To generate a lot that contains multiple items, a stream query must specify a simple projection or an aggregate projection that contains a `group by` clause. The stream query must also either receive lots that contain multiple items or must contain one of the following:

- A batched window
- A timed window with the `rstream` keyword (this must be a simple projection, and not an aggregate projection)
- A join of either type.

A query with a non-grouped aggregate projection never generates multiple items. It generates a single item or nothing.

A timed window with the `rstream` keyword can generate lots because multiple items can have the same timestamp. In a timed window, when items with the same timestamp expire they all leave the window at the same time. However, the correlator still maintains the order in which the items were generated or received.

Behavior of stream queries with lots

This topic provides advanced information about how queries process lots that they receive on their input streams. The information here requires a thorough understanding of streams, queries, and the information about lots presented so far.

To understand how stream queries behave when receiving lots that contain more than one item, consider the window content of the query before the lot is input and the window content of the query after the lot is input. The difference between these two states determines the output of the query. For example, consider the following queries:

```
// event A { float x; }
stream<A>     sA := from a in all A() retain 3 every 3 select a;
stream<float> sB := from a in sA select a.x;
stream<float> sC := from a in sA select sum(a.x);
```

The following table shows the lot output by each stream on each activation of the query.

	t0	t1	t2	t3	t4	t5
e0	A(1.)	A(1.)	A(1.)			
e1		A(2.)	A(2.)			
e2			A(3.)			
e3				A(4.)	A(4.)	A(4.)
e4					A(5.)	A(5.)
e5						A(6.)
sA Output	--	--	A(1.) A(2.) A(3.)	--	--	A(4.) A(5.) A(6.)
sB Output	--	--	1. 2. 3.	--	--	4. 5. 6.
sC Output	--	--	6.	--	--	15.

As can be seen, in the queries that contain aggregate functions, the aggregate expressions (and projections) are evaluated, at most, once per query activation. All queries, with the exception of those containing a `group by` clause, behave in this way.

Size-based windows and lots

When a size-based window is processing a lot that contains more than one item, all of the items are processed in the window before any of the rest of the stream query is processed. None of the intermediate states are visible to the query. This means that in the following query:

```
from a in sA retain 3 select sum(a.i);
```

if the window contains the events A(1), A(2) and A(3) and a lot containing both A(4) and A(5) arrives, those will displace A(1) and A(2) immediately. The state of the window A(2), A(3), A(4) will never have existed. This is more relevant when the lot contains more items than will fit in the window. In this case, if five more events arrived in a single lot, the three events will fall out of the window, the last three events will go into the window and the two interim events will disappear – never having been in the window at any point.

This behavior means that care must be taken with fixed-size windows when events might be processed in lots.

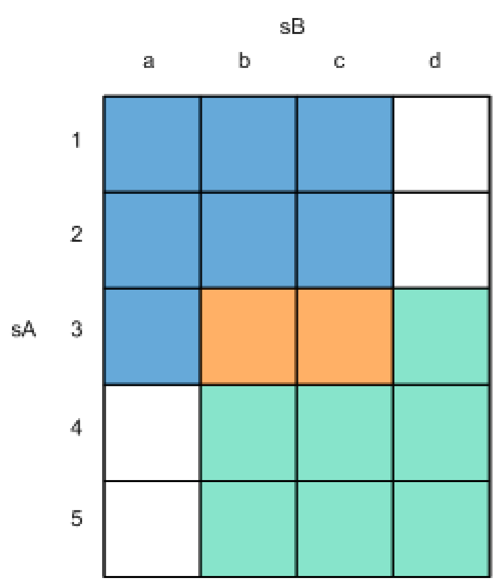
Join operations and lots

The principle of updating the state of a query in a single operation without the intermediate state being visible is most relevant for join operations. The two diagrams that follow illustrate how a cross-join behaves when several events arrive in a single lot.

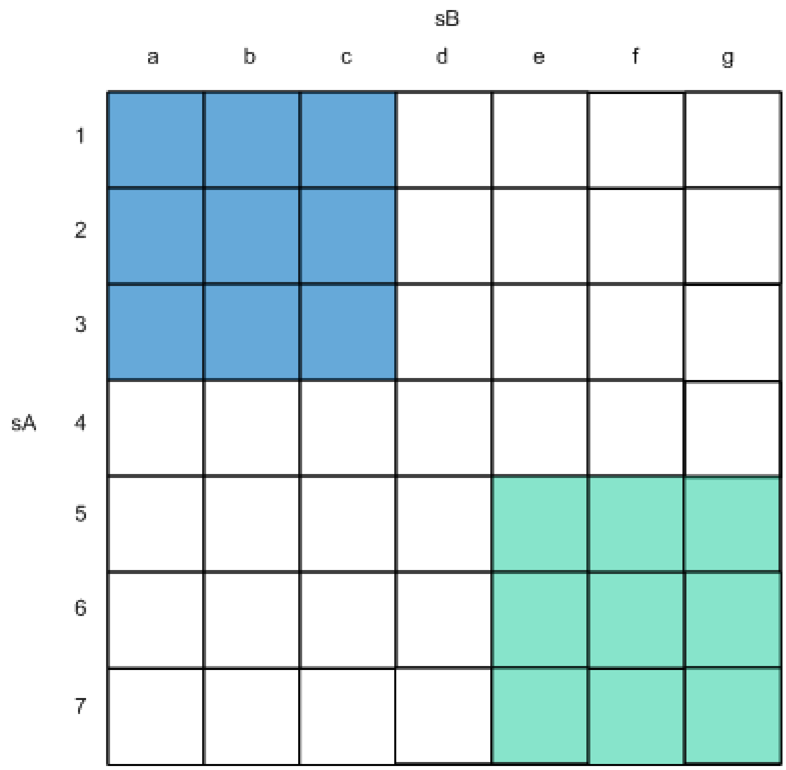
In the diagrams, the items on the left side of the join are represented by the numbered items that come in from the left side and the items on the right side of the join are represented by the lettered items that come in from the top. Each square in the grid can be a joined event. In both diagrams, the results of the join before the lot arrives are mostly highlighted in blue. The items joined after the lot arrives are mostly highlighted in teal. The relevant stream query in both examples is:

```
from a in sA retain 3
   from b in sB retain 3
   select C(a, b);
```

The complete set of values in the table represents all of the combinations of items from `sA` and items from `sB` that could possibly be generated by the join when considering alternative ways of ordering the `sA` and `sB` items arriving in the lot. In general, there is no particular ordering of the `sA` and `sB` items that is superior (more meaningful) than all other orderings. Thus, when considering the transitions, there is no preferred path from the initial window content to the final window content. Hence, it is considered that the correct output for the join is achieved by taking the difference between the initial window content and the final window content, ignoring any intermediate states.



In the first diagram, there are nine joined events before the lot arrives. These are represented by the seven blue squares and the two orange squares. Two items, `4` and `5`, arrive on `sA` and displace items `1` and `2`. Also, one item, `d`, arrives on `sB`. and displaces item `a`. The result is nine joined events after the lot arrives, of which two were there before (represented by the two orange squares, and seven are new, represented by the teal squares. A non-aggregating query that outputs the istream (as given above) would return the seven new items (shown in teal). If, instead, the query was selecting the rstream then it would return the seven items that are no longer a result of the join (shown in blue).



In the second example, there are again nine joined events before the lot arrives. These are represented by the nine blue squares. Four items, `4`, `5`, `6`, and `7` arrive on `sA` and displace items `1`, `2`, and `3`. Because this is a `retain 3` window, item `4`, as the oldest item in the lot, never makes it into the window. Also, items `d`, `e`, `f`, and `g` arrive on `sB`, which displaces items `a`. `b`, and `c`, and again, because it is a `retain 3` window, item `d` never appears in the window. After the lot arrives, the result is nine new joined events, which are represented by the teal squares.

Since there are no joined events that are present both before the lot arrives and after the lot arrives all nine events that were previously the result of the join would be returned by a query selecting the remove stream of this join. The nine new events are output by the query that selects the input stream. No events containing either '4' or 'd' are ever visible as a result of the query even though both values were present on one of the inputs.

Grouped projections and lots

Suppose that a query that contains a `group by` clause processes a lot that contains several items. The query generates new projected items for the groups where the state of the group after the lot is input differs from the state of the group before the lot is input.

Stream network lifetime

After you create a stream or stream listener, it exists until one of the following happens:

- You explicitly terminate it.
- The monitor that contains the stream or stream listener terminates.
- You terminate another stream or stream listener in the same stream network and that causes the stream or stream listener to terminate.

A stream or stream listener is explicitly terminated by calling the `quit()` method on a variable that refers to it. Hence, to explicitly terminate a stream or stream listener, you must retain a reference it. You can also terminate a stream or stream listener by terminating a related stream or stream listener in the same stream network (as detailed below).

You can create a stream or stream listener that is not referenced by any variable and cannot be terminated by quitting any other streams or stream listeners in the stream network. If this is unintentional then we refer to it as a stream or stream listener leak. This situation is similar to an event listener leak (see "Avoiding listeners and monitor instances that never terminate" on page 427. Here is an example:

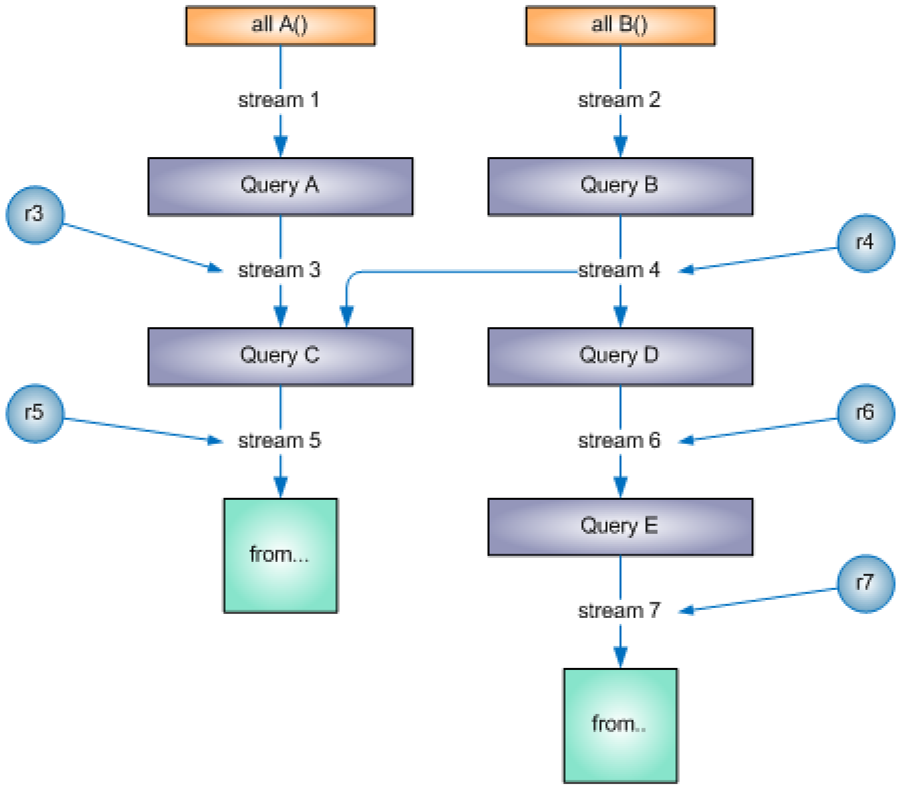
```
action createStreamListener() returns listener {
   stream <A> sA := all A();
   return from a in all A() select a.x: x { print x.toString(); }
   // error: meant to use sA in the query above
}
```

Although executing the code returns a listener variable that refers to the created stream listener, it inadvertently creates an unreferenced stream (the local variable `sA` did refer to this stream but is no longer in scope).

Calling `quit()` on a stream or stream listener in a stream network typically has side effects. A side effect can be one of the following:

- Termination of additional streams, stream queries, stream listeners, or stream event expressions.
- Disconnection between the terminated element and another element.

When determining which queries to terminate the correlator uses the following rule: when, due to another stream or query terminating, a query can no longer generate any output, it is also terminated. An example of how this works is probably beneficial. The following diagram shows a stream network with two stream source templates generating input events for five queries, eventually connected to two stream listeners. There are four stream variables pointing to the streams in the network.



Suppose you call `quit()` on either `r6` or `r7` (the `stream` variables on the right). The correlator terminates the whole of the branch from `Query D` down. This is because, whichever stream you quit, nothing can be generated by anything connected to those streams. `Stream 4`, however, is also feeding `Query C`, which can still generate output. Therefore, the rest of the network, including `Query B` and both stream event expressions, remains active.

If you subsequently call `quit()` on `r5` this will terminate the stream listener and `Query C`, which will then terminate `stream 3` and stream `4`, since they are not connected to any other queries, and also `stream 1`, `stream 2` and both stream source templates.

The `stream` variables after their streams are terminated will be dummy references. Subsequent attempts to create a query using those streams are ignored (the result is an inert stream).

Disconnection vs termination

In the example above, quitting `r6` disconnects `Query D` from `stream 4`. Because `stream 4` has other stream queries using it this disconnection does not terminate `stream 4` immediately. Streams terminate when all the queries using them have disconnected.

If you were instead to call `quit()` on `r4`, this would terminate everything on the right side of the diagram, no matter how many queries are using `stream 4`. However, the stream would just be disconnected from `Query C`. Whether this terminates `Query C` depends on the state of the join in `Query C`. If it is joining a size-based window from `stream 4` the items in the window would remain to be joined against new items in stream 3. If it was a time-based window then Query C would remain until everything in the window had been discarded. At that point, since nothing can ever be added to that side of a join, Query C terminates, causing the rest of the network to also be terminated.

Rules for termination of stream networks

The complete set of rules for when a part of a stream network is terminated are:

- Stream listeners:
  - `quit()` is called on a `listener` variable pointing at that stream listener.
  - The stream the listener is connected to is terminated.
- Streams:
  - `quit()` is called on a `stream` variable pointing at that stream.
  - The stream query generating the stream is terminated.
  - All the stream queries using the stream are terminated.
- Stream queries:
  - The stream the query generates is terminated.
  - All of the streams the query uses are terminated and either the query does not define a window or it defines a `within` or `within...every` window and there are no live items in the window.

    A live item is an item whose expiration (the item falls out of the window) can cause query output. For example, if the only items in a timed window fail to satisfy a `where` clause in the window definition then those items cannot change query output when they expire.

    If none of the items in the window are live the query terminates when all items have fallen out of the window. However, the query might terminate earlier if the correlator can determine that none of the items are live and that all streams that the query uses have terminated. Regardless of when such a query quits, there are no observable effects except in two situations:

    - The query is the only thing keeping the monitor active. That is, when the query terminates then the monitor's `ondie()` action is called.
    - Calculation of the size of the window has one or more side effects.
- Stream source templates:
  - The stream the stream source template generates is terminated.

Using dynamic expressions in stream queries

The expressions in stream queries can contain variables and action calls from EPL. Unlike parameters to event templates, the correlator evaluates these expressions each time the query is used and not just when it is created. This allows the behavior of the query to be altered during program execution.

Behavior of static and dynamic expressions in stream queries

A static expression is an expression that refers to only static elements. Static elements are:

- Constants (defined with the `constant` keyword)
- Literal values, for example:

  ```
  from a in all A() within 20.0 select sum(a.i);
  ```

- Primitive types that are local variables, for example:

  ```
  integer width := 10;
  from a in all A() retain width select sum(a.i);
  ```

The correlator can fully evaluate static expressions when it creates the stream query.

A dynamic expression is an expression that refers to one or more dynamic elements. In a query, the value of a dynamic expression can change throughout the lifetime of that query. Consequently, the correlator must re-evaluate each dynamic expression at appropriate points in the execution of the query.

Dynamic elements are:

- Any reference type
- Any monitor global variable
- Where the stream query is created by an action on an event, the members of that event
- Any action, method or plug-in call

The correlator fully evaluates an event template in a stream source template when the correlator creates the query. For example, consider the following two queries:

```
from a in all A(id=currentMatch) select a;
from a in all A() where id = currentMatch select a;
```

During execution, if `currentMatch` is a global variable, a change to the value of `currentMatch` affects the behavior of the second query but it does not affect the behavior of the first query.

When to avoid dynamic expressions in stream queries

Where possible, use static expressions in preference to dynamic expressions. This allows the compiler to optimize the query to improve performance. For example, consider the following query:

```
stream<float> vwaps := from t in all ticks
   within vwapPeriod
   select wavg(t.price,t.volume);
```

When `vwapPeriod` is a monitor global variable whose value does not change, then it is preferable to copy the value to a local variable first. For example:

```
float period := vwapPeriod;
stream<float> vwaps := from t in all ticks
   within period
   select wavg(t.price,t.volume);
```

Similarly, if it is known that a given action call always returns the same value, then it is preferable to copy the result to a local variable and use this in place of the action call. For example:

```
float period := getVwapPeriod(symbol);
stream<float> vwaps := from t in all ticks
   within period
   select wavg(t.price,t.volume);
```

Ordering and side effects in stream queries

To determine when it is safe to use dynamic expressions in stream queries, it is important to understand that:

- In a query, the order in which the correlator executes the action calls is not defined. Although the order is not defined, the correlator always executes the action calls in the same order for a particular Apama release.
- When processing each item passed to the query, if an action call with a given set of arguments appears multiple times within a stream query, then the number of times the correlator executes the action is not specified. It might be equal to or less than the number of times that the action call appears within the query. However, this number is always the same for a particular release.
- In a stream network, the order in which the correlator executes the queries is not defined except for when the output of a query forms the input to a second query. In this case, the correlator always executes the first query before the second. Again, in a particular release, the execution order is always the same.

Because of these points, it is best to avoid actions with side effects in expressions executed in stream queries. Such actions can make a program more difficult to understand and debug. Instead, execute any such actions in stream listeners.

A method or expression that produces a value has a side effect if it modifies something or interacts with something outside the program. This includes, but is not limited to:

- Modifying a global variable
- Changing the value of an argument
- Calling plug-in methods
- Routing, enqueuing, emitting or sending an event
- Calling another action that has side effects
- Setting up event listeners or new streams

Understanding when the correlator evaluates particular expressions

All expressions in a stream query can contain dynamic elements. To understand the behavior of a query that specifies dynamic elements, it is necessary to know under what circumstances the correlator re-evaluates an expression and uses the result in the query.

Using dynamic expressions in windows

A window definition can contain some or all of the following:

- A partition key expression
- The window duration, size or both duration and size
- An `every` batch period or size
- The key for a `with unique` clause

The following table shows when the correlator evaluates each of these:

Window Definition	Description
`retain n`	The correlator evaluates *n* every time an item arrives on the stream. The correlator uses the new value of *n* to calculate what should be in the window.
`retain n every m`	The correlator stores incoming items until the current value of *m* is satisfied. When *m* is satisfied, the correlator evaluates both *n* and *m*. The correlator uses the new value of *n* to calculate what should be in the window, including the stored items. Because *m* is evaluated only after it has been satisfied, meeting that condition is always based on the old value of *m*.
`within d`	The correlator evaluates *d* every time an item arrives on the stream and every time an item is due to be removed from the window. The correlator uses the new value of *d* to calculate what should be in the window.
`within d every p`	The correlator stores incoming items until *p* seconds have elapsed. When *p* seconds have elapsed, the correlator evaluates *p* and *d* only if there are any items in the window or stored. The correlator uses the new value of *d* to calculate what should be in the window, including stored events. The correlator uses the new value of *p* to determine the next time the window can change.

Window Definition	Description
	If there are no items in the window or waiting to enter the window then, for efficiency, the correlator does not evaluate *p*. When the correlator evaluates *p*, it is always based on the old value of *p*.
`...retain` *n*	If a `within` or `within every` window definition also specifies `retain`, the correlator evaluates *n* whenever the window content can change. The correlator uses the new value of *n* to calculate what should be in the window. If the window definition specifies `every`, the window content can change only when *p* is satisfied. Otherwise, the window content can change when an item arrives on the stream and when an item is due to be removed from the window.
`partition by` *k1*`[,` *k2*`]...`	If the window definition specifies a timed `every` *p* clause, the correlator evaluates each partition expression when *p* seconds have elapsed. Otherwise, the correlator evaluates each key expression when an item arrives on the stream. The correlator uses the new value of each key expression to calculate what should be in each partition.
`with unique` *w*	The correlator evaluates *w* once for each item whenever that item is about to enter the window. If there is an `every` clause, an item can enter the window only when *m* or *p* is satisfied. Otherwise, an item can enter the window when it arrives on the stream.

Using dynamic expressions in equi-joins

The format of a query that contains an equi-join is as follows:

```
from x in s1 join y in s2 on j1 equals j2 ...
```

Suppose that `j1` and `j2` are dynamic expressions that return the left and right join keys for each input item. The correlator evaluates these expressions once for each input item when it enters the window. This is regardless of how many items are joined from the other side.

Using dynamic expressions in where predicates

The correlator evaluates the predicate in a `where` clause once for each item. This happens as soon as a join operation produces an item, or if there is no join operation, as soon as an item enters a window.

Using dynamic expressions in projections

In a simple projection, the correlator evaluates the `select` expression once for each item. The correlator evaluates the `select` expression as soon as a join operation produces an item, or if there is no join operation, as soon as an item enters a window.

In a simple projection, regardless of whether the `select` clause specifies the `rstream` keyword, the correlator evaluates expressions in the projection when the items would be present on the insert stream and the results are stored until needed for the remove stream.

In an aggregate projection, the correlator evaluates expressions in the projection when the items would be present on the insert stream.

If an aggregate projection contains a `group by` clause the correlator evaluates the group key once for each item. This happens as soon as a join operation produces an item, or if there is no join operation, as soon as an item enters a window.

The correlator evaluates aggregate and grouped expressions in two stages. The correlator evaluates arguments to aggregate functions once for each item as soon as it is produced by a join or if there is no join, as soon as it arrives in the window. The correlator evaluates the rest of the aggregate expression once for each lot.

Examples of using dynamic expressions in stream queries

Following are some examples of using dynamic elements in stream queries. These examples are simplified, for brevity.

Example of altering query window size or period

The following code fragment shows part of a monitor that accepts requests from external entities to monitor/generate the VWAP for a given symbol. After you create a monitor like this, an external entity can, at any time, change the parameters that control the period over which the monitor calculates the VWAP and/or the output frequency of the VWAP events.

```
monitor VwapMonitor {
   VwapRequestParams params;
   action onload() {
      VwapRequest v;
      on all VwapRequest():v spawn monitorVwap(v);
         // Simplified. Assumes no duplicate requests.
   }
   action monitorVwap(VwapRequest v) {
      params := v.params;
      Vwap vwap;
      from t in all Ticks(symbol=v.symbol)
         within params.duration
         every params.period
```

```
         select Vwap(t.symbol,wavg(t.price,t.volume)):vwap {
            route vwap;
         }
      VwapRequestUpdate u;
      on all VwapRequestUpdate(symbol=v.symbol) : u {
         params := u.params;
      }
   }
}
```

When accumulating the raw tick data to generate the VWAP price, no prescience is involved. There is no anticipation that the window size is to be increased. Changing the `within` duration to a larger value causes the window duration to increase but does not recover historic events. Hence the effective sample duration over which the monitor calculates the VWAP will, over time (as new tick items arrive), extend from the smaller setting to the larger setting. When switching from a larger `within` duration to a smaller one, the change takes effect immediately. The correlator discards the items that are no longer in the `within` duration.

Example of altering a threshold

The following code fragment shows part of a monitor that accepts requests from external entities to monitor the value of the trades for a given symbol. After you create a monitor like this, an external entity can, at any time, change the thresholds at which the monitor recognizes the trade as a high value trade.

```
monitor CountHighValueTicks {
   float threshold;
   action onload() {
      CountHighValueTicksRequest r;
      on all CountHighValueTicksRequest():r spawn
         monitorHighValueTicks (r);
         // Simplified. Assumes no duplicate requests.
   }
   action monitorHighValueTicks(CountHighValueTicksRequest r) {
      threshold := r.threshold;
      stream<Tick> filtered := from t in all Ticks(symbol=v.symbol)
                               where t.price*t.volume > threshold
                               select t;
      integer c;
      from t in filtered within 60.0 every 60.0 select count(): c {
         print "Count of high value trades in previous minute: " +
            c.toString();
      }
      on all CountHighValueTicksRequestUpdate(symbol=r.symbol) : u {
         threshold := u.threshold ; }
   }
}
```

This example uses two queries. The first query filters out any ticks with values below the threshold. The second query accumulates the high-value ticks received in the last minute and outputs the count of high-value ticks in that period. This could have been written as a single query with the filtering performed after the window operation. For example:

```
from t in all Ticks(symbol=v.symbol) within 60.0 every 60.0
   where t.price*t.volume > threshold select count();
```

However this query's window contains all of the low value ticks received in the last 60 seconds, as well as the high value ticks. This is not an optimal use of memory resources. Hence the two query approach is preferred.

Alternatively, you can specify an embedded query to amalgamate the two queries into a single statement:

```
from t in
   (from t2 in ticks where t2.price*t2.volume > threshold select t2 )
   within 60.0 every 60.0
   select count(): c { ... }
```

The parentheses around the embedded query are optional.

Example of looking up values in a dictionary

The following statement shows a query that calculates the current value of a basket of stocks based on the most recent prices for those stocks. When using dictionaries in this way, be careful to ensure that all values used as keys are in the dictionary. A missing key value causes a runtime error and the correlator terminates the monitor instance. In the example, it is assumed that the `prices` stream was filtered to contain prices for only the stocks in the basket.

```
stream<Tick> basketPrices :=
   from p in prices
   partition by p.symbol
   retain 1
   select sum( p.price * basketVolume[t.symbol] );
```

Example of actions and methods in dynamic expressions

Actions and methods can be considered to be dynamic elements. There are various reasons why you might want to use actions and methods in queries:

- If you are using a particular common complex expression in several places in queries within a monitor, it might be preferable to implement this as an action.
- If you are using a method that is implemented in a plug-in.
- To add protection to expressions that, if unprotected, might cause run-time errors. For example:

```
stream<Tick> basketPrices :=
   from p in prices
   partition by p.symbol
   retain 1
   select sum( p.price * getBasketVolume(t.symbol) );
   ...
action getBasketVolume( string symbol) returns float {
   if ( basketVolume.hasKey(t.symbol) ) then {
      return basketVolume[t.symbol];
   } else {
      return 0.0;
   }
}
```

Troubleshooting and stream query coding guidelines

This section provides high-level guidelines for writing stream query applications that implement best practices.

For examples of common stream query coding patterns, see "EPL Streams: A Quick Tour" on page 977.

Prefer on statements to from statements

Do not use streams unnecessarily. If an event expression in an `on` statement meets your needs, use it. Take advantage of mixing code elements for listeners and event expressions, stream processing, and responsive program actions, all in the same monitor.

Know when to spawn and when to partition

As a rule, you should listen for only those events or streams that you are interested in now. Apama applications typically define monitors that spawn to handle a new situation, for example, to automatically manage the trading of a new large order. Each monitor instance is usually interested in only one particular substream of a larger stream, for example, `Tick` events for a particular stock rather than all `Tick` events.

Consequently, the common pattern is to create a new monitor instance and for that instance to set up stream queries that process the events of interest, for example, to calculate the average price. This is more efficient than defining a monitor that processes all events (for example, all `Tick` events for all stocks), generates added-value items and then forwards these items to client monitors. However, there are situations when the latter approach is required. You should decide which solution approach is best in which circumstances.

Filter early to minimize resource usage

To minimize processing and memory overhead it is preferable to filter streams as early as possible in the processing chain or network. Filtering early can reduce the number of items processed or retained in memory and can also reduce the size of the items held. If possible, filter items right at the beginning of the query chain, that is, in the event template.

For example, it is preferable to rewrite this query:

```
from l in all LargeEvent()
   within largeWindowPeriod
   where l.key = key
   select mean(l.value);
```

If the key is static, rewrite it this way:

```
from l in all LargeEvent(key=key)
   within largeWindowPeriod
   select mean(l.value);
```

If the key is dynamic, rewrite it this way:

```
from v in
   from l in all LargeEvent()
      where l.key = key select l.value
   within largeWindowPeriod select mean(v);
```

In the static case, the correlator filters the large event before the event gets to the window. In the dynamic case, the embedded query filters the event before the event gets to the window in the enclosing query. Because the `select` statement specifies only `l.value`, the correlator discards the rest of the event. There is no need to bring the whole event into the window.

Avoid duplication of stream source template expressions

When you are maintaining code, you might add a stream query whose *`streamExpr`* is an event template that is already used in a query elsewhere in the same monitor. However, duplicated stream source template expressions do not always produce the behavior you want. Consider the following two code fragments:

```
float d;
stream<float> means := from t in all Temperature()
   within 10.0
   select mean(t.temperature);
from t in all Temperature()
   from m in means select t-m : d {
      print "Difference from mean is " + d.toString();
   }
```

The first fragment behaves differently than this fragment:

```
float d;
stream<float> temperatures := all Temperature();
stream<float> means := from t in temperatures
   within 10.0
   select mean(t.temperature);
from t in temperatures
   from m in means
   select t-m : d {
      print "Difference from mean is " + d.toString();
   }
```

Of the two code fragments above, the second one has the desired behavior. The first example creates two event listeners — one for each `all Temperature()` clause. Each listener matches each incoming `Temperature` event, but the listeners trigger independently, one after the other. This means that there is no time when the second query has an item in each of its source streams. Consequently, the cross-join never produces any output.

In the second example, there is a single `Temperature` event listener that places matching events in the `temperatures` stream. The `temperatures` stream is the source stream for two queries. Now both source streams of the last query contain items at the same time and the query generates output.

Avoid using large windows where possible

In Apama, all data being processed is held in memory, including data within stream windows. If you specify query windows that contain a large number of items or hold items for a long period of time the memory that the application uses necessarily increases

A memory requirement that is more than the memory available to the application causes paging to occur, which can decrease application throughput. Where possible, consider reducing the size of any stream query windows by doing one or more of the following:

- Filter items to reduce the number or size of the items in the window.
- Use a complex event expression to achieve the same result.
- Use `retain all` instead of specifying a `within` clause. See the next topic for details.

In some cases prefer retain all to a timed window

When you specify `retain all` in a stream query the correlator does not retain the items indefinitely. The correlator processes each new item when it arrives (for example, it might execute an aggregate function) and then discards it. Consequently, queries that specify `retain all` use less memory than queries that define time-based or size-based windows.

A situation that typically tempts you to define a time-based window is when you want to calculate some aggregate values for a session. For example, a session could be from the start of a day to the end of a day, or an incoming event could initiate a session that requires aggregated values such as placing an order in an automated trading system.

After the session begins, interest in the aggregated values usually continues until the session ends, for example at the end or day or when the full volume of the placed order has been traded. In situations such as these, use a `retain all` window instead of a `within` session window.

Prefer equi-joins to cross-joins

In a query using an equi-join, the items from the two input sets are joined based on equality of key values. The identification of matching items is very efficient.

Cross-joins have no expressions so it is more efficient to calculate them than equi-joins. However, cross-joins are less preferable to equi-joins if they produce unwanted items that must subsequently be filtered out.

Be aware that time-based windows can empty

Consider the query below:

```
from s in Shipment(destination="SPQ")
   within 604800.0
   select sum(s.qty)/count()
```

After creation of the query, suppose that several shipments are sent in the first week and no shipments are sent in the second week. The value of the `count()` aggregate function drops to zero, which results in an attempt to divide by zero. This terminates the monitor instance.

Be aware that fixed-size windows can overflow

Consider the following example:

```
stream<temperature> batchedTemperatures :=
   from t in all Temperature(sensorId="S001")
   within 60.0 every 60.0 select t;
from t in batchedTemperatures
   retain 5
   select count():c { print c.toString(); }
```

During execution of the first query, suppose that more than 5 matching events are found within one minute. The query outputs all of the matching events as a single lot. A lot that contains more than 5 items overflows the `retain` window in the second query. All but the most recent five items are lost. Calculations operate on only the most recent 5 items.

Note that you are unlikely to need the query combination shown in the code example above.

Beware of accidental stream leaks

Just as it is possible to leak event listeners, it is also possible to leak streams. Suppose that you create a stream but you do not specify the stream as input to any query. This stream still remains in existence, keeps a monitor instance alive, and consumes resources so it is considered to be a stream leak. A stream leak causes memory to be used and not freed. It can also cause unnecessary computation to occur.

A stream leak can happen if you create a stream that you want to use later on in your code. To be able to use this stream you must assign it to a `stream` variable that is in scope in the location where you want to use the stream. If the `stream` variable goes out of scope or you assign another stream to that variable, the original stream still exists within the monitor instance's internal stream network but it is no longer accessible. For example:

- The `stream` variable that references the stream goes out of scope:

```
action streamLeakExample1(string s) {
   stream<float> prices :=
      from t in  all Tick(symbol=s) select t.price;
      ... // If the elided code does not use the stream
}         // a leak occurs when the prices variable goes out of scope.
```

- You overwrite the `stream` variable that refers to an unused stream:

```
action streamLeakExample2(pattern<string> symbols) {
   string s;
   stream<float> prices;
   for s in symbols {
      prices := from t in all Tick(symbol=s)  select t.price;
      ... // If the  elided code does not use the prices stream
          // a leak occurs when you overwrite prices.
```

```
    }
}
```

Any code that creates a stream leak is erroneous. Code that repeatedly creates unused, inaccessible streams quickly uses up machine resources.To avoid leaking streams:

- Avoid creating streams you do not intend to use immediately.
- Quit a stream before the variable referring to it goes out of scope.

6 Defining What Happens When Matching Events Are Found

In a monitor, when the correlator detects a matching event, it triggers the action defined by the listener for that event. This section discusses what you can specify in the triggered actions.

In a query, when a match set is found, it triggers execution of the procedural code block in the `find` statement. A subset of the EPL constructs that are available in a monitor are available in a query. See "Restrictions in queries" on page 151 to understand what is not allowed in a query.

Using variables

EPL supports the use of variables in monitors. Depending on where in the monitor you declare a variable, that variable is global or local:

- **Global.** Variables declared in monitors and not inside actions or events are global variables. Global variables are in monitor scope.
- **Local.** Variables declared inside actions are local variables. Local variables are in action scope.

A variable can be of any of the following types: `boolean`, `decimal`, `float`, `integer`, `string`, `action`, `context`, `dictionary`, `event`, `listener`, `location`, `sequence` or `stream`. For details about these types, see "Types" on page 767.

Information about variables is presented in the topics below.

See also "Using action type variables" on page 276.

Using global variables

Variables in monitor scope are global variables; you can access a global variable throughout the monitor. You can define global variables anywhere inside a monitor except in actions and event definitions. For example:

```
monitor SimpleShareSearch {
   // A monitor scope variable to store the stock received:
   //
   StockTick newTick;
```

This declares a global variable, `newTick`, that can be used anywhere within the `SimpleShareSearch` monitor including within any of its actions.

The order does not matter. In the following example, `f` is a global variable:

```
monitor Test {
   action onload() {
      print getZ().toString();
   }
   action getZ() returns integer {
      return f.z;
   }
   Foo f;
   event Foo{
      integer z;
   }
}
```

If you do not explicitly initialize the value of a global variable, the correlator automatically assigns a value to that global variable. (Note that the correlator does not automatically initialize local variables.) The following table shows the values that the correlator assigns to uninitialized global variables.

Global Variable Type	Value Correlator Assigns to Uninitialized Global Variable
`action`	A null value that causes the monitor instance to die if you try to execute the action. In the correlator log file, the error message is `Called uninitialized action value`.
`boolean`	`false`
`chunk`	Contains no state. Each plug-in must define what to do upon receiving a default-initialized chunk as an argument.
`context`	A null context that cannot be used in any meaningful way. To use this variable, you must explicitly assign a context that was created with a name.
`decimal`	`0.0d`
`dictionary`	Empty dictionary
`event`	Instance of the event where each of its fields has the standard default values as per this table.
`float`	`0.0`
`integer`	`0`
`listener`	A null listener that cannot be used in any meaningful way. To use this variable, you must assign a listener to it from within an on statement, from another listener variable, or from a stream listener in a `from` statement.
`location`	(0.0, 0.0, 0.0, 0.0)
`sequence`	Empty sequence
`stream`	A null stream that cannot be used in any meaningful way. To use the variable you must assign a non-null stream to it.
`string`	"" (empty string)

Using local variables

A variable that you declare inside an action is a local variable. You must declare a local variable (specifying its type) and initialize that variable before you can use it.

Although the correlator automatically initializes global variables that were not explicitly assigned a value, the correlator does not do this for local variables. For local variables, you must explicitly assign a value before you can use the variable.

If you try to inject an EPL file that declares a local variable and you have not initialized the value of that local variable before you try to use it, the correlator terminates injection of that file and generates a message such as the following: `Local variable 'var2' might not have been initialized`. EPL requires explicit assignment of values to local variables as a way of achieving the best performance.

When you declare a variable in an action, you can use that variable only in that action. You can declare a variable anywhere in an action, but you can use it only after you declare it and initialize it.

For example,

```
action anAction(integer a) returns integer {
   integer i;
   integer j;
   i := 10;
   j := a;
   return j + i;
}
```

You can use the local action variables, `i` and `j` in the action, `anAction()`, after you initialize them. The following generates an error:

```
action anAction2(integer a) returns integer {
   i := 10; // error, reference to undeclared variable i
   j := a; // error, reference to undeclared variable j
   integer i;
   integer j;
   i := 2;
   j := 5;
   return j + i;
}
```

Suppose that an action scope variable has the same name as a monitor scope variable. Within that action, after declaration of the action scope variable, any references to the variable resolve to the action scope variable. In other words, a local action variable always hides a global variable of the same name.

Consider again the definition for `anAction2()` in the previous code fragment, but with `i` and `j` variables declared in the monitor scope. The first use of `i` and `j` resolves successfully to the values of the `i` and `j` monitor scope variables. The second use occurs after the local declaration and initialization of `i` and `j`. That use resolves to the local (within the action) occurrence. This results in the following values:

- Global variable `i` is set to `10`.
- Local variable `i` is set to `2`.

- Global variable j is set to the value of a.
- Local variable j is set to 5.

Since you must explicitly initialize local variables before you can use them, the following example is invalid because j and i are not initialized to any value before they are used.

```
action anAction3(integer a) returns integer {
   integer i;
   integer j;
   return j + i; // error, i and j were not initialised
}
```

It is possible to initialize a variable on the same line as its declaration, as follows:

```
action anAction4(integer a) returns integer {
   integer i := 10;
   integer j := a;
   return j + i;
}
```

It is also possible to initialize a local variable by coassigning to it in an event listener. For example, the following is correct:

```
action onload() {
   Event e;
   on all Event():e {
      log e.toString();
   }
}
```

You can also initialize a local variable by coassigning to it from a stream. For example:

```
action onload() {
   float f;
   from x in all X() select x.f : f {
      log f.toString();
   }
}
```

Using variables in listener actions

Suppose you use a local variable in a listener action, as in the following example:

```
monitor MyMonitor {

   integer x;

   action onload() {
      integer y := 10;
      on all StockTick(*,*) {
         log x.toString();
         log y.toString();
      }
      y := 5;
   }
}
```

In this example, x is a global variable, and y is a local variable. There are references to both variables in the listener action.

A reference to a global variable in a listener action is the same as a reference to a global variable anywhere else in the monitor. However, a reference to a local variable in a listener action causes the correlator to retain a copy of the local variable for use when the event listener triggers. The value held by this copy is the value that the local variable has when the correlator instantiates the event listener.

When the event listener triggers the correlator executes the listener action. This will be at some point in the future, and after the rest of the body of the enclosing action has been executed. Since the action has already been executed, any of the original local variables no longer exist. This is why the correlator retains a copy of the local variable to make available to the listener action when it is executed.

In the example above, when the event listener triggers and the correlator executes the listener action

- `x` has a value of `0`, which is the value that the correlator automatically assigns
- `y` has a value of `10`, which is the value it was set to when the event listener was instantiated

The value of `y` that the correlator retained when it instantiated the event listener is not affected by the subsequent statement (after the `on` statement) that sets the value of `y` to 5.

Note: For "reference types" on page 785, retaining as a copy of the variable really means only retaining as a copy of its reference. Hence, if any code changes the contents of the referenced object(s) between event listener creation and event listener triggering, then this does affect the values used by the triggered event listener.

Specifying named constant values

In a monitor or in an event type definition, you can specify a named `boolean`, `decimal`, `float`, `integer`, or `string` value as constant. The format for doing this is as follows:

```
constant type name := literal;
```

Element	Description
type	Specify `boolean`, `decimal`, `float`, `integer`, or `string`. This is the type of the constant value.
name	Specify an identifier for the constant. This name must be unique within its scope — monitor, event, or action.
literal	Specify the value of the constant. The type of the value must be the type that you specify for the constant.

Benefits of using constants include:

- Using a named constant can often be better than using a literal because it lets you define that constant in a single place. There is no chance of one instance becoming incorrect when the value is changed elsewhere. An alternative to using a constant would be to define a variable to contain the value. The disadvantage with this approach is that someone could accidentally assign a new value to the "constant", which would cause errors.

- A named constant can make code easier to read because the name can be meaningful in a way that a magic number, such as `42`, is not.
- Constants appear in memory once. For example, spawning multiple copies of a monitor that contains a constant does not consume memory to store extra copies of the constant. A non-constant variable takes up space in memory for every copy of the event or monitor in the correlator.

You can refer to a declared constant in any code in the event or monitor being defined. When you define a constant in an event you can refer to it from outside the event by qualifying the name of the constant with the event name, for example, `MyEvent.myConstant`.

Following is an example of specifying and using a constant:

```
event Paper {
   constant float GOLDEN := 1.61803398874;
   float width;
   action getLength() {
      return GOLDEN * width;
   }
   action getWidth() {
      return width;
   }
}
```

You cannot declare a constant in an action.

Defining actions

Actions are similar to procedures.

A monitor can define any number of actions. Finding an event, or pattern of events, of interest can trigger an action.

A query can define any number of actions. If defined, actions must be after the `find` statement. Expressions in the `find` pattern or `find` block can invoke the actions defined in that query.

You can also trigger an action by invoking it from inside another action. You can also declare an action as part of an event type definition, and then call that action on an instance of that event.

The topics below provide information about defining actions.

Format for defining actions

The format for defining an action that takes no parameters and returns no value is as follows:

```
action actionName () {
   // do something
}
```

Optionally, an action can do either one or both of the following:

- Accept parameters
- Return a value

The format for defining an action that accepts parameters and returns a value is as follows:

```
action actionName (type1 param1 , type2 param2 , ...) returns >type3 {
   // do something
  return type3_instance ;
}
```

For example:

```
action complexAction(integer i, float f) returns string {
   // do something
  return "Hello";
}
```

An action that accepts input parameters specifies a list of parameter types and corresponding names in parentheses after the action name. Parentheses always follow the action name, in declarations and calls, whether or not there are any parameters. Parameters can be of any valid EPL type. The correlator passes primitive types by value and passes complex types by reference. EPL types and their properties are described in "Types" on page 767.

When an action returns a value, it must specify the `returns` keyword followed by the type of value to be returned. In the body of the action, there must be a `return` statement that specifies a value of the type to be returned. This can be a literal or any variable of the same type as declared in the action definition.

An action can have any name that is not a reserved keyword. Actions with the names `onload()`, `onunload()` and `ondie()` can only appear once and are treated specially as already described in "About monitor contents" on page 50. It is an EPL convention to specify action names with an initial lowercase letter, and a capital for each subsequent word in the action name.

Before Apama Release 4.1, actions and variables were allowed to have the same names. For example, you were allowed to coassign an event to a variable that had the same name as the action that handled the event:

```
on all Update():update update();
```

With Apama 4.1, this is no longer allowed since you can now declare `action` type variables. See "Using action type variables" on page 276. If you have any code that uses the same identifier for an action and a variable, you must change it. For example:

```
on all Update():update handleUpdate();
```

Invoking an action from another action

To invoke an action from another action, specify the action name followed by parentheses. If the action takes one or more input parameters, specify values for the parameters inside the parentheses. For example:

```
// First action:
```

```
action myAction1() {
   myAction2();
}

// Second action that is called by the first action:
action myAction2() {
   // . . .
}
```

In the example above, `myAction1()` calls `myAction2()` from inside the `myAction1()` declaration block. `myAction2()` takes no parameters and does not return a value.

When an action returns a value, you can invoke that action only from within an expression. You cannot specify a standalone statement that invokes an action that returns a value. Discarding the return value is illegal in EPL. For example:

```
action myAction3() returns string {
   return "Hello";
}

action myAction4() {
   string response;
   response := myAction3(); // Valid
   myAction3();             // Invalid
}
```

Consider this extended example:

```
// First action:
//
action myAction1() {
   myAction2();
}

// Second action that is called by the first action:
//
action myAction2() {
   string answer1, answer2;
   myAction5(5, 10.5);
   on anEvent() myAction5(5, 10.5);
   answer1 := myAction6(256, 1423.2);
   answer2 := myAction7();
}

// Action that is called by myAction2:
//
action myAction5 (integer i, float f) {
...
}

// Another action that is called by myAction2:
//
action myAction6 (integer i, float f) returns string {
   return "Hello";
}

// Yet another action that is called by myAction2:
//
action myAction7() returns string {
   return "Hello again";
}
```

`myAction2()` takes no parameters and does not return a value.

`myAction5()` accepts input parameters. You can invoke it from a standalone statement:

```
myAction5(5, 10.5);
```

You can also invoke it as a listener action:

```
on anEvent() myAction5(5, 10.5);
```

`myAction6()` accepts input parameters and returns a value. You can invoke `myAction6()` only from within an expression:

```
answer1 := myAction6(256, 1423.2);
```

`myAction7()` returns a value but does not take any parameters. You can invoke it only from within an expression:

```
answer2 := myAction7();
```

Specifying actions in event definitions

You can specify an action in an event type definition. This lets you call that action on an instance of the event, just as you would call a built-in method on some other type, such as calling the `toString()` method on the `integer` type.

When you define an `action` in an event, it behaves almost the same way as an `action` in a monitor or query. For example, an action in an event can

- Set up event or stream listeners (only in a monitor)
- Call other actions within that event
- Access members of that event

In a monitor, but not in a query, an action in an event has an implicit `self` argument that refers to the event instance that the action was called on. The `self` argument behaves in the same way as the `this` argument in C++ or Java.

Example

For example, consider the following event type definition:

```
event Circle {
   action area() returns float {
      return 3.14159 * radius * radius;
   }
   action circumference() returns float {
      return 2.0 * 3.14159 * self.radius;
   }
   float radius;
}
```

The specifications here of `radius` and `self.radius` are equivalent.

You can then write code that looks like this:

```
Circle c := Circle(4.0);
print "Circle area = " + c.area().toString();
print "Circle circumference = " + c.circumference().toString();
```

Of course, the output is as follows:

```
Circle area = 50.26544
```

```
Circle circumference = 25.13272
```

Behavior

The correlator never executes actions in events automatically. In an event, if you define an `onload()` action, the correlator does not treat it specially as it does when you define the `onload()` action in a monitor.

When you call an action in an event, the correlator executes the action in the monitor or query instance in which the call was made. In a monitor, if the action sets up any listeners, these listeners are in the context of this monitor instance. If this monitor instance dies, the listeners also die.

You can use plug-ins from within event actions. In the event definition, specify the `import` statement to give the plug-in an alias within the event. Specify the `import` statement in the same way that you specify it for a monitor or query. You use the plug-in alias to call functions on the plug-in in the same way as you use it for a monitor or query.

When you define an event, there are no ordering restrictions for the definition of fields, imports, or actions. You can define them in any order.

Spawning

From an action within an event, you can spawn to an action in the same event. The correlator spawns a monitor instance and executes the specified `action` on the event instance in the new monitor instance.

Note: In a query, `spawn` and `spawn...to` statements are not needed and so they are not allowed.

It is not possible to spawn from outside a particular event to an action that is a member of that particular event. Instead, spawn to an action that calls the action that is the event member. For example:

```
event E {
   action spawntotarget() {
      spawn target();                         // legal
   }
   action target() {
      log "Spawned "+self.toString();
   }
}

monitor m {
   action onload() {
      E e;
      spawn e.target();                     // not legal
      spawn calltarget(e);                  // legal
      e.spawntotarget();
   }
   action calltarget(E e) {
      e.target();
   }
}
```

Be sure to follow the `spawn` keyword with an `action` name identifier. Actions spawned to must have no return value, as before. See also "Utilities for operating on monitors" on page 73.

Restrictions

To summarize, when you define an action in an event, the following restrictions apply:

- If the action contains an `on` statement, you can coassign a matching event only to local variables. You cannot coassign a matching event to the event's fields nor to items outside the event or in the monitor.
- In a monitor, if you declare an instance of an event that has an action member, you cannot specify a call from that action to an action that is defined in the monitor.
- You cannot assign values to the implicit `self` parameter, any more than you can assign to `this` in Java.
- The following event listener call syntax is not valid within event actions:

  ```
  on A() foo;
  ```

  Instead, specify this:

  ```
  on A() foo();
  ```

Using action type variables

In addition to defining an action, you can define a variable whose type is `action`. This lets you assign an action to an `action` variable of the same `action` type. An action is of the same type as an `action` variable if they have the same argument list (the same types in the same order) and return type (if any).

Defining action variables

The format for defining an `action` type variable is as follows:

```
action<[type1 [, type2]...]>[returns type3]name;
```

Specify the keyword, `action`.

Follow the `action` keyword with zero, one or more parameter types enclosed in angle brackets and separated by commas. The angle brackets are required even when the action takes no arguments.

Optionally, follow the parameter list with a `returns` clause. Specify the `returns` keyword followed by the type of the returned value.

Finally, specify the name of the variable. For example:

```
action<string> a;
action<integer, integer> returns string b;
```

You can use an `action` variable anywhere that you can use a `sequence` or `dictionary` variable. For example, you can

- Pass an action as a parameter to another action.

- Return an action from execution of an action.
- Store an action in a local variable, global variable, `event` field, `sequence`, or `dictionary`.

You cannot route, emit, enqueue or send an event that contains an `action` variable field.

You must initialize an `action` variable before you try to invoke it.

When an action variable is a member of an event the behavior of the action depends on the instance of the event that the action is called on. Consequently, it can be handy to bind an action variable member with a particular event instance. See "Creating closures" on page 280.

Built-in methods are treated exactly the same as user-defined actions. This means you can assign a built-in method to an `action` variable. For example:

```
action<float> returns string f := float.toString;
```

Invoking action variables

The only operation that you can perform on an `action` variable is to call it. You do this in the normal way by passing a set of parameters in parentheses after an expression that evaluates to the `action` variable. For example:

```
monitor Test;
   integer i;
   action<string> x; // Uninitialized global action variable.
   action onload() {

      // Invoke the runMe action. The first argument to runMe is an
      // action variable for an action having a single argument of
      // type integer and no return value.
      // Since the printInteger action conforms to the argument
      // expected by runMe, you can pass printInteger to runMe.
      runMe(printInteger, 10);

      // Declare a local action variable, g. This action takes one
      // integer argument and does not return a result.
      // The printInteger action conforms to this so
      // assign printInteger to g.
      action<integer> g := printInteger;

      // Invoke the runMe action again.
      // Pass g instead of explicitly passing printInteger.
      runMe(g, 20);

      // Declare a local dictionary that contains action variables.
      // Each action variable takes a single integer argument and
      // and does not return a result.
      // Add printInteger to the dictionary.
      // Invoke printInteger and pass 30 as the argument.
      dictionary<string, action<integer> > do := {};

      do["printIt"] := printInteger;
      do["printIt"] (30);

      // Invoke x. Since this global variable was never
      // initialized, the monitor instance terminates.
      x("hello!");
   }
```

```
   action runMe(action<integer> f, integer i) {
      f(i);
   }

   action printInteger(integer i) {
      print i.toString();
   }
}
```

After injection, this monitor prints

```
10
20
30
```

and then terminates upon invocation of `x` because `x` was never initialized.

Calling an uninitialized, local `action` variable causes an error that prevents the correlator from injecting the monitor. While the correlator injects code that contains an uninitialized, global `action` variable, trying to call the uninitialized variable causes a runtime error and the monitor instance terminates.

Declaring action variables in event definitions

When you define an action as a member field in an event, that action has an implicit `self` argument as the first argument. (See "Specifying actions in event definitions" on page 274.) You must include this implicit argument when determining whether an action definition conforms to an `action` variable declaration. For example, the following is illegal:

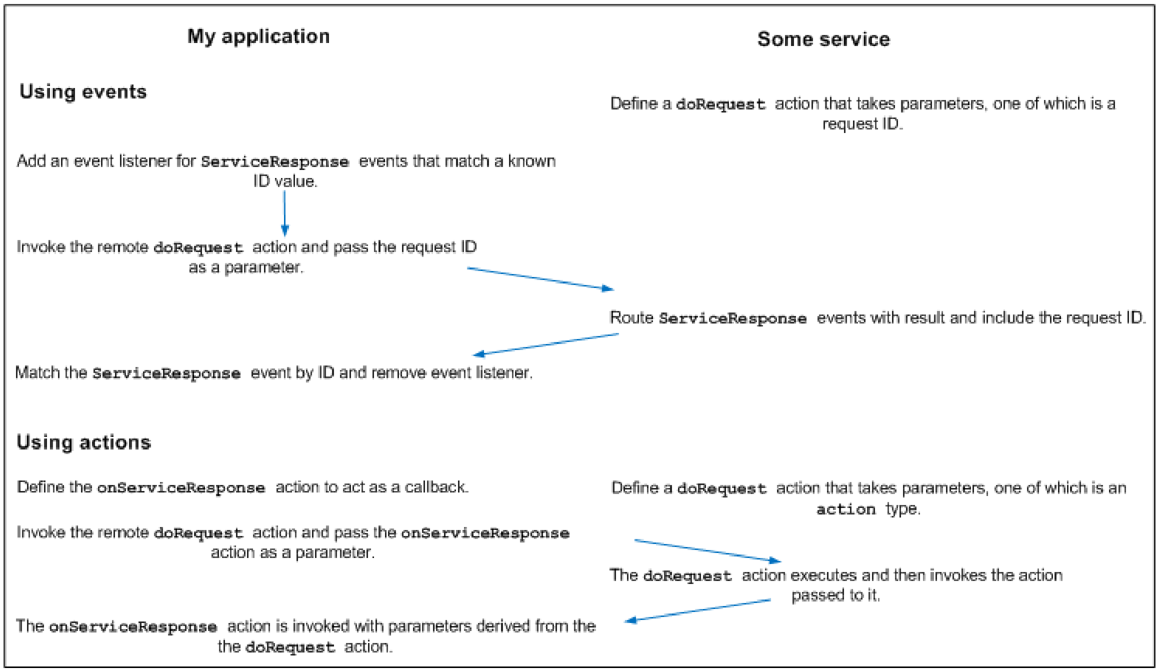
```
event A {
   action foo(float) returns string {
      return "Hello";
   }
   action bar() {
      action<float> returns string f := A.foo;
   }
}
```

In the previous code, you cannot assign the `A.foo` action to `f` because `f` takes a single `float` argument whereas `A.foo` has two arguments — the implicit `A` argument and then the `float` argument. To correct this example, specify `A` as the first `action` argument in the body of the `bar` action.

```
event A {
   action foo(float) returns string {
      return "Hello";
   }
   action bar() {
      action<A, float> returns string f := A.foo;
   }
}
```

Actions in place of routed events

In some situations, you might find it more efficient to use `action` type variables instead of routing events. For example, suppose you implement a service that takes an `action` variable as one of its parameters. Now suppose that the service needs a response from an adapter or some other service before it can send a response. When ready, the service can respond with a routed event, but that means you have to set up an event listener for that event. Routing events and setting up event listeners is more expensive than invoking actions. So instead of routing and listening, the service can respond by invoking the action on the event that initiated the service request. For example:



The following sample code uses a routed event. Following this code there is a sample that uses an action on an event.

```
event ServiceResponse {
   string requestId;
   ...
}

event Service {
   action doRequest( string requestId, ... ) {
   ...
   // when asynchronous 'service actions' are complete
      route ServiceResponse( requestId, ... );
   }
   ...
}

monitor Client {
   Service service;
   action onload() {
      ...
      string id := ...;
      ServiceResponse r;
      on Response( requestId=id ): r {
          ...
      }
      service.doRequest( id, ... );
   }
}
```

The following sample code uses an action on a `Client` monitor:

```
event Service {
   action doRequest( action< ... > callback, ... ) {
      ...
      // when asynchronous 'service actions' are complete
      callback( ... );
   }
   ...
}

monitor Client {
   Service service;
   action onload() {
      ...
      string id := ...;
      service.doRequest( onServiceResponse, ... );
   }
   action onServiceResponse(...) {
      ...
   }
}
```

Creating closures

When an action is a member of an event the behavior of the action depends on the instance of the event that the action is called on. Consequently, you might want to bind an action member with a particular event instance. When you bind an action member to an event instance you are creating a closure. The advantages of creating a closure are:

- Simpler syntax for executing the action
- Greater flexibility in making assignments to action variables

Consider the following event definition:

```
event E {
   integer i;
   action foo() { print "Foo "+i.toString(); }
   action times(integer j) returns integer { return i*j; }
}
```

With this definition, `E(1).foo()` would print "Foo 1", while `E(42).foo()` prints "Foo 42". The action `E.foo` always has a specific instance of `E` to work with. You can achieve this by specifying the action's implicit self argument when you call the action, as described earlier in this topic. When you use this technique you identify the event instance when you call the action variable.

Alternatively, you can create a closure that binds an action member with an event instance. You store the closure in an action variable. The action variable and the action member must be of the same action type. That is, they must take the same argument(s), if any, and return the same type, if any.

When you use this technique you identify the event instance when you assign the event's action member to the action variable.

The following code shows an example of binding an event instance to an action member by storing the closure in an action variable.

```
monitor m {
   action <> a;
   action onload() {
```

```
      E e := E(42);
      a := e.foo;
      a(); // Prints "Foo 42"
   }
}
```

In this example, `e.foo` denotes `E.foo` called on `e`. That is, when you assign the action `e.foo` to the `a` action variable you are identifying which instance of `E` to use when you call the `a` action. This closure binds a reference to E to the `E.foo` action and stores it in the `a` action variable. After you create a closure, you can call an action on an event as though it is a simple action. This gives you considerable flexibility in what you can assign to an action variable.

More about closures

EPL performs its own garbage collection. Consequently, you do not need to consider how long a bound object must last. This is handled automatically.

A closure binds by reference. Consider the following example, which uses the same event `E` as above:

```
monitor m {
   action <integer> returns integer a;
   action onload() {
      E e := E(3);
      a := e.times;
      print a(2).toString(); // Prints "6"
      e.i := 5;
      print a(2).toString(); // Prints "10"
   }
}
```

In a portion of code, you can define multiple action variables that contain closures for the same object. For example:

```
event Counter {
   integer i;
   action increment() { i := i+1; }
   action output() { print i.toString(); }
}
event Increment {}

event Finish {}

monitor m {
   action <> incrementAction;
   action <> outputAction;
   action onload() {
      Counter counter := new Counter;
      incrementAction := counter.increment;
      outputAction := counter.output;
      on all Increment() and not Finish() { incrementAction(); }
      on all Finish() { outputAction(); }
   }
}
```

In an event type, when an action member refers to another action member in the same event type a closure happens implicitly. For example:

```
event E {
   action <integer> returns integer a;
}
```

```
event Plus {
   integer i;
   action f(integer j) returns integer { return i+j; }
   action setA(E e) { e.a := f; }
}
```

Here, the `f` in `e.a := f` is equivalent to `self.f`, just as it would be if `setA` had called `f` instead of assigning it to an action variable. This creates a closure. After `setA` is called on some instance of `Plus`, `e.a` will call `f` on that same instance.

Other ways to specify closures

You can create a closure using any value and any action on that value. Thus, it is possible to:

- Bind a built-in method to a value.
- Bind actions to primitive types and other reference types instead of to events.
- Bind actions to a literal or a function's return value instead of a variable's value.

For example:

```
// Print "E(42)"
E e := E(42);
action <> printE42 := e.toString;

// Print "Foo 12345"
action <> printFoo12345 := E(12345).foo;

// Take a floating-point number and return e to that power:
action <float> returns float eToTheX := 2.718282.pow;

// Return a random integer from 0 to 9 inclusive.
// (The brackets around 10 are needed so that "10." is not treated as a
// floating-point number.)
action <> returns integer randomDigit := (10).rand;

// Return the strings in a sequence, separated by colons.
action <sequence<string> > returns string j := ":".join;
```

Restrictions

You cannot route, enqueue, emit or send an event that contains an `action` variable field. It is okay to route, enqueue, emit or send an event that contains an action definition.

An `action` variable cannot be a key in a dictionary. An event that contains an `action` field cannot be a key in a dictionary.

JMon

In a JMon application, you cannot declare event types that have `action` type members. Consequently, events that contain `action` type fields are invisible to JMon applications.

Getting the current time

In the correlator, the current time is the time indicated by the most recent clock tick. However, there are some exceptions to this:

- If you specify the `-Xclock` option when you start the correlator, the correlator does not generate clock ticks. Instead, you must send time events (`&TIME`) to the correlator. The current time is the time indicated by the most recent received, externally generated, time event. See "Externally generating events that keep time (&TIME events)" on page 197.
- If you have multiple contexts, it is possible for the current time to be different in different contexts. A particular context might be doing so much processing that it cannot keep up with the time ticks on its queue. In other words, if contexts are mostly idle, then they would all have the same current time.
- When the correlator fires a timer, the current time in the context that contains the timer is the timer's trigger time. See "About timers and their trigger times" on page 195.

The information in the remainder of this topic assumes that the current time is the time indicated by the most recent clock tick.

Use the `currentTime` variable to obtain the current time, which is represented as seconds since the epoch, January 1st, 1970 in UTC. The `currentTime` variable is similar to a global read-only constant of type `float`. However, the value of the `currentTime` variable is always changing to reflect the correlator's current time.

In the correlator, the current time is never the same as the current system time. In most circumstances it is a few milliseconds behind the system time. This difference increases when the input queues of public contexts grow.

When a listener executes an action, it executes the entire action before the correlator starts to process another event. Consequently, while the listener is executing an action, time and the value of the `currentTime` variable do not change. Consider the following code snippet,

```
float a;
action checkTime() {
   a := currentTime;
}

// ... Lots of additional code
// A listener calls the following action some time later
action logTime() {
   log a.toString(); // The time when checkTime was called
   log currentTime.toString(); // The time now
}
```

In this code, an event listener sets `float` variable `a` to the value of `currentTime`, which is the time indicated by the most recent clock tick. Some time later, a different event listener logs the value of `a` and the value of `currentTime`. The values logged might not be the same. This is because the first use of `currentTime` might return a value that is different from the second use of `currentTime`. If the two event listeners have processed the same event, the logged values are the same. If the two event listeners have processed different events, the logged values are different.

Generating events

As discussed previously, actions can perform calculations and log messages. In addition, actions can dynamically generate events. Specify the `route`, `send`, `enqueue`, or `emit` statement to generate an event.

Note: In a query, `route` is not allowed.

The topics below discuss this.

Generating events with the route command

The `route` command generates a new event that goes to the front of the input queue of the current context.

Note: In a query, `route` is not allowed.

Any active listeners seeking that event then receive it. There is only one difference between an externally sourced event (passed in through a live message feed) and an event that was generated internally through a `route` command. The difference is that internally routed events are placed at the front of the context's input queue in the same order as they are routed within an action, and after any previously internally routed events where multiple listener actions have been triggered by an event. The correlator processes the routed events on the input queue before it processes the next non-routed event on the input queue. See "Event processing order for monitors" on page 61.

For example:

```
action simulateCrash() {
  route StockTick(currentStock.name, 50.0);
  route StockTick(currentStock.name, 30.0);
  route StockTick(currentStock.name, 20.0);
  route StockTick(currentStock.name, 10.0);
  route StockTick(currentStock.name, 5.0);
  route StockTick(currentStock.name, 1.0);
}
```

The `simulateCrash()` action shown above routes six `StockTick` events for the monitor's specific stock name, with drastically reducing prices. Other monitors (or the same monitor) may receive these events and process them accordingly.

You cannot route the following types:

- `action`, `chunk`, `listener`, `stream`
- A `sequence` that contains a type that is unroutable
- A `dictionary` whose key or value is a type that is unroutable
- An `event` that contains a type that is unroutable

Note that you can route an event whose type is defined in a monitor.

Generating events with the send command

The `send` command sends an event to a channel, a context, a sequence of contexts, or a `com.apama.Channel` object.

When you send an event to a channel the correlator delivers it to all contexts and external receivers that are subscribed to that channel. To send an event, use the following format:

```
send event_expression to expression;
```

The result type of *`event_expression`* must be an event. It cannot be a string representation of an event.

To send an event to a channel, the *`expression`* must resolve to a string or a `com.apama.Channel` object that contains a string. If there are no contexts and no external receivers that are subscribed to the specified channel then the event is discarded. See "Subscribing to channels" on page 70.

The only exception to this is the default channel, which is the empty string. Events sent to the default channel go to all public contexts. All running Apama queries receive events sent on the default channel as well as events sent on the `com.apama.queries` channel. See "Defining Queries" on page 75.

To send an event to a context, the *`expression`* must resolve to a context, a sequence of contexts, or a `com.apama.Channel` object that contains a context. You must create a context before you send an event to the context. You cannot send an event to a context that you have declared but not created. For example, the following code causes the correlator to terminate the monitor instance:

```
monitor m {
   context c;
   action onload()
   {
      send A() to c;
   }
}
```

If you send an event to a sequence of contexts and one of the contexts has not been created first then the correlator terminates the monitor instance. Sending an event to a sequence of contexts is non-deterministic. You cannot send an event to a sequence of `com.apama.Channel` objects. For details, see "Sending an event to a sequence of contexts" on page 314.

All routable event types can be sent to contexts, including event types defined in monitors.

If a correlator is configured to connect to UM then a channel might have a corresponding UM channel. If there is a corresponding UM channel then UM is used to send the event to that UM channel.

See *Choosing when to use UM channels and when to use Apama channels* in *Connecting Apama Applications to External Components*.

Sending events to com.apama.Channel objects

A `com.apama.Channel` object is particularly useful when writing services that can be used in both distributed and local systems. For example, by using a `Channel` object to represent the source of a request, you could write a service monitor so that the same code sends a response to a service request. You would not need to have code for sending responses to channels and separate code for sending responses to contexts.

Consider the following `Request` event and `Service` monitor definitions:

```
event Request {
   ...
   Channel source;
}

monitor Service {
   action onload() {
      monitor.subscribe('Requests');
      Request req;
      on all Request():req {
         Response rep := Response(...);
         send rep to req.source;
      }
   }
}
```

EPL code in a context in the same correlator as the `Service` monitor could send a `Request` event with the `source` field set to `context.current()` and would receive the `Response` event that the `Service` monitor sends. For example:

```
monitor LocalRequester {
   action onload() {
      Request req := Request(...);
      req.source := Channel(context.current());
      send req to 'Requests';

      Response rep;
      on all Response():rep {
         ...
      }
   }
}
```

Now consider a monitor that is in a correlator that is connected to the `Service` monitor host correlator. For example, the correlators can be connected by means of `engine_connect`. The remote monitor could send a `Request` event with the `source` field set to a `Channel` object that contains the name of a channel that the remote monitor is subscribed to. For example:

```
monitor RemoteRequester {
   action onload() {
      monitor.subscribe('Responses');

      Request req := Request(...);
      req.source := Channel('Responses');
      send req to 'Requests';

      Response rep;
      on all Response():rep {
         ...
```

```
      }
   }
}
```

In this example, if the correlators are connected by means of `engine_connect` then the connections would need to be subscribed to the `Requests` channel and the `Responses` channel. As you can see, the service monitor does not require different code according to whether the request is coming from a local or remote context. The service monitor simply sends the response back to the source and it does not matter whether the source is a context or a channel.

You can send a `Channel` object from one Apama component to another Apama component only when the `Channel` object contains a string. You cannot send a `Channel` object outside a correlator when it contains a context.

Generating events with the enqueue command

The `enqueue` command generates an event and places the event on a special queue just for events generated by the `enqueue` command. A separate thread moves these events to the input queue of each public context. This arrangement ensures that if the input queue of a public context is full, the event generated by `enqueue` still arrives on its special queue, and is moved to each public context's input queue as soon as that queue has room. Active listeners will eventually receive events that are `enqueue`'d, once those events make their way to the head of the input queue alongside normal events.

There are two formats available for using `enqueue`. You can directly enqueue an event, as the example below does first, or else place the event in a string and enqueue that. If you use this latter format, you must ensure that you define the string to represent a valid event.

Use the `enqueue` statement when you want to ensure that the correlator processes the generated event after it has processed all routed events. Note that other external or enqueued events may be processed prior to processing this enqueued event. To defer processing an event until after processing of all routed events, enqueueing to `context.current()` might be preferable. The `enqueue` statement is also useful when you want to send events into all public contexts.

For example, consider a further revised version of the earlier example:

```
event StockTickPriceChange {
   string owner;
   string name;
   float price;
}

// A new processTicks action that dispatches an event to
// the input queue instead of logging
action processTicks() {

// The following enqueue format sends the event itself.
   enqueue StockTickPriceChange(currentStock.owner,
      newTick.name, newTick.price);

// Or, use the following enqueue format, which sends a string that
// contains the event.
   enqueue "StockTickPriceChange(\""+currentStock.owner+
```

```
      "\",\""+newTick.name+"\", "+newTick.price.toString()+")";
}
```

If the string does not represent an event that fully complies with an event type that has been defined elsewhere in EPL then it will be thrown away before being placed on the input queue. This is the same behavior as for any normal event received by the correlator. Unless the correlator understands its event type (by having had it defined in EPL) it ignores it.

You cannot enqueue the following events:

- An event whose type is defined inside a monitor.
- An unroutable event type, that is, an event type that contains a field whose type is something other than a primitive type, a `location` type, or a `context` type.

Enqueuing to contexts

To enqueue an event to a particular context, use the following form of the `enqueue` statement:

```
enqueue event_expression to context_expression;
```

Note: The `enqueue...to` statement is superseded by the `send...to` statement. The `enqueue...to` statement will be deprecated in a future release. Use the `send...to` statement instead. See "Generating events with the send command" on page 285.

The result type of *`event_expression`* must be an event. It cannot be a string representation of an event. The result type of *`context_expression`* must be a context or a variable of type `context`. It cannot be a `com.apama.Channel` object that contains a context.

The `enqueue...to` statement sends the event to the context's input queue and not to the special `enqueue` queue. Even if you have a single context, a call to `enqueue x to context.current()` is meaningful and useful.

You must create the context before you enqueue an event to the context. You cannot enqueue an event to a context that you have declared but not created. For example, the following code causes the correlator to terminate the monitor instance:

```
monitor m {
   context c;
   action onload()
   {
      enqueue A() to c;
   }
}
```

If you enqueue an event to a sequence of contexts and one of the contexts has not been created first then the correlator terminates the monitor instance. For details, see "Sending an event to a particular context" on page 312.

"Sending an event to a sequence of contexts" on page 314 is non-deterministic.

All routable event types can be enqueued to contexts, including event types defined in monitors.

Generating events to emit to outside receivers

The emit command dispatches events to external registered event receivers, which means that the events leave the correlator. Active listeners do not receive emitted events.

Note: The emit command is superseded by the send command. See "Generating events with the send command" on page 285. The emit command will be deprecated in a future release. Use send rather than emit.

There are two formats available for using emit. You can directly emit an event, as the example below does first, or else place the event in a string and emit that. If you use this latter format, you must ensure that you define the string to represent a valid event. The correlator does not check whether the string you specify represents an event that is compliant with any event type that has been injected. In fact, you can use this mechanism to emit an event of a type that has not been defined in EPL anywhere else.

For example, consider a revised version of an earlier example. The result, instead of being printed as a message on the screen, is now being sent out as an event message:

```
event StockTickPriceChange {
   string owner;
   string name;
   float price;
}

// A new processTicks action that dispatches an output event
// to external applications instead of logging
action processTicks() {

// The following emit format sends the event itself.
   emit StockTickPriceChange(currentStock.owner,
      newTick.name, newTick.price) to
      "com.apamax.pricechanges";

// Or, use the following emit format, which sends a string that
// contains the event.
   emit "StockTickPriceChange(\""+currentStock.owner+
      "\",\""+newTick.name+"\", "+newTick.price.toString()+")" to
      "com.apamax.pricechanges";
```

Events are emitted onto named channels. In the above code the StockTickPriceChange event is being published on the com.apamax.pricechanges channel. For an application to receive events from Apama it must register itself as an event receiver and subscribe to one or more channels. Then if events are emitted to those channels they will be forwarded to it.

Channels effectively allow both point-to-point message delivery as well as through publish-subscribe. As in the above example, channels can be set up to represent topics. External applications can then subscribe to event messages of the relevant topics. Otherwise a channel can be set up purely to indicate a destination and have only one application connected to it.

You cannot emit the following events:

- An event whose type is defined inside a monitor

- An unroutable event type

If a correlator is configured to connect to UM then a channel might have a corresponding UM channel. If there is a corresponding UM channel then UM is used to emit the event to that UM channel.

See "Choosing when to use UM channels and when to use Apama channels" in *Connecting Apama Applications to External Components*.

Assigning values

Valid examples of an assignment statement are:

```
integerVariable := 5;
floatVariable := 6.0;
stringVariable := "ACME";
stringVariable2 := stringVariable;
```

Assignments are only valid if the type of the literal or variable on the right hand side corresponds to the type of the variable on the left hand side.

When doing an assignment from a variable to another variable the behavior of EPL depends on the type of the variable.

- In the case of primitive types the variable on the left hand side is set to the same value as the variable on the right hand side. The value is therefore copied and the two variables remain distinct.
- In the case of complex reference types the variable on the left hand side is set to reference the same object as the variable on the right hand side. Only the reference is copied, while the underlying object remains the same. If the object is subsequently changed, both variables would reflect the change.

Defining conditional logic

EPL supports conditional `if-then` and `if-then-else` statements.

Syntactically an `if-then` statement consists of an `if` keyword followed by a `boolean` expression followed by a `then` keyword followed by a block. A block consists of one or more statements enclosed in curly braces, `{}`. If the `boolean` expression is true the contents of the block are executed. If the expression is false, the `if-then` statement exits.

The `boolean` expression must evaluate to the `boolean` values `true` or `false`.

An `if-then-else` consists of `if` followed by a `boolean` expression followed by `then` followed by a 'then' block followed by an `else` keyword followed by an 'else' block. If the `boolean` expression is true, the first block is executed, otherwise the second block is executed.

There is a special variant of the `if-then-else` allowed where a second nested `if-then` or `if-then-else` statement can replace the second block. This is only of relevance in that no curly braces are required in this special case.

In standard BNF notation this syntactic definition looks as follows:

```
ifStatement ::= if booleanExpression then block
| if booleanExpression then block1 else block2
| if booleanExpression then block3 else ifStatement block ::= {statementList }
```

Note: BNF is an acronym for "Backus Naur Form". John Backus and Peter Naur introduced for the first time a formal notation to describe the syntax of a given language in 1960, and since then BNF notation is the standard notation used to specify the syntax rules of programming languages.

An EPL example follows:

```
if floatVariable > 5.0 then {
   integerVariable := 1;
}  else if floatVariable < -5.0 then {
      integerVariable := -1;
}  else {
      integerVariable := 0;
}
```

Note that `if-then-else` statements can be nested. In other words, the body of a `then` or an `else` can contain another `if-then-else`, in addition to the explicit `else if` combination.

Defining loops

EPL supports two loop structures, `while` and `for`.

The `while` statement's BNF definition is:

```
whileStatement ::= while booleanExpression block
```

An EPL example is:

```
integerVariable := 20;
while integerVariable > 10 {
   integerVariable := integerVariable – 1;
   on StockTick("ACME", integerVariable) doAction();
}
```

The `for` looping structure allows looping over the contents of a `sequence`. In BNF its definition is:

```
forStatement ::= for counter in sequence block
```

The counter must be an assignable variable of the same type as the type of elements of the `sequence`. For example:

```
sequence<integer> s;
integer i;
s.append(0);
s.append(1);
s.append(2);
s.append(3);
for i in s {
   print i.toString();
}
```

The loop will iterate through all the indices in the sequence, checking whether there are any more indices to cover each time. In the example above, i will be set to s[0], then s[1], and so on up to s[3]. The counter continues incrementing by one each time, and is checked to verify whether it is less than s.size() before a further iteration is carried out. Looping only terminates when the next index would be beyond the last element of the sequence, or equal to size() (since indices are counted from 0).

When the correlator executes a for loop, it operates on a reference to the sequence. Consequently, if the code in the for loop assigns some other sequence to the sequence expression specified in the for statement this has no effect on the iteration. However, if the code in the for loop changes the contents of the sequence specified in the for statement, this can affect the iteration. For example:

```
sequence <string> tmp := ["X", "Y", "Z"];
sequence <string> seq := ["A", "B", "C", "D", "E"];
string s;
for s in seq {
   seq := tmp;
   print s;
}
```

The for loop steps through whatever seq referred to when the loop began. Therefore, assigning tmp to seq inside the loop does not affect the behavior of the loop. This code prints A, B, C, D, and E on separate lines.

In the following example, the code in the for loop changes the contents of the sequence specified in the for statement and this affects the behavior of the loop.

```
sequence<string> seq := ["A", "B", "C", "D", "E"];
string s;
for s in seq {
   seq[2] := "c";
   print s;
}
```

This code prints A, B, c, D, and E on separate lines.

In the following code, the changes to the contents of the specified sequence would prevent the for loop from terminating.

```
sequence<string> seq := ["x"];
string s;
for s in seq {
   seq.append(s);
}
```

EPL provides the following statements for manipulating while and for loops. Usage is intuitive and as per other programming language conventions:

- break exits the innermost loop. You can use a break statement only inside a loop.
- continue moves to the next iteration of the innermost loop. You can use a continue statement only inside a loop.
- return terminates both the loop and the action that contains it.

Catching exceptions

EPL supports the try-catch exception handling structure. The try-catch statement's BNF definition is:

```
tryCatchStatement ::= try block1 catch(Exception variable) block2
```

The statements in each block must be enclosed in curly braces. For example:

```
using com.apama.exceptions.Exception;
...
action getExchangeRate(
   dictionary<string, string> prices, string fxPair) returns float {
   try {
      return float.parse(prices[fxPair]);
   } catch(Exception e) {
      return 1.0;
   }
}
```

Exceptions are a mechanism for handling runtime errors. Exceptions can be caused by any of the following, though this is not an exhaustive list:

- Invalid operations such as trying to divide an `integer` by zero, or trying to access a non-existent entry in a `dictionary` or `sequence`
- Methods that fail, for example trying to parse an object that cannot be parsed
- Plug-ins
- Operations that are illegal in certain states, such as spawn-to in an `ondie()` or `onunload()` action, or sending an event to a context and specifying a variable that has not been assigned a valid context object

An exception that occurs in `try` *block1* causes execution of `catch` *block2*. An exception in `try` *block1* can be caused by:

- Code explicitly in `try` *block1*
- A method or action called by code in `try` *block1*
- A method or action called by a method or action called by code in `try` *block1*, and so on.

Note that the `die` statement always terminates the monitor, regardless of try-catch statements.

The variable specified in the `catch` clause must be of the type `com.apama.exceptions.Exception`. Typically, you specify `using com.apama.exceptions.Exception` to simplify specification of exception variables in your code. The `Exception` variable describes the exception that occurred.

The `com.apama.exceptions` namespace also contains the `StackTraceElement` built-in type. The `Exception` and `StackTraceElement` types are always available; you do not need to inject them and you cannot delete them with the `engine_delete` utility.

An `Exception` type has methods for accessing:

- A message — Human-readable description of the error, which is typically useful for logging.
- A type — Name of the category of the exception, which is useful for comparing to known types to distinguish the type of exception thrown. Internally generated exceptions have types such as `ArithmeticException` and `ParseException`. For a list of exception types, see "Exception" on page 800.
- A stack trace — A `sequence` of `StackTraceElement` objects that describe where the exception was thrown. The first `StackTraceElement` points to the place in the code that immediately caused the exception, for example, an attempt to divide by zero or access a dictionary key that does not exist. The second `StackTraceElement` points to the place in the code that called the action that contains the immediate cause. The third `StackTraceElement` element points to the code that called that action, and so on. Each `StackTraceElement` object has methods for accessing:
  - The name of the file that contains the relevant code
  - The line number of the relevant code
  - The name of the enclosing action
  - The name of the enclosing event, monitor or aggregate function

Information in an `Exception` object is available by calling these built-in methods:

- `Exception.getMessage()`
- `Exception.getType()`
- `Exception.getStackTrace()`
- `StackTraceElement.getFilename()`
- `StackTraceElement.getLineNumber()`
- `StackTraceElement.getActionName()`
- `StackTraceElement.getTypeName()`

In the `catch` block, you can specify corrective steps, such as returning a default value or logging an error. By default, execution continues after the `catch` block. However, you can specify the `catch` block so that it returns, dies or causes an exception.

You can nest try-catch statements in a single action. For example:

```
action NestedTryCatch() {
   try {
      print "outer";
      try {
         print "inner";
         integer i:=0/0;
      } catch(Exception e) {
         // inner catch
      }
   } catch(Exception e) {
      // outer catch
   }
}
```

The block in a `try` clause can specify multiple actions and each one can contain a try-catch statement or nested try-catch statements. An exception is caught by the innermost enclosing try-catch statement, either in the action where the exception occurs, or walking up the call stack. If an exception occurs and there is no enclosing try-catch statement then the correlator logs the stack trace of the exception and terminates the monitor instance.

Logging and printing

The following operations are provided for debugging and textual output:

- `print` *`string`*
- `log` *`string`* `[at` *`identifier`*`]`

The `print` statement outputs its text to standard output, which is normally the active display or some file where such output has been piped. See also "Strings in print and log statements" on page 299.

The `log` statement sends the specified string to a particular log file depending on the applicable log level. For details, see *Deploying and Managing Apama Applications*, "Correlator Utilities Reference", "Shutting down and managing components", "Setting logging attributes for packages, monitors, and events".

The topics below provide information for using the `log` statement.

Specifying log statements

The format of a `log` statement is as follows:

```
log string [at identifier]
```

Syntax description

Syntax Element	Description
`string`	Specify an expression that evaluates to a string.
`identifier`	Optionally, specify the desired log level. Specify one of the following values: `CRIT`, `FATAL`, `ERROR`, `WARN`, `INFO`, `DEBUG` or `TRACE`. If you do not specify an identifier, the default is `CRIT`.

For each encountered `log` statement, the correlator compares the specified identifier with the applicable log level to determine whether to send the specified string to a log file. If the string is to be sent to a log file, the correlator determines the appropriate log file to send it to.

The correlator uses the tree structure of EPL code to identify the applicable log level and the appropriate log file. See "Setting logging attributes for packages, monitors, and events" in the "Correlator Utilities Reference" section of *Deploying and Managing Apama Applications*.

Log levels determine results of log statements

The correlator supports the following log levels:

0	`OFF`	No entries go to log files.
1	`CRIT`	Least amount of entries go to log files.
2	`FATAL`	|
3	`ERROR`	|
4	`WARN`	|
5	`INFO`	|
6	`DEBUG`	|
7	`TRACE`	Greatest amount of entries go to log files.

You use log levels to filter out log strings. If the log level in effect is lower than the log level in the `log` statement the correlator does not send the string to the log file. For example, if the log level in effect is `ERROR` (3) and the log level in the `log` statement is `DEBUG` (6) the correlator does not send the string to the log file since the log level in effect is lower than the log level in the `log` statement.

Suppose that a string expression in a `log` statement executes an action or has side effects. In this situation, the correlator executes the `log` statement so that side effects always take place. However, if the log level in effect is lower than the log level in the `log` statement the correlator still does not send the string to the log file.

Here are some examples where the log level in effect is `WARN`:

```
log "foo bar" at CRIT; // Sends "foo bar" to the log file.
log "foo bar" at INFO; // Does not send anything to the log file.

log "foo" + "bar" + 12345.toString() at INFO;
   // Does not send anything to the log file.
   // The expression in the log statement is not evaluated as
   // the log level is too low to send output to the log file,
   // and the expression does not have side effects.

log "foo" + bar() + 12345.toString() at INFO;
   // Does not send anything to the log file.
   // Calls bar() since that action might have side effects,
   // for example, the action could send an event.
```

Actions on events or monitors are assumed to have side effects. The `com.apama.epl.SideEffectFree` annotation (see "Adding predefined annotations" on page 68) can be added to an action definition to mark it as side effect free. Note that with this annotation, actions will only be called from log statements if the log statement would write to the log file. This is more compact than checking the log level before executing the log statement. If the action does in fact have side effects, then changing the log level can change the behavior of your program. It is recommended to only add the `SideEffectFree` annotation on an action if a profile shows that a lot of time is spent in calling that action (premature optimizations add to program complexity for no benefit). Actions called via an action variable are always assumed to have side effects, as the EPL runtime does not know which action is invoked.

For more information on the profile, see *Profiling EPL Applications* in *Using Apama with Software AG Designer*.

To determine the log level in effect, the correlator checks whether you set a log level for the following in the order specified below:

1. The monitor or event that contains the `log` statement.
2. A parent of the monitor or event that contains the `log` statement. The correlator starts with the immediate parent and works its way up the tree as needed.
3. The correlator.

The log level in effect is the first log level that the correlator finds in the tree structure. See "Setting logging attributes for packages, monitors, and events" in *Deploying and Managing Apama Applications*, "Correlator Utilities Reference", "Shutting down and managing components". If the correlator does not find a log level, the correlator uses the correlator's log level. If you did not explicitly set the correlator's log level, the default is `INFO`.

After the correlator identifies the applicable log level, the log level itself determines whether the correlator sends the `log` statement output to the appropriate log file as follows:

Log Level in Effect	For Log Statements With These Identifiers, the Correlator Sends the Log Statement Output to the Appropriate Log File	For Log Statements With These Identifiers, the Correlator Ignores Log Statement Output
`OFF`	None	`CRIT, FATAL, ERROR, WARN, INFO, DEBUG, TRACE`
`CRIT`	`CRIT`	`FATAL, ERROR, WARN, INFO, DEBUG, TRACE`
`FATAL`	`CRIT, FATAL`	`ERROR, WARN, INFO, DEBUG, TRACE`

Log Level in Effect	For Log Statements With These Identifiers, the Correlator Sends the Log Statement Output to the Appropriate Log File	For Log Statements With These Identifiers, the Correlator Ignores Log Statement Output
`ERROR`	`CRIT, FATAL, ERROR`	`WARN, INFO, DEBUG, TRACE`
`WARN`	`CRIT, FATAL, ERROR, WARN`	`INFO, DEBUG, TRACE`
`INFO`	`CRIT, FATAL, ERROR, WARN, INFO`	`DEBUG, TRACE`
`DEBUG`	`CRIT, FATAL, ERROR, WARN, INFO, DEBUG`	`TRACE`
`TRACE`	`CRIT, FATAL, ERROR, WARN, INFO, DEBUG, TRACE`	None

An advantage of this framework is that there is no performance penalty for having `log` statements that do not specify actions in your application. You control the overhead of executing such `log` statements by specifying the appropriate log level.

Where do log entries go?

When the correlator needs to send the `log` statement output to a log file, the correlator checks whether you set a log file for the following in the order specified below:

1. The monitor or event that contains the `log` statement.
2. A parent of the monitor or event that contains the `log` statement. The correlator starts with the immediate parent and works its way up the tree as needed.
3. The correlator.

The log file that receives the `log` statement output is the first log file that the correlator finds. If the correlator does not find a log file, the default is that the correlator sends the string and identifier to `stdout`.

Examples of using log statements

Suppose you insert `DEBUG log` statements without actions in a monitor. You specify `ERROR` as the log level for that monitor. The correlator ignores `log` statement output of `log` statements with identifiers of `INFO` or `DEBUG`. But then there are some problems. You use the `engine_management` correlator utility to change the log level to `DEBUG`. Now the correlator sends output from all `log` statements to the appropriate log file.

Following is another example:

```
log "Log statement number " + logNo() at DEBUG;
action logNo() {
```

```
    logNumber := logNumber + 1;
    return logNumber.toString();
}
```

In this example, the correlator always executes the `log` statement because it calls an action. However, the log level in effect must be `DEBUG` for the correlator to send the string to the log file. If the log level is anything else, the correlator discards the string because the log level in effect is lower than the log level in the `log` statement.

Strings in print and log statements

In both `print` and `log` statements, the string can be any one of the following:

- Literal, for example: `print "Hello";`
- Variable, for example:

  ```
  string welcomeMessage;
  ...
  log welcomeMessage;
  ```

- Combination of both, for example:

  ```
  string welcomeMessage;
  ...
  print "Hello " + welcomeMessage + " Bye";
  ```

Internally, the correlator encodes all textual information as UTF-8. When the correlator outputs a string to a console or `stdout` because of a `print` statement, or sends a string to the log, the correlator translates the string from UTF-8 to the current machine's (where the correlator is running) local character set. However, if you redirect `stdout` to a file, the correlator does not translate to the local character set. This ensures that the correlator preserves as much information as possible.

Sample financial application

This section describes a complete financial example, using the monitor techniques discussed earlier in this chapter. See also: "Example of a query" on page 76.

This example enables users to register interest, for notification, when a given stock changes in price (positive and negative) by a specified percentage.

Users register their interest by generating an event, here termed `Limit`, of the following format:

```
Limit(userID, stockName, percentageChange)
```

For example:

```
Limit(1, "ACME", 5.0)
```

This specifies that a user (with the user ID `1`) wants to be notified if `ACME`'s stock price changes by 5%. Any number of users can register their interests, many users can monitor the same stock (with different price change range), and a single user can monitor many stocks.

In EPL, the complete application is defined as:

```
event StockTick {
```

```
   string name;
   float price;
}

event Limit {
   integer userID;
   string name;
   float limit;
}

monitor SharePriceTracking {

   // store the user's specified attributes
   Limit limit;

   // store the initial price (this may be the opening price)
   StockTick initialPrice;

   // store the latest price - to give to the user
   StockTick latestPrice;

   // when a limit event is received spawn; creating a new
   // monitor instance for each user's request
   action onload() {
      on all Limit(*,*,>0.0):limit spawn setupNewLimitMonitor();
   }

   // If an identical request from a user is discovered
   // stop this monitor and die
   // if a StockTick event is received for the stock the
   // user specified, store the price and call setPrice
   action setupNewLimitMonitor() {
      on Limit(limit.userID, limit.name, *) die;
      on StockTick(limit.name, *):initialPrice setPrice();
   }

   // Search for StockTick events of the specified stock name
   // whose price is both greater and less than the value
   // specified - also converting the value to percentile format
   action setPrice() {
      on StockTick(limit.name, > initialPrice.price * (1.0 +
         (limit.limit/100.0))):latestPrice notifyUser();

      on StockTick(limit.name, < initialPrice.price * (1.0 -
         (limit.limit/100.0))):latestPrice notifyUser();
   }

   // display results to user
   action notifyUser() {
      log  "Limit alert. User=" +
         limit.userID.toString() +
         " Stock=" + limit.name +
         " Last Price=" + latestPrice.price.toString() +
         " Limit=" + limit.limit.toString();
      die;
   }
}
```

The important elements of this example lie in the life-cycle of different monitor states. Firstly a monitor instance is spawned on every incoming `Limit` event where the limit is greater than zero. Within `setupNewLimitMonitor`, the first `on` command listens for other `Limit` events from the same user, upon detection of which the monitor instance is killed. This effectively ensures that there is a unique monitor instance per user per stock. This scheme also allows a user to send in a `Limit` event with a zero limit to indicate that they actually no longer want to monitor a particular stock. While this will not be caught by the original monitor instance's event listener and will not cause spawning, it will trigger the event listener in the monitor instance of that user for that stock and cause it to die.

Then a single `on` command (without an `all`) sets up an event listener to look for all `StockTick` events for that stock type for that user. Once a relevant `StockTick` is detected, new event listeners start seeking a specific price difference for that user. If such a price change is detected it is logged. Note that the `log` command exploits data from variables used before and after the `spawn` command (that is, `limit` and `latestPrice`, respectively).

This example also demonstrates how mathematical operations may be used within event expressions. Here, two `on` commands create event listeners that look for `StockTicks` with prices above and below the calculated price. The calculated price in this case is based on the initial price multiplied by the percentage specified by the user. The first event listener is looking for an increase in the share price to 105% of its original value, while the second is looking for a decrease to 95% of its original value.

7 Implementing Parallel Processing

By default, the correlator operates in a serial manner. In a monitor, you have the option of implementing contexts for parallel processing.

Note: Queries automatically take advantage of parallel processing. You do not need to implement parallel processing in queries. The information in this section of the documentation is for application developers who are writing monitors.

During serial correlator operation, the correlator processes events in the order in which they arrive. Each external event matches zero or more listeners. The correlator executes a matching event's associated listeners in a rigid order. The correlator completes the processing related to a particular event before it examines the next event.

For some applications, this serial behavior might not be necessary. In this case, you might be able to improve performance by implementing parallel processing. Parallel processing lets the correlator concurrently process the EPL in multiple monitor instances. To implement parallel processing, you create one or more contexts.

Note: If a license file cannot be found, the number of contexts that the correlator allows to be created is limited. See "Running Apama without a license file" in *Introduction to Apama*.

Parallel processing in the correlator is quite different from the parallel processing provided by Java, C++, and other languages. These languages allow shared state, and rely on mutexes, conditions, semaphores, monitors, and so on, to enforce correct behavior. The correlator does not automatically provide shared state. Data sharing happens by sending events between contexts and by using the MemoryStore. See "Using the MemoryStore" on page 365. Parallel processing in the correlator is a message-passing system.

Introduction to contexts

Contexts allow EPL applications to organize work into threads that the correlator can execute concurrently.

In EPL, `context` is a reference type. When you create a variable of type `context`, or an event field of type `context`, you are actually creating an object that refers to a context. The context might or might not already exist. You can then use the context reference to spawn to the context or send an event to the context. When you spawn to a context, the correlator creates the context if it does not already exist.

What is inside/outside a context?

When you start a correlator it has a single main context. You can then create additional contexts. A context consists of the following:

- One or more monitor instances. Except, the main context exists even if it does not contain any monitor instances.
- An event input queue.

- Listeners that belong to the contained monitor instances.

The correlator maintains event definitions and monitor definitions outside contexts. This lets all contexts share the same event and monitor definitions.

Instances of the same monitor can exist in multiple contexts. Each monitor instance belongs to a single context. For example, suppose you inject monitor `A`. Monitor `A` spawns within its own context (the main context) twice and spawns once to the `alpha` context. This creates three additional monitor instances. Two instances are in the main context and one instance is in the `alpha` context. These instances do not share any data, other than by means of passing events.

About context properties

A context has the following properties:

- Name — A string that you specify when you create the context. This name does not need to be unique. The name is a convenient identifier that you can use in your code.
- ID — The correlator assigns a unique integer.
- `receiveInput` flag — A Boolean value that indicates whether the context can receive external input events on the default channel, which is the empty string (`""`).

  A value of `true` lets the context receive external events on the default channel; this is a public context. A value of `true` is equivalent to a subscription to the default channel; there is no requirement for a monitor instance in this context to subscribe to the default channel.

  A value of `false` indicates a private context that does not receive external events on the default channel. This is the default.

  Note that the main context is public.
- Channel subscriptions — A context is subscribed to the union of the channels each of the monitor instances in that context is subscribed to. This is a property of the monitor instances running in a context and is not accessible by means of the context reference object.

You can spawn to other contexts. When the last monitor instance in a context terminates, that context stops doing work and stops consuming resources until you spawn another monitor instance to it.

In a context, when you route an event, the event goes to the front of that context's input queue. You can route events only within a context.

You can send an event to a particular context. When you do this, the event goes to the end of the specified context's input queue. The correlator processes it after it processes any other events that are already on the context's input queue. See "Sending an event to a particular context" on page 312.

You can use a context as part of the key for a dictionary. You can route an event that contains a `context` field. You cannot parse a context. Context objects are immutable reference objects.

Context lifecycle

A context has a lifecycle that starts when a `spawn...to` operation occurs and ends when the last monitor instance in the context terminates. This is completely independent of any context objects that refer to the context. It is possible for a context to be running when no references to it exist, and it is possible for a context object to refer to a context that is no longer running. In the latter case, spawning to a context that is not running is permissible. The correlator restarts the context as required.

Note: If a license file cannot be found, the number of contexts that the correlator allows to be created is limited. See "Running Apama without a license file" in *Introduction to Apama*.

Comparison of a correlator and a context

Upon injection, each monitor's initial instance runs in the main context. You must explicitly create additional contexts. Conceptually, a context is like a correlator but with the following differences:

- All contexts share the same namespace, and thus share all monitor and event definitions that have been injected.
- A monitor instance must have a context reference to pass an event to that context.
- There is one enqueued events queue for all contexts. When you specify the `enqueue` command (not the `enqueue` *`event`* `to` *`context`* command), the enqueued event goes to the special queue for enqueued events. The correlator then places the event on the input queue of each public context. The correlator ensures that an enqueued event always arrives on the appropriate input queue(s). An `enqueue` operation never blocks. However, if the input queue of a context is full and the enqueued events queue gets very large, the result can be an `unbounded memory usage` error.
- Execution of Java is allowed in only the main context.
- The `engine_receive` utility receives events from all contexts or it can be configured to receive events from only specified channels.
- The `engine_send` utility sends events to all public contexts or to the contexts that are subscribed to the channels it is configured to send events on.

Creating contexts

In EPL, you refer to a context by means of an object of type `context`. The `context` type is a reference type.

The recommendation is to use private contexts and have monitor instances subscribe to the channels they require events from. This gives greater flexibility over using public contexts. For information on the constructors needed to create a context, see "context" on page 790.

The name of a context does not have to be unique, and is only used for diagnostic purposes (it is recommended that context names be meaningful and distinct). Creating a new context object with the same name as another context creates a reference to a different context, not the same context. Context references are independent to the actual context where monitors run. A context continues running if there are no references to it. A reference to a context may exist even though no active monitors are running in that context. You use the context reference to spawn to the context or send an event to the context. When you spawn to a context, the correlator creates the context if it does not already exist.

When you start a correlator, it has a single main context. You can then create additional contexts. Context reference objects are lightweight and creating one only creates a stub object and allocates an ID. In other words, when you create an EPL context object, you are actually creating a context reference.

The following example creates a reference, `c`, to a private context whose name is `test`:

```
context c:=context("test");
```

For information on the methods you can call on a context, see "context" on page 790.

See also "How many contexts can you create?" on page 307.

How many contexts can you create?

You can create any number of contexts. A context is a very lightweight object. Creating a context just allocates an identifier and creates a small object. Consequently, it is possible to create a thousand contexts with little performance penalty.

You can have any number of running contexts. A running context means that the context contains at least one monitor instance that has work to do. The more CPU cores you have, the more contexts it is practical to be running at a given time. The performance of multiple contexts running concurrently should scale approximately according to the number of CPU cores available on the host.

Because the cost of each context is low, it is possible to divide applications into the finest level of parallelism possible and let the correlator balance running those contexts across all CPU cores. This is true even if that means creating very many contexts.

Using channels to communicate between contexts

Contexts can subscribe to channels, using the `monitor.subscribe(`*`channelName`*`)` operation. When a monitor executes `monitor.subscribe(`*`channelName`*`)`, it causes the context it is running in to be subscribed to that channel. The subscription's lifetime is tied to the lifetime of the monitor instance that executes `subscribe()`. The subscription is active until that monitor instance terminates or executes `monitor.unsubscribe(`*`channelName`*`)`.

Subscriptions are reference counted. That is, if one monitor instance subscribes twice to the same channel then it needs to unsubscribe twice from that channel. If two monitor instances each subscribe once to the same channel then the subscription is active while either monitor instance exists or until both monitor instances unsubscribe from that channel.

When a context is subscribed to a channel it receives all events sent on that channel. This includes:

- Events sent to the correlator from
  - An IAF adapter
  - `engine_send`
  - Another correlator connected with `engine_connect` and using `parallel` mode
  - Clients
  - Universal Messaging
- Events sent from EPL using the `send...to` command
- Events sent from correlator plug-ins to a specific channel

It does not include events emitted with the `emit...to` command. Even if the target of an `emit...to` statement is a channel that the context is subscribed to, an event sent by the `emit` statement goes only to external receivers and not to any contexts.

By using a channel for each stream of data an application may be interested in, an application can control which streams of data it receives through execution of the appropriate `monitor.subscribe(`*`channelName`*`)` and `monitor.unsubscribe(`*`channelName`*`)` commands. The correlator can efficiently distribute events within the correlator to multiple contexts, plug-ins or receivers subscribed to channels. If further scale-out is required, using channels allows some application components to be deployed to correlator processes running on other hosts, which are connected using the `engine_connect` correlator utility or Universal Messaging. See "Tuning Correlator Performance" in *Deploying and Managing Apama Applications*.

Obtaining context references

To obtain a reference to the context that a piece of code is running in, call the `context.current()` method. This is a static method that returns a `context` object that is a reference to the current context. The current context is the context that contains the EPL that calls this method.

For a monitor instance to interact with the EPL by means of a context object in another context, the monitor instance must have a reference to that context. A monitor instance can obtain a reference to another context in only the following ways:

- By creating the context.
- By receiving a context reference, which must be of type `context`. A monitor instance can receive this reference by means of a routed or sent event, or a spawn operation.

For example:

```
Calculate calc;
```

```
on all Calculate():calc {
   integer calcId:=integer.getUnique();
   spawn doCalculation(calc, calcId, context.current())
      to context("Calculation");
do something
}
action doCalculation(Calculate req, integer id, context caller) {
   do something
   send CalculationResponse(id, value) to caller;
}
```

If a monitor instance that creates a context does not send a context reference outside itself, and does not subscribe to any channels, no other context can send events to that context, except by means of correlator plug-ins. This affords some degree of privacy for the context.

A `context` object (a context reference) does not do anything. It is simply the target of the following:

- `spawn ActionIdentifier([ArgumentList]) to ContextExpression;`

  See "Spawning to contexts" on page 309.

- `send EventExpression to ContextExpression;`

  See "Sending an event to a particular context" on page 312.

Spawning to contexts

In a monitor, you can spawn to a context. The format for doing this is as follows:

```
spawn ActionIdentifier([ArgumentList]) to ContextExpression;
```

Replace *ContextExpression* with any valid EPL expression that is of the `context` type. Typically, this is the name of a `context` variable. It is possible to spawn to only a context; it is not possible to spawn to a channel.

This statement asynchronously creates a new monitor instance in the target context. The correlator can immediately create the new monitor instance and begin processing it. The correlator does not need to finish processing the monitor instance that spawned to the context before it starts processing the spawned instance. The correlator might create the spawned monitor instance before it finishes processing the action that spawned the new instance. Or, the correlator might create the spawned monitor instance some time after it completes processing the action that spawned the new instance. The order is unpredictable. For example:

```
action analyse(string symbol) {
   context c:=context(symbol);
   spawn submon(symbol) to c;
   ...
}
action submon(string symbol) {
   ...
}
```

If the target context does not yet exist, the correlator creates it.

It is possible for an operation that spawns to a context to block if the input queue of the target context is full. See "Deadlock avoidance when parallel processing" on page 324.

Like the regular `spawn` operation, the `spawn...to` operation does the following:

- Creates a new monitor instance by taking a deep copy of all of the spawning monitor instance's global variables
- Does not copy any listeners into the new monitor instance
- Runs the specified action in the new monitor instance

For general information about spawning, see "Spawning monitor instances" on page 55.

Unlike the regular `spawn` operation, the correlator runs the new monitor instance in the specified context. The correlator concurrently processes the new monitor instance and the instance that spawned it.

A context processes `spawn` operations and events in the order in which they arrive. For example, suppose a monitor contains the following statements:

```
spawn action1() to ctx;
send e1 to ctx;
spawn action2() to ctx;
send e2 to ctx;
```

The `ctx` context processes this in the following order: `action1(),e1,action2(),e2`.

Channels and contexts

Contexts can subscribe to particular channels to receive events delivered to those channels from adapters and from other contexts. See "Channels and input events" on page 46 and "Subscribing to channels" on page 70. Contexts that are public, that is, they were created with a true flag in the context constructor, have a permanent subscription to the default channel. The name of the default channel is the empty string.

Contexts can send events to channels without knowledge of whether the event is required by contexts, clients, adapters, or some combination. When an event is sent from a context to a channel the event is received by all contexts subscribed to that channel and by all external receivers that are listening on that channel. See "Generating events with the send command" on page 285.

An Apama query automatically runs in a context that has a permanent subscription to the default channel and to the `com.apama.queries` channel.

Channels are useful for:

- Identifying service monitors — If many monitors need to send events to a service monitor you can use a well known name (which can appear in EPL as a string literal or string constant) as a channel name. The service monitor (and only the service monitor) should subscribe to the channel and other monitors send events to that channel. When a request-response event protocol is required the sender can specify a channel to which it is subscribed, or a context to send the response to.

- Applications that have different contexts that consume different streams of data can use channels to send the data to the intended contexts, even if many contexts require the same data stream or one context requires multiple data streams. For example, statistical arbitrage trading strategies could run in many contexts, each subscribed to a channel for the pair of stock symbols it is trading against each other. If the adapter where the events are coming from is able to use a separate connection per channel, then the application will scale very well as more trading strategies on different symbols are added.
- Different components of an application can be de-coupled by using an event protocol that sends events to channels for each interaction point between components. This allows adapters to be replaced with monitors that simulate those adapters for testing, and makes it easy to scale an application across several hosts by running different parts on different correlators and then connecting them.

Sending an event to a channel

In a monitor, you can send an event to a channel by using either

- A string value that identifies the channel name
- A `com.apama.Channel` type that either names a channel or holds a context reference

The format for sending an event to a particular context is as follows:

```
send EventExpression to ChannelExpression;
```

Replace *`EventExpression`* with any valid EPL expression that is of an `event` type.

Replace *`ChannelExpression`* with any valid EPL expression that is of the `string` or `com.apama.Channel` type. Typically, this is a `string` value.

This statement asynchronously sends an event to everything subscribed to the specified channel. Subscribers can include

- Contexts
- Receivers connected to external components by means of Apama's messaging, JMS or Universal Messaging
- Correlator plug-ins that have subscribed an `EventHandler` object

For each target subscribed to a channel, the event goes to the back of the context's input queue.

In a target context, the correlator can immediately process the sent event. The correlator does not need to finish executing the action that sends the event before it processes the sent event in a target context. The correlator might process the sent event before it finishes executing the action that sent the event. Or, the correlator might process the sent event some time after it completes executing the action that sent the event. The order is unpredictable. The order in which the target contexts receive the sent event is also unpredictable. For example:

```
action analyse(string symbol) {
   spawn submon(symbol) to context(symbol);
```

```
   com.apama.marketdata.Tick tick;
   log "Listening for "+symbol;
   on all com.apama.marketdata.Tick(symbol=symbol):tick {
      send tick to symbol;
   }
   on com.apama.marketdata.Finished() {
      send com.apama.marketdata.Finished() to symbol;
   }
}

action submon(string symbol) {
   monitor.subscribe(symbol);...
}
```

It is possible for a `send...to` operation to block the sending context from further processing if the input queue of any target (context, receiver or plug-in) is full. Either an event that you send to a particular target arrives on the target's input queue or the sending context waits for room on the target's input queue.

If you send an event to a channel that has no subscribers, the correlator discards the event because there are no listeners for it. This is not an error.

See also:

- "Generating events with the send command" on page 285
- "Working with channels in C++ plug-ins " on page 742
- "Using Java plug-ins" on page 754

Sending an event to a particular context

In a monitor, you can send an event to a particular context, as described here, or you can send an event to a `sequence` of contexts, described in the next topic. The format for sending an event to a particular context is as follows:

```
send EventExpression to Expression;
```

or:

```
enqueue EventExpression to ContextExpression;
```

Note: The `enqueue...to` statement will be deprecated in a future release. Use the `send...to` statement. Both statements perform the same operation.

- Replace *`EventExpression`* with any valid EPL expression that is of an `event` type. You cannot specify a `string` representation of an event. For example, you cannot send `&TIME` pseudo-ticks.
- Replace *`Expression`*, in the first format, with any valid EPL expression that is of the `context` type or with a `com.apama.Channel` object that contains a context. See "Sending events to com.apama.Channel objects" on page 286.
- Replace *`ContextExpression`* with any valid EPL expression that is of the `context` type. This can be the name of a `context` variable or a method that returns a context. This cannot be a `com.apama.Channel` object that contains a context.

This statement asynchronously sends an event to the specified context. The event goes to the back of the context's input queue.

In the target context, the correlator can immediately process the sent event. The correlator does not need to finish executing the action that sent the event before it processes the sent event in the target context. The correlator might process the sent event before it finishes executing the action that sent the event. Or, the correlator might process the sent event some time after it completes executing the action that sent the event. The order is unpredictable. The order in which the target contexts receive the sent event is also unpredictable. For example:

```
action analyse(string symbol) {
   context c:=context(symbol);
   spawn submon(symbol) to c;
   com.apama.marketdata.Tick tick;
   log "Listening for "+symbol;
   on all com.apama.marketdata.Tick(symbol=symbol):tick {
      send tick to c;
   }
   on com.apama.marketdata.Finished() {
      send com.apama.marketdata.Finished() to c;
   }
}
action submon(string symbol) {
   ...
}
```

The `send...to` and `enqueue...to` statements do not place the event on the special enqueued events queue. Instead, they put the event on the end of the target context's input queue. Consequently, it is possible for a `send...to` or `enqueue...to` operation to block the sending context from further processing if the input queue of the target context is full. Either an event that you send to a particular context arrives on the target context's input queue or the sending context waits for room on the target context's input queue.

If you send an event to a context that does not contain any monitor instances, the correlator discards the event because there are no listeners for it.

If you do not have a reference to a particular context, then send an event to a channel. See "Generating events with the send command" on page 285.

In some situations, for example when you change a single-context application to use parallel processing, you might want to explicitly send an event to only the context that contains the monitor instance that contains the `send` statement. To send an event to only this context specify:

```
send eventExpression to context.current()
```

You must set a valid value to a context variable before you send an event to the context. You cannot send an event to a context that you have declared but has not been set to a valid value. For example, the following code causes the correlator to terminate the monitor instance:

```
monitor m {
   context c;
   action onload()
   {
      send A() to c;
   }
```

```
}
```

See also "Generating events with the enqueue command" on page 287. and "Generating events with the send command" on page 285.

Sending an event to a sequence of contexts

In a monitor, you can send an event to a sequence of contexts. The format for doing this is as follows:

```
send EventExpression to ContextSequenceExpression;
```

or

```
enqueue EventExpression to ContextSequenceExpression;
```

Note: The `enqueue...to` statement will be deprecated in a future release. Use the `send...to` statement. Both statements perform the same operation.

- Replace *`EventExpression`* with any valid EPL expression that is an event. You cannot specify a `string` representation of an event.
- Replace *`ContextSequenceExpression`* with any valid EPL expression that resolves to `sequence<context>`. You cannot specify a sequence that contains `com.apama.Channel` objects.

Each statement asynchronously sends a copy of an event to each context in the specified sequence. The event goes to the back of the input queue of each context.

In each target context, the correlator can immediately process the sent event. The correlator does not need to finish executing the action that sent the event (in the source context) before it processes the sent events in the target contexts. The correlator might process a sent event before it finishes executing the action that sent the event. Or, the correlator might process a sent event some time after it completes executing the action that sent the event. The order is unpredictable, depending on the relative execution speeds of the contexts.

The following example uses the `sequence` type:

```
action analyse(string symbol) {
   context c1:=context(symbol + "-1");
   context c2:=context(symbol + "-2");
   context c3:=context(symbol + "-3");

   spawn submon(symbol) to c1;
   spawn submon(symbol) to c2;
   spawn submon(symbol) to c3;
   sequence <context> ctxs := [ c1, c2, c3 ];

   com.apama.marketdata.Tick tick;
   log "Listening for "+symbol;
   on all com.apama.marketdata.Tick(symbol=symbol):tick {
      send tick to ctxs;
   }
   on com.apama.marketdata.Finished() {
      send com.apama.marketdata.Finished() to ctxs;
   }
}
```

```
action submon(string symbol) {
   ...
}
```

The following example uses the `values()` method on a dictionary of contexts to obtain a sequence of contexts:

```
action analyse(string symbol) {
   context c1:=context(symbol + "-1");
   context c2:=context(symbol + "-2");
   context c3:=context(symbol + "-3");

   spawn submon(symbol) to c1;
   spawn submon(symbol) to c2;
   spawn submon(symbol) to c3;

   dictionary <string, context>
      ctxs := [ "c1": c1, "c2": c2, "c3": c3 ];

   com.apama.marketdata.Tick tick;
   log "Listening for "+symbol;
   on all com.apama.marketdata.Tick(symbol=symbol):tick {
      send tick to ctxs.values();
   }
   on com.apama.marketdata.Finished() {
      send com.apama.marketdata.Finished() to ctxs.values();
   }
}
action submon(string symbol) {
...
}
```

The `send...to` and `enqueue...to` statements do not place the event on the special enqueued events queue. Instead, they put the event on the end of the input queue of each target context. Consequently, it is possible for a `send...to` or `enqueue...to` operation to block the sending context from further processing if the input queue of a target context is full. The sending context does not continue beyond a `send...to` or `enqueue...to` statement until the event has been placed on the input queues of all target contexts.

If one of the contexts in the sequence does not contain any monitor instances the correlator ignores the sent event in that context because there are no listeners for it.

If one of the contexts in the sequence does not have a valid value before you send an event to it then the correlator terminates the monitor instance.

Consider the following two code fragments:

```
for c in mySequence {
   send myEvent to c;
}

send myEvent to mySequence;
```

Execution of each of these fragments is typically equivalent. However, you cannot rely on equivalence. When the correlator executes the first fragment, it always delivers the event to the contexts according to their order in the sequence. When the correlator executes the second fragment it can deliver the event to contexts in any order. For example, if a context's input queue is full this can affect the order in which the correlator delivers the event to the contexts.

Common use cases for contexts

See "Tuning contexts" on page 429.

Samples for implementing contexts

Apama provides a number of applications that illustrate the use of contexts. These examples are in the `samples\monitorscript\contexts` directory and in the `samples\monitorscript\concurrency-theory` directory.

Information for using these examples is given in the topics below.

Simple sample implementation of contexts

In your Apama installation directory, in the `samples\monitorscript\contexts` directory, there are two versions of a simple application. One version implements serial processing and the other implements parallel processing. Open the `analyse-parallel.mon` and `analyse-serial.mon` files in Software AG Designer to compare the implementations.

To run the applications, execute `run-sample.bat` on Windows or `run_sample.sh` on UNIX. The script runs the serial application and then the parallel version.

On a 2.4GHz Quad core Intel Q6600 machine, the serial implementation completes in about 63 seconds, while the parallel implementation completes in about 17 seconds. For an equivalent dual-core processor, you can expect the parallel implementation to complete in about 30 seconds.

Look at `serial-results.evt` and `parallel-results.evt` to compare the results. While the per-symbol output for each implementation is identical, the ordering of sent events for different symbols is different. Also, in the parallel implementation, there is more variation in the time taken to process all events for one symbol. The sample uses eight worker contexts — each context is doing much the same work, but on different segments of the data. While it is not required, an application that has eight contexts typically working most of the time benefits from running on an 8-core host. You can expect an 8-core processor to run the sample parallel implementation more than seven times faster than it runs the serial implementation.

Running samples of common concurrency problems

Sample applications in the `samples\monitorscript\concurrency-theory` directory illustrate a few common concurrency problems. There are three implementations of a simple deposit bank:

- Race — implements `Get` and `Set` events, and corresponding `Response` events, so that a teller can find the value of an account, perform some modification and then set the new account value.
- Deadlock — lets tellers lock an account.

- Compareswap — is similar to the Race implementation but it does not rely on locking and it does not compute values based on out-of-date information.

To run these samples

1. Start an Apama Command Prompt as described in *Deploying and Managing Apama Applications* in the topic *Setting up the environment using the Apama Command Prompt*.
2. Change to the `$APAMA_INSTALL_DIR/samples/monitorscript/concurrency-theory` directory.
3. Invoke `run_sample.bat` (Windows) or `run_sample.sh` (UNIX) with an argument of `race`, `deadlock` or `compareswap`, according to which sample you want to run. The subsequent topics describe each sample.

The script starts a correlator on the default port (`15903`). Consequently, you should not have a correlator already running on the default port. If you do, the script causes the application to be injected into the running correlator and it also shuts the correlator down when the sample execution is complete. The script creates an event file in the `Output` directory (which it creates). The event file has the name of the sample with an `evt` file suffix (for example, `race.evt`, `deadlock.evt` or `compareswap.evt`.

About the samples of concurrency problems

The sample of concurrency problems try to implement a simple deposit bank. The customer-visible part of the bank consists of a number of tellers, who have the ability to transfer money from one account to another. In an effort to scale well, the bank is implemented with each teller running in a separate context, which lets all tellers work concurrently. Of course, the simple work of the tellers does not require or even justify this, but the purpose of these samples is to show potential bugs, not to be a practical system. Similarly, no security checks are enforced.

Because data cannot be shared between contexts, the application requires a separate monitor that acts as the bank's database. The tellers send requests to the bank's database and receive responses from the database. There is also a simple mechanism to initialize the state of the bank database (`SetupAccount` event) and for tellers to discover the context in which the database is running. The communication between the bank and the tellers typically needs to get or set an account's value. The tellers perform the actual arithmetic on a bank account's value. Each implementation (Race, Deadlock, and Compareswap) differs mainly in the way the tellers and database interact with each other.

Customer interactions with tellers are the same across all implementations. The customer sends a `TransferMoney` event, specifying which teller to use. It is assumed that customers know the names of tellers, the from and to account, and the amount to transfer. The customer receives a `TransferMoneyComplete` event when the transfer is complete.

The state of the bank's accounts can be inspected by sending a `SendBalances` event to the correlator, which causes the correlator to log and send the balances.

To expose the problems, there are calls to the `spinSleep` action at key places in the implementations. If the correlator receives an `ExposeRaces` event, the `spinSleep` action suspends work by the specified teller for the specified time. This simulates tellers working at different rates, and means that difficult to reproduce conflicts are easier to identify. While this is useful for exposing bugs, it is not suitable for general-purpose sleeps because it consumes CPU time while sleeping and does not let other work in that context get done. This strategy is useful for exposing problems only when you know exactly where to place the sleeps.

Each implementation has its own `transfer-`*`sample_name`*`.evt` file, which the script sends as each bug is exposed with a different set of input data.

About the race sample

The race sample is in `Bank-race.mon`. It implements `Get` and `Set` events, and corresponding `Response` events. A teller can find the value of an account, perform some modification and then set the new account value. To take money from one account, the protocol is as follows:

1. Send a `Get` event to obtain the current value of the account.
2. Wait for a `GetResponse` event that contains the current value.
3. Compute the new account value.
4. Send a `Set` event to set the new account value.
5. Wait for a `SetResponse` event.

This works well when a single transfer occurs at a time. However, there is a bug because between the time that teller 1 obtains an account value and the time that teller 1 sets the new account value, teller 2 can obtain the account value, compute a new value, and set a new account value. The following time line demonstrates this:

Time	Teller 1	Teller 2	Bank Database
0 (setup)	Transfer 50 from A to B		A: 100 B: 100 C: 100
	Get A, Get B		
	A=100, B=100		
	Sleep 1 second		
0.5		Transfer 25 from B to C	
		Get B, Get C	

Time	Teller 1	Teller 2	Bank Database
		B=100, C=100	
		newB=75, newC=125	
		Set B, Set C	
			A: 100, B: 75, C: 125
1.0	newA=50, newB = 150		
	Set A, Set B		
			A: 50, B: 150, C: 125

B's account should have 100 + 50 – 25 = 125. But it ends up with 150 because teller 1 overwrites teller 2's value for B's account (75). Teller 1 based its calculation on values that were out of date at the point they were sent to the database.

About the deadlock sample

While EPL does not provide any mutual exclusion locking primitives, you can implement something similar in a monitor. The deadlock sample's bank implements a locking mechanism. Tellers can send a `Lock` event for an account, and the database returns a `LockResponse` event when the account is locked. If another teller tries to lock the same account, the correlator queues the request until it processes an `Unlock` event to unlock the account. Note that the locking is fair; the correlator allocates locks in the order in which they are requested.

The deadlock implementation does no checking. For example, it does not check that the unlock event comes from the teller that locked an account, nor that a teller holds a lock for an account before performing an operation on that account. (A robust application would of course perform such checking.)

The deadlock sample fixes the problem shown in the Race sample where a value was overwritten by a value that resulted from computation on out-of-date values. If you replicate the Race pattern of events, teller 2 would wait to lock B's account until teller 1 had finished with it. (This assumes all tellers follow the correct protocols. A robust implementation would perform checks to ensure that was the case).

However, even when all tellers follow the locking protocol correctly, there is a different problem. If teller 1 locks account A and teller 2 locks account B, and teller 1 tries to lock account B and teller 2 tries to lock account A, then each teller waits for the other teller to release a lock. The following timeline shows this:

Time	Teller 1	Teller 2	Bank Database
0	Transfer 50 from A to B		A: 100 B: 100 C: 100
	Lock A		
			A: Locked by t1
	Sleep 1 second		
0.5		Transfer 25 from B to A	
		Lock B	
			A: locked by t1 B: locked by t2
		Lock A	A: locked by t1, t2 waitingB: locked by t2
		(waiting for `LockResponse(A)`)	
	Lock B		A: locked by t1, t2 waitingB: locked by t2, t1 waiting
1.0	(waiting for `LockResponse(B)`)		

At this point, neither teller can make any further progress.

One solution to this (not implemented here) is to implement a timeout. If a lock request is outstanding for more than some threshold, the correlator abandons the lock. When this happens, the tellers would wait a random amount of time and try again. The random wait should prevent the retries from overlapping, if not on the first retry, then on a subsequent retry. However, such a mechanism invariably performs poorly in the (hopefully rare) case that a lock times out.

Alternatively, you can prevent deadlock by defining priority orders for locks. For example, you can specify that A must always be locked before B. Applying this priority order to all transactions would prevent deadlock.

About the compareswap sample

This compareswap sample is more like the race sample. The protocol between tellers and the database consists of `Get` and `Set` events, except the `Set` event is a `CompareSet` event, which contains an expected old value. If the old value does not match the database account value, then the teller retries the operation — getting a new value and re-computing the account value.

This has the advantage that it does not rely on locking (so does not suffer from deadlock) and does not result in values computed from out of date data being set in the database.

The only disadvantage is that under some circumstances (the same as for the race sample), the tellers need to re-try a calculation. However, unlike the timeout on locking, tellers know about this as soon as they receive an event back from the database, and no timeouts are involved.

This strategy is the recommended way to share state between different contexts. Note that while it guarantees progress is made by at least one context, an interaction between the database and a single context can take an unbounded amount of time, as other contexts can require the context to re-try its transaction. A further refinement would be to use a generation counter that the correlator increments on every successful `Set` event. This detects the difference between the database's value being unchanged and the database's value being changed back to a previous value. While such a difference might not matter in many situations, it might when you are computing interest.

Note: Due to the requirement to retry, the compareswap implementation is slightly different from the race implementation. One account is modified at a time; the teller transfers money from the `fromAccount`, and then adds it to the `toAccount`.

Time	Teller 1	Teller 2	Bank Database
0 (setup)	Transfer 50 from A to B		A: 100 B: 100 C: 100
	Get A		
	A=100		
	newA=50		
			A: 50, B: 100, C:100

Time	Teller 1	Teller 2	Bank Database
			Set A success
	Get B		
	B = 100		
	Sleep 1		
0.5		Transfer 25 from B to C	
		Get B	
		B=100	
		newB=75	
		Set B (old=100)	
			A: 100, B: 75, C: 100
			Set B success
		Get C	
		C=100	
		newC=125	
		Set C (old=100)	
			A: 50, B: 75, C: 125
			Set C success
1.0	newB = 150		
	Set B (old=100)		

Time	Teller 1	Teller 2	Bank Database
			A: 50, B: 75, C: 125
			Set B FAILED
	Get B		
	B = 75		
	newB = 125		
	Set B (old=75)		
			A: 50, B: 125, C: 125
			Set B success

Contexts and correlator determinism

Creating one or more contexts makes the correlator non-deterministic. In other words, injecting the same monitor can produce different results if the monitor contains statements that spawn to contexts.

For example, suppose an application creates two contexts, spawns to each of them, and each context runs code that calls `integer.getUnique()`. The assignment of unique integers to contexts is not deterministic; if you re-run the code, each context might receive an integer that is different from the integer it received during the previous run. Other behavior that can be non-deterministic in a parallel processing application includes the following:

- The assignment of particular IDs to particular contexts
- The order in which contexts send events
- The order in which contexts spawn to other contexts

See also "About input logs and parallel processing" on page 324.

How contexts affect other parts of your Apama application

When you implement contexts in an EPL application, an understanding of how contexts affect other parts of your Apama application is required.

The topics below provide information to help you understand the behavior.

About input logs and parallel processing

Applications that implement parallel processing might have non-deterministic behavior. While you can inject a parallel application into a correlator that you started with the `--inputLog` option, you cannot expect to use that input log to exactly duplicate correlator execution.

For applications that use multiple contexts or that send events, just re-sending the events and EPL sent to the correlator is insufficient to reproduce the same output and state. The timing of which context ran which `send`, `emit`, `enqueue...to` or other operation is important. Operations that can affect the state of other contexts or the sent events are non-deterministic when run in parallel.

Deadlock avoidance when parallel processing

Parallel processing in the correlator uses a message passing system. Each context has a fixed-size input queue for events (messages). A deadlock is possible when all of the following conditions are true:

- Context `1` is enqueuing an event to context `2`.
- Context `2` is enqueuing an event to context `1`.
- The input queues for context `1` and context `2` are both full.

In this situation, each context is blocked from further processing until the queue of the other context is no longer full. Neither context can process the next event on its input queue. Such a deadlock is not limited to two contexts but can occur with any number of contexts enqueuing events to each other.

The correlator avoids such a deadlock by detecting the potential for it to occur and then expanding input queues as needed. Also, the correlator logs a warning that a potential deadlock was detected. The correlator expands input queues only when not doing so causes a deadlock. The correlator does not expand input queues when one or more contexts are blocked from further processing while one or more contexts are processing as usual. However, it is still possible to create applications that result in out of memory errors or other kinds of deadlocks. Out of memory errors can result from requiring excessive expansion of input queues through the deadlock avoidance mechanism, or other means, such as creating a very large `sequence`.

Clock ticks when parallel processing

Since all contexts receive clock ticks, timers work in all contexts. However, it is possible for some contexts to run behind others. That is, a timer in a particular monitor for which there are monitor instances in multiple contexts might fire at different points in real time. In each context, the timer can process the series of clock ticks at a speed that is different from the other contexts.

A context that is running a monitor instance in a very long running loop might not remove entries from its input queue for a long time. If a context has a full input queue the clock tick distributer thread does not block. Instead, the correlator quashes clock ticks onto the end of the context's input queue. This means that the correlator unpacks the clock tick event when the context input queue either drains or accepts a new event. There is no perceptible difference between normally received clock ticks and quashed clock ticks.

Using correlator plug-ins in parallel processing applications

The standard MemoryStore and Time Format plug-ins are thread safe, which means that you can use them in parallel applications. The MemoryStore can be quite helpful in a parallel application and is very efficient when used simultaneously by multiple contexts.

For information about writing correlator plug-ins for use with parallel applications, see "The EPL Plug-in APIs for C and C++" on page 747.

Note: The C class `AP_Context`, and the C++ class `Context`, which you use for correlator plug-in development, are completely different and unrelated to contexts that you define for parallel processing.

8 Using Correlator Persistence

When the correlator shuts down, the default behavior is that all state is lost. When you restart the correlator, no state from the previous time the correlator was running is available. You can change this default behavior by using correlator persistence.

Correlator persistence means that the correlator automatically periodically takes a snapshot of its current state and saves it on disk. When you shut down and restart that correlator, the correlator restores the most recent saved state.

To enable persistence, you indicate in your EPL code which monitors you want to be persistent. Optionally, you can write actions that the correlator executes as part of the recovery process. When code is injected for a persistence application, the correlator that the code is injected into must have been started with a persistence option.

Persistent monitors must be written in EPL. State in JMon monitors cannot be persistent. State in chunks, with a few exceptions, also cannot be persistent.

Note: If a license file cannot be found, the number of persistent monitors that the correlator allows is limited. See "Running Apama without a license file" in *Introduction to Apama*.

Description of state that can be persistent

A correlator that is running with persistence enabled automatically stores state on disk and automatically recovers state when it restarts. Saved state includes the following:

- For a persistent EPL monitor, all of that monitor's state is saved. This includes all events, strings, primitives, sequences, dictionaries, action variables, closures, and global variables. It also includes all the state of listeners, streams and queries — local variables captured by them and all active listeners, sublisteners and queries, including the events currently flowing through them.
- All source code that was injected into the correlator, including any non-persistent EPL monitors and JMon monitors. EPL files that were injected from a Correlator Deployment Package are not stored in plain text.

  Code that is not injected includes the following:

  - Correlator plug-ins, which are imported at runtime. The actual plug-in file must be on a specified path that the correlator can load it from.
  - Any Java class files on the correlator's classpath but not injected.
  - The correlator runtime itself.
- Contents of all context queues.
- Some correlator-global state including `integer.getUnique()` IDs and context IDs.

Note: In general, chunks cannot be persistent. However, chunks used by the Apama Time Format correlator plug-in and the Apama MemoryStore plug-in can be persistent.

When persistence is useful

Enabling correlator persistence is a good fit for applications in which it is unacceptable to lose any information. For example, an application for processing mortgage requests does not need to be available continuously. A small amount of downtime, especially outside business hours, might be acceptable. However, losing any state associated with a mortgage application would be unacceptable.

In such a mortgage processing application, there is unlikely to ever be a point at which there are no open applications and thus no state to preserve. But state might change over the course of weeks, rather than seconds. Enabling correlator persistence lets you implement complex event expressions such as the following:

```
on all LoanRequest() -> (PropertyValuation() and ProofOfIncome())
  within (4 * week) ...
```

With persistence enabled, the event expression can still be running even if weeks elapse between when it is created and when it finally completes. Without persistence, the event expression's state is susceptible to being lost if there are system restarts, software upgrades, and the like.

When non-persistent monitors are useful

A correlator that is running with persistence enabled can have persistent and non-persistent monitors injected. Non-persistence is a good choice for a monitor that does one or more of the following:

- Uses legacy code that does not use the persistence feature. See "Designing applications for persistence-enabled correlators" on page 336.
- Interacts with user-defined correlator plug-ins or Apama correlator plug-ins other than the Time Format or MemoryStore plug-ins.
- Contains large amounts of fast-changing state that is undesirable to persist for performance reasons.
- Operates as a stateless utility that just responds to incoming events.
- Contains minimal state that can be reconstructed by the `onBeginRecovery()` action on a persistent monitor.

Also, all JMon monitors are non-persistent monitors.

How the correlator persists state

When persistence is enabled the correlator periodically writes data to disk to reflect the correlator's runtime state. To do this, the correlator

1. Suspends all execution in the correlator across all contexts.
2. Takes an in-memory snapshot of what needs to be stored.

3. Resumes processing while the state is written to disk.

The correlator waits to suspend execution until all contexts have completed any in-progress event processing and any in-progress deletions. It can take time for the correlator to pause all contexts. Consequently, it is best practice that a single event listener does not take a long time to process. When there is a need to perform a large amount of work try to split the work across multiple events.

How fine-grained to split work depends on the performance requirements of the application. Avoid very fine-grained work units as the overhead of scheduling will start to dominate and lead to the application running slowly.

Committing the snapshot to disk is an atomic operation. That is, a failure while storing state reverts the stored data to the previously successfully stored snapshot.

By default, when you enable persistence the correlator does the following:

- Takes a snapshot of state changes every 200 milliseconds. This is the snapshot initerval. The correlator tracks the in-memory objects that have changed since the last snapshot and writes only that state to disk. If only a small fraction of the correlator's state changes then only a fraction of the correlator's state must be stored for each snapshot.
- Automatically adjusts the snapshot interval. For example, if a significant percentage of the correlator's state changes then the correlator increases the snapshot interval, so that the overall throughput is not adversely affected.
- Stores persistent state in the current directory, which is the directory in which the correlator was started.
- Uses `persistence.db` as the name of the file that contains persistent state. This is the recovery datastore.
- Copies the recovery datastore to the input log if one was specified when the correlator was started. This happens only upon restarting the correlator.
- For applications that do not use the correlator's internal clock (correlators started with the `-Xclock` option), the correlator uses the time of day in the last committed snapshot as the current time in the restarted correlator.

Enabling correlator persistence

Before you enable persistence, you should design and develop your application to handle persistence and recovery. See "Designing applications for persistence-enabled correlators" on page 336.

> **Note:** If a license file cannot be found, the number of persistent monitors that the correlator allows is limited. See "Running Apama without a license file" in *Introduction to Apama*.

To enable correlator persistence, you must proceed as follows:

- Insert the word `persistent` before the monitor declaration for each monitor written in EPL that you want to be persistent. For example:

```
persistent monitor Order {
   action onload() {
   ...
   }
}
```

  For a monitor declared as persistent, the correlator persists the state of all monitor instances of that name, and all instances of events that the monitor instances create.

  You do not mark event types as persistent. Whether or not an event is persisted depends on whether it is used from a persistent or non-persistent monitor. If an event is on a context queue when the correlator takes a snapshot the event is persisted.

- Optionally, define `onBeginRecovery()` and `onConcludeRecovery()` actions in your persistent monitors. The correlator executes any such actions as part of the recovery process. To determine whether you need to define these actions, see "Designing applications for persistence-enabled correlators" on page 336, "Defining recovery actions" on page 335 and "Sample code for persistence applications" on page 338.

- Specify one or more persistence options when you start the correlator. You must always specify the `-P` option to enable correlator persistence.

  Specify only the `-P` option to implement default behavior for correlator persistence. To change default behavior, also specify one or more of the options described in the table below. The correlator uses the default when you do not specify an option that indicates otherwise. For example, if you specify `-P`, `-PsnapshotInterval` and `-PstoreLocation`, the correlator uses the values you specify for the snapshot interval and the recovery datastore location and uses the default settings for all other persistence behavior. For more information on these options, see "Starting the event correlator" in *Deploying and Managing Apama Applications*.

  Note: During development of a persistence application, it varies whether you want to specify a persistence option when you start the correlator. In the earlier stages of development, you might choose not to specify a persistence option since you might make many and frequent changes to early versions of your program, thereby making recovery of a previous version impossible. For example, you might have changed the structure and perhaps added new variables. Once your program structure becomes relatively stable, you must take into account what happens during recovery and you will want to define `onBeginRecovery()` and `onConcludeRecovery()` actions. These actions never get called in a correlator that was not started with a persistence option. To deploy a persistence application, the correlator must be started with a persistence option.

- If you are using both correlator persistence (`-P` option) and the compiled runtime (`--runtime compiled` option), we recommend the use of the `--runtime-cache` option to improve recovery times. For more information on these options, see "Starting the event correlator" in *Deploying and Managing Apama Applications*.

The following table describes correlator persistence behavior, the default behavior, and the options you can specify to change default behavior.

Correlator Persistence Behavior	Default	Option for Changing
The correlator waits a specified length of time between snapshots.	200 milliseconds	`-PsnapshotInterval=`*`interval`* Specify an integer that indicates the number of milliseconds to wait.
The correlator can automatically adjust the snapshot interval according to application behavior. It can be useful to set this to false to diagnose a problem or test a new feature.	True. The correlator automatically adjusts the snapshot interval.	`-PadjustSnapshot=`*`boolean`*
The correlator puts the recovery datastore in a specified directory.	The directory in which the correlator was started. That is, the current directory.	`-PstoreLocation=`*`path`* You can specify an absolute or relative path. The directory must exist.
The correlator copies the snapshot into a specified file. This is the recovery datastore.	`persistence.db`	`-PstoreName=`*`filename`* Specify a filename without a path.
For correlators that use an external clock, the correlator uses a specified time of day as its starting time when it restarts.	The time of day captured in the last committed snapshot.	`-XrecoveryTime` *`num`* To change the default, specify an integer that indicates seconds since the epoch.

Correlator Persistence Behavior	Default	Option for Changing
This behavior is useful only for replaying input logs that contain recovery information.		
The correlator can automatically copy the recovery datastore to the input log when a persistence-enabled correlator restarts.	The correlator copies the recovery datastore to the input log.	`-noDatabaseInReplayLog` You might set this option if you are using an input log as a record of what the correlator received. The recovery datastore is a large overhead that you probably do not need. Or, if you maintain an independent copy of the recovery datastore, you probably do not want a copy of it in the input log.

How the correlator recovers state

When you restart a correlator for which persistence has been enabled the correlator

- Detects, recompiles, and reinjects all code that was injected and not deleted as of the last committed snapshot
- Restarts and restores the state of all persistent monitors as of the last committed snapshot
- Restarts non-persistent EPL monitors and JMon monitors at their `onload()` action
- Executes any `onBeginRecovery()` and `onConcludeRecovery()` actions. See "Defining recovery actions" on page 335 .
- Recovers persistent connections (connections created with `engine_connect -p`) and resumes them at the first opportunity

Code is reinjected in the order in which it was originally injected. The correlator tracks which objects (monitors, events, Java objects) were deleted and does not re-inject them. Such objects might have been deleted explicity with the `engine_delete` utility or implicity as when all instances of a monitor have terminated. If a snapshot shows that an object was deleted and then re-injected, recovery ignores the first injection and re-injects the monitor or event at the point of its second injection.

For a persistent monitor, recovery appears to be a pause in processing. This pause has the potential to be long enough to cause some events to be stale. All non-persistent monitors appear to have spontaneously reverted to their onload state. Communication channels to external components have been interrupted and can be assumed to not yet be connected. Except, the correlator treats connections created with `engine_connect -p`, which are persistent connections, the same as it treats persistent state. Persistent connections continue until you explicitly remove them. Upon recovery, the correlator tries to reconnect to the external components that were connected with persistent connections. However, events sent or received after the last committed snapshot might have been dropped because there is no reliable delivery on persistent connections.

For a non-persistent monitor, recovery appears the same as starting the correlator. The correlator's current time is up-to-date. The monitor is in the state it would be if it were just injected. External components have not yet connected to the correlator. If a monitor initiates a request of a non-persistent monitor then the non-persistent monitor might have to queue the request until a connection is made to an external component, for example, the correlator subscribes to a data stream from an external adapter.

Recovery order

When the correlator recovers state from a recovery datastore it does the following in the following order:

1. Recompile and reinject all source except for deleted events and monitors, which are ignored.
2. Restore objects and listeners in persistent monitors. The correlator does not execute any user code in the first two steps. While it sets up listeners, the listeners cannot yet change state.
3. Set `currentTime` to the `currentTime` of the last committed snapshot, which might be considerably earlier than the current time of day if the correlator was down for some time before recovering.
4. Initiate execution of any `onBeginRecovery()` actions on instances of restored events, monitors, and custom aggregate functions in all persistent monitor instances in all contexts. The order of execution of these actions is undefined. See "Defining recovery actions" on page 335.
5. Quiesce — The correlator waits for all events that have been sent to a context to be processed, and also waits for any events that are sent to a context as a result of those events to be processsed, and so on, until no more events are generated and sent to a context. The correlator also does this for `spawn...to` statements. This is similar to processing all events in all queues. Be careful not to generate an infinite loop of `send...to` statements.
6. Restore events, clock ticks, pending `spawn...to` statements, and so on, that were waiting on context queues when the snapshot was taken.
7. Send a single clock tick of the time at which the correlator is recovered, that is, the current time of day. If `-XrecoveryTime` was set when the correlator was started, the correlator uses that time for the current time of day.
8. Initiate execution of `onload()` actions in all non-persistent monitors in injection order.
9. Quiesce.

10. Initiate execution of any `onConcludeRecovery()` actions on instances of restored events, monitors, and custom aggregate functions in all persistent monitor instances in all contexts. The order of execution of these actions is undefined. See "Defining recovery actions" on page 335.
11. Quiesce.
12. Start generating clock ticks.
13. Start taking persistence snapshots.
14. Open the server port. External components can now connect with the correlator, for example, IAF, `engine_send`, and `engine_receive`.

Defining recovery actions

In a persistent monitor, you can define one or two actions that the correlator executes as part of the recovery process:

- `onBeginRecovery()` — The correlator executes this action after it reinjects all source code and restores state in persistent monitors. The order of execution of `onBeginRecovery()` actions is undefined.
- `onConcludeRecovery()` — The correlator executes this action just before it begins sending clock ticks, taking persistent snapshots, and becoming available for connections to external components. The order of execution of `onConcludeRecovery()` actions is undefined.

Whether you define zero, one or both actions in each persistent monitor is application-dependent. See "Designing applications for persistence-enabled correlators" on page 336 and "Sample code for persistence applications" on page 338.

You can define an event and specify one or both of these actions as fields in the event. If an event defines a recovery action and an instance of the event is live in a persistent monitor, then the correlator calls the action(s) on those objects as well. A live event is reachable from a global variable or listener-captured local variable and consequently is not a candidate for garbage collection.

You can define `onBeginRecovery()` and `onConcludeRecovery()` actions in custom aggregate functions in the same way as you define them in events. When an aggregate function contains an `onBeginRecovery()` or `onConcludeRecovery()` action this action is called on each custom aggregate function instance in a live query in a persistent monitor along with the `onBeginRecovery()` and `onConcludeRecovery()` actions in persistent monitors and events.

The order in which the correlator executes instances of `onBeginRecovery()` actions and instances of `onConcludeRecovery()` actions for objects in a monitor is not defined. If a monitor terminates after execution of `onBeginRecovery()` and before recovered queues have been flushed, the correlator does not call that monitor's `onConcludeRecovery()` action (if it has one). If the correlator terminates all of a monitor's listeners in one execution of `onBeginRecovery()`, later calls to `onBeginRecovery()` for that monitor instance still occur because they might instantiate new listeners. If no listeners exist in a monitor after `onBeginRecovery()` and `onConcludeRecovery()` have been executed for every object in that monitor, the monitor instance terminates as usual.

See "Recovery order" on page 334 for more details about when `onBeginRecovery()` and `onConcludeRecovery()` are executed.

Simplest recovery use case

When you observe the following restrictions the correlator's recovery behavior is straightforward:

- All monitors are persistent. The correlator contains no Java and no chunks.
- There are no implementations of `onBeginRecovery()` or `onConcludeRecovery()` actions.

EPL code that adheres to these restrictions appears to behave as if it is running in a completely reliable and fault tolerant system. The downside is that while the correlator is down, incoming or outgoing events are dropped. If you implement a "retransmit until acknowledge" protocol then the correlator can have a large number of events (and retransmits) to process when it restarts, depending on how long it is down.

Designing applications for persistence-enabled correlators

When you are designing an application that you will deploy on a persistence-enabled correlator you should consider the following issues.

- You do not need to re-inject code after you restart a persistence-enabled correlator. During recovery, the correlator obtains injected code from the recovery datastore.
- To recover from a hardware failure, you must maintain a copy of the recovery datastore on some form of reliable, shared storage. You want to ensure that the storage medium for the recovery datastore is not a single point of failure. This typically means putting it on a fileserver with suitable levels of redundancy (disk, power supply, network and controller) that is accessible by two correlator host servers.
- The length of time between when a correlator shuts down and when it restarts is unpredictable. Consequently, you might want to implement `onBeginRecovery()` actions that do the following:
  - Specify behavior according to how long the down time was. For example, you could write a listener that ignores a subset of old events but matches on a new event.
  - Terminate `on all wait(...)` listeners. Such listeners have the potential to fire many times because the time jumps from the time of the last committed snapshot to the time at which the correlator was restarted.
- It is possible for persistent monitors to communicate with non-persistent monitors and to set up state, such as subscriptions to a stream of data, in a non-persistent monitor. If you need to recover this state, you must write code to do it in the `onConcludeRecovery()` action of a persistent monitor or an event within a

persistent monitor. In a persistent monitor, having an event that manages an activity in a non-persistent monitor is a recommended practice.

Upgrading monitors in a persistence-enabled correlator

While injection order is fixed and you cannot change it, you might want to upgrade a monitor and this would appear to require a change in the injection order. That is, upon recovery, you want the correlator to restore the upgraded monitor and not the older version of the monitor.

Remember that it is an error if you try to inject a monitor while instances of that monitor are already running in the correlator. The correlator never injects a duplicate monitor definition.

In a correlator without persistence enabled, you can terminate all monitor instances and then inject the updated monitor definition. Since all old versions of the monitor had terminated, the correlator would correctly inject the updated monitor even though it had the same name. Also, since persistence is not enabled, there is no recovery process and so recovery of the older version of the monitor is not an issue.

In a persistence-enabled correlator, terminating all instances of a monitor you want to upgrade is unlikely to be an option. To upgrade a monitor without first terminating all old instances of the monitor:

1. Initially deploy a monitor that contains code that enables that monitor to give its state to a new version of the monitor and to terminate upon request. If a deployed monitor does not contain such code it is not possible to upgrade it without terminating all instances.
2. Modify your monitor code to the new behavior you want and be sure to change the name of the monitor. For example, if the old monitor is `RequestLoan`, you might name the new monitor `RequestLoan2`.
3. Add code to your upgraded monitor so it atomically routes events that do the following:
    a. Retrieves the current state of the old monitor.
    b. Checks that the new monitor can upgrade from the old monitor.
    c. Requests the old monitor version(s) to terminate.
    d. Sets up its own listeners.
4. Inject the new version of your monitor.

When your upgrade procedure terminates all instances of the old monitor the recovery process does not restore that monitor since all instances were deleted.

You might find that it makes more sense for your upgrade procedure to leave the instances of the old monitor running while changing the interface for whatever creates new instances of the monitor to create instances of the upgraded monitor instead of instances of the old monitor. The correlator would then be running some old versions of the monitor and some new versions of the monitor. Upon recovery, the correlator would recover both versions until all instances of the old monitor had terminated. This approach might be appropriate when the logic has changed so much that it is not practical to upgrade monitor instances, or when maintaining behavior for existing instances is desired.

Sample code for persistence applications

The topics below provide sample code for persistence applications.

Sample code for discarding stale state during recovery

The following code provides an example of discarding stale data during recovery. This application discards all recovered `Data` events because their data has become stale. However, the application always processes and does not discard `ControlEvent` events.

```
persistent monitor eg1 {
   listener l;
   listener lt;
   action onload() {
      initializeState();
      initiateListeners();
      ControlEvent c;
      on all ControlEvent():c { handleControl(c); }
   }
   action initiateListeners() {
      Data d;
      l:=on all Data():d { process(d); } // Process is moderately expensive
      lt:=on all wait(0.1) { send Average(state) to "output"; }
   }
   action onBeginRecovery() {
      l.quit();  // Discard all recovered Data events.
      lt.quit(); // Stop sending intermittent updates.
                 // Do not flood receivers.
                 // Note that the ControlEvent listener is still present.
                 // The code throttles only Data events. If the
                 // ControlEvent listener is not present, this monitor
                 // would have no listeners and would terminate
                 // after this action.
   }
   action onConcludeRecovery() {
      initiateListeners(); // Go back to normal.
   }
}
```

Sample code for recovery behavior based on downtime duration

The following sample is the same as the discard-stale-data sample with some changes that provide a downtime policy. Downtime is the duration between the last committed snapshot and the time of day upon recovery.

This code sample ignores downtimes that are less than two hours. However, if recovery starts just under the two-hour limit the processing of old data might appear to be beyond the two hour threshold. The downtime policy must take this into account.

```
persistent monitor eg1 {

   import "TimeFormatPlugin" as timeFormatPlugin;
```

```
   // ... onload() and so on
   boolean longDowntime;
   action onBeginRecovery()  {
      // currentTime is the time of the last snapshot, which is
      // approximately when the correlator went down.
      // timeFormatPlugin.getTime() is the actual time of recovery.
      if (timeFormatPlugin.getTime() - currentTime > (60.0 * 60.0 * 2)
         then {
            // If we were down for less than 2 hours, pretend nothing
            // happened.  For longer gaps, skip stale data as it will be
            // too expensive to process it.
            longDowntime:=true;
            log "Correlator was down for a long time - will discard stale
               data.";
            l.quit();  // Discard all recovered Data events.
            lt.quit(); // Stop sending intermittent updates.
                       // Do not flood receivers.
      }
   }
   action onConcludeRecovery() {
      if longDowntime then {
         longDowntime:=false;
         initiateListener(); // Go back to normal.
      }
   }
}
```

Sample code that recovers subscription to non-persistent monitor

This sample code defines a persistent monitor that subscribes to a non-persistent service monitor. Note that the service monitor can handle the case where the subscription is received before the adapter is connected.

```
monitor service_monitor {
   action onload() {
      Subscribe s;
      on all Subscribe():s {
         if not connected then {
            pendingSubscribes.append(s);
         } else {
            if(incrRefCount(s.subkey) then {
               send Adapter_Subscribe(s.subkey) to "output";
            }
         }
      }
      on all wait(1.0) {
         send IsAdapterUp() to "output";
      }
      on all AdapterUp() {
         connected:=true;
         for s in pendingSubsscribes {
            route s;
         }
         pendingSubscribes.clear();
      }
   }
}
persistent monitor eg2 {
   listener l;
   Instance i;
   context svcCtx;
   action spawnedInstance(context c) {
```

```
      svcCtx:=c; // Contains anything required to recover subscription.
      send Subscribe(i.subkey) to svcCtx;
      Data d;
      l:=on all Data():d { process(d); }
   }
   action onConcludeRecovery() {
        // Non-persistent service monitor is now reset to its onload state.
        // Re-subscribe.
      send Subscribe(i.subkey) to svcCtx;
   }
}
```

Requesting snapshots

A persistent or non-persistent monitor can request a snapshot to occur as soon as possible, and be notified of when that snapshot has been committed to disk. You use Apama's Management interface to do this. The Management interface lets you create instances of `Persistence` events and then call the `persist()` action on those events. When the correlator processes a `Persistence` event it takes and commits a snapshot and executes the specified callback action after the snapshot is committed.

To use the Management interface, you add the `Correlator Management` bundle to your Apama project. For details, see "Using the Management interface" on page 399.

Developing persistence applications

While you are writing the EPL code for your persistence application, use Software AG Designer as you usually do and do not enable persistence. When your application is near completion and has been successfully tested, start testing execution of the `onBeginRecovery()` and `onConcludeRecovery()` actions you defined in your application. Do this as follows:

1. Select **Run**, **Run configurations**, **Correlator** component.
2. Add `-P` to the command line of the correlator.
3. Start the correlator.
4. In the **Run configuration**, **Correlator** component, **Initialization** tab, disable all checkboxes so that nothing is reinjected.
5. Stop and restart the correlator. It will have persisted the injected monitors.
6. Test the behavior of `onBeginRecovery()` and `onConcludeRecovery()` actions.
7. If everything is working correctly, you can stop here. Otherwise, modify your code and continue with the following steps.
8. Delete the `persistence.db` file.
9. In the **Run configuration**, **Correlator** component, **Initialization** tab, re-enable all checkboxes so that your code is injected.
10. Start again at step 3 and continue until your code is working as desired.

Ensure that you delete the `persistence.db` file and re-inject fresh monitors only when loss of all state is acceptable, for example, during testing.

Using correlator plug-ins when persistence is enabled

A persistent monitor can import a correlator plug-in only when one of the following conditions is met:

- None of the plug-in's functions/actions, including unused functions/actions, refer to a `chunk` type.
- The plug-in is capable of persisting its chunks. In this release, only the Time Format plug-in and the MemoryStore plug-in are capable of persisting chunks. User-defined correlator plug-ins and other Apama-provided plug-ins cannot persist chunks.

Using the MemoryStore when persistence is enabled

When persistence is enabled a persistent monitor can use the MemoryStore only with a correlator-persistent store. A correlator-persistent store is a store that was created by execution of the `storage.prepareCorrelatorPersistent(store name)` action. A persistent monitor cannot use a store that was created by executing any other `storage.prepare()` action . The only exception to this is if the persistent monitor is in a correlator for which persistence is not enabled. In this situation, the correlator treats persistent monitors in the same way it treats non-persistent monitors.

In a persistence-enabled correlator, both persistent and non-persistent monitors can use correlator-persistent stores. If you try to prepare an in-memory, on-disk or distributed store from a persistent monitor in a persistence enabled correlator, the correlator terminates the monitor that tries to do this. These are runtime errors. The compiler cannot catch these errors. The following table shows when you can use each kind of store.

Store type	Persistent correlator and persistent monitor	Persistent correlator and non-persistent monitor	Non-persistent correlator and persistent monitor	Non-persistent correlator and non-persistent monitor
In-memory		Yes	Yes	Yes
On-disk		Yes	Yes	Yes
Correlator-persistent	Yes	Yes*	Yes*	Yes*
Distributed		Yes	Yes	Yes

* Correlator-persistent store behaves as an in-memory store.

Snapshots include the contents of all correlator-persistent stores that are open. A snapshot can occur at any time, and it is not possible to commit only certain states of correlator-persistent stores or the tables in them. However, when using corelator-persistent stores from persistent monitors, failure and recovery of a correlator should appear as though nothing has happened. That is, all monitor state and table state should be as it was when the most recent snapshot was taken.

Just as you cannot execute `Store.persist()` for in-memory stores, you cannot execute the `Store.persist()` action on correlator-persistent stores. You can, however, use Apama's Management interface to request a snapshot of the entire correlator state and wait for that to complete. See "Using the Management interface" on page 399.

In persistent monitors, `Store`, `Table`, `Row` and `Iterator` events are persistent and their state can be recovered to the latest snapshot. Persistent monitors should not see any inconsistency between the contents of the table and any state in the monitor, including `Store`, `Table`, `Row`, and `Iterator` events. Correlator-persistent stores behave the same as an in-memory stores, except that the state of correlator-persistent stores is preserved across correlator restarts.

When the correlator takes a snapshot, it includes `Row` events held by persistent monitors. Such `Row` events are, of course, versions of rows in a table that is in a correlator-persistent store. A persistence snapshot does not include `Row` events held by non-persistent monitors, even if they represent rows in tables that are in correlator-persistent stores.

Note: The recovery datastore in which the correlator saves snapshots is different from the stores used with the MemoryStore. The recovery datastore contains the state of all persistent monitors, which might include `Row` events, `Iterator` events, and other MemoryStore-related events, and also the state of any correlator-persistent stores created with the MemoryStore. Thus, the recovery datastore contains any correlator-persistent stores. If non-persistent monitors have opened in-memory and/or on-disk stores, those stores operate independently of the recovery datastore. For example, a non-persistent monitor can request persistence for an on-disk store and this on-disk store would not be persisted in the recovery datastore.

In a DataView, you can expose only in-memory and on-disk stores; you cannot expose correlator-persistent stores.

See also "Using the MemoryStore" on page 365.

Comparison of correlator persistence with other persistence mechanisms

Correlator persistence is not the only way to persist Apama application data. The table below compares the various features you can use to persist Apama data. As you can see, correlator persistence provides the most comprehensive, automatic persistence.

Persistence characteristic	Correlator persistence	MemoryStore	Apama Database Connector Adapter (ADBC)
Completeness of what is persisted	All state in persistent EPL monitors	Only state that you explicitly store. Partial listener evaluations are impossible to store.	Only state that you explicitly store. Partial listener evaluations are impossible to store.
Recovery mechanism	Automatic	Manual	Manual
EPL monitors can be notified about recovery	Yes	Yes	Yes
Supported across Apama versions	Yes *	Yes	Yes
Incremental snapshots	Yes	Yes	Yes
Storage type	Embedded	Embedded	Shared servers are supported. You can use any database server or driver.
Atomic snapshots	Yes	Yes	Yes
Performance benefit from pipelining disk writes with processing	Yes	Yes	Yes
Supports multiple contexts	Yes	Yes	Yes

* Please note those upgrading to 5.3 onwards with applications using persistence should read the information about backwards incompatibility at *Release Notes*, "What's New In Apama 5.3", "Backwards Incompatibility with persisted projects recovered to 5.3 from older versions".

Restrictions on correlator persistence

JMon monitors cannot be persistent.

A persistent monitor can use the Apama Time Format and MemoryStore correlator plug-ins and the `chunk` types contained by the events defined by those plug-ins. A persistent monitor cannot use any other `chunk` types. This means that a persistent monitor cannot use an event or plug-in that references a `chunk` type even if the application does not use those chunks.

Please note those upgrading to 5.3 onwards with applications using persistence should read the information about backwards incompatibility at *Release Notes*, "What's New In Apama 5.3", "Backwards Incompatibility with persisted projects recovered to 5.3 from older versions".

9 Common EPL Patterns in Monitors

When developing EPL monitor applications it can be helpful to be familiar with common EPL patterns.

Contrasting using a dictionary with spawning

The sample code in this topic contrasts the use of a dictionary with spawning. Usually, the dictionary approach is preferred. This is because the spawning approach uses an `unmatched` event expression, which is vulnerable to maintenance issues if someone else loads an event listener for a pattern that you expect to have no other matches.

Translation using a dictionary

The events to be processed:

```
event Input { string value; }
event Output { string value; }
event Translation {
   string raw;
   string converted;
}
```

The monitor:

```
monitor Translator {
   dictionary < string, string > translations;

   action onload() {
      Translation t;
      on all Translation():t addTranslation(t);
      Input i;
      on all Input():i translate(i);
   }
   action addTranslation(Translation t) {
      translations[t.raw] := t.converted ;
   }
   action translate(Input i) {
      if translations.hasKey(i.value) then {
         send Output( translations[i.value] ) to "output";
      }
      else { fail(i); }
   }
   action fail(Input i ) {
      print "Cannot translate: " + i.value;
   }
}
```

Translation using spawning

Same events as translation using dictionary.

The monitor:

```
monitor Translator {
   action onload() {
      Translation t;
      on all Translation():t addTranslation(t);
      Input i;
      on all unmatched Input():i fail(i);
```

```
   }
   action addTranslation(Translation t) {
      spawn translation(t);
   }
   action translation(Translation t) {
      on all Input(t.raw) translate(t.converted);
   }
   action translate(string converted) {
      send Output(converted) to "output";
   }
   action fail(Input i) {
      print "Cannot translate: " + i.value;
   }
}
```

Factory pattern

The factory pattern creates a new monitor instance to handle each new item/request. Its essential features include:

- The `onload()` action sets up an event listener for creation events,
- Each creation event causes a monitor instance to be spawned.

There are two common forms of the factory pattern:

- Canonical form

  The monitor instance spawns to an action that initializes the state of the new monitor instance and creates event listeners specific to that monitor instance. The spawned monitor instances use local variables for coassignment and passes them into the action.

  It is likely that some of the data from the creation event is copied into global variables.

- Alternate form

  The initial monitor instance uses coassignment to global variables to set some state before spawning.

  This is a "lazy" form in that it stores the complete creation event inside the monitor. You should not use this form if you are spawning large number of monitor instances and you have a large creation event, where only part of the creation event data needs to be retained.

As an exercise, consider rewriting the example in "Translation using spawning" on page 346, to use the alternate factory form.

Canonical factory pattern

The event:

```
event NewOrder {...}
```

The monitor:

```
monitor OrderProcessor {
```

```
   ...
   action onload() {
      NewOrder order;
      on all NewOrder():order spawn processNewOrder(order);
   }
   action processNewOrder(NewOrder order) {
   ...
   }
}
```

Alternate factory pattern

The event:

```
event NewOrder {...}
```

The monitor:

```
monitor OrderProcessor {
   NewOrder order;
   action onload() {
      on all NewOrder():order spawn processOrder();
   }
   action processOrder() {
   ...
   }
}
```

Using quit() to terminate event listeners

The example below demonstrates the use of `quit()` to terminate an event listener. This example is somewhat contrived in order to demonstrate a situation where it might be desirable to use `quit()`. Typically, other methods are often more appropriate, for example, you can use `die` to kill a monitor instance and you can specify `and not` to terminate an event listener.

The example shows a monitor that trades received orders by breaking them into smaller orders, which it might place concurrently (perhaps on several exchanges). The monitor listens for fills on these orders, and sums up the fills. (A real monitor might also send status on what the filled volume is for each child order together with the total volume filled for the order. The logic for this is not shown here.) When each order is completely filled the monitor terminates the `Trade` event listener for that order.

The events:

```
event OrderIn {integer id; ... }
event OrderOut {integer id; integer volume; ... }
event Trade {integer orderOutId; integer volume; ... }
```

The monitor:

```
monitor TradeOrderAsSeveralSmallerOrders {
   event PlacedOrderRecord {
      listener listener;
      integer volumeToTrade;
      integer volumeTraded;
   }
   dictionary < integer, PlacedOrderRecord > records;
   OrderIn theOrder;
   action onload() {
```

```
      on all OrderIn():theOrder spawn tradeOrder();
   }
   action tradeOrder() {
      // some logic determining when and what volume to trade
   ...
      placeOrder( volume ); //called multiple times
   ...
   }
   action placeOrder(integer volume) {
      PlacedOrderRecord r := new PlacedOrderRecord;
      integer id := integer.getUnique();
      Trade t; r.listener := on all Trade(orderOutId=id):t
         processTrade(t);
      records[id] := r;
      r.volumeToTrade := volume;
      route OrderOut(id,volume,...);
   }
   action processTrade(Trade t) {
      PlacedOrderRecord r := records[t.orderOutId];
      r.volumeTraded := r.volumeTraded + t.volume;
      if (r.volumeToTrade - r.volumeTraded) <= 0 then {
         r.listener.quit();
         ...
      }
      ...
   }
}
```

As stated earlier, for real-world solutions there is generally a better option that using `quit()`. For example, the exchange(s) probably also send `OrderComplete` events. In this case you can change the `on` statement as follows:

```
on all Trade(orderOutId=id):t and not OrderComplete(orderOutId=id)
   processTrade(t);
```

Of course, you must be certain that the `OrderComplete` event can be received only after all trades for that order have been received.

Combining the dictionary and factory patterns

The dictionary and factory patterns are often combined. This pattern achieves separation of concerns by using two monitors. The first monitor is responsible for managing global concerns, for example, it ensures that each order has a unique key. The second monitor is responsible for local concerns, for example, it manages all data associated with processing that order.

The example does the following:

1. The `OrderFilter` monitor accepts `NewOrder` events and checks for uniqueness of the order key.
2. For all orders with unique keys, the `OrderFilter` monitor routes a `ValidOrder` event.

Testing uniqueness

The events:

```
event OrderKey{...}
event NewOrder {
   OrderKey key; //You can use anything for key as long as it is unique
   ...
}
event ValidNewOrder {
   NewOrder order;
}
```

The monitors:

```
monitor OrderFilter {
   dictionary < OrderKey, NewOrder > orders;
   action onload() {
      NewOrder order;
      on all NewOrder():order validateOrder(order);
   }
   action validateOrder(NewOrder order){
      if orders.hasKey(order.key) then{
         print "Duplicate order!"
         print "Original: " + orders[order.key].ToString();
         print "Incoming: " + order.ToString();
      }
      else {
         orders.add(order.key,order);
         route validNewOrder(order);
      }
   }
}

monitor OrderProcessor {
...
   action onload() {
      ValidNewOrder valid;
      on all ValidNewOrder():valid spawn processOrder(valid.order);
   }
   action processOrder( NewOrder order ) {
   ...
   }
}
```

Reference counting

The following pattern is another example that you can use to to keep a count of how many clients are using a particular service object, which in turn can be used to determine the lifetime of these service objects. The example subscription management mechanism is fairly sophisticated, possibly too sophisticated, but it provides the big advantage of separating the concerns by using two monitors. If you decide to change the subscription mechanism, you can do so simply by changing the `ServiceManager` monitor. There is no impact at all on the `ServiceItem` monitor.

The events:

```
package com.apamax.service;
event Subscribe {
   string toWhat;
   string originator;
}
event Unsubscribe {
   string fromWhat;
   string originator;
```

```
}
event CreateServiceItem {
   string what;
}
event DestroyServiceItem {
   string what;
}
```

The monitors:

```
monitor ServiceManager {
   dictionary < string, dictionary < string, integer > > items;

   action onload() {
      Subscribe s;
      Unsubscribe u;
      on all Subscribe():s subscribe(s);
      on all Unsubscribe():u unsubscribe(u);
   }

   action subscribe(Subscribe s){
      if items.hasKey(s.toWhat) then {
         dictionary < string, integer > subscriptions :=
            items[s.toWhat];
         if subscriptions.hasKey(s.originator) then {
            subscriptions[s.originator] :=
               subscriptions[s.originator] + 1;
         }
         else {
            subscriptions[s.originator] := 1;
         }
      }
      else {
         items[s.toWhat] := subscriptions;
         route CreateServiceItem(s.toWhat);
      }
   }

   action unsubscribe(Unsubscribe u) {
      if items.hasKey(u.fromWhat) then {
         dictionary < string, integer > subscriptions :=
            items[u.fromWhat];
         if subscriptions.hasKey(u.originator) then {
            if subscriptions[u.originator] <= 1 then {
               subscriptions.remove(u.originator);
               if subscriptions.size() = 0 then {
                  items.remove(u.fromWhat);
                  route DestroyServiceItem(u.fromWhat);
               }
            }
            else {
               subscriptions[u.originator] :=
                  subscriptions[u.originator] - 1;
            }
         }
         else {
            print "Unsubscribe failed: no originator: " +
               u.toString();
         }
      }
      else {
         print "Unsubscribe failed: no item: " + u.toString();
      }
   }
```

```
}

monitor ServiceItem {
   //...

   action onload() {
      CreateServiceItem c;
      on all CreateServiceItem():c spawn createServiceItem(c);
   }

   action createServiceItem(CreateServiceItem c) {
   //...
      DestroyServiceItem d;
      on all DestroyServiceItem():d destroyServiceItem(d);
   }

   action destroyServiceItem(DestroyServiceItem d) {
   //...die;
   }
}
```

Inline request-response pattern

You can use the `route` command to write EPL that exhibits inline (synchronous) request-response behavior. The following example shows that when you want to perform an ordered pattern of operations that contain (as one operation) a request to another monitor, the subsequent operations must wait until the requesting monitor receives the response.

The ordering of the `route` and `on` statements is not relevant. The correlator sets up the event listener before processing the routed event.

A common mistake is to place code after the `on` statement code block and expect that code to execute after the code in the `on` statement code block.

Routing events for request-response behavior

The events:

```
event Request { integer requestId; ... }
event Response { integer requestId; ... }
```

The monitors:

```
monitor Client {
   action doWork() {
      //do some processing
      ...
      integer id := integer.getUnique();
      route Request(id, ... );
      Response r;
      on Response(requestId=id):r {
      // continue processing
      ...
      // Beware! Any code here will execute immediately
      // (before processing the response)
   }
}
```

```
monitor Server {
   action processRequests() {
      Request r;
      on all Request():r {
         // evaluate response
         route Response(r.id,...);
      }
   }
}
```

Canonical form for synchronous requests

The next example show the canonical form for when you want to code a pattern that specifies two or more synchronous requests.

The events:

```
event RequestA { integer requestId; ... }
event ResponseA { integer requestId; ... }
event RequestB { integer requestId; ... }
event ResponseB { integer requestId; ... }
```

The monitor:

```
monitor Client {
   action doWork() {
      //do some processing
      integer requestId := integer.getUnique();
      route RequestA(requestId,...);
      ResponseA ra;
      on ResponseA(id=requestId):ra doWork2(ra);
   }
   action doWork2(ResponseA ra) {
      //do some more processing
      integer requestId := integer.getUnique();
      route RequestB(requestId,...);
      Response rb;
      on ResponseB(id=requestId):rb doWork3(rb);
   }
   action doWork3(ResponseB rb) {
      //do yet more processing
   }
}
```

Writing echo monitors for debugging

A common practice is to write an echo monitor for debugging purposes. Typically, an echo monitor listens for the same events as your production monitor and tracks various behavior.

Writing an echo monitor is typically straightforward, but keep the following caveat in mind. If your production monitor uses the `unmatched` keyword for a certain event, and your echo monitor listens for the same event, and both monitors are in the same context, your `unmatched` event listener will never trigger. This is because the event listener in the echo monitor matches the event and this prevents the `unmatched` event listener from ever triggering. The scope of an `unmatched` event listener is the context that it is in.

To avoid an `unmatched` event listener that never triggers, specify the `completed` keyword in the event listener in the echo monitor. For example, suppose you have the following code in your production monitor:

```
on all unmatched SubscribeDepth():subDepth {
   doSomething();
}
```

If you want to track `SubscribeDepth` events in your echo monitor, write the event expression in the echo monitor as follows:

```
on all completed SubscribeDepth():subDepth {
   doSomethingElse();
}
```

The `completed` event listener in the echo monitor triggers after the correlator finishes processing the `unmatched` event listener in the production monitor.

10 Using Correlator Plug-ins in EPL

In EPL programs (monitors and queries), you can use standard correlator plug-ins provided with Apama and you can also use correlator plug-ins that you define yourself. A correlator plug-in consists of an appropriately formatted library of C or C++ functions that can be called from within EPL. The event correlator does not need to be modified to enable or to integrate with a plug-in, as the plug-in loading process is transparent and occurs dynamically when required.

To write custom correlator plug-ins, see "Developing Correlator Plug-ins" on page 717.

When using a plug-in, you can call the functions it contains directly from EPL, passing EPL variables and literals as parameters, and getting return values that can be manipulated.

Overhead of using plug-ins

The overhead when using correlator plug-ins is very small.

However, you do need to ensure that you do not block the correlator for a long period of time. For example, you do not want to use a plug-in for doing extensive, synchronous, time-consuming calculations.

If you need to perform a time-consuming operation, use asynchronous processing and use the Apama client SDK to write a separate process that does the computations. For example, the correlator might communicate with this external process by sending `ComputeRequest` events on a particular channel and the process would respond by sending `ComputeResult` events.

When to use plug-ins

A custom plug-in is a suitable solution in the following situations:

- You have an in-house or third-party library of (possibly complex) C/C++ functions that you want to re-use.
- The operations you need to perform are more easily/efficiently performed using the C/C++ language than using EPL. For example, you need to use data structures that are not easily represented in EPL.

When not to use plug-ins

In general, when you can efficiently write the desired operation in EPL, an all-EPL solution is preferable to one that involves custom-developed plug-ins. Apama customers who experience problems with correlator stability when using custom-developed plug-ins will be asked by Software AG Global Support to remove the plug-in and reproduce the problem prior to being offered further technical help. Software AG Global Support lifts this restriction only if the plug-ins have certification from Apama product management.

Using the TimeFormat Event Library

The TimeFormat event library uses the Time Format plug-in.

The `TimeFormat` event provides routines to obtain the current time and convert to or from string representations of time.

Internally, the correlator expresses time as seconds since the Unix Epoc (1 Jan 1970, midnight UTC) - this is the form of `currentTime` and is convenient for performing arithmetic, such as differences between times. For more information on this variable, see "currentTime" on page 912.

To convert from string form to float form, use a `parseTime` method. To convert from float form to string form, use a `format` method. Both take a `format` String, which is a string which describes the string form of the time. For more information, see "Format specification for the TimeFormat functions" on page 359.

The `parseTime` method is available on the `TimeFormat` event directly. Or you can pre-compile a pattern and then perform parsing using the compiled pattern. A `CompiledPattern` object is obtained from the `TimeFormat` event using one of the `compilePattern` methods (depending on which time zone the pattern should use by default). The `CompiledPattern` object can be stored in a monitor variable, as an instance of an event or in a local variable and used by listeners. Re-using a `CompiledPattern` is more efficient than calling one of the `TimeFormat.parseTime` methods as the `format` String only needs to be read and compiled once. Calling parse on the `TimeFormat` event is equivalent to passing the same `format` String to generate a `CompiledPattern` and calling parse on that event. It is also possible to create multiple `CompiledPattern` events if your application needs to use several different formats for time.

For example, the following will behave the same:

```
TimeFormat timeFmt := new TimeFormat;
timeFmt.parseTime(pattern, time);
timeFmt.compilePattern(pattern).parseTime(time);
```

There are also functions to obtain the current system time. `getSystemTime()` provides an absolute time while `getMicroTime()` provides a high precision time, which is suitable for high precision relative times (the absolute value of `getMicroTime()` depends on the host operating system).

Patterns with textual elements operate by default in English, but will instead both produce output and expect input in another language if that has been set in the environment. For example, under Linux, if the correlator is running with the `LC_ALL` environment variable set to `"fr_FR"`, the format `"EEEE dd MMMM yyyy G"` produces and expects `"jeudi 01 janvier 1970 ap. J.-C."` for time `0.0`.

When you use the TimeFormat event library you can use the `TZ` environment variable to select a particular locale to be used by the event library. Specify the value in either of the following formats:

```
Continent/City
Ocean/Archipelago
```

For example: `TZ=Europe/London`. The alternative shortened format will not work correctly. For example, `TZ=GB` will not be recognized. If you specify something like this, Coordinated Universal Time (UTC) is used instead.

Note: For a list of time zones, see "Timezone ID Values" in the "Using Dashboard Viewer" part of *Building and Using Dashboards*.

TimeFormat format functions

The format functions convert the `time` parameter to the local time and return that time in the format you specify.

For usage information, see the *API Reference for EPL (ApamaDoc)*.

TimeFormat parse functions

The parse functions parse the value contained by the `timeDate` parameter according to the format passed in the `format` parameter or wrapped by the `CompiledPattern`.

All functions return the result as a float of seconds since the epoch.

For usage information, see the *API Reference for EPL (ApamaDoc)*.

Notes

For all parse functions:

- If the `timeDate` parameter specifies only a time, the date is assumed to be 1 January 1970 in the appropriate timezone. If the `timeDate` parameter specifies only a date, the time is assumed to be the midnight that starts that day in the appropriate timezone. Adding them together as seconds gives the right result.
- If *`timeDate`* string specifies a time zone, and there is a matching `z`, `Z`, `v`, or `V` in the *`format`* string, the time zone specified in the *`timeDate`* string takes precedence over any other ways of specifying the time zone. For example, when you call the `parseUTC()` or `parseWithTimeZone()` function, and you specify a time zone or offset in the *`timeDate`* string, the time zone or offset specification in the *`timeDate`* string overrides the time zone you specify as a parameter to the `parseWithTimeZone()` function and the normal interpretation of times and dates as UTC by the `parseUTC()` function.
- Parsing behavior is undefined if the format string includes duplicate elements such as `"MM yyyy MMMM"`, has missing elements such as `"MM"`, or it includes potentially contradictory elements and is given contradictory input, for example, `"Tuesday 3 January 1970"` (it was actually a Saturday).
- Dates before 1970 are represented by negative numbers.

Example

The following example returns `837007736`:

```
timeFormat.parseTime("yyyy.MM.dd G 'at' HH:mm:ss", "1996.07.10 AD at 15:08:56")
```

See also "Midnight and noon" on page 365.

The following examples both parse the *timeDate* string as having a time zone of UTC +0900.

```
timeFormat.parseWithTimeZone("DD.MM.YY Z", "01.01.70 +0900", "UTC");
timeFormat.parseUTC("DD.MM.YY Z", "01.01.70 +0900");
```

In the first example, the +0900 specification in the *timeDate* string overrides the UTC specification for the time zone *name* parameter. In the second example, the +0900 specification in the *timeDate* string overrides the UTC specified by calling the parseUTC() function.

Format specification for the TimeFormat functions

The format and parse functions make use of the SimpleDateFormat class provided in the International Components for Unicode libraries. SimpleDateFormat is a class for formatting and parsing dates in a language-independent manner.

Pattern letters in format strings

The TimeFormat functions use the SimpleDateFormat class to transform between a string that contains a time and/or date and a normalized representation of that time and/or date. In this case, the normalized representation is the number of seconds since the epoch.

For the operation to succeed, it is important to define the format string so that it exactly represents the format of the time and/or date you provide as a string in the timeDate parameter to a parse function, or expect to be returned from a format function. You specify the format as a time pattern. In this pattern, all ASCII letters are reserved as pattern letters.

The number of pattern letters determines the format as follows:

- For pattern letters that represent text
  - If you specify four or more letters, the SimpleDataFormat class transforms the full form. For example, EEEE formats/parses Monday.
  - If you specify fewer than four letters, the SimpleDataFormat class transforms the short or abbreviated form if it exists. For example, E, EE, and EEE each formats/parses Mon.
- For pattern letters that represent numbers
  - Specify the minimum number of digits.
  - If necessary, SimpleDateFormat prepends zeros to shorter numbers to equal the number of digits you specify. For example, m formats/parses 6, mm formats/parses 06.
  - Year is handled specially. If the count of y is 2, the year is truncated to 2 digits. For example, yyyy formats/parses 1997, while yy formats/parses 97.
  - Unlike other fields, fractional seconds are padded on the right with zeros.

- For pattern letters that can represent text or numbers
  - If you specify three or more letters, the `SimpleDataFormat` class transforms text. For example, `MMM` formats/parses `Jan`, while `MMMM` formats/parses `January`.
  - If you specify one or two letters, the `SimpleDataFormat` class transforms a number. For example, `M` formats/parses `1`, and `MM` formats/parses for `01`.

The following table provides the meaning of each letter you can specify in a pattern. After the table, there are a number of combined examples.

Descriptions of pattern letters in format strings:

Symbol	Meaning	Presentation	Example	Sample Result
`G`	Era designator	Text	`G` `G`	`AD` `BC`
`y` (lowercase)	Year	Number	`yy` `yyyy`	`96` `1996`
`Y` (uppercase)	Year for indicating which week of the year. Use with the `w` symbol. See "Week in year" later in this table.	Number	See example for "Week in year".	
`u`	Extended year	Number	`uuuu`	`5769`

`M`	Month in year	Text or Number	`M`
			`MM`
			`MMM`
			`MMMM`
				`9`
				`09`
				`Sep`
				`September`

`d`	Day in month	Number	`d`
			`dd`
			`dd`
				`7`
				`07`
				`25`

Symbol	Meaning	Presentation	Example	Sample Result
`h`	Hour in AM or PM (1-12)	Number	`hh`	`05`

`H`	Hour in day (0-23)
	See also "Midnight and noon" on page 365.
		Number	`H`
			`HH`
			`HH`
				`0`
				`05`
				`14`

`m`	Minute in hour
	See also "Midnight and noon" on page 365.
		Number	`m`
			`mm`
			`mm`
				`3`
				`03`
				`55`

`s`	Second in minute	Number	`s`
			`ss`
			`ss`
				`5`
				`05`
				`59`

`S`	Fractional second	Number	`S`
			`SS`
			`SSS`
				`2`
				`20`
				`200`

`E`	Day of week	Text	`E`
			`EE`
			`EEE`
			`EEEE`
				`Fri`
				`Fri`
				`Fri`
				`Friday`

`e`	Day of week (1-7) This is locale dependent. Typically, Monday is 1.	Number	`e`	`4`
`D`	Day in year	Number	`D` `DD`	`7` `07`

Symbol	Meaning	Presentation	Example	Sample Result
			`DDD` `DDD`	`007` `123`
`F`	Day of particular week in month (1-7). Use with `W` (uppercase) for week in month. See "Week in month" later in this table.	Number	See example for "Week in month".	

`w` (lowercase)	Week in year. Use with uppercase `Y`.
	The week that contains January 1st is week 1.
	For example, if a week starts on Monday and ends on Sunday, and if January 1st is a Sunday, then week 1 contains December 26 - 31 plus January 1.
		Number	The first example below uses uppercase `Y`. The second example shows the difference when you use lowercase `y`.
			`"'Week' w YYYY"`
			`"'Week' w yyyy"`
				Suppose you are transforming December 31st, 2008, which is a Wednesday.
				`"Week 1 2009"`
				`"Week 1 2008"`

`W` (uppercase)	Week in month. The week that contains the 1st of the month is week 1. For example, if a week starts on Monday and ends on Sunday, and if July 1 is a	Number	`"'Day' F 'of Week' W"`	`"Day 2 of Week 3"`

Symbol	Meaning	Presentation	Example	Sample Result
	Friday (5), then week 1 of July contains June 27 - 30 and July 1 - 3.			
`a`	AM/PM marker	Text	`a` `a`	`AM` `PM`

`k`	Hour in day (1-24)	Number	`k`
			`kk`
			`kk`
				`1`
				`01`
				`24`

`K`	Hour in AM/PM (0-11)	Number	`K`
			`KK`
			`KK`
				`0`
				`07`
				`11`

`z`	Time zone	Text	`z`	`Pacific Standard Time`
`Z`	Time zone (RFC 822)	Number	`Z`	`-0800`
`v`	Generic time zone	Text	`v`	`Pacific Time`
`V`	Time zone abbreviation	Text	`V`	`PT`
`VVVV`	Time zone location	Text	`VVVV`	`United States (Los Angeles)`
`g`	Julian day	Number	`g`	`2451334`
`A`	Milliseconds in day	Number	`A`	`69540000`

Symbol	Meaning	Presentation	Example	Sample Result
'	Escape for text	Delimiter	"'Week' w YYYY"	"Week 1 2009"
''	Single quote	Literal	"KK 'o''clock'"	"11 o'clock"

Any character in the format pattern that is not in the range of ['a'..'z'] or ['A'..'Z'] is treated as quoted text. For example, the following characters can be in a timeDate string without being enclosed in quotation marks:

:
.
,
#
@

A pattern that contains an invalid pattern letter results in a -1 return value.

The following table gives examples that assume the US locale:

Format pattern	Suitable timeDate string
yyyy.MM.dd G 'at' HH:mm:ss z	1996.07.10 AD at 15:08:56 PDT
EEE, MMM d, ''yy	Wed, July 10, '96
h:mm a	12:08 PM
hh 'o''clock' a, zzzz	12 o'clock PM, Pacific Daylight Time
K:mm a, z	0:00 PM, PST
yyyyy.MMMMM.dd GGG hh:mm aaa	1996.July.10 AD 12:08 PM

When parsing a date string using the abbreviated year pattern (y or yy), SimpleDateFormat (and hence all parse functions) must interpret the abbreviated year relative to some century. It does this by adjusting dates to be within 79 years before and 19 years after the time the SimpleDateFormat instance is created. For example, using a pattern of MM/dd/yy and a SimpleDateFormat instance created on Jan 1, 1997, the string 01/11/12 would be interpreted as Jan 11, 2012 while the string 05/04/64 would be interpreted as May 4, 1964. During parsing, only strings consisting of exactly two digits, as defined by `Unicode::isDigit()`, will be parsed into the default century. Any other numeric string, such as a one digit string, a three or more digit string, or a two digit string that is not all digits (for example, `-1`), is interpreted literally. So `01/02/3` or `01/02/003` are parsed, using the same pattern, as Jan 2, 3 A.D. Likewise, `01/02/-3` is parsed as Jan 2, 4 B.C. Behavior is undefined if you specify a two-digit date that might be either twenty years in the future or eighty years in the past.

If the year pattern has more than two `y` characters, the year is interpreted literally, regardless of the number of digits. So using the pattern `MM/dd/yyyy`, `01/11/12` parses to Jan 11, 12 A.D.

When numeric fields abut one another directly, with no intervening delimiter characters, they constitute a run of abutting numeric fields. Such runs are parsed specially. For example, the format `HHmmss` parses the input text `123456` to 12:34:56, parses the input text `12345` to 1:23:45, and fails to parse `1234`. In other words, the leftmost field of the run is flexible, while the others keep a fixed width. If the parse fails anywhere in the run, then the leftmost field is shortened by one character, and the entire run is parsed again. This is repeated until either the parse succeeds or the leftmost field is one character in length. If the parse still fails at that point, the parse of the run fails.

For time zones that have no names, `SimpleDateFormat` uses strings `GMT +hours:minutes` or `GMT-hours:minutes`.

The calendar defines what is the first day of the week, the first week of the year, whether hours are zero based or not (`0` vs. `12` or `24`), and the time zone. There is one common number format to handle all the numbers; the digit count is handled programmatically according to the pattern.

Midnight and noon

The format `"HH:mm"` parses `"24:00"` as midnight that ends the day. Given the formal `"hh:mm a"`, both `"00:00 am"` and `"12:00 am"` parse as the midnight that begins the day. Note that `"00:00 pm"` and `"12:00 pm"` are both midday.

Using the MemoryStore

The MemoryStore provides an in-memory, table-based, data storage abstraction within the correlator. All EPL code running in the correlator in any context can access the data stored by the MemoryStore. In other words, all EPL monitors running in the correlator have access to the same data.

The Apama MemoryStore can also be used in a distributed fashion to provide access to data stored in a MemoryStore to applications running in a cluster of multiple correlators. For more information on the distributed MemoryStore, see "Using the distributed MemoryStore" on page 379.

The MemoryStore can also store data on disk to make it persistent, and copy persistent data back into memory. However, the MemoryStore is primarily intended to provide all monitors in the correlator with in-memory access to the same data.

Use the MemoryStore to share data among monitors in the correlator or to persist data on disk. If the situations listed below apply to you, the standard Apama ADBC

(Apama Database Connector) adapter is likely to be a better option for you than the MemoryStore.

- You want to interoperate directly with data users other than Apama.
- You need access to more data than can fit in memory.
- You need to key on more than one field.
- You want to join tables.

See also "Using the MemoryStore when persistence is enabled" on page 341.

See "Using the Apama Database Connector" in *Connecting Apama Applications to External Components*.

For details about the event types that provide the MemoryStore interface, see the *API Reference for EPL (ApamaDoc)*.

Introduction to using the MemoryStore

Data that the MemoryStore stores must be one of the following types: `boolean`, `float`, `integer` or `string`.

To use the MemoryStore, you add the **MemoryStore Plugin** bundle to your Apama project. This lets you create instances of MemoryStore events and then call actions on those events. Available actions include the following:

- Creating stores that contain tables
- Defining the schema for the rows in a table
- Creating tables and associating a schema with each table
- Storing, retrieving, updating, and committing rows of data
- Copying tables to disk to make the data persistent
- Making stored data available in data views for use by dashboards

You can use the MemoryStore in parallel applications. You can use the MemoryStore in a persistent monitor in a persistence-enabled correlator. See "Using the MemoryStore when persistence is enabled" on page 341.

For information on using the MemoryStore in a distributed fashion, see "Using the distributed MemoryStore" on page 379.

Overview of MemoryStore events

The MemoryStore defines the following events in the `com.apama.memorystore` package. Most of these events contain `action` fields that serve as the MemoryStore interface.

- `Storage` — The event type that provides the interface for creating stores.
- `Store` — A `Store` event represents a container for a uniquely named collection of tables.

- `Table` — A `Table` event represents a table in a store. A table is a collection of rows. Each table has a unique name within the store. A table resides in memory and you can store it on disk if you want to.
- `Schema` — A `Schema` event specifies a set of fields and the type of each field. Each `Schema` event represents the schema for one or more tables. Each table is associated with one schema. All rows in that table match the table's schema.
- `Row` — A `Row` event represents a row in a table. A row is an ordered and typed set of named fields that match the schema associated with the table that the row belongs to. Each row is associated with a string that acts as its key within the table. You can change the values of the fields in a row.
- `Iterator` — Provides the ability to manipulate each row of a table in turn.
- `Finished` — The MemoryStore enqueues a `Finished` event when processing of an asynchronous action is complete.
- `RowChanged` — The `RowChanged` event is used only in a distributed store. In a distributed store, the `RowChanged` event is sent to all applications that have subscribed to a specific table whenever changes to data in a row in that table have been successfully committed. This behavior is optional and is supported by some, but not all, third-party distributed cache providers.

For details about these events, see the ApamaDoc documentation for MemoryStore.

Adding the MemoryStore bundle to your project

To use the MemoryStore, you need only add the `MemoryStore` bundle to your project as described below.

Note: To use the distributed MemoryStore, you add the Distributed MemoryStore adapter instead. The procedure for this is different and is described in "Adding distributed MemoryStore support to a project" on page 384.

Adding the `MemoryStore` bundle to your project makes the `MemoryStore.mon` file available to the monitors in your project. When you run your project, Software AG Designer automatically injects `MemoryStore.mon`. If you want to examine this file, it is in the `monitors/data_storage` directory of your Apama installation directory. `MemoryStore.mon` is the interface between the monitors in your application and the MemoryStore plug-in. Your application creates events of the types defined in that file and calls actions on those events to use the MemoryStore's facilities. There is never any need to import or call the plug-in directly.

Note: If you use the `engine_inject` utility to manually inject your EPL, instead of using Software AG Designer, and you want to expose MemoryStore tables to dashboards, you need to inject the `MemoryStoreScenarioImpl.mon` monitor, which is in the same directory as the `MemoryStore.mon` file.

To add the MemoryStore bundle

1. In Software AG Designer, open the project in the Apama Developer perspective.
2. In the **Project Explorer**, right-click the project name and select **Apama > Add Bundle** from the context menu. The Add Bundle dialog is displayed.
3. In the Add Bundle dialog, select **The MemoryStore** bundle and click **OK**.

Steps for using the MemoryStore

To use the MemoryStore, you must first add the MemoryStore bundle to your project, unless you are using the distributed MemoryStore. (If you are using the distributed MemoryStore, instead of adding the MemoryStore bundle, you need to add the Distributed MemoryStore adapter. For more information on this, see "Adding distributed MemoryStore support to a project" on page 384.) After you add the MemoryStore bundle, you write EPL that does the following:

1. Prepare and then open a store that will contain one or more tables.
2. Define the data schema for the rows that will belong to the table.
3. Prepare and then open a table in a store.
4. For applications that will access data in a distributed store, if the underlying third-party distributed cache provider supports notifications, optionally subscribe to the table in order to receive notifications when data has changed. For see further information, "Notifications" on page 387.
5. Get a new or existing row from the table.
6. Modify the row.
7. Commit the modified row to the table.
8. Repeat the three previous steps as often as needed.
9. Optionally, use an iterator to step through all rows in the table.
10. Optionally, store the in-memory table on disk.

Preparing and opening stores

The first step for storing data in memory is to create an instance of a `Storage` event. You use the `Storage` event to prepare and open a store to which you can add tables. `Storage` events define actions that do the following:

- Request preparation of a store.
- Open a store that has been prepared.

`Storage` events contain no data. All `Storage` events are alike and exist only to provide the interface for preparing and opening stores.

If you do not require on-disk persistence, you can prepare a store in memory. If you do require on-disk persistence, you can specify the file that contains (or that you want to contain) the store. Depending on the action you call to open the store, the MemoryStore does one of the following:

- Opens the store for read-write access.
- Opens the store for read-only access.
- Opens the store for read-write access. Create the store if it does not already exist.

Preparation of stores is asynchronous. Actions that prepare stores return an ID immediately. When the MemoryStore completes preparation it enqueues a `Finished` event that contains this ID. You should define an event listener for this `Finished` event. The `Finished` event indicates whether or not preparation was successful.

You can open a store only after receiving a `Finished` event that indicates successful preparation.

For example, the following code fragment declares a `Storage` type variable and a `Store` type variable. It then calls the `prepareOrCreate()` action on the `Storage` type variable and saves the returned ID in the `Store` type variable. The name of the new store is `storename` and the store will be made persistent by saving it in the `example.dat` file. Finally, this code fragment declares a `Finished` event variable and an event listener for a `Finished` event whose ID matches the ID returned by the preparation request.

```
using com.apama.memorystore.Storage;
using com.apama.memorystore.Store;
using com.apama.memorystore.Finished;

monitor Test {
   Storage storage;
   Store store;

   action onload() {
      integer id := storage.prepareOrCreate("storename", "/tmp/example.dat");
      Finished f;
      on Finished(id,*,*):f
      onStorePrepared(f);
      ...
  }
}
```

After a store has been successfully prepared, you can open it:

```
action onStorePrepared(Finished f) {
   if not f.success then { log "Whoops"; die; }
   store := storage.open("storename");
```

All subsequent examples assume that the appropriate `using` statements have been added.

Any monitor instance can open a store after that store has been successfully prepared. However, monitor `A` has no information about whether or not monitor `B` has prepared a particular store.

Therefore, each monitor should prepare any store it needs, and then prepare any tables it needs within that store. There is no way to pass `Store` or `Table` events from one monitor to another. Multiple monitors can prepare and open the same store or table at the same time.

There are several different actions available for preparing a store:

- `Storage.prepareInMemory(string name)` returns `integer` prepares an in-memory store with the name you specify. All tables are empty when prepared for the first time. Persistence requests are ignored and immediately return a successful `Finished` event.
- `Storage.prepare(string name, string filename)` returns `integer` does the same thing as `Storage.prepareInMemory` and it also associates that store with the database file you specify. If there is data in the database file the MemoryStore loads the store with the data from the file when you prepare a table. Persistence requests write changes back to the file. The specified file must exist.
- `Storage.prepareOrCreate(string name, string filename)` returns `integer` does the same thing as `Storage.prepare()` except that it creates the file if it does not already exist.
- `Storage.prepareReadOnly(string name, string filename)` returns `integer` does the same thing as `Storage.prepare` and it also opens for read-only access the database file you specify. The MemoryStore will load the store with data from the file when you prepare the table. Persistence requests are refused and return a failure `Finished` event
- `Storage.prepareCorrelatorPersistent(string name)` returns `integer` prepares a store that the correlator automatically persists. Each time the correlator takes a snapshot, the snapshot includes any correlator-persistent stores along with the contents of those stores.
- `Storage.prepareDistributed(string name)` returns `integer` prepares a distributed store which will be available to applications running in a cluster of correlators. The *name* argument is a unique identifier that specifies the name of a configured distributed store. For information on adding a distributed store to a project, see "Adding a distributed store" on page 385.

Suppose a monitor instance calls one of the `Storage.prepare()` actions and the action is successful. Now suppose another monitor instance calls the same `Storage.prepare()` variant with the same table name and, if applicable, the same filename, as the previously successful call. The second call does nothing and indicates success immediately. However, if a monitor instance makes a `Storage.prepare()` call and specifies the same table name as was specified in a previously successful `prepare()` call, that call fails immediately if at least one of the following is different from the successful call:

- The variant of the `prepare()` action called
- The specified file name or store name (if applicable)

For example, suppose a monitor made the following successful call:

```
Storage.prepare("foo", "/tmp/foo.dat")
```

After this call, the only prepare call that can successfully prepare the same table is

```
Storage.prepare("foo", "/tmp/foo.dat")
```

The following calls would all fail:

```
Storage.prepareInMemory("foo")
Storage.prepareOrCreate("foo", "/tmp/foo.dat")
Storage.prepareReadOnly("foo", "/tmp/foo.dat")
Storage.prepare("foo", "/tmp/bar.dat")
```

If a monitor makes a call to `prepare()` that matches a prepare action that is in progress, the result is the same as the result of the prepare that is in progress.

Description of row structures

A schema consists of an ordered list of the names and types of fields that define the structure of a row. For example, the following schema consists of one field whose name is `times_run` and whose type is `integer`:

```
Schema schema := new Schema;
schema.fields := ["times_run"];
schema.types := ["integer"];
```

The `Schema` event has additional members that indicate how to publish the table. See "Exposing in-memory or persistent data to dashboards" on page 378.

The schema does not include the row's key. The key is always a string and it does not have a name. Each row in a table is associated with a key that is unique within the table. The key provides a handle for obtaining a particular row. The row does not contain the key.

Two schemas match when they list the same set of field names and types in the same order and choose the same options for exposing dataviews.

`Table` events define actions that do the following:

- Retrieve a row by key. The returned object is a `Row` event.
- Remove a row by key
- Remove all rows
- Obtain a `sequence` of keys for all rows in the table
- Obtain an iterator to iterate over the rows in the table
- Determine if any row in the table has a particular key
- Store on disk the changes to the in-memory table
- Subscribe (and unsubscribe) to a table to be notified when a row has changed. (Note, this is only supported for tables in a distributed store, and only if the underlying provider supports this feature.)
- Modify a row by key
- Modify all rows
- Obtain the position in a schema of a specified field.
- Obtain the name of the table

- Obtain the name of the store that contains the table

For details about these `Table` event actions, see the MemoryStore ApamaDoc at `APAMA_HOME\doc\ApamaDoc\index.html`.

Retrieval of a row from a table by key always succeeds (although retrieving a row from a table in a distributed store can throw an exception). If the row already exists, the MemoryStore returns a `Row` event that provides a local copy of the row. The content of this `Row` event does not change if another user modifies the in-memory version of the row in the table. If the row does not already exist, the MemoryStore populates a `Row` event with default values and returns that with field values as follows:

- `boolean` types are false
- `float` types are `0.0`
- `integer` types are `0`
- `string` types are empty (`""`)

`Row` events define actions that do the following:

- Get and set `boolean`, `float`, `integer`, and `string` fields by name. These actions modify only the local copy (your `Row` event) and not the in-memory version of the row. The in-memory version of the row is available to all monitors. If another user of the table retrieves the same row, that user receives a `Row` event that contains a copy of the in-memory version of the row; that user does not receive a copy of your modified, local version of the row.
- Commit a modified `Row` event. That is, you modify your local `Row` event, and commit the changes, which updates the shared row in the table. This makes the update available to all monitors.
- Get the value of a row's key.
- Determine whether a row was present in the table when the local copy was provided.
- Obtain the name of the table the row is in.
- Obtain the name of the store the row's table is in.

The `Row.commit()` action modifies only the in-memory copy of the row so it is a synchronous and non-blocking operation. Note, in a distributed store, `Row.commit()` writes the value to the distributed store, which may be a fast, local operation or it may involve writing data to one or more remote nodes. If any other user of the table modifies the in-memory row between the time you obtain a `Row` event that represents that row and the time you try to commit your changes to your `Row` event, the `Row.commit()` action fails and the monitor instance that called `Row.commit()` dies. Therefore, if you are sharing the table with other users or using a distributed store, you should call `Row.tryCommit()` instead of `Row.commit()`. If it fails you must retry the commit operation by retrieving the row again (that is, obtaining a new `Row` event that contains the latest content of the in-memory row), reapplying the changes, and then calling the

`Row.tryCommit()` action. This ensures that you always make changes that are consistent and atomic within the shared version of the row.

However, it is not possible to make atomicity guarantees across rows or tables.

Preparing and opening tables

After you have an open store, you can add one or more tables to that store. You call actions on `Store` events to create tables. `Store` events define actions that do the following:

- Prepare a table. You specify a table name and a schema. This call is asynchronous. The MemoryStore enqueues a `Finished` event that indicates success or failure. If the table does not exist, the MemoryStore creates an empty table.
- Open a table that has been prepared
- Store on disk the in-memory changes to tables.

If the store that contains the table is persistent and the table exists on disk then the on-disk schema must match the schema that you specify when you call the action to prepare the table. The schemas must also match if the table is a distributed table that already exists in a distributed store. If the schemas do not match, the `Finished` event that the MemoryStore enqueues includes an error message.

Note: A persistent table can be an on-disk table or a table in a correlator-persistent store.

If a monitor instance calls `Store.prepare()` with the same table name and schema as those of a previously successful `Store.prepare()` call, the call does nothing and indicates success immediately. If a monitor instance calls `Store.prepare()` and specifies the same table name but the schema does not exactly match, that call fails immediately. If a monitor makes a call to `Store.prepare()` that matches a preparation that is in progress, the result is the same as the result of the preparation that is in progress.

If the table you want to prepare is persistent and it has not yet been loaded into memory then the MemoryStore loads the table's on-disk data into memory in its entirety. The MemoryStore enqueues the `Finished` event when loading the table is complete.

To use a table that is in memory, you must retrieve a handle to it from the store that contains it. Obtaining a handle to a prepared (loaded) table is a synchronous action that completes immediately and does not block. The calling monitor instance dies if you try to obtain a handle to a table that is not prepared or that is in the process of being prepared.

For example:

```
integer id := store.prepare("tablename", schema);
on Finished(id,*,*):f onTablePrepared(f);

action onTablePrepared(Finished f) {
   if not f.success then { log "Whoops"; die; }
   Table tbl := store.open("tablename");
```

Note: The term "`table`" is a reserved keyword. Consequently, you should not use "`table`" as a variable name.

Preparation of a table can fail for a number of reasons including, but not limited to, the following:

- You call `prepare()` on an existing table and the schema of that table and the schema specified in the `prepare()` call do not match.
- You call `prepare()` on an existing in-memory table and the `exposePersistentView` setting is true for the schema you specify in the `prepare()` call.
- You call `prepare()` on a table that does not exist and the store has been opened read-only.
- You call `prepare()` on a table that does not exist in a persistent store and the attempt to create a new table in the persistent store fails, perhaps because the disk is full.
- The on-disk version of the table is corrupt in some way.
- You set `exposePersistentView` on a table in a correlator-persistent store.
- You set `exposeMemoryView` or `exposePersistentView` to true for a distributed store .
- The third-party distributed store implementation throws an exception for some reason such as unrecoverable network failure.

Using transactions to manipulate rows

In a monitor, any changes you make to `Row` events are local until you commit those changes. In other words, any changes you make actually modify the `Row` events that represent the in-memory rows. After you commit the changes you have made to your `Row` events, the updated in-memory rows are available to all monitors in the correlator and to all other members of the distributed cluster if you are using a distributed store.

Note: When you modify a `Row` event and you want to update the actual row with your changes, you must commit your changes. It does not matter whether or not the table is in a correlator-persistent store.

The `Row` event defines the following actions for committing changes:

- `Row.commit()` —Tries to commit changes to `Row` events to the in-memory table. If nothing else modified the in-memory row in the table since you obtained the `Row` event that represents that row the MemoryStore commits the changes and returns. The update is available to all monitors. If the in-memory row in the table has been modified, the monitor instance that called this action dies, leaving the in-memory table unchanged.
- `Row.tryCommit()` — Behaves like `commit()` except that it does not kill the monitor instance upon failure. If the in-memory row in the table has been modified, this action returns false and leaves the in-memory table unchanged. If this action is successful, it returns true.

- `Row.tryCommitOrUpdate()` — Behaves like `tryCommit()` except that when it returns false it also updates your local `Row` event to reflect the current state of the in-memory row. In other words, if the in-memory row has been modified, this action does the following:
    - Leaves the in-memory row unchanged.
    - Updates the local `Row` event that represents this row to reflect the current state of the table. Any local, uncommitted modifications are lost.
    - Returns false.

Determining which commit action to call

If you are certain that you are the only user of a table and if it is okay for your monitor instance to be killed if you are wrong, you can use `commit()`.

If you want to use a simple loop like the one below, or if you intend to give up if your attempt to commit fails, then use `tryCommit()`.

```
boolean done := false;
while not done {
   Row row := tbl.get("foo");
   row.setInteger("a",123);
   done := row.tryCommit();
}
```

However, the loop above calls `tbl.get()` every time around. If you think there might be a high collision rate, it is worth optimising to the following, more efficient design:

```
Row row := tbl.get("foo");
boolean done := false;
while not done {
   row.setInteger("a",123);
   done := row.tryCommit();
   if not done then { row.update(); }
}
```

The `row.tryCommitOrUpdate()` action makes the example above a little simpler and considerably more efficient:

```
Row row := tbl.get("foo");
boolean done := false;
while not done {
   row.setInteger("a",123);
   done := row.tryCommitOrUpdate();
}
```

Alternatively, there is a packaged form of that loop that you might find more convenient:

```
action doSomeStuff(Row row) {
   row.setInteger("a",123);
}
tbl.mutate("foo", doSomeStuff);
```

This example is equivalent to the previous one, both in behavior and performance. Which to use is a matter of context, style and personal preference.

Creating and removing rows

To create a row in a table, call the `get()` or `add()` action on the table to which you want to add the row. The action declaration for the `get()` action is as follows:

```
action get(string key) returns Row
```

The `Table.get()` action returns a `Row` event that represents the row in the table that has the specified key. If there is no row with the specified key, this action returns a `Row` event that represents a row that contains default values. A call to the `Row.inTable()` action returns false. For example:

```
boolean done := false;
integer n := -1;
while not done {
   Row row := tbl.get("example-row");
   n := row.getInteger("times_run");
   row.setInteger("times_run", n+1);
   done := row.tryCommit();
}
send Result(
   "This example has been run " +n.toString() +" time(s) before")
   to "output";
```

The `add()` action does the same as the `get()` action, except that it does not check if the row that is to be added already exists in the table until `commit()` is called and it therefore never throws an exception. If you are sure that the row does not yet exist, you can use `add()` as this is faster than `get()`.

To remove a row from a table, call the `Table.remove()` action on the table that contains the row. The action declaration is as follows:

```
action remove(string key)
```

The `Table.remove()` action removes the row with the specified key from the table. If the row does not exist, this action does nothing.

It is also possible to remove a row transactionally, by calling `Table.get()` and then `Row.remove()` and `Row.commit()`. This strategy lets you check the row's state before removal. The `Row.commit()` action fails if the shared, in-memory row has been updated since the `Table.get()` action.

In some circumstances, using `Row.remove()` is essential to guarantee correctness. For example, when decrementing a usage counter in the row and removing the row when the count reaches zero. Otherwise, another correlator context might re-increment the count between it reaching zero and the row being removed.

Iterating over the rows in a table

Iterators have operations to step through the table and determine when the end has been reached. Provided an iterator is not at the table's end, the key it is at can be obtained.

`Iterator` events define actions that do the following:

- Step through the rows in a table.
- Determine when the last row has been reached.

- Obtain the key of the row that the iterator is at. The iterator must not be at the end of the table for this action to be successful.
- Obtain a `Row` event to represent the row that the iterator is at.

The following sample code reads table content:

```
Iterator i := tbl.begin();
while not i.done() {
   Row row := i.getRow();
   if row.inTable() then {
      // Put code here to read the row in the way you want.
   }
   i.step();
}
```

The following sample code modifies table content:

```
Iterator i := tbl.begin();
while not i.done() {
   Row row := i.getRow();
   boolean done := false;
   while row.inTable() and not done {
      // Put code here to modify the row in the way you want.
      done := row.tryCommitOrUpdate();
   }
   i.step();
}
```

Iterating through a table is always safe, regardless of what other threads are doing. However, if another context adds or removes a row while you are iterating in your context, it is undefined whether your iterator will see that row.

Furthermore, it is possible for another context to remove a row while your iterator is pointing at it. If this happens, a subsequent `Iterator.getRow()` returns a `Row` event that represents a row for which `Row.inTable()` is false.

If an EPL action loops, the correlator cannot perform garbage collection within that loop. (See "Optimizing EPL programs" on page 422.) Performing intricate manipulations on many rows of a large table could therefore create so many transitory objects that the correlator runs out of memory. If this becomes a problem, you can divide very large tasks into smaller pieces, each of which is performed in response to a routed event. This gives the correlator an opportunity to collect garbage between delivering successive events.

Requesting persistence

After changing a MemoryStore table, you can call the `Table.persist()` action to store the changes on disk. Note that you can call `persist()` only on tables in an on-disk store; you cannot call `persist()` on tables in correlator-persistent, in-memory, or distributed stores. The correlator automatically persists correlator-persistent stores and their contents at the same time as the rest of the correlator runtime state. Updating a table on disk is an asynchronous action. The MemoryStore enqueues a `Finished` event to indicate success or failure of this action. The persistent form of the database that contains the tables is transactional. Consequently, if there is a hardware failure either all of the grouped changes are made or none of them are made.

Following is an example of storing a table on disk:

```
integer id := tbl.persist();
on Finished(id,*,*):f onPersisted(f);

action onPersisted(Finished f) {
   if not f.success then { log "Whoops"; die; }
   emit "All OK";
```

When you update a table, the MemoryStore copies only the changes to the on-disk table.

To improve performance, the MemoryStore might group persistence requests from multiple users of a particular store. This means that calling `persist()` many times in rapid succession is efficient, but this does not affect correctness. If the MemoryStore indicates success, you can be certain that the state at the time of the `persist()` call (or at the time of some later `persist()` call) is on disk.

You can call the `Store.backup()` action to backup the on-disk form of a store while it is open for use by the correlator. This is an asynchronous action that immediately returns an ID. The MemoryStore enqueues a `Finished` event that contains this ID to indicate success or failure of this action. Be sure to define an event listener for this event.

Exposing in-memory or persistent data to dashboards

You can expose committed in-memory data or committed persistent data as DataViews for use by dashboards. Note, however that is not supported for distributed stores. The `Schema` event defines the following fields for this purpose:

- `exposeMemoryView` — When this field is true, the MemoryStore makes the rows in the in-memory table associated with this schema available to Apama's scenario service. That is, the MemoryStore creates DataViews that contain this data.
- `exposePersistentView` — When this field is true, the MemoryStore makes the rows in the on-disk table associated with this schema available to Apama's scenario service. That is, the MemoryStore creates DataViews that contain this data. You cannot expose a persistent view of a table in a correlator-persistent store.
- `memoryViewDisplayName` — Specifies the display name for the exposed DataView created from the in-memory table.
- `memoryViewDescription` —Specifies the description for the exposed DataView created from the in-memory table.
- `persistentViewDisplayName` — Specifies the display name for the exposed DataView created from the on-disk table.
- `persistentViewDescription` — Specifies the description for the exposed DataView created from the on-disk table.

The MemoryStore exposes in-memory changes after successfully committing them to the table. The MemoryStore exposes on-disk changes after the transaction that contains the changes is committed.

The `exposeMemoryView` and `exposePersistentView` fields have an impact on the time it takes to prepare a table for the first time. When a table is prepared the rows that are loaded from disk need to be reflected to the Scenario Service.

If you prepare the same table multiple times the display names and descriptions must match or the MemoryStore rejects the contradicting request.

When a display name or description field is blank (an empty string), the MemoryStore chooses the display name or the description for the exposed DataView. You can specify a non-empty string for one or more fields to override the default. Leave the display name and description fields blank when you are not exposing the corresponding DataView.

The fields of the exposed views are the same as those of the table, in the same order as they are defined in the table schema. The key is not part of the exposed views. Each row in the table forms a single exposed view.

See "Making Application Data Available to Clients" on page 413. See also: *Building and Using Dashboards*.

Restrictions affecting MemoryStore disk files

At any one time, only one correlator should be accessing a particular MemoryStore disk file.

To minimize the risk of data corruption in the event of a system failure, keep MemoryStore files on your local disk and not on a remote file server.

Do not create hard or symbolic links to MemoryStore files. Linking to the directory that contains a MemoryStore file is not a problem.

Using the distributed MemoryStore

The topics below describe Apama's distributed MemoryStore. With a distributed MemoryStore you can access data shared among Apama applications running in separate correlators. Distributed stores make use of distributed caching software from a variety of third-party vendors. The topics below describe typical use cases for the distributed MemoryStore, how to add and configure distributed stores, and how to write drivers for integrating with third party caching software.

Note: If a license file cannot be found, the correlator refuses to start if a distributed MemoryStore is enabled. See "Running Apama without a license file" in *Introduction to Apama*.

Overview of the distributed MemoryStore

The MemoryStore supports several types of stores as described in "Using the MemoryStore" on page 365. In addition to those stores that are local to a single Apama process, Apama also supports a *distributed* store in which data can be accessed by applications running in multiple correlators. You prepare a distributed store with a prepareDistributed call on a Storage object. When this sends a Finished event with success set to true, the Store can be opened, and Table objects created.

A distributed store makes use of Terracotta's BigMemory Max or a third party distributed cache or datagrid technology that stores the data (table contents) in memory across a number of processes (nodes), typically across a number of machines. The collection of nodes is termed a *cluster*.

Advantages

Arranging a number of nodes into a cluster provides the following advantages:

- It is possible to store more data than would fit on one node.
- As the data is in memory, a distributed store is typically faster than persisting the store contents to disk.
- Every piece of data is typically stored on more than one node, so the failure of any one node should not cause the loss of any committed data.
- If a node fails, other nodes can access any of the data without waiting to 'recover' or reload the entire datastore. Note, however, that it may take time to detect that the failed node is down.
- The number of correlators can be changed at runtime, allowing the processing capacity of the system to be increased.
- Different providers can be used, allowing a single Apama application to integrate with different distributed caches. However, each provider must have a driver. Apama provides a Service Programming Interface (SPI) with which you can write a custom driver.
- Data is accessible to multiple correlators; if they distribute workload appropriately, more processing capacity can use the same shared store of data. A distributed store is a building block for such a system, not a complete solution in itself.
- Applications can be notified of changes to data in the store; see "Notifications" on page 387.

Disadvantages

A distributed store has the following disadvantages compared with the other types of store:

- A network request may be required to get or commit any Row; this is slower than the in-process local-memory get and commit requests made against local stores.
- The network request may fail because either more than one node has failed, or there is a network failure such that the correlator cannot contact other nodes in the cluster.
- Multiple access to a single row will cause contention and will not scale (and will be slower than an in-memory store).
- It is not permitted to expose dataviews with a distributed store. A distributed store may contain a very large number of entries, which would not be practical to expose

as dataviews (as it requires storing a copy of the entire table in the dashboards/scenario service client).

Use cases

Based on the advantages and disadvantages of distributed stores, the typical use cases for using them are:

- Requires more data to be stored than will fit on any single node.
- Elastic (changing) processing capacity required.
- Highly available system needs continuous access to data, even if some nodes fail, and with minimal recovery time.
- High throughput across a large number of different rows, with only a small amount of contention for a single row.

The typical use cases where a distributed store is not suitable:

- Very low latency (sub-millisecond) access to data.
- Very high throughput (>10,000 requests/second) to a single row - the distributed store only scales out well if different rows are being accessed.

Supported providers

Apama includes a driver for connecting to Terracotta BigMemory Max, which provides unlimited in-memory data management across distributed servers. See "BigMemory Max driver specific details" on page 391 for using the BigMemory Max driver.

Apama also provides an interface to integrate with third-party distributed caching software that provides compare-and-swap operations for adding, updating, and removing data. For example, software that provides methods similar to the `putIfAbsent`, `replace`, and `remove` operations on `java.util.concurrent.ConcurrentMap`.

For other distributed cache providers, you need to write a driver using the Apama Service Provider Interface (SPI) to serve as a bridge between the MemoryStore and the caching software. For information on creating a driver, see "Creating a distributed MemoryStore driver" on page 397.

Configuration

In order to use a distributed memory store, a set of configuration files must be created in your project and provided to the correlator. These configuration files typically come in pairs, a `.properties` and `-spring.xml`. Multiple pairs of files can be created and can make use of more than one distributed cache provider. See "Configuring a distributed store" on page 385.

Distributed store transactional and data safety guarantees

The `commit()` action on a `Row` object from a distributed store by default behaves similarly to an in-memory store's `Row` object, in that the commit succeeds only if there have been no commits to the `Row` object since the most recent `get()` or `update()` of the `Row` object.

However, providers can be configured differently. For example, if using BigMemory Max, and the `.properties` specifies `useCompareAndSwap` as `false` then the commit will always succeed, even if another monitor committed a different value for that entry.

Unlike in-memory stores, for `Row` objects from a distributed store, a `Table.get()` or `Row.update()` may return an older value, that is, a previously committed value, even if a more recent commit has completed. This is because a distributed store may perform caching of data. After some undefined time, the `get()` should be eventually consistent - a later `get()` or `update()` of the `Row` object should retrieve the latest value. Typically, a commit of a `Row` object where the `get()` has not retrieved the latest value will flush any local cache of the value, thus the first commit will fail, but a subsequent update and commit will succeed.

Again, providers can be configured differently. For the BigMemory Max driver, setting the `terracottaConfiguration.consistency` property to `STRONG` will ensure that after a `commit()`, a `get()` on any node will retrieve the latest version. This `STRONG` consistency mode is more expensive than `EVENTUAL` consistency.

An example: `Monitor1` gets and modifies a row and sends an EPL event to `Monitor2` which in response to the event gets and updates the row. In the table below, the event has "overtaken" the change to the row; the effects of changing the row and sending the event are observed in the reverse order (the event is seen before the change to the row).

Time	Monitor1 (on node 1)	Monitor2 (on node 2)
1	`Table.get("row1") = "abc"`	
1.2	Change row to be `"abcdef"`	`Table.get("row1") = "abc"` (cached locally)
1.3	`Row.commit("row1" as "abcdef"`) succeeds	
1.301	Send event to Host 2	
1.302		Receive event from Host 1
1.303		`Table.get("row1") = "abc"` from local cache)
1.4		Update row to be `"abcghi"`

Time	Monitor1 (on node 1)	Monitor2 (on node 2)
1.5		`Row.commit("row1 as "abcghi")` fails (not last value)
1.6		`Row.update() = "abcdef"`
1.7		Update row to be `"abcdefghi"`
1.8		`Row.commit("row1" as "abcdefghi")` succeeds

At 1.303, an in-memory cache (when two contexts are communicating in the same process) would be guaranteed to retrieve the latest value, `"abcdef"` - but a distributed store may cache values locally. The commit is guaranteed to fail when a stale value is read, as it does not rely on cached values for checking whether the row is up to date or not.

Using a distributed store

Distributed stores make use of Java Distributed cache technologies (the specific technologies depend on the driver you select). When you start a correlator with the `--distMemStoreConfig` option (enabled automatically if you use the Software AG Designer to add a Distributed MemoryStoretore configuration to your Apama project), the correlator automatically starts with an embedded Java virtual machine. This JVM is shared by any Apama applications using a distributed MemoryStore or correlator-integrated messaging for JMS and any Apama JMon applications.

A distributed store is defined by a bean in a Spring XML configuration file. The bean specifies the properties that configure the distributed store and the bean's name, which is the name of the store. When an Apama application prepares a distributed store, using the `prepareDistributed()` action, it supplies the name of the bean. For more information on properties used in the configuration file, see "Configuring a distributed store" on page 385 and "Configuration files for distributed stores" on page 387.

Depending on the distributed cache provider you select, the data may be stored in the Java heap. If so, you may need to set an appropriate size for the Java heap, for example, by specifying `-J-Xmx2048M` (to specify a 2GB heap) on the command line that starts the correlator. If you are using BigMemory Max off-heap data, you may need to supply a `-J-XX:MaxDirectoryMemorySize=` command line argument as well. For details, see BigMemory Max documentation. JVM options must be placed on the correlator command line and prefixed with `-J`. In Software AG Designer, this can be configured by opening the project's launch configuration, editing the properties of the Correlator component and selecting the **Maximum Java off-heap storage in Mb** option. See *Correlator arguments* in *Using Apama with Software AG Designer*.

The main steps in configuring a distributed store are:

- If using BigMemory Max, configure and start at least one Terracotta Server Array Node.
- In Software AG Designer, add the Distributed MemoryStore adapter to the project.
- Add a store to the Distributed MemoryStore settings.
- Choose a store name that will be used in the EPL application to refer to the store. This is used as the bean's name in the configuration files.
- Provide a driver class name to use a distributed cache of your choice. (If using BigMemory Max, Software AG Designer creates a BigMemory Max configuration with the classpath already set)
- Specify a "cluster name". The exact meaning of "cluster name" depends on the driver. For the BigMemory Max driver, it is a comma-separated list of the `host:port` pairs that identify the Terracotta Server Array nodes. Best practice is to list all nodes configured in the cluster.
- Specify the classpath for both the driver and the distributed cache implementation `.jar` files. (If using Apama's BigMemory Max support in Software AG Designer, you only need to specify the installation directory for BigMemory Max)
- Specify any other parameters needed by the driver. For further reference, see "Creating a distributed MemoryStore driver" on page 397.

Specifying a cluster name

A cluster name should be provided when opening a distributed store. Some third-party drivers and distributed caches use the cluster name as an identifier, that is, they do not interpret the name in any way. Many distributed caches use broadcast or multicast to automatically discover other cluster nodes on the same network with the same name configured. Thus, during development and testing, a name that is different to the name used by your production system should be used. This is a good practice to follow even if the systems are on separate networks. Cluster names are specified in properties files, which should be different between development and production environments.

You should not create more than one store with the same cluster name on any one correlator.

Configuring a distributed store

Configuring a distributed store consists of adding the Apama Distributed MemoryStore adapter bundle to an Apama project, adding a distributed store to the project, and specifying property settings.

Adding distributed MemoryStore support to a project

To add a distributed store to a project using Software AG Designer

1. In the Project Explorer, right-click the project name and select **Apama > Add Adapter** from the pop-up menu. The Add Adapter Instance dialog is displayed.

2. In the **Choose adapter** field, select **Distributed MemoryStore (Supports using a distributed cache from MemoryStore)** from the list of available adapters.
3. Click **OK**.

The adapter bundle is added to the project's **Adapters** node and the adapter instance is opened in the Distributed MemoryStore editor. The editor is initially blank and the **Distributed Stores** field contains no distributed stores.

Adding a distributed store

To configure a new distributed store for use in this project

1. In the Distributed MemoryStore editor's **Distributed Stores** panel, click the **Add Store** button ( ). The Distributed MemoryStore Configuration wizard appears.
2. In the Distributed MemoryStore Configuration wizard, specify the following:
   a. In the **Store Provider** field, select the third-party cache provider from the drop-down list. If you are using a driver supplied by Apama, such as BigMemory Max, select it from the drop-down list; otherwise select **Other**.
   b. In the **Store Name** field, specify the name of the store as it will be known in the configuration files and EPL code. The name must be unique and cannot contain spaces.
3. Click **Finish**.

Software AG Designer adds the name of the store to the **Distributed Stores** panel in the editor and adds the resources for the store to the project. The default configuration settings for the store are displayed in the editor.

Configuring a distributed store

You can configure the frequently used settings for a distributed store in Apama's Distributed MemoryStore editor in Software AG Designer. These settings are those in the `.properties` file. For other settings, you need to edit the `.xml` file directly.

To configure a distributed store

1. In the **Standard Properties** section of the editor, specify the properties required by the third-party distributed cache in use.
2. (Only required if **Other** was used as the store type.) In the **Classpath** section, specify the names of the required provider-specific `.jar` files.
   a. Click the **Add Location** button ( ).
   b. In the new entry, specify the name of the `.jar` file. When you specify the path to a `.jar` file, you should use substitution values rather than a full path name. (e.g. use `${installDir.mystore}/lib/my.jar`)
3. In the **Custom Property Substitution Variables** section, specify the name and values of additional substitution ${...} variables (if any) used by the distributed cache.

The `.properties` file contains substitution variables that are used by the `.xml` configuration file.

a. Click the **Add** button (+). A new line will be added to the list of substitution variables.

b. In the new entry, specify the name and value of the substitution variable you want to add.

4. (If needed.) In the **Configuration Files** you can access the Spring `.xml` and `.properties` files. Click on the file name link to open them in the appropriate editor.

For more information on specifying property values, see "Configuration files for distributed stores" on page 387

Launching a project that uses a distributed store

When you add the Distributed MemoryStore adapter bundle to an Apama project in Software AG Designer, the launch configuration is automatically updated to set the `--distMemStoreConfig` start-up option.

The maximum Java heap size and off-heap storage can be set in the **Correlator Configuration** dialog in the **Run Configurations** dialog.

Interacting with a distributed store

Once prepared, a distributed store behaves much like other MemoryStore `Store` objects as described in "Using the MemoryStore" on page 365. However, be aware of the following differences:

- The schema for tables in a distributed store is not allowed to expose dataviews.
- A distributed store (as opposed to other, non-distributed stores) supports notifications. For more information, see "Notifications" on page 387, below.
- Exceptions – In an in-memory store, only the `Row.commit()` action can throw exceptions. However, in a distributed store, most actions can throw exceptions. Exceptions represent a runtime error that can be caught with a try-catch statement. This allows developers to choose what corrective action to take (such as logging, sending alerts, taking corrective steps, retrying later, or other actions). If no try-catch block is used with these actions and an exception is thrown, the monitor instance will be terminated, the `ondie()` action will be called if one exists, and the monitor instance will lose all state and listeners. Exceptions can be thrown because of errors raised by third-party distributed cache providers. To discover what errors could be thrown because of third-party integration, you should refer to the documentation for the third-party provider in use. For more information on exceptions, see "Catching exceptions" on page 293. The following are some of the actions that can throw exceptions:
  - `Table.get()`
  - `Table.begin()`
  - `Iterator.next()`

  - `Row.commit()`
  - `Row.update()`
- Performance differences – See "Overview of the distributed MemoryStore" on page 379 for the advantages and disadvantages of using a distributed store as compared to an in-memory store.

Notifications

Distributed store `Table` objects may support the `subscribeRowChanged()` and `unsubscribe()` actions. If subscribed to a table, `RowChanged` events will be sent to that context. Subscriptions are reference counted per context, so multiple subscriptions to the same table in the same context will only result in one `RowChanged` event being sent for every change. Monitors should unsubscribe when they terminate (for example, in the `ondie()` action) to avoid leaking subscriptions.

The store factory bean property `rowChangedOldValueRequired` indicates whether subscribers receive previous values in `RowChanged` notification events for updated rows. When this property is set to true and the `RowChanged.changeType` field is set to `UPDATE` the `RowChanged.oldFieldValues` field is populated.

Notifications can impact performance, so are not recommended for tables in which a large number of changes are occurring. While BigMemory Max supports notifications, it does not support population of the old value in `RowChanged.changeType = UPDATE` events.

Within a cluster of correlators, if a table has subscriptions to `RowChanged` notifications, then all correlators must subscribe `RowChanged` notifications for that table, even if some correlators do not consume the events. This ensures all nodes receive all events correctly.

Support for notifications is optional, but if the driver does not support notifications, calls to `Table.subscribeRowChanged()` and `Table.unsubscribe()` will throw `OperationNotSupportedException` errors.

Configuration files for distributed stores

The configuration for a distributed store consists of a set of `.xml` and `.properties` files. Each distributed store in a project will have the following files:

- *`storeName`*`-spring.xml`
- *`storeName`*`.properties`

A distributed store is configured using a `bean` element in the Spring XML configuration file. The `bean` element has the following attributes:

- `id` – The unique name for this distributed store, which must match the name used in calls to `Storage.prepareDistributed()` and `Storage.open()` in EPL.
- `class` – The name of the `StoreFactory` implementation used by this distributed store.

When the correlator is started with the `--distMemStoreConfig` *`configDir`* argument, it will load all XML files matching `*-spring.xml` in the specified configuration directory, and also all `*-spring.properties` files in the same directory. (Note, the correlator will not start unless the specified directory contains at least one configuration file.)

When using Software AG Designer, these files are generated automatically. New *`storeName`*`-spring.xml` and *`storeName`*`.properties` files are created when a Store is added to a project. The most commonly used settings can be changed at any time using the Distributed MemoryStore editor (which rewrites the `.properties` file whenever the configuration is changed). In addition, the *`storeName`*`-spring.xml` files can be edited manually in Software AG Designer to customize more advanced configuration aspects. To edit the XML, open the Distributed MemoryStore editor and in the **Configuration Files** section, click the name of the file to open it in the appropriate editor. Once the editor for an XML file has been opened, you can switch between the **Design** and **Source** views using the tabs at the bottom of the editor window.

Some property values usually need to be changed when a development and testing configuration is deployed to a different environment such as one for production use. Making use of substitution variables is the best way to maintain different bean property values in different environments, as you can use the same XML file, with a different `.properties` file for each environment. For more details on using substitution variables to specify configuration properties, see "Substitution variables" on page 389. For more information on modifying property values when moving from a test environment to a production environment, see "Changing bean property values when deploying projects" on page 397.

XML configuration file format

The configuration files for a distributed store use the Spring XML file format, which provides an open-source framework for flexibly wiring together the different parts of an application, each of which is represented by a *bean*. Each bean is configured with an associated set of *properties*, and has a unique identifier which can be specified using the `id` attribute.

It is not necessary to have a detailed knowledge of Spring to configure a distributed store, but some customers may wish to explore the Spring 3.0.5 documentation to obtain a deeper understanding of what is going on and to leverage some of the more advanced functionality that Spring provides.

The Apama distributed MemoryStore configuration will load any bean that extends the Apama `AbstractStoreFactory` class.

Setting bean property values

Most bean properties have primitive values (such as string, number, boolean) which are set like this:

```
<property name="propName" value="my value"/>
```

However, it is also possible to have properties that reference other beans, such as a configuration bean defined by the third-party distributed cache provider. These property values can be set by specifying the id of a top-level bean as in the following example (where it is assumed that myConfig is the id of a bean defined somewhere in the file):

```
<property name="someConfigProperty" ref="myConfig"/>
```

Any top-level bean may be referenced in this way, that is, any bean that is a child of the <beans> element and not nested inside another bean. Referencing a bean that is defined in a different configuration file is supported.

Instead of referencing a shared bean, it is also possible to configure a bean property by creating an 'inner' configuration bean nested inside the property value like this:

```
<property name="terracottaConfiguration">
  <bean class="net.sf.ehcache.config.TerracottaConfiguration">
    <property name="consistency" value="STRONG"/>
  </bean>
</property>
```

Note, advanced users may want to exploit Spring's property inheritance by using the parent attribute on an inner bean to inherit most properties from a standard top-level bean while overriding some specific subset of properties or by type-based 'auto-wiring'.

You can use the Spring syntax for compound property names to set the value of a property held by another property. For example to set a property stringProp on a bean held by the property beanProp, use the following:

```
<property name="beanProp.stringProp" value="myValue"/>
```

Or, to set the value of the key myKey in a property that holds a Map called mapProp, use the following:

```
<property name="mapProp[myKey]" value="myValue"/>
```

Substitution variables

Substitution variables in the form ${*varname*} can be used to specify bean property values. Instead of specifying bean property values directly in an XML configuration file, you use ${*varname*} substitution variables in the XML file and specify the values of those variables in a .properties file inside the configuration directory. This makes it possible to edit the variable values in Software AG Designer and to use different values during deployment to a production environment using the Apama Ant macros.

Although .properties and -spring.xml files often have similar names, there is no explicit link between them, so *any* properties file can define properties for use by *any*-spring.xml file. Although in some cases it may be useful to share a single substitution variable across multiple XML files, this is not normally the desired behavior, and therefore the recommendation is that all properties follow the naming convention ${*varname.storeName*}.

In addition to the standard substitution variables shared by most drivers, you can add your own substitution variables for important or frequently changed properties specific to the driver specific to the cache integrated with your application. This is especially important when changing from a development environment to a production environment.

It is also possible to provide property values at runtime as Java system properties, such as specifying `-J-Dvarname=value` on the correlator command line.

The special variables `${APAMA_HOME}` and `${APAMA_WORK}` are always available.

Substitution variables are evaluated recursively, so a substitution variable can refer to another substitution variable, for example, `classpath=${installDir}/foo.jar`.

Standard configuration properties

The following four standard properties are supported by Apama distributed cache drivers. These properties should be supported by customer-developed implementations as well.

- `clusterName` – This is a required property. It is a provider-specific string. For BigMemory Max, this is a comma-separated list of *host*:*port* pairs that identify the servers in the Terracotta Server Array. Some other caches use this as just a name, used to group together distributed store nodes that communicate with each other and share data. Store objects with the same `clusterName` values should operate as a single cluster, sharing data between them. Most providers require this property and will fail to start if it is not set. Care must be taken to ensure that different clusters, and thus `clusterName` values, are used for development/testing and production environments, as serious errors would be introduced if the production and testing nodes were able to communicate with each other. Apama's BigMemory Max driver makes it easy to avoid this pitfall since it requires a list of *host*:*port* pairs. However, if you are using another driver, then for this reason, as well as whatever firewalls may exist between development/testing and production, the recommendation is to explicitly add a suffix such as `_testing` or `_production` to the `clusterName` to indicate clearly which environment it belongs to.
- `logLevel` – This is an optional property; the default is provider-specific, but typically is the same as the correlator log level. The `logLevel` property is an Apama log level string (compatible with `com.apama.util.Logger`) such as `ERROR`, `WARN`, `INFO`, `DEBUG` which will be used to set the log level for the provider if possible (some providers will write to the main correlator log file, through log4j or the Apama Logger, but others may write to a separate file). If not specified, the default log level is determined by the author of the driver, based on the criteria of avoiding the correlator log or stdout being filled with third party distributed store messages while logging a small number of the most important messages.
- `backupCopies` – This is an optional property; the default is 1. The `backupCopies` property specifies the number of additional redundant nodes that should hold a backup copy of each key/value data element. The minimum value for this property is 0 (indicating no redundancy, that is, all data is held by a single node). Note, some providers may allow customizing the backup count on a per-table basis, in which case this property specifies an overridable default value for tables that do not specify it explicitly. For BigMemory Max, this setting has no effect. The number of backup copies is determined by the Terracotta Server Array configuration, which is separate from the Apama configuration.

- `initialMinClusterSize` – This is an optional property. It specifies the minimum number of nodes a cluster must have before the `Finished` event is sent in response to a call to `prepareDistributed`. This provides a way to make sure that a cluster is fully ready for correlator nodes to request and process data. The default is `1`, which specifies that a `Finished` event is sent without waiting for additional nodes when preparing the distributed store.
- `rowChangedOldValueRequired` - Indicates whether the old value is required when there is a notification that a row has changed. If set to false, the value of `oldFieldValues` is empty for `RowChanged.changeType.UPDATE` events. If true, the previous value is available. This currently cannot be set to true for BigMemory Max. The default is true.

If all four standard properties were set, the bean configuration would look like:

```
<bean id="MyStore" class="com.foobar.MyStoreFactory">
  <property name="clusterName" value="host1:port1, host2:port2"/>
  <property name="logLevel" value="WARN"/>
  <property name="backupCopies" value="1"/>
  <property name="initialMinClusterSize" value="2"/>
</bean>
```

BigMemory Max driver specific details

You can create configuration files for BigMemory Max when using Apama in Software AG Designer. The BigMemory Max installation directory (where the zip files were unpacked) needs to be specified as the **providerDir** property.

See the BigMemory Max documentation for information about the following:

- The `.properties` file for a distributed store contains an option for choosing consistency. The options are `STRONG` or `EVENTUAL` consistency you will want to understand the trade-offs between these two modes.
- You can set BigMemory Max driver properties (described in the table below) in the `-spring.xml` configuration file. Alternatively, you can specify many of these properties in an `ehcache.xml` configuration file and then specify the path for that file in the `-spring.xml`configuration file using the `ehcacheConfigFile` property. If this is done, many of the properties in the `spring.xml` configuration file will be ignored; the settings derived from the `ehcache.xml` file will be used instead.
- Use the `*storeName*-spring.properties` file to set configuration properties for the BigMemory Max driver.
- Using off-heap storage requires setting `-XX:MaxDirectMemorySize=`. Specify this in the command line for starting the correlator as `-J-XX:MaxDirectMemorySize=`. The documentation provides recommendations for specifying the value of this property. When you add a correlator to a correlator launch configuration in Software AG Designer, you can select the **Maximum Java off-heap storage in Mb** option. See *Correlator arguments* in *Using Apama with Software AG Designer*.

For more information on Ehcache types, see the Ehcache Javadoc and search for the required type such as `CacheConfiguration`.

Property Name	Type / Description
`cacheConfiguration`	Type: `CacheConfiguration` Ehcache `CacheConfiguration` bean, shared by all caches (`Tables`). Typically used as a compound bean name, for example, `cacheConfiguration.overflowToOffHeap`.
`cacheDecoratorFactory`	Type: `String` Name of a class to use as a `cacheDecoratorFactory`. The named class must be on the classpath and must implement Ehcache's `CacheDecoratorFactory` interface.
`cacheDecoratorFactoryProperties`	Type: `Properties` Properties to pass to a `cacheDecoratorFactory`. Allows use of the same class for many caches.
`clusterName`	Type: `String` Comma-separated list of `host:port` identifiers for the servers, or a `tc-config.xml` file name. Best practice is to list all Terracotta Server Array (TSA) nodes.
`configuration`	Type: `Configuration` Ehcache Configuration bean. Typically used as a compound bean name, for example, `configuration.monitoring`.
`maxMBLocalOffHeap`	Type: `long` Number of MB of local off-heap data. Total across all tables, per correlator process.
`pinning`	Type: `String` Either an attribute value of `"inCache"` (default) or `"localMemory"` or a `<null/>` XML element (i.e.`<property name="pinning"><null/></property>`.)

Property Name	Type / Description
	Pinning prevents eviction if the cache size exceeds the configured maximum size. Recommended if the cache is being used as a system of record.
`terracotta Configuration`	Type: `Terracotta Configuration` Ehcache `TerracottaConfiguration` bean. Typically used as a compound bean name, for example, `terracottaConfiguration.consistency`.
`ehcacheConfigFile`	Type: `String` Path to an `ehcache.xml` configuration file. **Note** If this is specified, any other properties listed in this table will be ignored.

You can set the following BigMemory Max driver properties in the `spring.xml` configuration file, but not in the `ehcache.xml` configuration file as they modify how the driver accesses the BigMemory Max Cache.

Property Name	Type / Description
`backupCopies`	Type: `int` Ignored. Not supported. The number of backups is governed by the TSA topology defined in the BigMemory Max documentation and used to configure the TSA nodes.
`initialMinClusterSize`	Type: `int` The minimum cluster size (number of correlators) that must be connected for prepare to finish.
`logLevel`	Type: `String` The log level.
`rowChangedOldValueRequired`	Type: `boolean` Whether to expose old values in `rowChanged` events. Must be set to false.

Property Name	Type / Description
`useCompareAndSwap`	Type: `boolean` Whether to use compare and swap (CaS) operations or just put/remove. Some versions of BigMemory Max support only CaS in `Strong` consistency.
`useCompareAndSwapMap`	Type: `Map(String, Boolean)` Per-table (cache) configuration for whether to use CaS or put/remove.
`exposeSearchAttributes`	Type: `boolean` Enable exposing search attributes. If true, then the MemoryStore schema columns are exposed as BigMemory search attributes and are indexed, so that other clients of BigMemory can perform searches on the data set. If `exposeSearchAttributesSet` is non-empty, then only the named columns are exposed as BigMemory search attributes. See notes below about non-Apama applications accessing the data in a BigMemory cluster.

`exposeSearchAttributesSet`	Type: `Set(String)`
	
	Limits the set of columns in each table that should be exposed as search attributes. Entries are in the form *tableName .columnName* . If empty, all schema columns are exposed as search attributes. There is an incremental cost per column that is exposed, so for performance, only expose the columns which need to be used in searches.
	
	For example, to expose only the "Surname" and "FirstName" columns of "myTable":
	
	`<property name="exposeSearchAttributes"`
	`   value="true"/>`
	`<property name="exposeSearchAttributesSet">`
	`  <set>`
	`    <value>myTable.Surname</value>`
	`    <value>myTable.FirstName</value>`
	`  </set>`
	`</property>`

The following compound properties are also exposed in the .properties file, or set by default in the spring.xmlconfiguration file:

Property Name	Type / Description
cacheConfiguration.eternal	Type: boolean Disables expiration (removing old, unused values) of entries if true. Set to true in the default spring.xml configuration file.
cacheConfiguration. maxEntriesLocalHeap	Type: int The number of entries for each table. This is the maxEntriesLocalHeap entry in the .properties file.
cacheConfiguration. overflowToOffHeap	Type: boolean Whether to use off-heap storage. For scenarios where data is fast changing and being written from multiple correlators, the cache may perform better if this is disabled. This is the cacheConfiguration.overflowToOffHeap entry in the .properties file.
pinning	Type: String Set to inCache by default.
terracottaConfiguration. localCacheEnabled	Type: boolean Whether to cache entries in the correlator process. Set to true in the default spring.xml configuration file.
terracottaConfiguration. clustered	Type: boolean Whether to use a TSA. Set to true in the default spring.xml configuration file.
terracottaConfiguration. consistency	Type: String Either 'STRONG' or 'EVENTUAL'. STRONG gives MemoryStore-like

Property Name	Type / Description
	guarantees, while `EVENTUAL` is faster but may have stale values read. This is the `terracottaConfiguration.consistency` entry in the `.properties` file.
`terracottaConfiguration.synchronousWrites`	Type: `boolean` If true, then data is guaranteed to be out of process by the time a `Row.commit()` action completes. Disabling this can increase speed. This is the `terracottaConfiguration.synchronousWrites` entry in the `.properties` file.

Note: When using the BigMemory Max driver, all correlators accessing the same data in a BigMemory cluster must have the same configuration. If accessing from non-Apama applications, clients will need the correct cache configuration (available from the Terracotta Management Console) and have the appropriate Apama classes available on their classpath (available in the `distmemstore` and `ap-distmemstore-bigmemory.jar` files) in order to access the cache.

For reference, the following table maps Apama MemoryStore terminology to BigMemory Max classes; this may be useful when referring to the BigMemory Max documentation:

MemoryStore Event Object	BigMemory Max Class
`Store`	`CacheManager`
`Table`	`Cache`
`Row`	`Element`

By default, a distributed MemoryStore `Store` uses the BigMemory Max default cache manager. To specify the use of a different cache manager, specify the `name` property on the `configuration` bean. For example:

```
<property name="configuration.name" value="myCacheManager"/>
```

In a cluster, if one correlator calls `subscribeRowChanged()` for a given MemoryStore table, then all correlators in that cluster that modify the entries in that table must also call `subscribeRowChanged()` on that table even if they do not consume the events.

Iterating over a table may require pulling the entire table into memory. It may fail if the table is being modified.

Changing bean property values when deploying projects

Some bean property values will usually need to be changed when a development/testing configuration is deployed to a different environment such as production, which is typically achieved by ensuring all such bean property values are specified using `${varname}` substitution variables specified in `.properties` files for test vs. production environments. For example, for distributed memory stores the `clusterName` should be changed so that the nodes cannot talk to each other (although Apama also recommends production nodes to be located on a different network to reduce the chance of accidental errors). For more details on using substitution variables to specify configuration properties, see "Substitution variables" on page 389.

Tip: Due to the flexibility and simplicity of `.properties` files, there are many ways this requirement can be addressed. For customers using Apama's Ant macros for deployment, one option is to maintain a separate set of `.properties` files for each environment, and customize your project's Ant script to copy the correct version of the files into the `distMemStoreConfig` directory just before starting the correlator. Another option is to use Ant's `<propertyfile>` task (see the Apache Ant documentation for more information on how to do this) to modify the `.properties` files in-place, overriding or adding to existing property values as required for the new deployment.

Creating a distributed MemoryStore driver

The Apama installation includes a driver for integrating the distributed MemoryStore with the BigMemory Max distributed caching software. If you use other third-party distributed caching software, you need to write a driver that provides the bridge between Apama's MemoryStore and the third-party software in use. Apama provides a Service Provider Interface (SPI) for you to use when writing drivers. This section of the Apama documentation presents an introduction to the SPI and a description of its essential elements.

Complete Javadoc information for the SPI is available in `doc/javadoc/index.html` in your Apama installation. See the `com.apama.correlator.memstore` package.

Overview

A driver for a distributed cache needs to extend the following abstract classes:

- `AbstractStoreFactory`
- `AbstractStore`
- `AbstractTable`

Implementation details:

- `AbstractStoreFactory` – This is the abstract class that holds the configuration used to instantiate a distributed `Store`. The starting point for creating an Apama distributed cache driver is to create a concrete subclass of `AbstractStoreFactory`. The subclass should have the following:

- A public no-args constructor
- JavaBean-style setter and getter methods for all provider-specific configuration properties
- An implementation of `createStore()` that makes use of these product-specific properties, in addition to the generic properties defined on this factory, which are `getClusterName()`, `getLogLevel()`, and `getBackupCopies()`.
- `afterPropertiesSet()` (optional, but useful)

Implementers are encouraged to do as much validation as possible of the configuration in the `afterPropertiesSet()` method. This method will be called by Spring during correlator start-up after setters have been invoked for all properties in the configuration file. The `createStore()` action will never be called before this has happened.

The `StoreFactory` class that is implemented must then be named in the distributed store `-spring.xml` configuration file.

- `AbstractStore` – This is the abstract class that provides access to Tables whose data is held in a distributed store. Implementers should create a subclass of `AbstractStore`.

  A driver's implementation of the `AbstractStore` needs to implement or override the following methods:

  - `createTable()`
  - `init()`
  - `close()`
  - `getTotalClusterMembers()`

- `AbstractTable` – This is the abstract class that holds `Row` objects whose data is held in a distributed store.

  If the distributed store provides a `java.util.concurrent.ConcurrentMap`, Apama recommends that implementers of Apama distributed stores create a subclass of the `ConcurrentMapAdapter` abstract class for ease of development and maintenance. If the distributed store does not provide a `ConcurrentMap`, implementers should create a subclass of Apama's `AbstractTable` class.

  If you are implementing from `AbstractTable` you need to implement or override the following methods:

  - `get()`
  - `clear()`
  - `remove()`
  - `replace()`

- `putIfAbsent()`
- `containsKey()`
- `size()`

Drivers may also optionally provide support for EPL subscribing to 'row changed' data notifications. To allow EPL application to subscribe to these notifications, subclasses of `AbstractTable` (or `ConcurrentMapAdapter`) must provide an instance of `RowChangedSubscriptionManager` that provides implementations of `addRowChangedListener` and `removeRowChangedListener`, and calls `fireRowChanged` when changes are detected. Also, if a subclass implements notifications, it should override the `getRowChangedSubscriptionManager` method and have it return the instance of `RowChangedSubscriptionManager` for this table. Calls to `subscribeRowChanged` and `unsubscribe` are passed to this instance. The default implementation of `getRowChangedSubscriptionManager` returns null, indicating that row changed notifications are not supported; in this case calls to `subscribeRowChanged` and `unsubscribe` will throw `OperationNotSupportedException`.

- `RowValue` – The `RowValue` class is not inherited from or implemented, but a driver must be able to store and retrieve objects of the Apama `RowValue` class. Typically a cache can store any suitable Java class, but some mapping may be required as well. For more information about this class, see the Javadoc for `com.apama.correlator.memstore.RowValue`.

Sample driver

To help get started writing a driver, the BigMemory Max driver is provided in source form as a sample; it implements the SPI described above and invokes the EHCache API in order to use BigMemory Max. The sample is provided under the `samples/distmemstore_driver/bigmemory` path in the Apama installation directory. To avoid confusion with the pre-compiled driver supplied in the product, the sample BigMemory Max driver uses the package name `com.apamax.memstore.provider.bigmemory`. A `README.txt` file describes how to build the sample.

Using the Management interface

The Management interface defines actions that let you do the following:

- Obtain information about the correlator
- Control logging
- Request a persistence snapshot
- Manage user-defined status values

Actions in the Management interface are defined on several event types, which are documented in the *API Reference for EPL (ApamaDoc)*.

To use the Management interface, add the `Correlator Management` bundle to your Apama project. Alternatively, you can directly use the EPL interfaces provided in `APAMA_HOME\monitors\Management.mon`.

Obtaining information about the correlator

The Management interface provides the following actions for obtaining information about the correlator that the Management interface is being used in:

- `getHostname()` - Returns the host name of the host the correlator is running on. The host name is dependent on the environment's name resolution configuration, and the name can be used only if the name resolution is correctly configured. The name is the same as that logged in the correlator log file, for example, `dev3.acme.com`.
- `getComponentPort()` - Returns the port the correlator is running on.
- `getComponentPhysicalId()` - Returns the physical ID of the correlator.
- `getComponentLogicalId()` - Returns the logical ID of the correlator.
- `getComponentName()` - Returns the name that is used to identify the correlator. You can set this name by specifying the `-N` correlator command line flag (or by means of the `extraArgs` attribute in the Ant macros). The default name of the correlator is `correlator`.

These actions are defined in the `com.apama.correlator.Component` event.

There are `engine_management` utility options that you can specify

- To retrieve the same information from outside the correlator
- Or to retrieve the same information for IAF or sentinel agent processes

The correlator also logs all of these values to its log file at startup.

Controlling logging

You can configure logging using the Management interface. The `com.apama.correlator.Logging` event provides actions such as `setApplicationLogFile`, `setLogFile` and `setApplicationLogLevel`. These actions are the equivalent of using the `engine_management` options to configure logging (see also "Shutting down and managing components" in *Deploying and Managing Apama Applications*).

The `rotateLogs()` action, which is also defined in the `com.apama.correlator.Logging` event, is used for closing the log files in use, opening new log files, and then sending messages to the new log files. This action applies to:

- The correlator status log file
- The correlator input log file if you are using one
- Any application log files you are using

For details about log file rotation, see "Rotating the correlator log file" and "Rotating all log files" in *Deploying and Managing Apama Applications*.

You can write an EPL monitor that triggers log rotation on a schedule. For example, the code below rotates logs every 24 hours at midnight:

```
using com.apama.correlator.Logging;

monitor Rotator {
   Logging logging;

   action onload() {
      on all at(0, 0) {
         logging.rotateLogs();
      }
   }
}
```

Requesting a snapshot

In a persistence-enabled correlator, you can use the Management interface to request a snapshot to occur as soon as possible, and be notified of when that snapshot has been committed to disk. The Management interface lets persistent and non-persistent monitors create instances of `Persistence` events and then call the `persist()` action on those events.

When the correlator processes the `persist()` call it takes and commits a snapshot and executes the specified callback action at some point after the snapshot is committed. There are no guarantees about the elapsed time between the `persist()` call, the snapshot and the callback, especially when large amounts of correlator state are changing. Your code resumes executing immediately after the call to the `persist()` action. See "Using Correlator Persistence" on page 327.

The Management interface defines the `Persistence` event:

```
package com.apama.correlator;
event Persistence {
   action persist(action<> callback) {
   ...
   }
}
```

Consider the following sample code:

```
using com.apama.correlator.Persistence;
event Number {
   integer i;
}

persistent monitor MyApplication {
   integer counter := 0;
   sequence<integer>  myNumbers;
   action onload() {
      Number n;
      on all Number(*):n {
         myNumbers.append(n.i);
         counter := counter + 1;
         if(counter % 10 = 0) then {
            doCommit();
         }
      }
   }
```

```
   action doCommit() {
      Persistence p := new Persistence;
      p.persist(logCommit);
   }

   action logCommit() {
      log "Commit succeeded";
   }
}
```

Because `MyApplication` is a persistent monitor the correlator copies its state to disk as that state changes. This monitor listens for `Number` events and stores their content in the `myNumbers` sequence. After every tenth `Number` event, the code executes the `doCommit()` action, which uses the `Persistence` event in the Management interface to request that the correlator commits persistent state to disk. When that commit has succeeded, the Management interface calls the action variable that was passed to the `persist()` action. This action writes "`Commit succeeded`" to the correlator log.

The Management interface guarantees that at the moment the callback action (`logCommit()` in this example) is executed, the state of all persistent monitors at a particular point in time will have been committed. The particular point in time is guaranteed only to be between the point at which `persist()` was called and the point at which the callback action was executed. For example, suppose the following event stream is being sent into the correlator:

```
Number(1)
Number(2)
Number(3)
...
Number(10)
Number(11)
Number(12)
```

At the point that `Number(10)` is received, the `myNumbers` sequence contains the ten items `1`, `2`, `3`, `4`, `5`, `6`, `7`, `8`, `9`, `10` and so the application initiates a snapshot commit. Suppose that the correlator suddenly terminates after notification of success appears in the log. When the correlator recovers, `MyApplication` has a `myNumbers` sequence that contains *at least* ten items. However, the sequence might contain 11 or even 12 items, if more `Number` events were received after the commit was requested but before the snapshot was actually taken. The correlator also persists state periodically, or as directed by other monitors that call the Management interface, so the sequence can be persisted at other points as well.

Managing user-defined status values

The Management interface provides actions for managing the user-defined status values.

- Use the following action to set a user-defined status value, note that the name of the status and the value of the status passed in are stored as strings and must be converted as required:
  - `setUserStatus()`
- Use the following actions to return the user-defined status values:
  - `getUserFloat()` - Returns float values.

  - `getUserInteger()` - Returns integer values.
  - `getUserBoolean()` - Returns Boolean values.
  - `getUserString()` - Returns string values.

  There are also matching actions for the above get actions that allow for default values if a status does not exist. These actions have an additional "Or" in their names, for example, `getUserFloatOr()`.

- Use the following action to delete any of the user-defined status values:
  - `deleteUserStatus()`

Note that the correlator status statements that appear in the log files will not have the user-defined status values, and will remain unaffected.

Using MATLAB® products in an application

To use MATLAB analysis and modeling capability in an Apama application or in an application built using the Apama Capital Markets Foundation, you need to add the MATLAB bundle to your project and ensure that MATLAB executables and libraries are available to the correlator. The MATLAB bundle provides access to the MATLAB analysis and modeling toolkit from Apama EPL code and includes a correlator plug-in.

For information about supported versions, see the *Supported Platforms* document for the current Apama version. This is available from the following web page: http://documentation.softwareag.com/apama/index.htm.

This MATLAB plug-in lets you connect to and use the MATLAB engine. However, there are some functions/toolkits for which MATLAB does not support integration with C or Fortran on some operating platforms. Check the MATLAB documentation before using the MATLAB correlator plug-in.

The recommended way to use the MATLAB plug-in is to use the `MatlabManager` event, and call the relevant action and supply a callback. The call goes directly to the MATLAB plug-in so you do not need to route a request event. `*Response` events are routed from the MATLAB plug-in to the calling context. Each request action automatically sets up a listener for the `*Response` event that will call the supplied callback. You can supply the relevant `doesNothing*Callback()` action from the `MatlabManager` event if you are not interested in the results of the callback. If you use the `MatlabManager` actions you do not need to call the `#initialize()` action.

The legacy way to use the MATLAB plug-in is to route `*Request` events and set up listeners for the `*Response` events. If you are using the MATLAB plug-in in only the main context, injecting `MatlabService.mon` sets up all required listeners for the `*Request` events that call into the MATLAB plug-in. To use the MATLAB plug-in from another context, instantiate a `MatlabManager` variable, spawn to the other context, and call `#initialize()` on the variable. This sets up the required listeners in the current (non-main) context, and the `*Response` events are routed to this context.

Note: The MATLAB plug-in is asynchronous (except the `OpenSession` requests) so the processing of the input queue, or calling the request actions, does not block.

The MATLAB plug-in is multi-context aware. The `*Response` events are routed to the calling context.

To include MATLAB capabilities in your application, follow these steps:

1. Ensure that the directory containing the MATLAB plug-in library is included in the library search path: `%APAMA_HOME%\bin` should be in the `PATH` on Windows platforms, or for deployment on Linux operating systems, `$APAMA_HOME/lib` should be in the `LD_LIBRARY_PATH`.
2. Import the MATLAB plug-in in the application's EPL code.
3. Set the appropriate values for your `PATH` environment variable:
   - 64-bit Windows: Add *`MATLAB_HOME`*`/bin` and *`MATLAB_HOME`*`/bin/win64` to `%PATH%`.
   - 64-bit Linux: Add *`MATLAB_HOME`*`/bin` to `$PATH`. Also, add *`MATLAB_HOME`*`/sys/os/glnxa64` and *`MATLAB_HOME`*`/bin/glnxa64` to `$LD_LIBRARY_PATH`.

MatlabManager actions

The `MatlabManager` event provides the following actions. For complete reference information, see the *API Reference for EPL (ApamaDoc)*.

Action	Description
`openSession( string sessionID, string messageID, boolean singleUse, integer precision, action<string, string, boolean, string> callback)`	Starts a MATLAB process for the purpose of using MATLAB as a computational engine. Uses the MATLAB API function `engOpen()` if `singleUse` = false and `engOpenSingleUse()` if `singleUse` = true. Single use is unavailable on Linux. The response to this action call is an `OpenSessionResponse` event routed from the plug-in to the calling context and the supplied callback is invoked.
`closeSession( string sessionID, string messageID, action<string, string, boolean, string> callback)`	Closes a MATLAB session. Uses the MATLAB API function `engClose()`. The response to this action call is a `CloseSessionResponse` event routed from the plug-in to the calling context and the supplied callback is invoked.

Action	Description
`initialize()`	You must call this action when you are using MATLAB by means of routed events in a context other than the main context. Spawn to another context, set up the relevant listeners in the new context, and then call `initialize()`. You do not need to call `initialize()` when you are calling the `MatlabManager` actions.

`putFloat(`
`   string sessionID,`
`   striing messageID,`
`   string name,`
`   float value,`
`   action <string, string,`
`      boolean, string>`
`   callback)`
	Puts a `float` variable into a MATLAB engine workspace. Uses the MATLAB API function `engPutVariable()`. The response to this action call is a `PutFloatResponse` event routed from the plug-in to the calling context and the supplied callback is invoked.
	
	Note: By default, this event creates a local variable in the MATLAB session. If you need the variable to have a global scope, call `evaluate()` before you call the `putFloat()` action. In the `evaluate()` call, declare the variable as being global (for example, "`global x`").

`getFloat(`
`   string sessionID,`
`   string messageID,`
`   string name,`
`   action<string, string,`
`      float, boolean, string>`
`   callback)`
	Gets a `float` variable from the MATLAB engine workspace. Uses the MATLAB API function `engGetVariable()`. The response to this action call is a `GetFloatResponse` event routed from the plug-in to the calling context and the supplied callback is invoked.

`putFloatSequence(`
`   string sessionID,`
`   string messageID,`
`   string name,`
`   sequence<float> values,`
`   action<string, string,`
`      boolean, string>`
`   callback)`
	Puts a `float` sequence variable in a MATLAB engine workspace. Uses the MATLAB API function `engPutVariable()`. The response to this action call is a `PutFloatSequenceResponse` event routed from the plug-in to the calling context and the supplied callback is invoked.

Action	Description
getFloatSequence(string sessionID, string messageID, string name, action<string, string, sequence<float>, boolean, string> callback)	Gets a float sequence variable from the MATLAB engine workspace. Uses the MATLAB API function engGetVariable(). The response to this action call is a GetFloatSequenceResponse event routed from the plug-in to the calling context and the supplied callback is invoked.
putFloatMatrix(string sessionID, string messageID, string name, sequence<sequence<float>> values, action<string, string, boolean, string> callback)	Puts a two-dimensional matrix variable into a MATLAB engine workspace. Uses the MATLAB API function engEval(). The response to this action call is a PutFloatMatrixResponse event routed from the plug-in to the calling context and the supplied callback is invoked.
getFloatMatrix(string sessionID, string messageID, string name, action<string, string, sequence<sequence<float>>, boolean, string> callback)	Gets a two-dimensional matrix variable from the MATLAB engine workspace. Uses the MATLAB API function engGetVariable(). The response to this action call is a GetFloatMatrixResponse event routed from the plug-in to the calling context and the supplied callback is invoked.
evaluate (string sessionID, string messageID, string expression, integer outputSize, action<string, string, string, sequence<string> boolean, string> callback)	Evaluates an expression for the MATLAB engine session and returns textual output from evaluating the expression, including possible error messages. Uses the MATLAB API function engEvalString(). The response to this action call is an EvaluateResponse event routed from the plug-in to the calling context and the supplied callback is invoked.
setVisible(string sessionID, string messageID, boolean value, action<string, string, boolean, string> callback)	Makes the window for the MATLAB engine session either visible or invisible on the Windows desktop. Uses the MATLAB API function engSetVisible(). The response to this action call is a SetVisibleResponse event routed from the plug-in to the

Action	Description
	calling context and the supplied callback is invoked.
`getVisible( string sessionID, string messageId, action<string, boolean, boolean, string> callback)`	Returns the current visibility setting for the MATLAB engine session. Uses the MATLAB API function `engGetVisible()`. The response to this action call is a `GetVisibleResponse` event routed from the plug-in to the calling context and the supplied callback is invoked.

MATLAB examples

To use MATLAB features in your Apama or Apama Capital Markets Foundation application, you must create a MATLAB session. The following examples show how to create a MATLAB session and how to use it to set or get floating point scalar values, arrays or matrices. Each get or set request has an associated response that indicates whether the request successfully completed.

Creating a MATLAB session

The following example creates a MATLAB session. A `boolean` value indicates whether MATLAB should open a new session or re-use an existing session.

```
monitor MatlabExample2
{
   // ***** Creating a MATLAB session:
   com.apamax.matlab.MatlabManager matlabManager;

   action onload() {
      // Spawn to a new context:
      spawn run() to context("New Context");
   }

   action run() {
      // Running in a context other than main, open a MATLAB session:
      matlabManager.openSession(
         "Session1", "openSessionRequest", false, 6, sessionOpened);
   }

   action sessionOpened(
      string sessionID, string messageID, boolean success, string error) {
         if (success) then {
            log "Session Opened";
         } else {
            log "Session failed to open - " + sessionID + ", "
               + messageID + ", " + success.toString() + ", " + error;
         }
   }
```

Working with scalar values

The following example shows how to set a scalar value:

```
action putFloatExample() {
   matlabManager.putFloat(
      "Session1", "putFloatRequest", "x", 10.0, putFloatCallback);
}

action putFloatCallback(
   string sessionID, string messageID, boolean success, string error) {
      if (success) then {
         log "Put Float Succeeded";
      } else {
         log "Put Float Failed - " + sessionID + ", " + messageID + ", "
             + success.toString() + ", " + error;
      }
}
```

The following example shows how to get a scalar value:

```
action getFloatExample() {
   matlabManager.getFloat(
      "Session1", "getFloatRequest", "x", getFloatCallback);
}

action getFloatCallback(string sessionID, string messageID, float value,
   boolean success, string error) {
      if (success) then {
         log "Get Float Succeeded - value = " + value.toString();
      } else {
         log "Get Float Failed - " + sessionID + ", " + messageID + ", "
            + success.toString() + ", " + error;
   }
}
```

Working with arrays

To set an array:

```
action putFloatSequenceExample() {
   sequence<float> y := [0.0, 1.0, 2.71828, 3.14159];
   matlabManager.putFloatSequence("Session1", "putFloatSequenceRequest",
      "y", y, putFloatSequenceCallback);
}

action putFloatSequenceCallback(
   string sessionID, string messageID, boolean success, string error) {
      if (success) then {
         log "Put Float Sequence Succeeded";
      } else {
         log "Put Float Sequence Failed - " + sessionID + ", "
            + messageID + ", " + success.toString() + ", " + error;
      }
}
```

To get an array:

```
action getFloatSequenceExample() {
   matlabManager.getFloatSequence(
      "Session1", "getFloatSequenceRequest", "y", getFloatSequenceCallback);
}
```

```
action getFloatSequenceCallback(string sessionID, string messageID,
   sequence<float> value, boolean success, string error) {
      if (success) then {
         log "Get Float Sequence Succeeded - value = " + value.toString();
      } else {
         log "Get Float Sequence Failed - " + sessionID + ", "
            + messageID + ", " + success.toString() + ", " + error;
      }
}
```

Working with matrices

To set a matrix:

```
action putFloatMatrixExample() {
   sequence< sequence<float> > matrix := [];
   sequence<float> row1 := [-2.1, 3.5];
   sequence<float> row2 := [5.0, 1.0, 7.9, 17.0];
   sequence<float> row3 := [-20.0, -90.0, 25.0];

   matrix.append(row1);
   matrix.append(row2);
   matrix.append(row3);
   matlabManager.putFloatMatrix("Session1", "putFloatMatrixRequest",
      "m", matrix, putFloatMatrixCallback);
   }

action putFloatMatrixCallback(
   string sessionID, string messageID, boolean success, string error) {
      if (success) then {
         log "Put Float Matrix Succeeded";
      } else {
         log "Put Float Matrix Failed - " + sessionID + ", "
            + messageID + ", " + success.toString() + ", " + error;
      }
}
```

To get a matrix:

```
action getFloatMatrixExample() {
   matlabManager.getFloatMatrix(
      "Session1", "getFloatMatrixRequest", "m", getFloatMatrixCallback);
}

action getFloatMatrixCallback(string sessionID, string messageID,
   sequence< sequence<float> > value, boolean success, string error) {
      if (success) then {
         log "Get Float Matrix Succeeded - value = " + value.toString();
      } else {
         log "Get Float Matrix Failed - " + sessionID + ", "
            + messageID + ", " + success.toString() + ", " + error;
   }
}
```

As well as setting MATLAB variables, applications may also send requests to the MATLAB plug-in to evaluate any appropriate MATLAB expressions using the `evaluate()` action.

The following example shows how to use the MATLAB plug-in to add two matrices and get the result:

```
action evaluateRequestExample() {
   // First matrix:
```

```
      sequence<sequence<float> > matrix1 := [];
      sequence<float> m1row1 := [1.0,2.0,3.0];
      sequence<float> m1row2 := [4.0,5.0,6.0];
      sequence<float> m1row3 := [7.0,8.0,9.0];
      matrix1.append(m1row1);
      matrix1.append(m1row2);
      matrix1.append(m1row3);

      // The MATLAB manager also provides 'doesNothing*' callbacks that can
      // process the returns silently if the response is not needed.
      matlabManager.putFloatMatrix("Session1", "putFloatMatrixRequest1",
         "matrix1", matrix1, matlabManager.doesNothingCallback);

      // Second matrix:
      sequence<sequence<float> > matrix2 := [];
      sequence<float> m2row2 := [2.0,5.0,8.0];
      sequence<float> m2row3 := [3.0,6.0,9.0];
      matrix2.append(m2row1);
      matrix2.append(m2row2);
      matrix2.append(m2row3);
      matlabManager.putFloatMatrix("Session1", "putFloatMatrixRequest1",
         "matrix2", matrix2, matlabManager.doesNothingCallback);

      // Use MATLAB to add the two matrices.
      // The expected size of the string to be returned:
      integer STANDARD_OUTPUT_SIZE := 256;

      // Although use of the MATLAB plug-in is asynchronous, requests are
      // queued. This guarantees that the two putFloatMatrix() actions
      // have already been processed.
      matlabManager.evaluate("Session1", "evaluateRequest",
         "matrix3 = matrix1 + matrix2", STANDARD_OUTPUT_SIZE, evaluateCallback);
   }

   action evaluateCallback(
      string sessionID, string messageID, string output,
      sequence<string> outputLines, boolean success, string error) {
         if (success) then {
            matlabManager.getFloatMatrix(
               "Session1", "getMatrixRequest", "matrix3", getMatrix3Callback);
         } else {
            log "Evaluate Failed - " + sessionID + ", "
               + messageID + ", " + success.toString() + ", " + error;
         }
   }

   action getMatrix3Callback(string sessionID, string messageID,
      sequence< sequence<float> > value, boolean success, string error) {
         if (success) then {
            log "Get Float Matrix Succeeded - value = " + value.toString();
         } else {
            log "Get Float Matrix Failed - " + sessionID + ", "
               + messageID + ", " + success.toString() + ", " + error;
         }
   }
}
```

Interfacing with user-defined correlator plug-ins

Although EPL is very powerful and enables complex applications, it is foreseeable that some applications might require additional specialized operations. For example, an application might need to carry out advanced arithmetic operations that are not provided in EPL.

A developer can address this situation by writing custom correlator plug-ins using Apama's C and C++ Plug-In Development Kits. A plug-in consists of an appropriately formatted library of C or C++ functions which can be called from within EPL while Apama is executing monitors. Apama and its event correlator components do not need to be modified to enable or to integrate with a plug-in, as the plug-in loading process is transparent and occurs dynamically when required.

Once a plug-in is developed, a developer can call the functions it contains directly from a monitor in EPL, passing EPL variables and constants as parameters, and getting return values that can be manipulated. For information on developing your custom event correlator plug-in, see "Developing Correlator Plug-ins" on page 717.

Note: The correlator's plug-in interface is versioned. For a correlator plug-in to be compatible with an event correlator they both need to support the same plug-in interface version. See "Developing Correlator Plug-ins" on page 717 for information about how to ensure that your correlator plug-in is compatible with the event correlator it will run in.

In order to access a function implemented in an event correlator plug-in, the developer must first import the plug-in, for example:

```
import "apama_math" as math;
```

This will look for Apama Plug-in file `libapama_math.so` (on Solaris or Linux) or for `apama_math.dll` (on Windows). These must be located on the standard library path (in `LD_LIBRARY_PATH` in Unix, and in the `bin` folder on Windows). It will then map it to the internal alias `math`.

Note: Insert the `import` statement in the monitor that uses the plug-in functions.

If the `apama_math` plug-in defines a method in C or C++ called `cos` that takes a single floating point value as an argument and returns a `float` value, this would be called from EPL as follows:

```
float a, b;
// ... some other EPL
a := math.cos(b);
```

Standard `float`, `integer` and `boolean` types are passed by-value to external functions while `string` types and `sequence`s (which map to native arrays in the plug-in) are passed by-reference. In addition, the `chunk` type can be used to ‘pass-through' data returned from one function call to another plug-in function, as shown below.

About the chunk type

The `chunk` type allows data to be referenced from EPL that has no equivalent EPL type. It is not possible to perform operations on data of type `chunk` from EPL directly; the `chunk` type exists purely to allow data output by one external library function to pass through to another function. Apama does not modify the internal structure of `chunk` values in any way. As long as a receiving function expects the same type as that output by the original function, any complex data structure can be passed around using this mechanism.

To use `chunks` with plug-ins, you must first declare a variable of type `chunk`. You can then assign the chunk to the return value of an external function or use the chunk as the value of the *`out`* parameter in the function call.

The following example illustrates this. The `complex.test4()` method prints output to `stdout`. The source code for `complex_plugin` is in the `samples\correlator_plugin\cpp` directory of your Apama installation directory.

```
monitor ComplexPluginTest {

   // Load the plugin
  import "complex_plugin" as complex;

   // Opaque chunk value
   chunk myChunk;

   action onload() {
      // Generate a new chunk
      myChunk := complex.test3(20);

      // Do some computation on the chunk
      complex.test4(myChunk);
   }
}
```

Although the `chunk` type was designed to support unknown data types, it is also a useful mechanism to improve performance. Where data returned by external plug-in functions does not need to be accessed from EPL, using a `chunk` can cut down on unnecessary type conversion. For example, suppose the output of a `localtime()` method is a 9-element array of type `float`. While you could declare this output to be of type `sequence<float>`, there is no need to do so because the EPL never accesses the value. Consequently, you can declare the output to be of type `chunk` and avoid an unnecessary conversion from native array to EPL `sequence` and back again.

11 Making Application Data Available to Clients

Apama provides the `DataViewService`, which enables EPL (or Java) application writers to expose a view onto some of their data for easy consumption by remote client applications, such as Dashboard Builder dashboards.

The service uses two central concepts:

- DataView definition
- DataView item

A DataView definition specifies a unique DataView name, a set of field names and field types (each type is one of `string`, `float`, `integer`, and `boolean`), and optionally a set of key fields.

Each DataView item is associated with a DataView definition, and specifies values for the defined fields.

Note: The topics below briefly describe the event types that are used for managing the DataView definitions and items. For detailed information on the fields that are available for these events, see the `com.apama.dataview` package in the *API Reference for EPL (ApamaDoc)*.

Note that a DataView definition is not intended to serve as a central data structure for your application, but rather is intended merely to expose your application's data to remote client applications.

The programming interface is defined by `DataViewService_Interface.mon` in the `monitors` directory of your Apama installation directory. It defines the API for working with DataView definitions and DataView items.

You can create DataViews in only the main context. You cannot create them in any contexts you create.

Metadata properties can be specified for a DataView by adding keys with the prefix `DataViewDefinition.EXTRA_PARAMS_METADATA_PREFIX` to the *`extraParams`* dictionary of `DataViewAddDefinition` when adding the new DataView definition.

You can also use the MemoryStore to create DataViews and you can do this in any context. See "Exposing in-memory or persistent data to dashboards" on page 378.

Adding the DataView Service bundle to your project

To use the `DataViewService`, you have to add the **DataView Service** bundle to your Apama project. Adding this bundle ensures that the following EPL files are loaded before any monitors that use them. These monitors are in the `monitors` directory of your Apama installation:

- `ScenarioService.mon`
- `DataViewService_Interface.mon`
- `DataViewService_Impl_Dict.mon`

Note: The `DataViewService` is designed primarily to interact with other EPL or JMon applications that reside in the same correlator. However, it can also be used with multiple correlators. See "Using multiple correlators" on page 419 for further information.

To add the DataView Service bundle to your Apama project

1. In Software AG Designer, go to the Apama Developer perspective.
2. In the **Project Explorer**, right-click the project name and select **Apama > Add Bundle** from the context menu.
3. Select the **DataView Service** bundle and click **OK**.

Creating DataView definitions

Use the following event types to create DataView definitions.

DataViewAddDefinition

Create and route an event of this type in order to create a DataView definition. The response is provided by a `DataViewDefinition` or `DataViewException` event.

DataViewDefinition

These events are responses to `DataViewAddDefinition` events. They indicate the successful creation of a DataView definition. The contents of the fields are exactly those of the `DataViewAddDefinition` event to which this is a response, except possibly for *`extraParams`*.

DataViewException

These events occur under exceptional circumstances in response to `DataViewAddDefinition` or `DataViewDeleteDefinition` events, or any circumstance under which a DataView cannot be identified.

Here is an example of creating a DataView definition and handling `DataViewException` events:

```
using com.apama.dataview.DataViewAddDefinition;
using com.apama.dataview.DataViewException;
...
DataViewAddDefinition add := new DataViewAddDefinition;
add.dvName := "Weather";
add.dvDisplayName := "Weather";
add.fieldNames := ["location","temperature","humidity","visibility"];
add.fieldTypes := ["string","integer","integer","integer"];
add.keyFields := ["location"];
route add;
DataViewException dvException;
on all DataViewException(): dvException {
log "*** Weather monitor error: " +
   dvException.toString() at ERROR;
}
```

Deleting DataView definitions

Use the following event types to delete DataView definitions.

DataViewDeleteDefinition

Create and route events of this type in order to delete a DataView definition. The response is provided by a `DataViewDefinitionDeleted` or `DataViewException` event.

DataViewDefinitionDeleted

These events are responses to `DataViewDeleteDefinition` events. They indicate the successful deletion of a DataView definition.

Creating DataView items

Use the following event types to create DataView items.

DataViewAddItem

Create and route an event of this type to create a DataView item. This item must not exist already. A response is provided by a `DataViewItem` or `DataViewException` event.

Here is an example that creates and routes a `DataViewAddItem` event, and handles the `DataViewItem` response by logging the addition of the item:

```
using com.apama.dataview.DataViewAddItem;
using com.apama.dataview.DataViewItem;
...
string location ;
integer temp;
integer humidity;
integer visibility;
...
DataViewAddItem item := new DataViewAddItem;
item.dvName := "Weather";
item.fieldValues :=
   [location,temp.toString(),humidity.toString(),
   visibility.toString()];
route item;
DataViewItem added;
on DataViewItem (dvName="Weather"):added {
   log("Weather monitor - DataViewItem: " +
      added.dvItemId.toString());
}
```

DataViewAddOrUpdateItem

Create and route an event of this type to create a DataView item if it does not already exist, or update a DataView item if it already exists. A response is provided by a `DataViewItem` or `DataViewException` event.

This will only work when keyFields are used. Any attempts to change the owner of an existing item will be rejected with a `DataViewItemException`.

DataViewItem

These events are responses to DataViewAddItem events. They indicate the successful creation of a DataView item. The contents of the fields are exactly those of the DataViewAddItem event to which this is a response, except possibly *extraParams*, and with the addition of the *dvItemId* field.

DataViewItemException

These events occur under exceptional circumstances in response to DataViewDeleteItem, DataViewUpdateItem or DataViewUpdateItemDelta events.

Deleting DataView items

Use the following event types to delete DataView items.

DataViewDeleteItem

Create and route an event of this type to delete a DataView item. A response is provided by a DataViewItemDeleted, DataViewException or DataViewItemException event.

Here is an example that creates and routes a DataViewDeleteItem event and handles the DataViewItemDeleted response by logging the deletion of the item:

```
using com.apama.dataview.DataViewDeleteItem;
using com.apama.dataview.DataViewItemDeleted;
string location;
...
DataViewDeleteItem delete := new DataViewDeleteItem;
delete.dvName := "Weather";
delete.dvItemId := -1;  // Set the ID to -1 when using keyFields
delete.keyFields := [location];
route delete;
DataViewItemDeleted deleted;
on DataViewItemDeleted (dvName="Weather"):deleted {
   log("Weather monitor - DataViewItemDeleted:
      "+deleted.dvItemId.toString());
}
```

DataViewItemDeleted

These events are responses to DataViewDeleteItem events. They indicate the successful deletion of a DataView item.

DataViewDeleteAllItems

Create and route an event of this type to delete all DataView items associated with a specified DataView definition. A response is provided by a DataViewAllItemsDeleted, DataViewException or DataViewItemException event.

DataViewAllItemsDeleted

These events are responses to DataViewDeleteAllItem events. They indicate the successful deletion of all items associated with a given DataView definition.

Updating DataView items

Use the following event types to update DataView definitions.

Note: In addition to the event types listed below, you can also use the DataViewAddOrUpdateItem event to either create new DataView items or to update existing ones. See "Creating DataView items" on page 416.

DataViewUpdateItem

Create and route an event of this type to update a data item by specifying a sequence of new filed values. If the update does not succeed, a response is provided by a DataViewItemException event.

Here is an example of creating and routing a DataViewUpdateItem event:

```
using com.apama.dataview.DataViewUpdateItem;
...
string location;
integer temp;
integer humidity;
integer visibility;
...
DataViewUpdateItem update := new DataViewUpdateItem;
update.dvName := "Weather";
update.dvItemId := -1;  // Set the ID to -1 when using keyFields
update.fieldValues :=
   [location,temp.toString(),humidity.toString(),visibility.toString()];
route update;
```

DataViewUpdateItemDelta

Create and route an event of this type to update a data item by specifying a dictionary of field-position/field-value pairs. If the update does not succeed, a response is provided by a DataViewItemException event.

Here is an example of creating and routing a DataViewUpdateItemDelta event:

```
using com.apama.dataview.DataViewUpdateItemDelta;
...
string location;
integer temp;
integer humidity;
integer visibility;
...
DataViewUpdateItemDelta update := new DataViewUpdateItemDelta;
update.dvName := "Weather";
update.dvItemId := -1;  // Set the ID to -1 when using keyFields.
update.fieldValues :=
   {0:location,1:temp.toString(),2:humidity.toString(),
      3:visibility.toString()};
route update;
```

Looking up field positions

Use the following event types to look up the numerical position of a given field-name for a given DataView definition.

DataViewGetFieldLookup

Create and route an event of this type to request a helper dictionary that supports lookup of field position for a given field name. The response is provided by a `DataViewFieldLookup` or `DataViewException` event.

DataViewFieldLookup

These events are responses to `DataViewGetFieldLookup` events. They contain a dictionary that supports lookup of the field position for a given field name.

Using multiple correlators

The `DataViewService` is designed to primarily interact with other EPL or JMon applications that reside in the same correlator. Therefore, the `DataViewService` implementation does not emit any events. You can inject the following optional additional monitors, which are in the `monitors` directory of your Apama installation, to emit the events when that is required:

- `DataViewService_ServiceEmitter.mon`
- `DataViewService_ApplicationEmitter.mon`

This enables Dashboard Builder clients to visualize the state of a number of applications, each of which is running in a separate correlator, and each of which may fail-over to another correlator. Since configuring all of the dashboards to know about each of these correlators might be difficult and fragile, you can designate an additional single correlator as the "view correlator", which holds the `DataViewService` and `ScenarioService` to which any client dashboard can connect.

With this architecture, the individual applications in the separate correlators need to emit `DataViewService` request events to a channel that has been connected to the view correlator. These applications can either emit the events directly, or with the Application Emitter injected they can route the events and the extra monitor will emit them to the channel. The `DataViewService` in the view correlator routes its responses (as normal), but the Service Emitter monitor will then emit those events out on the `com.apama.dataview` channel so that the originating correlators can receive them.

Note that these two emitters are entirely optional, and are not required for most deployments. Moreover, you normally do not inject these two monitors into the same correlator. Also, there is no bundle in Software AG Designer that provides these monitors.

12 Testing and Tuning EPL monitors

This section provides information about testing and tuning your EPL monitors.

Optimizing EPL programs

Best practices for optimizing EPL programs include:

- Minimize cost of spawning— avoid repeated spawning of monitors that contain a large number of variables.
- Allocate events — but not unecessarily. See "Avoiding unnecessary allocations" on page 423.
- Specify `wildcard` on non-essential event fields. See "Wildcard fields that are not relevant" on page 423.
- Use plug-ins when you cannot write efficient EPL to accomplish your purpose. See "When to use plug-ins" on page 356.
- Minimize the effect of garbage collection

EPL, like languages such as Java or C#, relies on garbage collection. Intermittently, the correlator analyses the objects that have been allocated, including events, dictionaries and sequences, and allows memory used by objects that are no longer referenced to be re-used. Thus, the actual memory usage of the correlator might be temporarily above the size of all live objects. While running EPL, the correlator might wait until a listener, `onload()` action or stream network activation completes before performing garbage collection. Therefore, any garbage generated within a single action, listener invocation or stream network activation might not be disposed of before the action/listener/activation has completed. It is thus advisable to limit individual actions/listeners/activations to performing small pieces of work. This also aids in reducing system latency.

The cost of garbage collection increases as the number of events a monitor instance creates and references increases. If latency is a concern, it is recommended to keep this number low, dividing the working set by spawning new monitor instances if possible and appropriate. Reducing the number of object creations, including string operations that result in a new string being created, also helps to reduce the cost of garbage collection. The exact cost of garbage collection could change in future releases as product improvements are made.

Best practices for writing EPL

EPL is a programming language with some special features. As such, it shares the characteristic with every other programming language that it is possible to write poor, inefficient code. All the techniques that apply to other languages to minimize wasted cycles can also be applied to EPL.

Basic programming optimization techniques all apply:

- Move code out of tight loops
- Avoid unnecessary allocation, for example, strings

- Put common tests first in `if .. then .. else` form

There is no substitute for empirical evaluation of the performance of your application. You must measure performance and compare measurements when modifications are made. Also, ensure that you are comparing like-with-like. Understanding performance implications is invaluable and it helps in avoiding unnecessary performance costs.

You should know how fast your application needs to be.

Wildcard fields that are not relevant

Once a design has stabilized and event interfaces are well defined, it is possible to wildcard fields that do not need to be matched on in event listeners. Designating an event field as a wildcard prevents the correlator from creating an index for that field. Most importantly, a wildcard field means that the correlator does not need to traverse that index when receiving an event of that type to try to find interested event listeners (as there will not be any). This can give tangible performance benefits, particularly with large events.

Premature wildcarding is not advised but is not harmful. You can easily remove the `wildcard` annotation from event fields with no impact on existing code. The compiler gives an error if any code attempts to match on a field that is a wildcard.

The correlator can index up to 32 fields for each event type. If you are using an event that has more than 32 fields, you must designate the additional fields as wildcards.

See "Improving performance by ignoring some fields in matching events" on page 174.

Avoiding unnecessary allocations

You should eliminate unnecessary allocations, especially when the size of an event is very large. For example:

```
event LargeEventWith1000Fields {}      // field definitions omitted

integer i := 0;
while (i < 1000) {
   route LargeEvent(0,0,i, ...);       // bad
   i := i + 1;
}

LargeEvent le := new LargeEvent();     // good
while (i < 1000) {
   le.foo := i;
   route le;
   i := i + 1;
}
```

Implementing states

When you want to write a process that passes through one or more states it is good practice to have one action per state. For example:

```
action inAuction() {
   on AuctionClosed outOfAuction();
}
```

```
action outOfAuction() {
   on all Price (stock,*):p and not InAuction() {
      on Price(stock,>p.price*1.01) and not InAuction() {
         sellStock();
      }
   }
   on InAuction() inAuction();
}
```

Structure of a basic test framework

Apama lends itself to automated testing because

- You can define test cases in event files that you feed into the correlator.
- Apama includes a comprehensive set of command line utilities, all of which are scriptable using standard scripting languages on different platforms.
- The correlator is deterministic when there is only the main context. When there is more than one context, each context is deterministic but the correlator as a whole is not.

If the advocated event interface pattern is employed for encapsulation, then modules can be tested in isolation (unit testing) as well as in more comprehensive integration-level tests.

A basic test case includes the following:

- EPL files (`.mon`) to deploy (or references to them)
- Input event files (`.evt`) to send to the correlator
- Reference event files (`.evt)` to compare to actual output
- Script to orchestrate execution of the test-case

You should assemble all of these files in an Apama project in Software AG Designer and then use Software AG Designer to launch the test case.

Each test-case can reside in its own project with all relevant files local to it. The basic test process is to launch the application, send in some events, capture outputs, then compare to expected output, printing the results of the test to the console or log file at the minimum.

Using event files

The following example shows how to use `&TIME` (Clock) events to explicitly set the correlator clock. To do this, the correlator must have been started in external clocking mode (the `&TIME` events give errors otherwise). Times are in seconds since the midnight, Jan 1970 epoch.

```
#seed initial time (seconds since Jan 1970 epoch)
&TIME(1)

# Send in configuration of heartbeat interval to
```

```
# 5 SecondsSetHeartbeatInterval(5.0)
# Advance the clock (5.5 seconds)
&TIME(6.5)

# Correlator should have sent heartbeat with id 1 -
# acknowledge all is well
HeartbeatResponse(1,true)
```

Notice that the input event file has a lot of knowledge regarding the way in which the module will (should) respond. For example, the `HeartbeatResponse` event expects that the first `HeartbeatRequest` will have the ID of `1`. There is necessarily a close coupling between the input scripts and the implementation of the module being tested. This is another reason why as much of this information should be extracted into the module's message exchange protocol and made explicit, and perhaps enforced by one or more interface intermediaries.

A single correlator context is guaranteed to generate the same output in the same order, even when EPL timers (such as `on all wait()`) are employed. This is a benefit of correlator determinism, and makes regression testing, even of temporal logic, possible.

Note: The correlator's behavior can be nondeterministic when events are sent between multiple contexts, or when plug-ins are used.

Handling runtime errors

EPL eliminates many runtime errors because of the following:

- Strict, static typing, so there are no class cast exceptions.
- No implicit type conversion so there are no number format exceptions.
- No concept of null, so there are no null pointer exceptions.

However, EPL cannot entirely eliminate runtime errors. For example, you receive a runtime error if you try to divide by zero or specify an array index that is out of bounds. Some runtime errors are obscure. For example:

```
mySeq.remove(mySeq.indexOf("foo"));
```

If `foo` is not in `mySeq`, `indexOf()` returns `-1`, which causes a runtime error.

See also "Catching exceptions" on page 293 .

What happens

When the correlator detects a runtime error, it kills the monitor instance that contains the code that caused the error. This protects the other monitor instances that are running in the same correlator. Upon a runtime error, the correlator also terminates any listeners that were set up by the monitor instance being killed, and the state of the killed monitor is lost.

Using ondie() to diagnose runtime errors

You cannot catch and handle runtime errors like you can handle exceptions in other languages. You cannot prevent the correlator from terminating the monitor instance. However, you can specify some logging in the `ondie()` action to help diagnose the problem and to alert other system modules that a problem occurred. For example:

```
action ondie() {
   log "sub-monitor terminating for " + myId;
   route InternalError("Foo");
}
```

In some circumstances, you can move into a suspended or safe state, or initiate damage limitation activities, for example, such as pulling all active orders from the market. For example, Apama scenarios use the `ondie()` action to route an `InstanceDied()` event to a `ScenarioService` monitor. This in turn sends the event to connected clients so the termination of the instance can be handled, perhaps displayed, in a dashboard)

An alternative to using `ondie()` in this manner is to use a basic `ACK`, `NACK`, and timeout message exchange protocol so that a client is robust against its services being unavailable.

Using logging to diagnose errors

Logging is an effective means of generating diagnostic information. When writing log entries, consider the overhead of string allocation, garbage collection, and writing data to disk. Use conditional tests to reduce this overhead and minimize unnecessary logging.

The EPL `log` statement is a simple means of generating logging output. The EPL `log` statement writes to the correlator log file by default so any messages your program sends to the log file are mixed in with all other correlator logging messages. However, you can configure the correlator to send your EPL logging to a separate file. See *Deploying and Managing Apama Applications*, "Correlator Utilities Reference", "Setting logging attributes for packages, monitors, and events". The logging attributes you can specify include a particular target log file and a particular log level for any number of individual packages, monitors and events.

When sending messages to the correlator log file, consider the following:

- Log messages can be lost if the correlator is logging to `stdout`.
- Using the correlator log is relatively expensive if there are many `log` statements in the critical path.
- Anything you send to the log might be lost if the correlator log level is `OFF`.

See also "Logging and printing" on page 295.

Standard diagnostic log output

By default, the correlator outputs diagnostic information every five seconds, and sends it to the correlator log file at `INFO` log level. You can use this information to diagnose common problems. See "Descriptions of correlator status log fields" in *Deploying and Managing Apama Applications* for further information.

The correlator sends this information to its log file during normal operation. While it is possible to disable this output (by setting the correlator's log level to `WARN`), doing so is not advisable. In the unlikely event that you run into a problem, Apama Technical Support always ask for a copy of this log file, as the information in it is often useful for diagnosing the nature of a failure.

Capturing test output

All receivers should be started before any events are sent in to the correlator and set to write events to file. The file(s) can be easily compared to reference output using standard operating system tools.

Other tools are also useful in checking the output. The `engine_inspect` correlator utility is good for verifying that the right number of monitor instances and listeners is present after (stages of) a test. Also, you can use this utility to detect listeners and monitor instances that never terminate, or premature existence of monitor instances.

Use the `engine_receive` utility to capture event output. You can specify the `-f` option to pipe received events to a file. Start multiple receivers on different channels as required

The `engine_inspect` utility provides useful data for testing including the number of monitor instances, listeners, receivers, events generated and so on. Split input event files and run the `engine_inspect` utility after each file.

Capture the correlator log and compare to reference data. This is useful if your application logs errors or there are interesting diagnostics.

Avoiding listeners and monitor instances that never terminate

An `Out of Memory` condition causes the correlator to exit. This condition can be caused by listeners and monitor instances that never terminate — also referred to as listener leaks. For example, the following `on` statement defines event listeners that never terminate:

```
on all ( Foo(id=1) or all Foo(id=2) ) {      // second "all" is bogus
...
}
```

The following example spawns monitor instances that never terminate:

```
on all Trade():t spawn handle();         // missing "unmatched" action
...
action handle() {
   on all Trade(symbol=t.symbol):t {
      ...
   }
}
```

The `sm` (number of monitor instances) and `ls` (number of listeners) counts in the log file are often revealing in the case of a memory leak. An increasing trend can be seen in these counts over a period of time, when there is no valid reason for this given the intended logic of the application.

Handling slow or blocked receivers

You can use correlator diagnostic output to identify slow or blocked receivers.

- The `oc` (number of events on the output queue) can grow to 10,000 maximum. If you see a steady trend that it is growing, it probably indicates a slow receiver.
- The `tx` (number of events transmitted) should always be increasing. If it is static, or not increasing as fast as it should, it probably indicates a slow receiver.

Slow receivers include:

- Receivers that are not consuming events as quickly as the correlator is generating them.
- Blocked receivers that are not accepting new events.

When the correlator's output queue fills, operations that are sending events from the processing thread (or threads, if there is more than one context) are blocked. If the output queue remains filled, and the processing thread(s) remain blocked, the input queue(s) start(s) to fill. Events are never dropped.

If you specify the `-x` correlator option when you start the correlator, it causes the correlator to disconnect any receiver that becomes slow. If you discover that your application is producing events at too high a rate for a particular receiver you might be able to publish the events to separate channels so that the receiver needs to handle fewer events. Alternatively, or in addition, you might be able to modify your application to throttle the rate at which it sends events to this receiver.

If you cannot speed the receiver up, or install faster hardware, you can partition the correlator's output event flow into channels so that the receiver needs to handle fewer events. Alternatively, you can use throttling in the correlator to output events less frequently.

See also *Deploying and Managing Apama Applications*, "Correlator Utilities Reference", "Starting the event correlator", "Determining whether to disconnect slow receivers".

Diagnosing infinite loops in the correlator

A correlator live lock occurs when events are recursively routed without a termination mechanism. The following example shows this in its simplest form:

```
on all Foo() {
   route Foo();
}
```

More complex forms might recurse after a connected chain of several events being routed between different monitors.

There are no limits on how many routed events can be queued. Consequently, depending on the nature of the bug, the correlator might run out of memory. Note that an overloaded correlator would show similar symptoms, but can be distinguished by the fact that work is still being done (events are being sent out from the correlator).

When the correlator is in an infinite loop, it quickly uses an entire CPU and if there are events being routed as part of the loop then the correlator will run out of memory. Use the following correlator diagnostics to diagnose an infinite loop:

- `rq` —sum of the number of routed events on the input queues of all contexts. When the correlator is in an infinite loop, this will always be 1 or it will always be increasing. It depends on the application.
- `iq` — sum of the number of entries on the input queues of all contexts. When the correlator is in an infinite loop, this number is continuously increasing.
- `tx` — number of transmitted events. This number is static when the correlator is in an infinite loop.

To identify an infinite loop in a particular context, run `engine_inspect -x` a few times. This lists each context along with the number of events on its input queue. See if there are contexts that have input queues that are getting bigger and bigger.

Tuning contexts

You should implement contexts whenever you want the correlator to perform concurrent processing. Work to be divided among contexts should have minimum or no interdependencies and no ordering requirements. Many applications present a natural way to partition work that is largely independent. For example, you could partition a financial application by stock symbol, or by user, or by strategy.

The following topics describe common ways to optimize use of contexts.

Parallel processing for instances of an event type

A candidate for implementing parallel processing is when an application performs calculations for a number of events that are of the same type, but that have different identifiers. For example, different stock symbols from a stock market data feed. You can use either of the following strategies to implement parallel processing for this situation:

- Create multiple public contexts. Each context listens for one identifier, operates on the events that have that identifier, and discards events that have any other identifier.
- Have one context distribute data to multiple contexts, which are each dedicated to processing the events that have a particular identifier.

The performance of these strategies varies according to the work being done. A distributor can be a bottleneck. However, there is a cost in every context discarding events for which it is not interested. In the following situations, the distributor strategy is likely to be more efficient:

- There is a very large set of identifiers but a relatively low overall rate of arriving events.

- Events must be pre-processed.
- Events are not arriving from external sources. Instead, you must explicitly send events.

The sample code below shows the distributor strategy.

```
event Tick {
   string symbol;
   integer price;
}

/** In the main context, the following monitor distributes Tick events
    to other contexts. There is one context to process each unique symbol. */
monitor TickDistributor {

    /** The dictionary maps each unique Tick symbol to the (private)
        context that ultimately processes it. */
 dictionary<string, context> symbolMapping;

   action onload() {
      Tick t;
      on all Tick():t {
         // If the context for this symbol does not yet exist, create it.
         if(not symbolMapping.hasKey(t.symbol)) then {
            context c := context("Processing-"+t.symbol);
            symbolMapping[t.symbol] := c;
            spawn processSymbol(t.symbol) to c;
         }

         // Send each Tick event to the context that handles its symbol.
         send t to symbolMapping[t.symbol];
      }
   }

 /** The following action handles Tick events with the given symbol.
     This action executes in a private context that processes all Tick
     events that have one particular symbol. */
   action processSymbol(string symbol) {
      Tick t;
      // Because this context receives a homogeneous stream of Tick events
      // that all have the same particular symbol, there is no need to specify
      // an event listener that discriminates based on symbol.
      on all Tick():t {
         ...
      }
   }
}
```

Parallel processing for long-running calculations

Suppose a required calculation takes a relatively long time. You can do the calculation in a context while the main context performs other operations. Or, you might want multiple contexts to concurrently perform the long calculation on different groups of the incoming events.

The following code provides an example of performing the calculation in another context.

```
monitor parallel {
   action onload() {
```

```
      on all Tick() {
         numTicks:=numTicks+1;
         send NumberTicks(numTicks) to "output";
      }
      Calculate calc;
      on all Calculate():calc {
         integer atNumTicks:=numTicks;
         integer calcId:=integer.getUnique();
         spawn doCalculation(calc, calcId, context.current())
            to context("Calculation");
         CalculationResponse response;
         on CalculationResponse(calcId):resp {
            send CalculationResult(resp, atNumTicks, numTicks) to "output";
         }
      }
   }
   action doCalculation(Calculate req, integer id, context caller) {
      float value:=actual_calculation_function(req);
      send CalculationResponse(id, value) to caller;
   }
}
```

For each `Calculate` event found, the event listener specifies a `spawn...to` statement that creates a new context. All contexts have the same name — `Calculation` — and a different context ID. All contexts can run concurrently.

A `Calculation` context might send a `CalculationResponse` event to the main context before the main context sets up the `CalculationResponse` event listener. However, the correlator completes the operations, including setting up the `CalculationResponse` event listener, that result from finding a `Calculate` event before it processes the sent `CalculationResponse` event.

While the calculations are running, other `Tick` events might arrive from external components and the correlator can process them.

The order in which `CalculationResponse` events arrive on the main context's input queue can be different from the order of creation of the contexts that generated the `CalculationResponse` events. The order of responses depends on when the calculation started and how long it took to complete the calculation. The monitor instance in the main context uses the `calcId` variable to distinguish responses.

13 Generating Documentation for Your EPL Code

Just as you can use the Javadoc tool to generate documentation for Java, you can use the ApamaDoc tool to generate documentation for EPL. ApamaDoc, which is based on Javadoc, generates reference documentation from EPL source code. To enhance what ApamaDoc automatically generates, you can insert annotations in block comments. Annotations are a mixture of text and tags.

ApamaDoc is an export wizard in Software AG Designer. It generates static HTML pages that document the structure of all EPL code in a project. This includes the `.mon` files that you create as well as all `.mon` files in all bundles that have been added to a project.

Alternatively, you can generate ApamaDoc in headless mode by invoking the `apamadoc` utility from the command line.

Note: ApamaDoc does not operate on `.qry` files. That is, you cannot use ApamaDoc to generate reference documentation for Apama queries.

Code constructs that are documented

The ApamaDoc generates documentation for the following code constructs:

- Packages
- Events (defined outside monitors)
- Monitors
- Custom aggregate functions
- Wildcard modifiers

By default, the ApamaDoc export wizard does not generate documentation for inner fields of a monitor. If you want to include inner fields of a monitor, generate ApamaDoc in headless mode using the `--includeMonitorMembers` option. See "Generating ApamaDoc in headless mode" on page 441 for more information.

Steps for using ApamaDoc

The general steps for using ApamaDoc are as follows:

1. Create an Apama project in Software AG Designer.
2. Add a `.mon` file to your project.
3. In the `.mon` file, enhance the automatically generated documentation by adding annotations. See "Inserting ApamaDoc comments" on page 435, "Inserting ApamaDoc tags" on page 436, and "Inserting ApamaDoc references" on page 439.
4. Save and build the project.
5. Right-click the project name and select **Export** from the context menu.

6. In the **Export** dialog, expand **Software AG**, select **ApamaDoc Export**, and click **Next**.
7. Identify the folder that you want to contain the ApamaDoc output, and click **Finish**.

To view the ApamaDoc output, go to the output folder you identified and double-click the `index.html` file. The generated ApamaDoc opens in your browser.

Try this with any project you already have, or with one of the demo projects. Even if you have not added any ApamaDoc annotations, you can see that ApamaDoc automatically generates a lot of documentation.

Inserting ApamaDoc comments

To augment the documentation automatically generated by ApamaDoc, insert comments in your EPL files in the following format:

1. Start the comment with the `/**` characters, rather than the usual `/*` notation.
2. Enter the text you want to appear in the generated documentation.
3. After each newline, to continue the ApamaDoc comment, insert a `*` character at the beginning of the next line.
4. As needed, insert one or more tags for particular constructs. See "Inserting ApamaDoc tags" on page 436. Any tags must occur at the beginning of a newline (ignoring `*` and whitespace characters). Documentation for a tag ends when you declare another tag or end the comment.
5. End the comment with the usual `*/` characters.

For example, your EPL code might look like this:

```
/**
 * Called by the monitor when it executes the onload() action.
 * This action maintains the configuration for this scenario.
 * @param sId The scenario ID.
 * @param updateCallback The callback after the configuration is updated.
 */
action init(string sId, action<> updateCallback) {
    scenarioId:=sId;
    route GetConfiguration(scenarioId);
    Configuration c;
    listener l:=on Configuration(scenarioId=scenarioId):c {
        config := c.configuration;
        defaultConfig := c.defaults;
        configurationUpdated();
        updateCallback();
    }
    listeners.append(l);
}
```

When ApamaDoc processes these comments, it removes initial and trailing whitespace and `*` characters. For example, the ApamaDoc output would look like this:

```
init
void init(string sId, action< > updateCallback)
Called by the monitor during execution of the onload() action. This action
maintains the configuration for this scenario.
Parameters:
```

```
   sId - The scenario ID.
   updateCallback - The callback after the configuration is updated.
Listens:
com.apama.scenario.Configuration
```

Inserting ApamaDoc tags

ApamaDoc automatically generates documentation for EPL code constructs. To enhance the quality of the documentation, you can insert tags that let you provide and link to additional information. A tag begins with an `@` symbol and is immediately followed by a name and other information. The following table describes the tags you can insert.

Tag	Description	Use For
`@author` *`name`*	There are no restrictions on the name. It can span multiple lines. It is ended by the start of the next tag.	Imports, events, monitors, aggregate functions
`@deprecated [` *`description`* `]`	The optional description can be anything pertinent to the deprecated construct. For example, you might want to suggest a newer equivalent or provide a reason for the deprecation.	Imports, events, monitors, actions, and members (variables and named constants)
`@emits` *`eventRef`* `[` *`description`* `]`	Documents events that are emitted. *`eventRef`* specifies a link to an event definition. The optional description can be anything pertinent to the emitting of the event. See "Inserting ApamaDoc references" on page 439.	Actions and their return types
`@enqueues` *`eventRef`* `[` *`description`* `]`	Documents events that are enqueued. *`eventRef`* specifies a link to an event definition. The optional description can be anything pertinent to the enqueueing of the event. See "Inserting ApamaDoc references" on page 439.	Actions and their return types

Tag	Description	Use For
`@sends` *`eventRef`* `[` *`description`* `]`	Documents events that are sent to a channel. *`eventRef`* specifies a link to an event definition. The optional description can be anything pertinent to the sending of the event to a channel. See "Inserting ApamaDoc references" on page 439.	Actions and their return types
`@listens` *`eventRef`* `[` *`description`* `]`	Documents events that are being listened for. *`eventRef`* specifies a link to an event definition. The optional description can be anything pertinent to the event listener. See "Inserting ApamaDoc references" on page 439.	Actions and their return types
`@param` *`codeRef`* `[` *`description`* `]`	Documents arguments to actions and custom aggregate functions. *`codeRef`* specifies the parameter name. The description should be a sentence describing the purpose of the parameter and any constraints on the permitted values that may be specified.	Actions and custom aggregate functions
`@private`	Hides constructs from ApamaDoc. On a line by itself, immediately precede the construct that you do not want to generate documentation for with the following: `/** @private /*`	All code constructs except packages and action contents
`@returns` *`description`*	Documents the return value of an action or aggregate function. The description should be a sentence describing the purpose of the return value, and	Actions and aggregate functions

Tag	Description	Use For
	any pertinent information about the possible values that may be returned. Note that for backwards compatibility reasons @return is maintained as an alias for @returns.	
@routes *eventRef* [*description*]	Documents events that are being routed. *eventRef* specifies a link to an event definition. The optional description can be anything pertinent to the routing of the event. See "Inserting ApamaDoc references" on page 439.	Actions and their return types
@see	There are three forms of this tag. Each form documents a relationship between a code fragment and some other information. @see "*description*" Lets you insert text that explains the relationship. @see *codeRef description* Lets you reference an EPL code construct and describe the relationship between this construct and that construct. *codeRef* specifies a link to some other EPL code. See "Inserting ApamaDoc references" on page 439. @see *linkText* [*description*] Lets you specify an HTML link to an external resource. Optionally, you can add more information.	All code constructs except packages and action contents

Tag	Description	Use For
`@sends` *`eventRef`* `[` *`description`* `]`	Documents events that are sent. *`eventRef`* specifies a link to an event definition. The optional description can be anything pertinent to sending the event. See "Inserting ApamaDoc references" on page 439.	Actions and their return types.
`@since` *`version`*	Documents when a code construct was introduced. Replace *`version`* with a particular version number, for example, `9.9`.	All code constructs except packages and action contents
`@spawns` *`actionRef`* `[` *`description`* `]`	Lets you document the lifecycle of a monitor. *`actionRef`* specifies a link to an action definition. See "Inserting ApamaDoc references" on page 439.	Monitors and actions
`@version` *`version`*	Lets you specify a version of the current incarnation of this code. Replace *`version`* with a particular version number, for example, `9.9`.	Monitor definitions, event type definitions, custom aggregate function definitions, and actions

Inserting ApamaDoc references

Many ApamaDoc tags contain links to other parts of the EPL code. These tags specify one of the following link types:

- Code references
- Type references
- Event references
- Action references

A *code reference* is a link to a monitor definition, an event type definition, an action definition, a member (variable or named constant) declaration or an import declaration. A code reference has two forms.

The first form links to constructs that are in the monitor definition or event type definition that contains this ApamaDoc comment. The target of the link can be a variable declaration, named constant declaration, import declaration, or action definition. The format for this code reference is as follows:

```
[ # ] (member | import | ( action() ) )
```

The hash symbol is optional. You must specify one of the following:

- Name of a member (variable or named constant) that is in the monitor or event type definition that contains this ApamaDoc comment.
- Name of an item that is being imported in the monitor or event type definition that contains this ApamaDoc comment.
- Name of an action that is in the monitor that contains this ApamaDoc comment. If you specify an action, the name of the action must end with parentheses. For example:

  ```
  #updateOrder()
  ```

The second form links to constructs that are not in the monitor or event type definition that contains this ApamaDoc comment. You can link to code constructs that are in the same package or in other packages. The format for this code reference is as follows:

```
[ package [. monitor ].]type[ #(member | import | ( action() ) )]
```

Replace `type` with the name of a monitor or event type definition. If the ApamaDoc comment is in the same package as the link target, the package specification is optional. If you replaced `type` with the name of an event that is defined in a monitor, you must replace `monitor` with the name of that monitor and you must specify the package name.

The hash symbol followed by a name is required when the link target is a variable declaration, named constant declaration, import declaration, or action definition. If you specify an action, the name of the action must end with parentheses.

If the code reference is valid the rendered HTML output contains a hyperlink to the referenced code construct's documentation followed by the descriptions text, if any. If the reference is not valid, the output displays only the tag's description text if you provided it.

A *type reference* is a subset of a code reference. It always links to a monitor or event type definition.

An *event reference* is a subset of a type reference. It always links to an event type definition.

An *action reference* is a subset of code reference. It always links to an action. The action can be in an event type definition, in a monitor, or in an event type definition that is in a monitor.

Inserting EPL source code examples

The ApamaDoc supports `<code>…</code>` HTML tag in ApamaDoc comments. You can use this tag in ApamaDoc comments text to specify code snippets. The indentation and line breaks of the code snippet between the `<code>…</code>` tag will be retained.

Note: If you have to use the special character @ within the `<code>…</code>` tag, you must use the HTML ASCII code `@` instead of the character.

Generating ApamaDoc in headless mode

Headless mode lets you generate ApamaDoc from a command line as a standalone operation on Windows platforms. This is useful if you want to control what ApamaDoc generates without user-interface intervention, for example, when you are running nightly build integrations. Also, from the command line, you can control which files are exported and which files are omitted.

To generate ApamaDoc in headless mode, run the `apamadoc.bat` file, which is in the `%APAMA_HOME%\bin` folder. The `apamadoc.bat` file uses the `%APAMA_HOME%\utilities\apamadoc.xml` Ant script to generate ApamaDoc.

The format for invoking the `apamadoc` utility is as follows:

```
apamadoc [-v] output_folder
   monitor_file_base_folder|monitor_file_path|file_path ...
```

Note: The `apamadoc` utility requires Apache Ant. To set the path appropriately, it is recommended that you run the `apamadoc` utility from the Apama Command Prompt (see "Setting up the environment using the Apama Command Prompt" in *Deploying and Managing Apama Applications*). If you do not use the Apama Command Prompt, then you must ensure that the `PATH` variable for the headless ApamaDoc command line contains an entry for the Ant installation folder (such as `C:\ant`), which makes the Apama `ant.bat` file accessible to ApamaDoc generation.

Element	Description
`-v`	Optional. Displays verbose output on `stdout` about the process that is generating ApamaDoc.
`output_folder`	Identifies the folder that will contain the generated ApamaDoc.
`monitor_file_base_folder`	Specifies a folder that contains EPL `.mon` files for which you want to generate ApamaDoc. You can specify zero, one, or more folders.

Element	Description
	Insert a space between names. The `apamadoc` utility recursively processes specified folders.
monitor_file_path	Specifies an EPL `.mon` file for which you want to generate ApamaDoc. You can specify zero, one, or more `.mon` files. Insert a space between names.
file_path	File that lists the EPL source files for which you want to generate ApamaDoc. Specify this file by prepending an @ sign at the beginning of the path, for example, `@C:\docfiles\inputEPLFilePaths.txt`. In the specified file, specify one source file on each line. You cannot specify `@`*location* in the specified file; that is, this facility is not recursive.
`-h`	Optional. Specify `-h` to display usage information.
`--includeMonitorMembers`	Generates documentation for inner fields of a monitor. For example, inner events, variables and constants, fields in events, and actions.

On the command line, you can mix file paths, monitor file paths, and folder paths in any combination. The following example generates ApamaDoc for all monitor files in the `C:\mon_files_dir` folder as well as for the `C:\Apama_monfiles\MyMonitor.mon` file and all the files listed in the `inputEPLFilePaths.txt` file. The `mon_files_dir` folder is processed recursively. The generated ApamaDoc is put into the `C:\generated_apamadocs` folder.

```
apamadoc C:\generated_apamadocs
   C:\mon_files_dir
   C:\Apama_monfiles\MyMonitor.mon
   @C:\docfiles\inputEPLFilePaths.txt
```

The next example generates ApamaDoc and puts it in the `C:\MyApplication\ApamaDoc` folder. Specification of the `-v` option displays names of the files being processed on the command line. The files being processed are listed in the `EPLsource.txt` file.

```
apamadoc -v C:\MyApplication\ApamaDoc @C:\MyApplication\doc\EPLsource.txt
```

Headless mode for generating ApamaDoc is available only on Windows platforms.

II Developing Apama Applications in Event Modeler

Developing Apama Application in Event Modeler provides information and instructions for defining independent, real-time, business strategies, referred to as scenarios. Each scenario can contain any number of states, and transitions between states happen according to rules that you define.

You use the Event Modeler to create scenarios. You inject completed scenarios into the correlator, and then use a dashboard to create and configure one or more instances of the scenario. Each scenario instance listens for particular events or sequences of events. When the scenario instance finds events or sequences of interest, it performs specified actions according to the rules defined in the scenario.

After you develop a scenario in Event Modeler, you use Dashboard Builder to create a graphical dashboard for the scenario. The dashboard lets end users create and interact with scenario instances through an intuitive and easy to manipulate graphical user interface, which is described in *Building and Using Dashboards*.

It is assumed that you have read *Introduction to Apama*, which introduces scenario concepts, discusses the scenario development lifecycle, and covers Apama architecture and other Apama concepts.

14 Overview of Using Event Modeler

This chapter introduces the concepts underlying the layout and functionality of the Apama's Event Modeler in Software AG Designer. It does not attempt to describe how to use the tool or how to interact with its various tabs and panels. That explanation is provided in "Using Event Modeler" on page 467, once the underlying concepts are understood.

Before using *Developing Apama Applications in Event Modeler*, we recommend that you take advantage of the Apama tutorials numbered 7, 8, and 9. These tutorials let you quickly start using Event Modeler by adding to a partially formed scenario. To access the tutorials, open Software AG Designer, invoke the Welcome page and click **Tutorials** under the **Apama** heading.

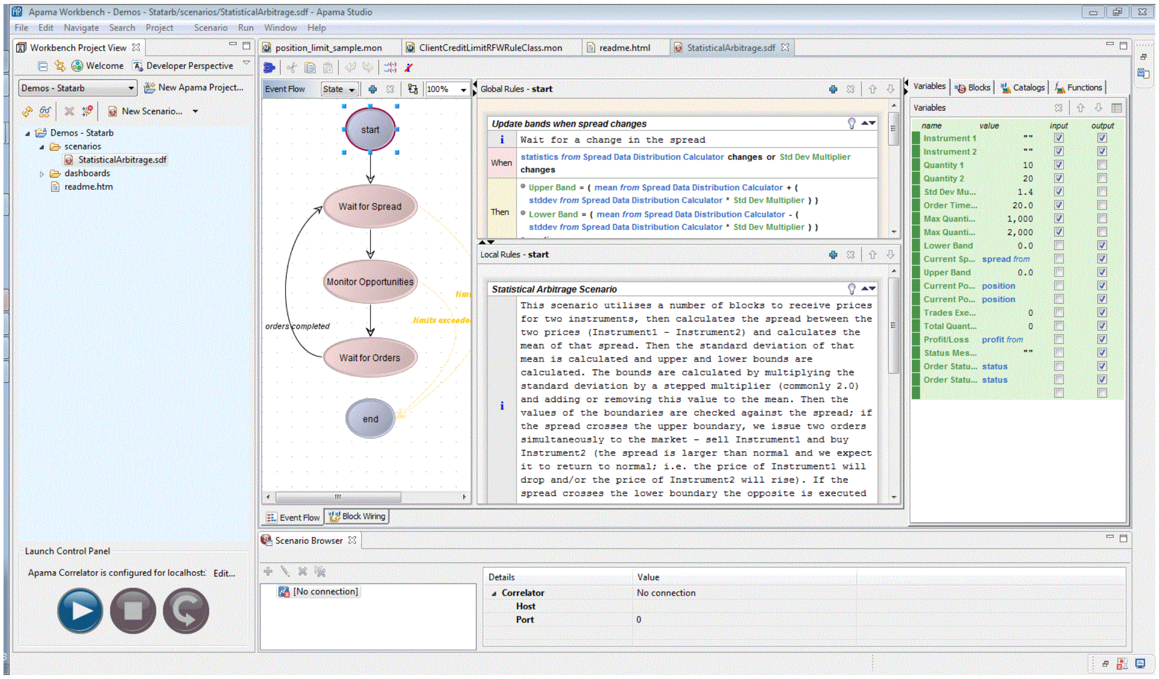
It is assumed that you have read *Description of Event Modeler* and *Understanding scenarios and blocks* in *Introduction to Apama*, which introduces scenario concepts and discusses the scenario development lifecycle.

Event Modeler layout

To begin learning how to use Event Modeler, it is helpful to examine a demo scenario in Event Modeler. To do this:

1. Start Software AG Designer.
2. From the **Help** menu, choose **Welcome**.
3. Click **Demos** under the **Apama** heading.
4. In the list of demos that appears, click **Statistical Arbitrage** and click **Open** to open the demo application's project.
5. In the **Workbench Project View**, expand **Scenarios** and double-click **StatisticalArbitrage.sdf**. This is the scenario definition file. When you double-click it, it opens in Apama's Event Modeler editor.

The Event Modeler editor is divided into a number of areas. In the panel on the left (the **Event Flow** tab) click on the double-bordered oval shape marked **start**. Your display will now look as follows:



This is the default view. Event Modeler displays the following primary areas:

- **Event Flow**
- **Global Rules** and **Local Rules**
- Tabs for **Variables**, **Blocks**, **Catalogs**, and **Functions**.

At the bottom of Event Modeler, there are tabs for **Event Flow** and **Block Wiring**. When you click the **Block Wiring** tab, the **Event Flow** and **Rules** panels diappear and the **Block Wiring** tab appears.

During its lifetime, a scenario instance transits through a number of execution states, starting from the **start** state, and eventually ending at the **end** state (shown in the **Event Flow** tab). Event flows are described in "About event flow states" on page 448.

Each state consists of a list of rules that are executed in a particular sequence. Each has a condition that needs to be met for its embedded actions to be executed, and once those actions are complete, it can specify whether the following rules are to be processed next or the scenario should transit directly to another state. These rules appear in the **Global Rules** and **Local Rules** panels. Rules are examined in "How rules define scenario behavior" on page 450

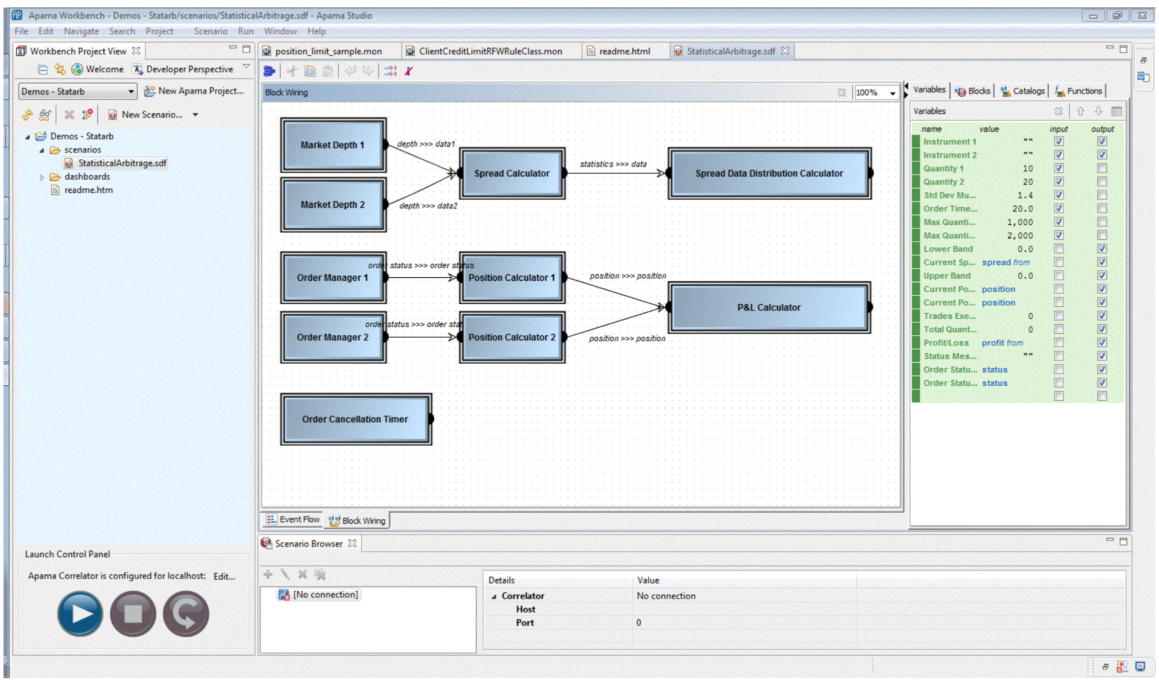
The **Variables** tab lists any variables defined in the scenario. Scenario variables are placeholders for important information that needs to be referred to and modified during the scenario's execution. They also reflect what data can be collected from the user or sent back to be displayed to the user as results or progress updates. Variables will be described in "About scenario variables" on page 460.

The **Blocks** tab lists any blocks that are being used by this scenario. Blocks are pre-packaged modules that can be imported and used within scenarios. They can accept inputs, execute some logic of their own, and generate output. Like a scenario, blocks can themselves have configuration parameters as well as input and output feeds. Blocks can also carry out specialized operations. See "About blocks" on page 463 for details.

The **Catalogs** tab lists the reusable, ready packaged blocks that are available for use in this scenario. Event Modeler comes with a selection of standard blocks, and these are documented in "Using Standard Blocks" on page 521. "Using the Catalogs tab" on page 504 describes usage of the **Catalogs** tab.

The **Functions** tab lists the functions that are available for use in this scenario. Event Modeler comes with a selection of standard functions, and these are documented in "Using the Functions tab" on page 506.

Minimize the panels that are not part of Event Modeler and then click the **Block Wiring** tab that appears below the **Event Flow** tab. The main view changes to show the **Block Wiring** tab. The Event Modeler display now looks like this:



This tab shows the blocks that are being used within this scenario, and whether those blocks are wired together; that is, whether the outputs of one block are acting as the inputs of another. This functionality will be described in "Switching blocks" on page 511. The specific functionality of all the tabs will be covered in depth in "Using Event Modeler" on page 467.

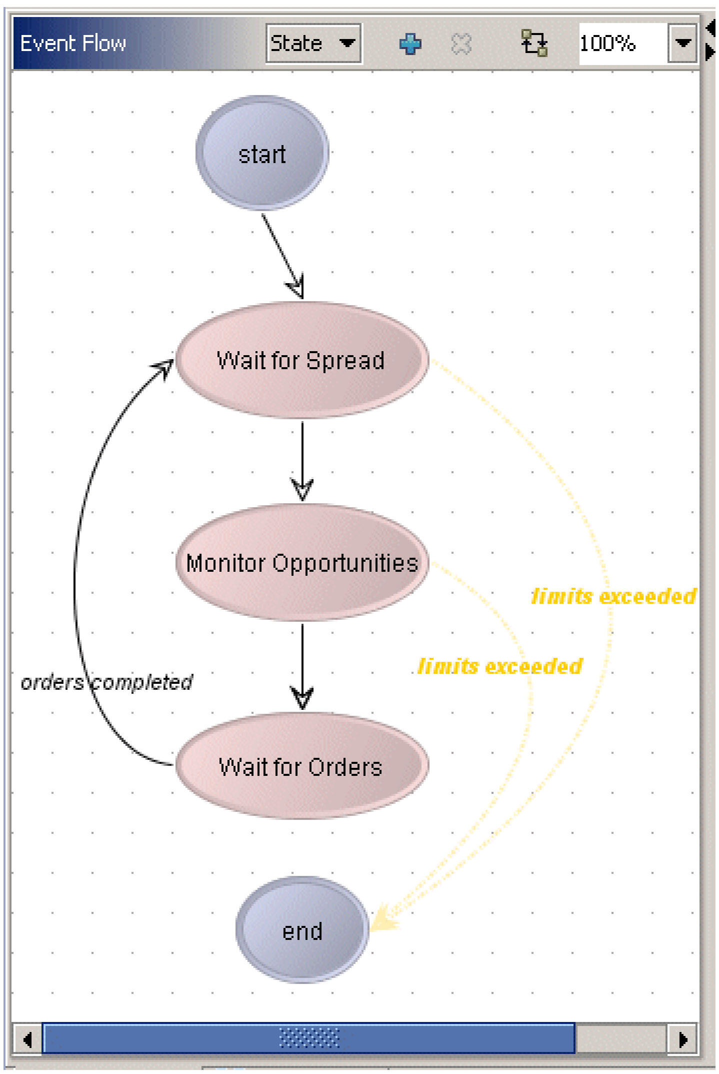
About event flow states

At any moment in a scenario instance's execution, it is said to be in a particular *state* in the event flow. The activities and actions that a scenario instance will be doing at any moment depend on its state, and are defined by that state's *rules*.

The execution of a scenario instance consists of progressing through a sequence of states, starting from the **start** state, and ending at the **end** state. For this reason, all scenarios must have a **start** and an **end** state.

A scenario instance can only ever be in one state, but there might be a choice of states it can advance to from that state. It is also possible for a scenario instance to move from a state back to the same state again. A scenario instance will continue executing until it reaches the **end** state, then it will terminate.

The **Event Flow** tab illustrates all the possible states that the scenario instance can be in while it is running inside the correlator. Note how when the Statistical Arbitrage sample is loaded the **Event Flow** tab is showing the following states (the arrows indicate possible transitions between states):



Using this scenario as an example, when the Statistical Arbitrage scenario is deployed to the correlator, it will start execution from the **start** state. From this state it can only transit to the **Wait for Spread** state. In **Wait for Spread**, however, it can go directly to the **end** state and terminate its execution (by means of a global rule - shown as an orange line; more on this later), or else transit to the **Monitor Opportunities** state by means of a local rule.

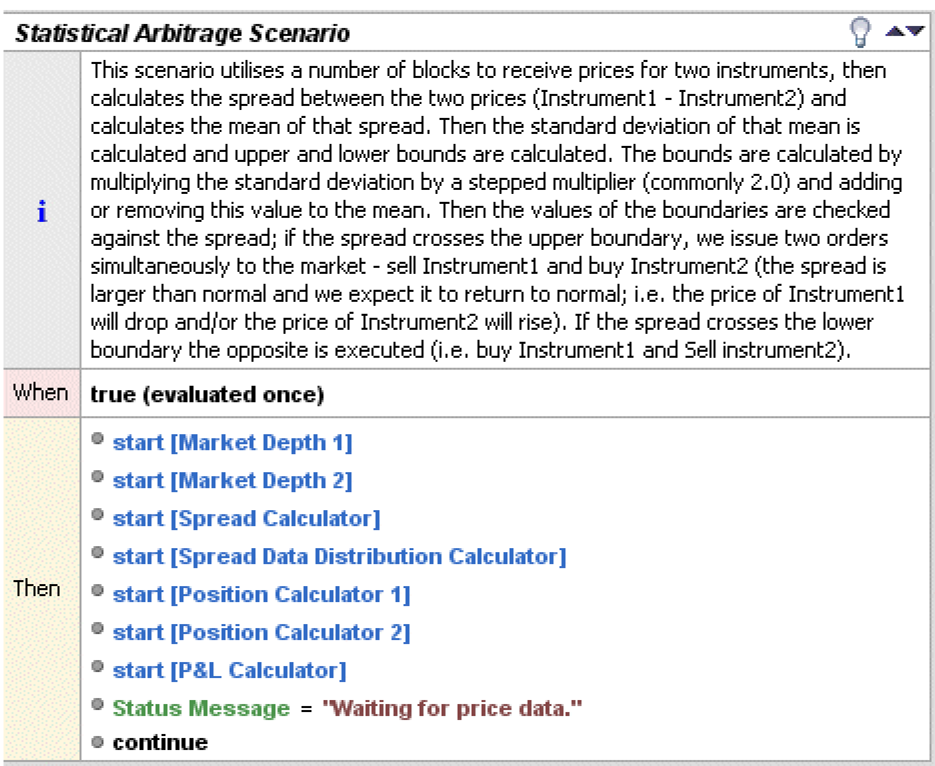
From the **Monitor Opportunities state**, the scenario can advance to the **Wait for Orders** state, or it can terminate execution and go to the **end** state. If execution does reach the **Wait for Orders** state, it can only transit back to the **Wait for Spread** state. What causes a scenario instance to change from one state to another state, and what it does while it is in a state, depends on its *rules*.

How rules define scenario behavior

States matter because of the distinct behavior that the scenario instance will follow while in a particular state. And that is defined in each state's set of *rules*. A state can have one or more rules defined in it. Each rule has the following structure; "if a condition is true then do the following …".

The center panel has two parts: **Global Rules** and **Local Rules**. A global rule can apply to more than one state. A local rule can apply to exactly one state. When you select a state in the **Event Flow** tab, the rules defined for that state appear in the **Rules** panel.

Each rule has a *condition* part, denoted by **When**, and an *action* part, indicated by **Then**. The part indicated by the **i** symbol is just a descriptive comment that you can set to whatever you like. You can hide or show the comment by selecting in the Event Modeler toolbar. The **start** state illustrated in the previous topic has two local rules, including this rule:



This is stating:

- when true, which means: always do this,
- then do the following:
  - carry out the `start` operation on the following block instances
    - `Market Depth 1`
    - `Market Depth 2`
    - `Spread Calculator`
    - `Spread Data Distribution Calculator`
    - `Position Calculator 1`
    - `Position Calculator 2`
    - `P&L Calculator`
  - set the `StatusMessage` variable to “`Waiting for price data`”
  - `continue`, that is, evaluate the next local rule

Variables: For now it is enough to know that, as in other programming environments, scenario variables are placeholders for useful information that the scenario needs to keep track of and perhaps modify during its execution. They also identify the information that will be required by a running instance of the scenario from the end-user in order to configure and start it off, as well as representing the information that will be sent back to be displayed to the user as progress updates or results.

- Variables are typed; each can be of type `text`, `number`, `choice` or `true/false`.
- Variables are described in "About scenario variables" on page 460.

Blocks: Likewise, blocks are ready-packaged modules that you can import and use within your scenarios. They can accept inputs, execute some logic of their own, and generate output. A block can consist of *Input feeds* (which contain one or more *input fields*), *Output feeds* (which contain one or more *output fields*), *Parameters*, and *Operations*. Block parameters and fields are typed; each can be of type `text`, `number`, `choice` or `true/false`. Blocks are described in "About blocks" on page 463.

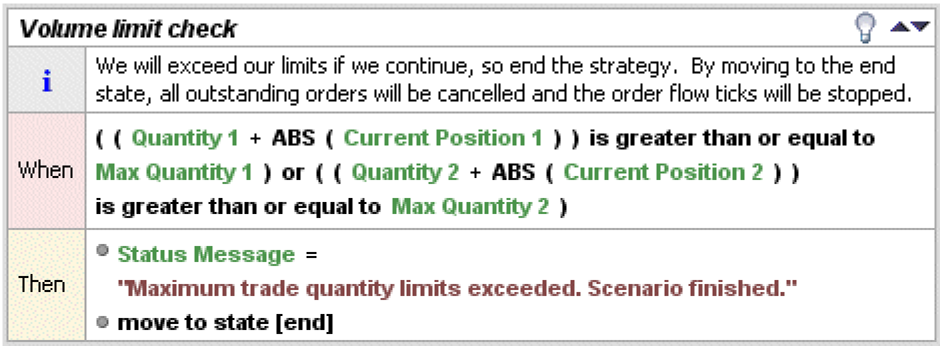
In addition to the standard blocks provided with Event Modeler, you can build custom blocks in Software AG Designer.

Description of rule conditions

The condition specified in a rule must be true for the action part to be executed. Conditions can be as straightforward as the example seen so far, such as a condition that specifies just `true (evaluated once)`. This condition causes the action part to execute whenever the rule is evaluated. However, more often a condition will specify a constraint on the value of a variable, field or parameter, for example, “*is a particular variable at present greater than this value*”. It can also be a complex composition of various conditions defined using the operators `and` and `or`. For example:

1. Click on the **Wait for Spread** state.

2. In the global rules pane, scroll down to the last global rule, the one labeled `Volume limit check`.



Consider the condition for this first rule. This condition will be true if:

```
( Quantity 1 + ABS(Current Position 1) ) is greater than or equal to Max
Quantity 1
or
( Quantity 2 + ABS(Current Position 2) ) is greater than or equal to Max
Quantity 2
```

This condition contains two clauses:

- Whether the result of the variable `Quantity 1` being added to the absolute value of `Current Position 1` is greater than or equal to the variable `Max Quantity 1`.
- Whether the result of the variable `Quantity 2` being added to the absolute value of `Current Position 2` is greater than or equal to the variable `Max Quantity 2`.

As the two clauses are joined with an `or`, only one needs to be true for the condition to be true as a whole. Had the operator used been an `and`, then both of the clauses would have needed to be true for the condition as a whole to evaluate to true.

A condition needs to evaluate to the value `true` or `false`. Apart from the literal values `true` and `false` themselves, a condition can also consist of any of the following:

- The inverse of any other condition. This can be achieved by expressing `not` before that condition
- A variable (or block parameter or block output field) that is of type `True/False` (or *condition*)
- A check on whether a variable's value (or block parameter or block output field) has changed since the beginning of this state or since it was last checked by this rule

  For example, `Max Quantity changes`
- A function call whose result is either true or false

  For example, `isWeekday("Friday")`
- Any *numeric* expression being compared with another numeric expression. A numeric expression equates to a numeric value, and can be arrived at by any combination of arithmetic operations, functions and/or number variables. Numeric expressions can be compared to each other with `is less than`, `is less than or`

`equal to`, `is greater than`, `is greater than or equal to`, `is equal to`, and `is not equal to`.

For example, `Price is less than 20`

or

`((Price * 2) / Quantity) is greater than POW(Upper Limit, 5)`

- Any *text* expression being compared with another text expression. A text expression is a string (that is, a word or phrase) and can be arrived at by any number of operations, functions and/or text variables. Text expressions can be compared to each other with `is equal to`, `is not equal to`, and `contains`.

  For example, `Name is equal to "Tom"`

  or

  `"Bookmark" contains "book"`

- Any choice variable being compared with a valid choice value. The latter can be another choice variable or a text expression. A choice variable is one whose valid values are limited to a particular selection of text values. The valid comparisons here are `is equal to`, and `is not equal to`.
- Any number of nested conditions joined with `and` or `or`

  For example, `Max Quantity changes and ( Price is less than 15 or Price is greater than or equal to 20 )`

Details on how to specify conditions in the **Rules** panel are given in "Working in the Rules panel" on page 480.

Description of rule actions

If a condition evaluates to true, then the corresponding action part of that rule will be processed.

Actions consist of a number of *action statements*, and a *state transition statement*. The former are optional; it is possible to have an action that does not have any action statements. However, there must always be a state transition statement.

The state transition statement is straightforward; it will either be `continue`, or else `move to state [`one of the scenario's states`]`. It is important to note that the latter format could indicate a transition back to the same state, and that this is in fact different to stating `continue`. The distinction will be explained in "About rule evaluation" on page 454.

An action statement can be:

- Assign the value of a numeric expression (that is, a number) to a numeric variable or block parameter. For example:

  `Trades Executed = Trades Executed + 2`

- Assign the value of a text expression (that is, a word or phrase) to a text variable or block parameter. For example:

  ```
  Status Message = "Both orders filled"
  ```

- Assign the value of a condition (true or false) to a conditional variable or block parameter. What constitutes a valid condition here is the same as listed in "Description of rule conditions" on page 451. For example:

  ```
  Active = ((Price * 2) / Quantity) is greater than POW(Upper Limit, 5)
  ```

- Assign the value of a text expression or choice variable to a choice variable or block parameter
- Invoke a block operation

See "Working in the Rules panel" on page 480 for details about specifying rules.

Description of functions in rules

As you might have noticed from some of the examples used so far, functions are available in both conditions and actions.

Functions in Event Modeler take a fixed set of parameters, with each parameter being of a particular type. A function will return a single value of a particular type. The types available for both parameters and results are `text`, `number` and `True/False` (or condition).

Functions are each defined in a *function definition file* or `.fdf` file.

The bundled functions include commonly used arithmetic and string functions, like *abs* (the absolute value of a number), *ceil* (the whole number ceiling of a number), *floor* (the whole number floor of a number), *pow* (to the power of) and *concat* (concatenate). These functions are documented in "Using Functions in Event Modeler" on page 573.

Note that any `.fdf` files located in the folder `functions` are automatically picked up by the Event Modeler at startup time, and made available when defining rules.

About rule evaluation

When scenario execution enters a state, the rules of that state are examined in the order they are defined. If there are global rules as well as local rules, Event Modeler evaluates the first global rule first.

The first rule's condition is checked to verify whether it is true or false.

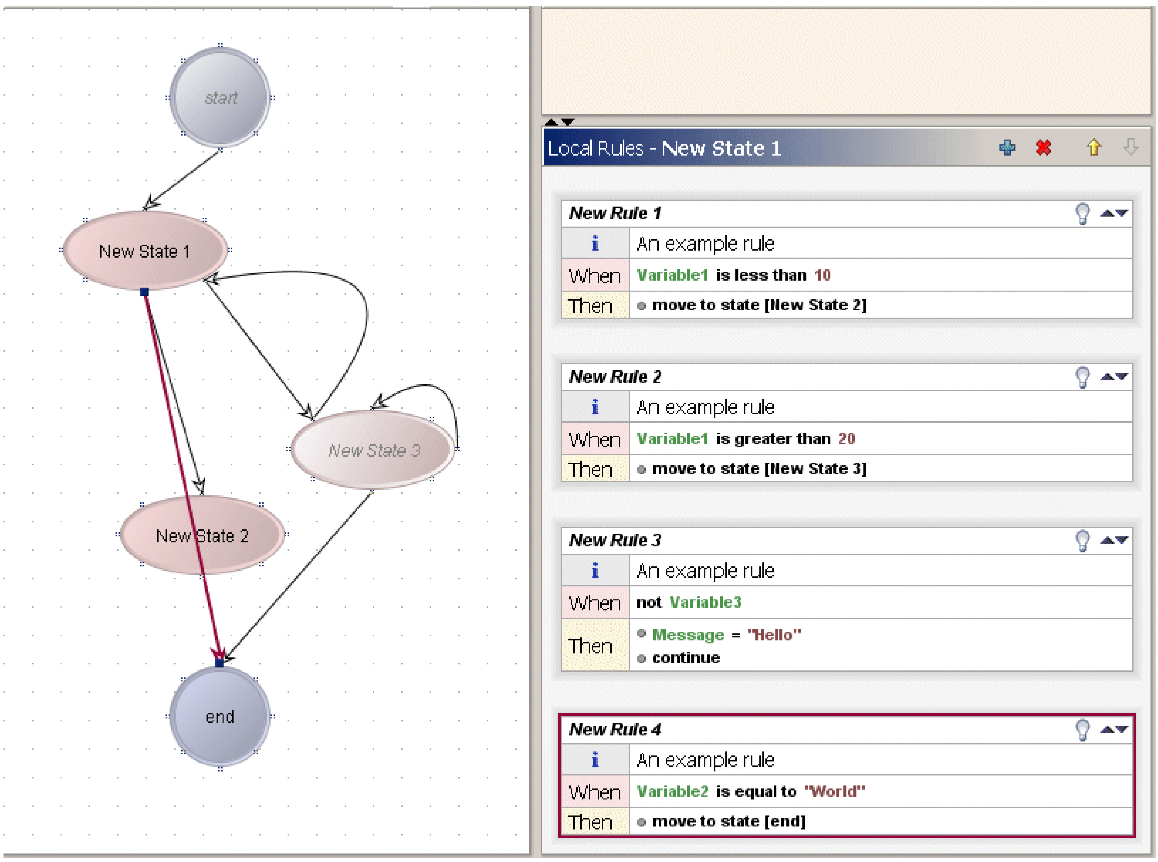
If the condition is false, then execution moves on to the next rule, and the procedure is repeated in the same way for that rule. If there are global rules, the next rule is the next global rule. If there are no more global rules, the next rule is the first local rule. If Event Modeler processes all rules assigned to a state, the order is top to bottom in the combined **Global** and **Local Rules** panel.

If, on the other hand, the rule's condition is true, then its action part is processed. The action statements are executed, and then the state transition statement is examined. If it is continue, then execution moves on to the next rule. If, on the other hand it is move to state [some state] then the scenario will proceed directly to that state and ignore all other rules. Their conditions will not be reviewed and their action parts never processed. In the new state, the same procedure highlighted here is followed.

Note that as stated previously continue, and move to state [this same state] are different. The former causes execution to proceed to the next rule, while the latter causes the state's execution to restart from the first rule as if we had entered this state from a completely different state.

Basic view of rule processing

Consider the set of rules shown in this screen.



This example scenario has four variables, called Variable1 (number), Variable2 (text), Variable3 (condition) and Message (text). These variables could have any value when execution enters NewState 1. Their initial values would normally have been set by a user on creation of the scenario instance, or else they could have been set and modified by some rule in the start state.

Consider NewState 1, which specifies four rules. When the scenario instance's execution first enters NewState1, its rules will be processed as follows:

1. New Rule 1 will be examined first.

2. If the value of `Variable1` is less than `10` then its condition will be true, its action part will be processed, and this will move the scenario's execution to `NewState 2` right away. `New Rule 2`, `New Rule 3` and `New Rule 4` will be ignored, and the rest of the steps outlined here would not apply.
3. If the value of `Variable1`, however, was greater than or equal to `10`, then the condition of `New Rule 1` will be false. In this case, `New Rule 2` will be examined.
4. In `New Rule 2`, if `Variable1` was actually greater than `20`, then the action part of `New Rule 2` gets processed, and this time the scenario moves to `NewState 3`. `New Rule 3` and `New Rule 4` will be ignored. No further steps apply.
5. On the other hand, in `New Rule 2`, if the condition was false, we move to `New Rule 3`.
6. In `New Rule 3`, if the value of `Variable3` was false, then `not Variable3` would be true, and the condition of `New Rule 3` would be true. In this case, `Message` would get set to the text "`Hello`". Since the state transition statement is `continue`, then `New Rule 4` will be processed.
7. Had the condition of `New Rule 3` been false, `Message` would not get set to the text "`Hello`". However, `New Rule4` would have been processed anyway.
8. The condition of `New Rule 4` checks whether `Variable2` contains the text "`World`". If so, execution proceeds to the `end` state. If not, then all rules would have been processed and the scenario would go into a monitoring stage. This will be described later.

This illustrates the way in which rules are processed, in order, from top to bottom.

Expanded view of rule processing

While the previous top-to-bottom rule processing occurs in the majority of scenarios, the full picture of how rules are processed is more elaborate.

In practice, when execution enters a state, the rules of that state are placed on a queue in the order shown in the `Rules` panel — first global rules and then local rules. This queue is known as the *rule queue*. Rules are taken off the head of this queue and processed.

The sequence can differ if any of the action statements modify a scenario variable (or block parameter or block field) that is referenced by the condition of *any rule within that state*.

In that case, *all rules whose condition references that variable, and that are no longer on the queue, will be added to the end of the queue*. If those rules had already been on the queue waiting to be processed, then they would not be added again. For example, consider the following rules:

- R1: f(b): continue;
- R2: f(a): continue;
- R3: f(c): a=7; continue;

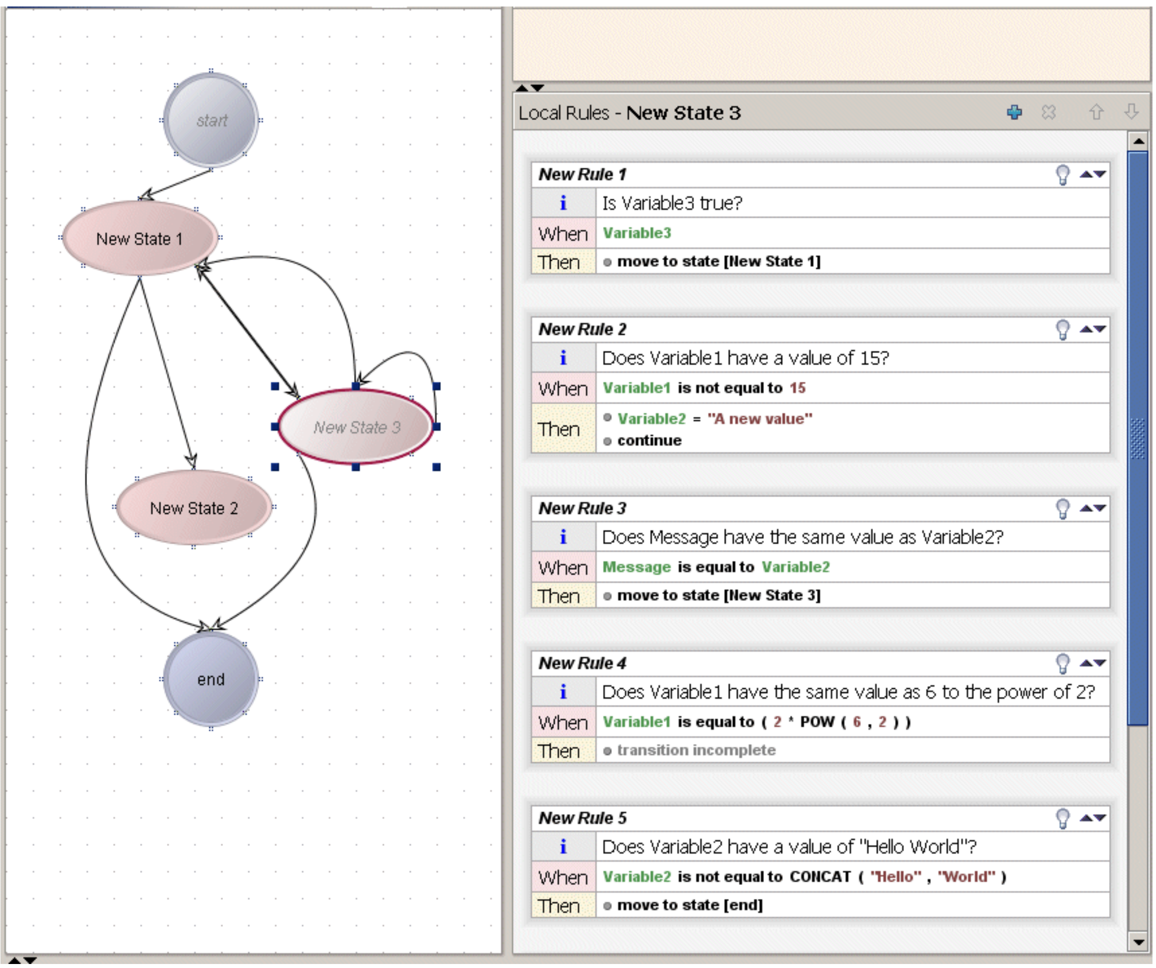
- R4: f(d): b=0; continue;
- R5: f(a,b): continue;

Suppose that a, b, c, and d are variables and f(a) means “some function of 'a'”. Assume that f(c) and f(d) are both true. Event Modeler places the rules on the queue as follows:

R1 R2 R3 R4 R5 R2 R1

As you can see, when Event Modeler adds a rule to the queue, it always adds it to the end of the queue.

Consider the set of rules shown in the next screen:

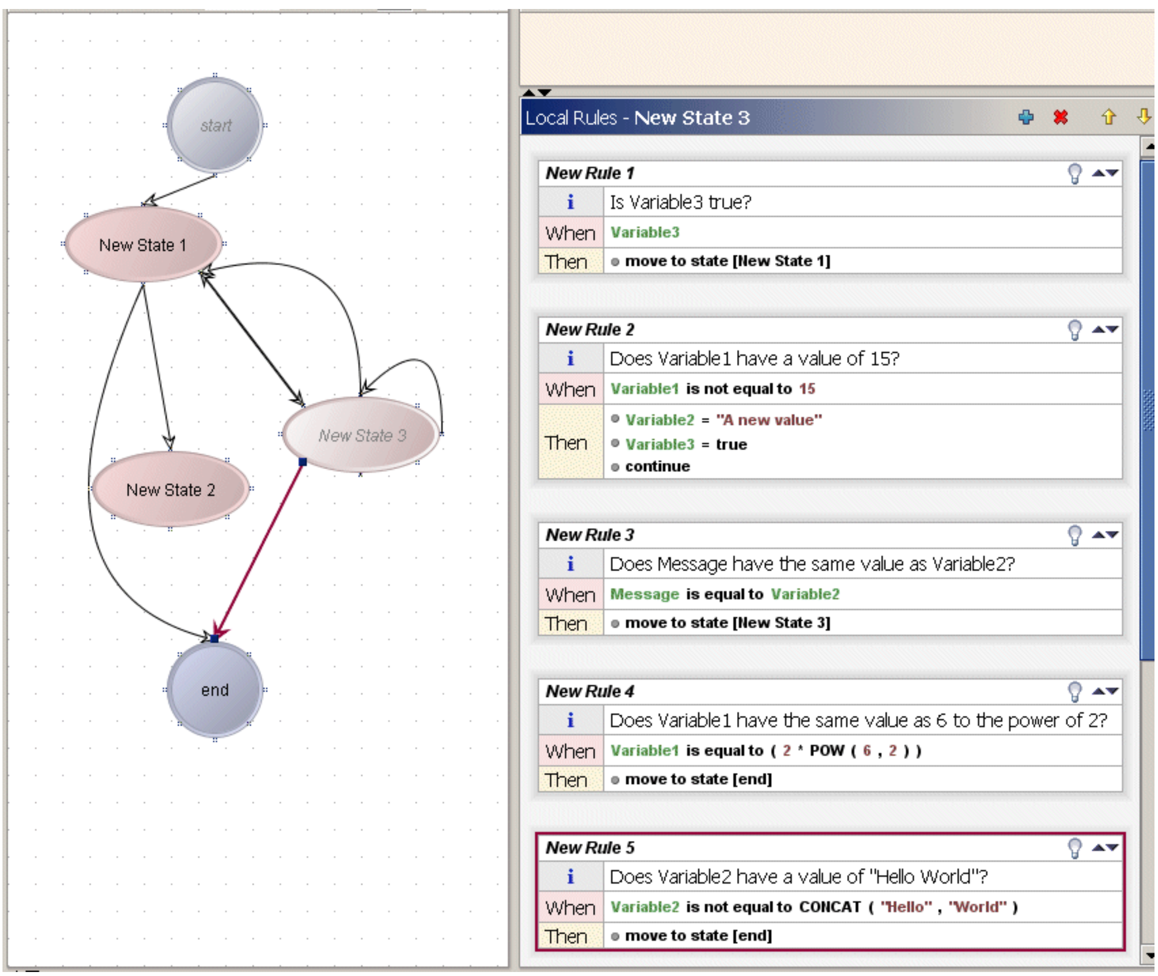


1. When execution enters `NewState 3` any rules of the previous state are removed from the rule queue, and the following rules will be placed on it, in this order: `New Rule 1`, `New Rule 2`, `New Rule 3`, `New Rule 4` and `New Rule 5`.
2. `New Rule 1` will be taken off the queue and its condition examined. If `Variable3` is true, then the scenario will move to `NewState1`. The rule queue will be emptied of all `New State 3` rules, and no further steps apply.

3. However, if Variable3 is false, then New Rule 2 is taken off the queue and its condition checked. Note that at this point the rule queue would contain New Rule 3, New Rule 4 and New Rule 5. New Rule 2's condition states that if Variable1 is not equal to 15 its action part must be processed. Let us assume that Variable1 is indeed not equal to 15 and its single action statement changes Variable2 to the value "A new value".

4. What happens next in this case depends on the state transition statement of New Rule 2. If it had caused a transition to another state, then the scenario would have emptied the rule queue, moved to that state, and then repopulated the queue with the rules from the new state. However, in this case the state transition statement is continue. Note that Variable2 is referred to in the condition part of New Rule 3 and New Rule 5, and that it has now been changed. Therefore, New Rule 3 and New Rule 5 must be added to the rule queue. However, they are already on the queue, so nothing happens. If either of these two rules had not been on the queue, they would have been added to the end of the queue.

Now, consider this slightly changed set of rules, specifically New Rule 2.



New Rule 2 is now also changing Variable3. This time, starting with step 3 from the previous sequence, the following is what happens:

1. If `Variable3` is false, then `New Rule 2` is taken off the queue and its condition checked. Note that at this point the rule queue would contain `New Rule 3`, `New Rule 4` and `New Rule 5`. `New Rule 2`'s condition states that if `Variable1` is not equal to `15` its action part must be processed. Let us assume that `Variable1` is indeed not equal to `15` and action statements change `Variable2` to the value "`A new value`", and `Variable3` to `true`.
2. What happens next in this case depends on the state transition statement of `New Rule2`. If it had caused a transition to another state, then the scenario would have emptied the rule queue, moved to that state, and then repopulated the queue with the rules from the new state. However, in this case the state transition statement is `continue`. Note that `Variable2` is referred to in the condition part of `New Rule 3` and `New Rule 5`, and that it has now been changed. Therefore, `New Rule 3` and `New Rule 5` must be added to the rule queue. Also, `Variable3` is referred to in the condition part of `New Rule 1`, and it has also now been changed. Therefore, `New Rule 1` must be added to the rule queue. Now, `New Rule 3` and `New Rule 5` are already on the queue, so they are not added. `New Rule 1` is no longer on the queue, so it is added. Therefore, at the end of processing `New Rule 2`'s action part, the rule queue will now be: `New Rule 3`, `New Rule 4`, `New Rule 5` and `New Rule 1`.

Scenario monitoring stage

If all rules on the rule queue are processed and the queue becomes empty, the scenario instance goes into a monitoring stage.

The scenario instance stays in this state until some external source changes a variable, block parameter or block field that is referred to in any condition of any of its rules. This can occur because of a user sending in a scenario modification, or a block changing its properties in response to some external event feed.

If this occurs, then the affected rules are added to the rule queue and processed in the order as described previously.

This process of placing rules on the rule queue and processing them continues until a rule condition is true and the corresponding action requests a state transition to another state. After moving to the new state, Event Modeler places the new rules on the queue and evaluates them. Rule processing stops only when there are no rules left to be evaluated.

Summary of adding rules when a variable value changes

When a rule action or an external source changes a variable, block parameter or block field that is referred to in any condition of any rule in the current state, that rule is added to the current rule queue, unless it is already on the queue. If the queue was empty when the rule was added, then the rule is processed immediately. If multiple rules need to be added to the queue, they are added in the order they are listed, top to bottom.

About scenario variables

Typically, each scenario has a number of *variables*.

As in other programming environments, variables are placeholders for useful information that the scenario needs to keep track of and perhaps modify during its execution. They also indicate the information that will be required by a running instance of the scenario from the end-user in order to configure and start it off, as well as representing the information that will be sent back to be displayed to the user as progress updates or results.

The variables defined in a scenario are shown in the **Variables** tab. Each variable has a distinct *type*. If you click on the green box to the left of each variable you can examine its type and other properties.

Variable types

Variables can be of four types in Event Modeler:

- `Text` (or *string*)
- `Number` (*integer* or *float* depending on constraint)
- `Choice` (or *enumeration*)
- `True/False` (or *conditional*, or *boolean*)

`Text` variables contain textual information, like words, phrases or sentences. An example of valid text is "`Hello World`", "`Monday`", "`ACME`" or "`Trading Strategy executed successfully`". Text values are normally shown in double quotes. If you want to have quotes in your text, you can escape them as follows: "`he said \"hello\" and left`".

`Number` variables can contain numbers. Valid examples are `1`, `25.0`, `-45.62`, or `8902e8`.

`Choice` variables are constrained so that they can only have values from a specific set of pre-defined values. For example, the choice variable `Day` could be constrained so that it can only have one of the values "`Monday`", "`Tuesday`", "`Wednesday`", "`Thursday`", "`Friday`", "`Saturday`"or"`Sunday`".

`True/False` variables, also known as *condition* variables, can only take the values `true` or `false`.

You can also specify constraints on variables according to their type. For example, you can specify maximum and minimum values for a `Number` variable.

Auto-typing of variables

Variables are "auto-typed" by default. This means that the type is automatically inferred from the value assigned to the variable in the **Variables** tab . If such a variable is wired to another variable or a block field, it inherits the source's type.

If you subsequently change the wiring so that the auto-typed variable is then wired to another variable or block field, its previously inferred type will be changed to the type of the new source.

Note that this means that type mapping (as described in "Linking variables, block parameters, and block output fields" on page 464) will not be necessary for variables that are auto-typed.

Variable properties

Variable properties only apply to, and are enforced by, dashboards. That is, they only apply when a variable is presented to, and is interacted with by, an end user of the scenario. By design, variable properties do not apply to scenario rules or variable wiring within the **Variables** tab.

Each variable has a mutability property, which can take the following values:

- `Mutable` – This property is of relevance to the dashboard. If set it means that the end-user should be able to set and change the value of this variable at any time, via a dashboard.
- `Immutable` – This property is of relevance to the dashboard. If set it means that the end-user should only be allowed to set the value of this variable upon creation of the scenario instance, and should not be able to modify it afterwards.
- `Fixed` – This means that this variable is a constant; it cannot be modified through a dashboard. If a variable is set as `Fixed` but no value is provided for it in the **Variables** tab, the Event Modeler will automatically set it to the default value for its type.

Furthermore, each variable can also be set to be `Unique`. This means that if multiple instances of a scenario are started concurrently, the value of this variable must be unique across all instances. The dashboard used to enter values for this variable will ascertain that this is the case before accepting the value from the user. Note that if a variable is set to be `Unique`, it must also be `Immutable`.

Variable constraints

Depending on its type, each variable can also have *value constraints* set on it.

Variable constraints only apply to dashboards. That is, they only apply when a variable is presented to, and is interacted with by, an end user of the scenario. By design, variable constraints do not apply to scenario rules or variable wiring within the **Variables** tab.

For `Text` variables the possible constraints are:

- `Minimum length`: a whole number specifying the minimum acceptable length of the text string. Setting this constraint is optional.

  For example, if set to `5`, then “`book`” would not be valid, but “`library`” would.
- `Maximum length`: a whole number specifying the maximum acceptable length of the text string. Setting this constraint is optional.

For example, if set to `8`, "`library`" would be a valid value, but "`librarian`" would not.

- One of `All Upper Case`, `All Lower Case` or `Mixed Case`. One of these constraints must be set, `Mixed Case` being set by default.

  For example, if set to `All Upper Case`, "`test`" and "`Test`" would be invalid, but "`TEST`" would be fine. Conversely, only "`test`" would have been valid if set to `All Lower Case`, but all three variants would be fine with the default `Mixed Case` setting.

- `Trim Whitespace`: If enabled, all leading and trailing white space characters (space, tabs, new line and other formatting characters) will be removed from the text string whenever its value is set. Note that if the minimum length and maximum length constraints were set, they would apply to the final 'trimmed' text string. The default is for this constraint to be disabled.

  For example, "` Hello World `" would be automatically changed to "`Hello World`" if `Trim Whitespace` were enabled.

For `Number` variables the possible constraints are:

- `Minimum`: a number specifying the minimum acceptable value of the variable. Setting this constraint is optional.

  For example, if set to `2` or `2.0`, then only numeric values greater than or equal to `2.0` would be valid.

- `Maximum`: a number specifying the maximum acceptable value of the variable. Setting this constraint is optional.

  For example, if set to `5` or `5.0`, then only numeric values less than or equal to 5.0 would be valid.

- `Whole Number`: If enabled, all values set for this variable will be changed to whole numbers by being *rounded down*. The default is for this setting to be disabled.

  For example, `3.1` would be automatically changed to `3`, as would `3.9736`., while `-3.1` would be changed to `-4`.

For `Choice` variables, the constraints specify the set of valid text values that this variable can take. These are distinct values, and choice variables can only take the values specified in their constraints.

For example, the choice variable `Day` should have its constraints set to the set of values "`Monday`", "`Tuesday`", "`Wednesday`", "`Thursday`", "`Friday`", "`Saturday`" and "`Sunday`".

No constraints are available for `True/False` (condition) variables.

User input and output

Each scenario variable can be tagged as being an input variable, an output variable, or both.

Variables whose values can be collected directly from the user should be marked `input`. Those whose value can change during the execution of a scenario, and whose changing values may be of interest to the user, should be marked as `output`.

About blocks

Blocks are ready packaged modules that you can use in your scenarios. They can accept inputs, execute some logic of their own, and generate output.

A block is defined in a *Block Definition File*, or `.bdf`. This XML file describes the functionality of the block and its implementation in Apama Event Processing Language (EPL). EPL is the native language of the correlator.

A block can consist of:

- **Input feeds.** An input feed can be hooked up to a live stream of event data, like a price quote stream. Within it, an input feed will define one or more *input fields*, which can be mapped to data in the stream. When event data arrives, the fields' values are updated. These fields are typed in the same way as scenario variables.
- **Output feeds.** An output feed is a stream of output data that can be generated by the block. Each output feed corresponds to an event that can be generated by the block, and embeds one or more *output fields*. The fields are updated as a result of operations carried out by the block. These fields are typed in the same way as scenario variables.
- **Parameters.** A block can have a number of parameters, which, when set, configure its behavior. Parameters differ from input fields, in that the latter are like work packages for the block to process. Typically, you use parameters to initialize the block or change its core behavior. Parameters are typed in the same way as scenario variables. Parameters are all provided at initialization time and can then be updated individually. Input fields are expected to change often and at any time.
- **Operations.** In addition to any standard behavior that is hard-wired into it, a block can also have a number of explicit operations that can be invoked by the scenario. For example, typical operations are `start` and `stop`, which cause the block to begin processing events or to cease. If an operation requires any configuration information, this is usually passed in through a block parameter.

Apama provides a library of useful blocks, which can be viewed and selected from the **Catalogs** tab. For information about provided blocks, see "Using Standard Blocks" on page 521.

There is no restriction on the number of block instances that can be added to a scenario. The **Blocks** tab shows the blocks that have been added to a scenario. When you add a block to a scenario you are effectively specifying that instances of that scenario should create an instance of that block running within them. Whether the block instance then starts executing some activity immediately or waits for some operation on it to be called depends entirely on how the block itself was written.

It is possible to add multiple instances of the same block to a scenario. Each instance will have its operations, parameters and fields clearly tagged by its unique name to ensure there is no conflict.

If there is no standard block that meets your needs, you can create a custom block. There are several ways to do this:

- Use the Apama block editor in Software AG Designer to create a block by defining its parameters, operations, input feeds and output feeds.
- Use the Apama block editor in Software AG Designer to create a block from an event definition.
- Save a scenario as a block. This lets you create composite scenarios when you use such blocks in other scenarios. However, you cannot save a scenario as a block if you mark that scenario as parallel. Nor can you save a non-parallel scenario as a block and then mark the block as parallel-aware. For details, see "Working with Blocks Created from Scenarios" on page 615.

For more information on the structure of a block and for instructions on how to create your own blocks, see "Creating Blocks" on page 591.

Linking variables, block parameters, and block output fields

One of the facilities provided by the Event Modeler is the linking of:

- Block output fields to scenario variables

  This creates a relationship between an output field of a block and a scenario variable. Once set up, Event Modeler automatically updates the value of the variable to the value of the output field. If the output field changes, the variable's value immediately reflects the new value of the block output field.

  If the field and the variable are not of the same type, Event Modeler converts the field's value to the type of the variable before it updates the variable. If the conversion is not possible, Event Modeler assigns a default value to the variable. See "Conversion rules for variable types" on page 503 for more information.

  If the variable is of auto-type, it inherits the type of the block output field.

  After you link a block output field to a scenario variable, you can still explicitly modify the value of the scenario variable. If you do, keep in mind that Event Modeler will continue to update the value of the scenario variable each time the value of the linked block output field changes. Consequently, after you link a block output field to a scenario variable, the recommendation is that you do not explicitly modify the value of that scenario variable.

- *Scenario variables* or *block output fields to block parameters*

  This creates a relationship between a scenario variable or block output field and a block parameter. Once set up, Event Modeler automatically updates the value of the block parameter to the value of the scenario variable. If the value of the scenario variable or block output field changes, the value of the linked block parameter immediately changes to reflect the new value.

If the variable or field and the parameter are of different types, Event Modeler converts the variable's value or the output field's value to the type of the parameter before updating the value of the parameter. If the conversion is not possible, Event Modeler assigns a default value. See "Conversion rules for variable types" on page 503 for more information.

After you link a scenario variable or block output field to a block parameter, you can still explicitly modify the value of the block parameter. If you do, keep in mind that Event Modeler will continue to update the value of the block parameter each time the value of the linked scenario variable or block output field changes. Consequently, after you link a scenario variable or block output field to a block parameter, the recommendation is that you do not explicitly modify the value of that block parameter.

15 Using Event Modeler

Now that the important concepts underlying the definition of a scenario have been introduced, this section will illustrate how to use the Event Modeler's interactive functionality.

This section will describe each of the tabs available in Event Modeler and how to use them effectively.

Adding scenarios to projects

To open or create a scenario, the scenario must belong to an Apama project. This section uses an example to show you how to create a project, create a new scenario, and add a scenario to a project.

Creating the GlobalRuleExample project

The following steps provide an example of how to create an Apama project.

To create the GlobalRuleExample project

1. Ensure that **Apama Workbench** appears in the title bar of Software AG Designer. If it does not, choose **Window > Perspective > Open Perspective > Apama Workbench**.
2. From the **File** menu, choose **New > Apama Project** to display the New Apama Project dialog.
3. In the New Apama Project dialog, specify `GlobalRuleExample` for the project name, accept the default project location, and click **Next**.
4. In the list of standard bundles that appears, select **Scenario Service (required by all Scenario-based applications)**, and click **Finish**.

   Bundles are packages of Apama objects such as EPL files, event definition files, and event files or adapter configuration files that are required for specific types of applications.

   Your new project is shown in the Workbench Project View pane on the left of the perspective.

Adding GlobalRuleExample.sdf to the GlobalRuleExample project

To add `GlobalRuleExample.sdf` (an existing scenario) to the GlobalRuleExample project

1. From the **File** menu, choose **Import**.
2. Expand **General**, click **File System**, and then **Next**.
3. Click **Browse** and then navigate to and select *`your_Apama_install_directory`*`\samples\scenarios`, and click **OK**.
4. In the Import dialog, select **GlobalRuleExample.sdf** and click **Finish**.
5. In the **Workbench Project View** pane, expand **scenarios**, and double-click **GlobalRuleExample.sdf** to open it in Event Modeler.

Adding a new scenario to the GlobalRuleExample project

To add a new scenario to the GlobalRuleExample project

1. From the **File** menu, choose **New > Scenario**.
2. Enter a name for the new scenario and click **Finish**.

Opening and viewing multiple scenarios

In the **Apama Developer** perspective, Event Modeler can open multiple scenarios concurrently, but only one can be on active display; that is *on view* at any one time. You can tell which scenario is currently on view by examining the contents of the window title bar, as this lists the scenario's name and the location of its corresponding `.sdf` file.

At the top of the **Event Flow**/**Rules** display, there is a tab for each opened scenario. The last opened scenario always becomes the scenario on view. So depending on the sequence in which you open scenarios, one will be on view and the other will still be loaded. You can switch from one to the other by clicking its tab.

It is also possible to open multiple Apama Event Modeler windows and view different scenarios (or the same, for that matter) in each. This can be carried out from the **Window** menu, and is not the same as actually starting another instance of Software AG Designer. There should never be any need to do the latter.

To open a window for each scenario

1. From the **Window** menu, choose **New Window**.

   Another Software AG Designer window appears.
2. In this second Software AG Designer window, you can open the same scenario or a different scenario.

Notice how the title bars reflect which scenario is on view in each window.

If you have multiple windows open showing the same scenario, any *edits* done in one will be immediately reflected in the other if applicable. Selections and view changes are not reflected in this manner; so if in one window you are viewing the **start** state while in another you are editing the rules of another state, you will not see your edits in the first window until you select the edited state there.

If you close a window, the scenario on view in that window remains loaded in the Event Modeler and no changes are lost. If you close all the windows in Event Modeler, you have effectively exited the Event Modeler. You will be prompted with a warning dialog if you try to exit Event Modeler while there are modified (unsaved) scenarios open.

Selecting from the Scenario menu

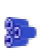
When Event Modeler is open, the Software AG Designer menu bar includes **Scenario**. The **Scenario** menu provides the following commands:

- **Diagnostic Logging** — When this is checked, the scenario is injected in debug mode when you run your project.
- **Generate Block** — When this is checked, your scenario is saved as a block template when you save and/or build your project. The block template is put into the **Generated scenario blocks** catalog in the `catalogs` directory of your project. You can use the block template in other scenarios. This option is available only if all of the scenario's states, and by consequence, all their rules' conditions and actions, are finished. You cannot mark a scenario as parallel and then export it as a block.
- **Toggle Block Field Feed Name Display**— In the **Block Wiring** tab, toggles the display of block field feed names.
- **Toggle Rule Comment Display** — In the **Rules** panel, toggles the display of the comments that can be associated with each rule.
- **Global Rule Arc Visibility** — Determines the **Event Flow** tab display of transitions controlled by global rules. Choices are:
  - **Emphasize All Global Rule Arcs** — All global transitions appear in a bright orange color.
  - **Emphasize State Global Rule Arcs** — The global transitions for only the selected state appear in bright orange. Other global transitions are in a very light orange.
  - **Deemphasize All Global Rule Arcs** — All global transitions appear in a very light orange color.

When you save a scenario, Event Modeler first tries to save a copy of the previously saved version of that scenario to create a backup. If Event Modeler is unable to make the backup, it displays a dialog that lets you know. You can save the scenario anyway or cancel and try to find out why the backup could not be made.

The Event Modeler toolbar

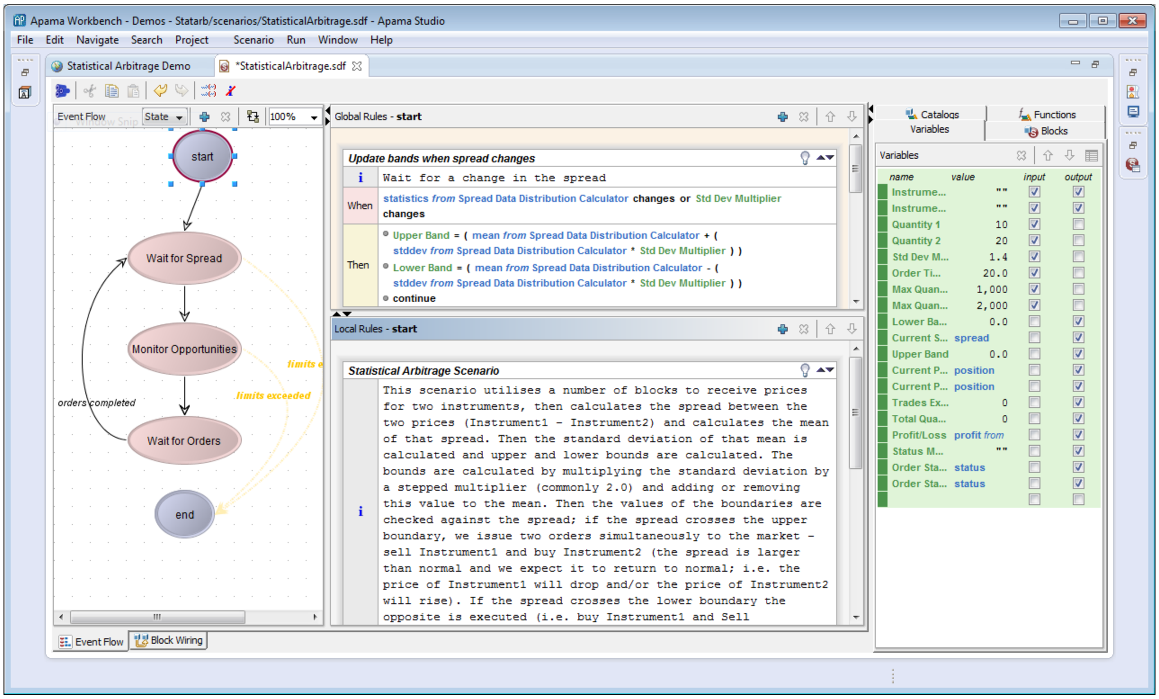
The Event Modeler toolbar contains a number of icons that correspond to commonly used operations:

Toolbar icon	Operation
	Enable/Disable parallel execution — Indicate that the instances of the scenario will be run in parallel. This selection is a toggle. A scenario that runs in parallel executes each scenario instance in a separate context. Contexts let Apama organize work into threads that the correlator can concurrently execute.

Toolbar icon	Operation
	For a scenario to run in parallel, each block that it uses must be parallel-aware. If a scenario uses one of the standard blocks provided with Apama, the scenario must use the latest version of the block. If a scenario uses a custom block, you must have created it in Callback or Callback (DEBUG) mode, or converted it to Callback or Callback (DEBUG) mode. You cannot create a block from a scenario that can run in parallel. Also, you cannot create a block from a non-parallel scenario and then mark that block as parallel-aware.
	Cut the currently selected element to the clipboard (that is, copy it and then delete it)
	Copy the currently selected element to the clipboard.
	Paste the current contents of the clipboard to the current selected location. This will not be available if the clipboard is empty or if its contents are not suitable for the current location. For example, you cannot paste a state in the **Variables** tab.
	Undo the last action.
	Redo the last action which was undone.
	Show feed names for block fields.
	Toggle display of rule comments.

Interacting with the tabs and panels

Certain operations require you to highlight or select one of the panels first. You can do this by clicking somewhere within the desired panel or on its title bar. When a panel is highlighted, its title bar changes color as shown below. The **Local Rules** panel's title bar is highlighted because it is the selected panel.

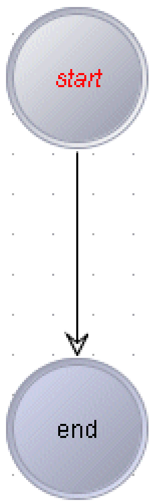


Working in the Event Flow panel

The **Event Flow** panel graphically illustrates the states that a scenario instance can be in during execution, and how it can transit from one state to another. The states are depicted as circles, and possible transitions are shown as a line between the two states, with the arrow head indicating the direction of the transition.

Upon creation, a new scenario has two states, marked **start** and **end**, with a single transition going from the **start** state to the **end** state. User-defined states have a single border, while mandatory states, the **start** and **end** states, have a double border. Mandatory states are also shown in a different color (pale blue) instead of rose. The name of an unfinished state appears in red italics. In a newly created scenario, the **start** state is unfinished because you have not yet defined any rules to indicate how the scenario can transit from the **start** state to the **end** state.

Mandatory start and end states



Note that all colors used in the Event Modeler can be changed in the Apama preferences. For more information, see the description of the Apama preference page **Scenarios** in *Using Apama with Software AG Designer*.

You can zoom the view in and out within the **Event Flow** panel by changing the zoom value from the pull down selector available on the panel's toolbar. You can adjust the zoom level from `25%` to `400%`, with `100%` being the default setting. Alternatively you can just type the zoom value you would like and press **Enter**.

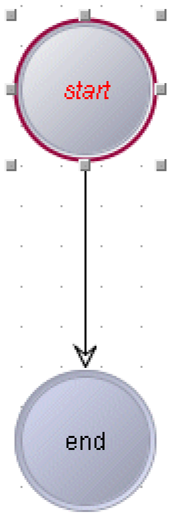
Interacting with states

You can interact with states in the **Event Flow** panel in a variety of ways.

Selecting a state

If you click on a state you will notice that it becomes highlighted. This is indicated by the border changing color and eight *drag handles* appearing around the state.

Selected start state



If a state is selected its rules will be displayed in the adjoining **Rules** panel if this is viewable. When the title of the state is in red italic the state is unfinished. When the title of the state is in black the state is finished. See "The finished status" on page 475.

Resizing a state

The drag handles allow you to resize the state in any of eight directions. Press and hold the left mouse button while pointing to any of the drag handles to resize while dragging. Notice how the mouse cursor changes to indicate that a directional resize is available.

If you hold down the **Shift** key while doing this, you will restore and preserve the aspect ratio of the circle.

Moving a state

You can move a state around by pressing the left mouse button while pointing to it, and then dragging it around while holding down the mouse button.

If a state is selected its rules will be displayed in the adjoining **Rules** panel if this is viewable.

Multiple selection

You can select multiple states concurrently by holding down the **Shift** key and clicking on multiple states; all will be selected. You can then drag them together by pressing and holding down the left mouse button while pointing to any of them. If more than one state is selected, only the rules for the first one will be displayed in the **Rules** panel.

You can also drag and select a rectangle around multiple states and transitions.

Adding a state

To add a state, click on the ✚ button on the **Event Flow** panel's toolbar. A new state will appear in the upper left corner of the **Event Flow** tab from where you can move it to a suitable location. This new state will be selected by default.

The finished status

To inject a scenario into the correlator, or for the `Export EPL` functionality to be available, all its states must be *finished*.

For a state to be finished, all its rules must be properly defined. This means that they need to have valid fully specified conditions, and if any action statements have been added to them, those also need to be fully specified.

You can ascertain visually whether a state is finished or not by how its name is displayed in the **Event Flow** panel. If the name is in regular black font, then the state is finished. On the other hand, a red italic font for the name indicates that the state is unfinished, that is one or more of its nested rules are not fully defined.

Note also that if the scenario has changed since the last time it was saved to a file, it must be saved again before you can export it.

Deleting a state

To delete a state, select it and then press the **Del** key, or click the ✖ button on the Event Modeler toolbar. If you selected multiple states, each of these actions deletes all selected states.

When you delete a state, if there are any rules with transitions to the deleted state, Event Modeler changes the transition section of those rules to **transition incomplete**. This makes the state that contains this rule incomplete. Event Modeler cannot generate EPL for this scenario until you complete the transition for this rule.

Labeling a state

To change the label on a state, double click on the state. Type the new name of the state, and press **Enter** when done. While typing, you can press **Esc** to undo the edit.

You can label a state with any name you want. Note that state names do not have to be unique although it is recommended that you make them so. Otherwise it could be confusing to pick the correct one when defining the target for a transition from the list of available states.

Using cut/copy/paste with states

You can *cut*, *copy*, and *paste* states.

For reference, recall that *cut* will copy the current selection into the clipboard and delete it from the scenario, while *copy* only places a copy of it in the clipboard.

To cut or copy a state, right-click it to display a context menu and select the operation you want. Alternatively, you can select it, and then do one of the following:

- Press the **Control X** and **Control C** shortcut keys
- Click the or buttons on the main toolbar, respectively.
- Select **Cut** or **Copy** from the **Edit** menu.

To paste a state, the **Event Flow** panel must be highlighted. You can do this by clicking somewhere within the **Event Flow** panel so that its toolbar is highlighted. If you right-click, you can select **Paste** from the popup context menu. Alternatively, press **CTRL+ V**, or click the button on the Event Modeler toolbar. The newly pasted state is renamed to `Copy of` *previous_name* if there is still a state with the same name. For example, if you copy a state and then paste it back in, the newly pasted state will be renamed.

Note also that all rule transitions in the newly pasted state will be reset to `continue`. You can then manually change them to your intended transitions.

You cannot cut the **start** or **end** states.

If you want to make a copy of a state that retains all its transitions, you should use the **Shift** key to first select the state and then select each of the transitions you want to retain. Copy the entire selection into the clipboard, and paste it to obtain a copy of the state with the rule transitions' destinations preserved.

Interacting with transitions

Once you have created your scenario's states, you can define transitions between them. The state where the transition starts is the *source* state, and the state where the transition ends is the *destination* state.

A transition in the **Event Flow** panel is the same as the action statement that defines it in the **Rules** panel. Any interaction with one affects the other; for example, deleting the transition link on the graph changes the rule's action statement to **transition incomplete**.

Adding a transition

You can add a transition in a number of ways:

- Having selected the source state, you can add a rule to it and then change the state transition statement for that rule so that it causes a transition to the destination state. This will automatically add the transition between the states in the **Event Flow** panel.

  Adding rules will be described in "Working in the Rules panel" on page 480.

- Alternatively, click the icon on the **Event Flow** panel's toolbar to activate *Connect* mode. Small pale red squares, or *connectors*, appear around the border of all the states except the **end** state. Point to a connector on the source state and note how the cursor changes. Press the left mouse button, and while still holding it, move to another connector on the destination state. Release the mouse button to create a transition between the two connectors, and thus the two states.

If you select the source state you will notice that a rule has been created in it that embodies the state transition you have just created. You can repeat this to create more transitions.

Click on the icon again to deactivate *Connect* mode when done.

Selecting a transition

In order to select a transition, click on it with the left mouse button. The transition changes color to a bold red to indicate it is selected. The corresponding rule is also highlighted in the **Rules** panel.

You can select multiple transitions by holding down the **Shift** key while clicking on them

Changing end-points

If a transition is selected and *Connect* mode is not enabled, you can change the end-points of the transition.

Point to one of the end-points of the selected transition. The mouse cursor will change. Press the left mouse button and drag along the border of the state until another connector appears. Release to move the end-point of the transition to this connector, or keep on dragging to locate another connector.

There are eight such connectors around the border of each state.

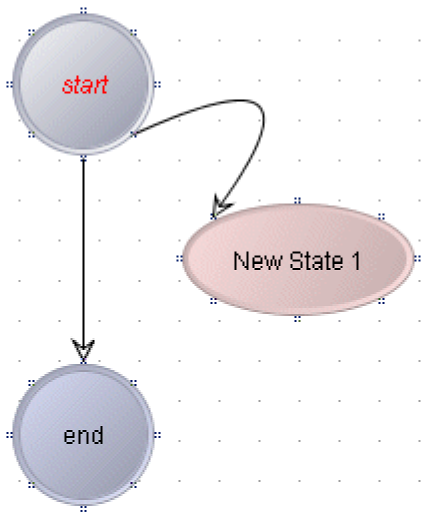
You can also use this to drag the source or destination to another state. This will move the state or change the transition statement (for the target).

Changing the shape of a transition

By default a transition will be a straight line between one state and another. You can change this into a curve if you wish.

Select the transition you wish to modify. Right click somewhere along the transition, ideally close to the centre of the line. A drag handle will appear on it. As before, press and hold the left mouse button while pointing to the drag handle, and drag to turn the line into a curve. You can do this at multiple points along the line to further shape the curve, and if you change your mind, you can delete each curve point by right clicking on its drag handle.

Changing transition shape

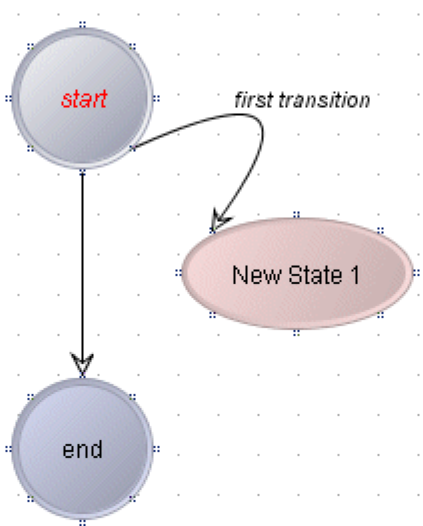


Labeling a transition

To add a label to a transition, double click on the transition. A text entry box will appear in the middle of the transition. Type the text you want to use for its label, and press **Enter** when done. If, while typing you press **Esc**, the edit will be undone. The label will appear at the center of the transition line.

If you want to move the label, point to it with your mouse. Notice how the mouse cursor changes. Simply drag the label to the new position.

Moving transition label



Deleting a transition

To delete a transition, select it and then either press the **Del** key, or click the button on the **Event Flow** toolbar.

When a transition is deleted, the action statement that defined that transition will be deleted.

If you selected multiple transitions, or even a selection of states and transitions, a delete operation deletes all selected entities at the same time.

Using cut/copy/paste with transitions

You can *Cut*, *Copy* and *Paste* transitions, although note that this is identical to doing this with the associated rules.

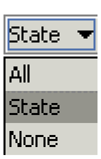
To cut or copy a transition, right-click it and select the desired operation from the popup context menu. Alternatively, you can select it in the **Event Flow** panel, and then press the **Control X** and **Control C** shortcut keys, or click the or buttons on the Event Modeler toolbar, respectively. This is the same as cutting or copying the transition's associated rule from the **Rules** panel.

To paste a transition, the **Rules** panel must be highlighted. You can do this by clicking somewhere within the **Rules** panel so that its toolbar is highlighted.

Then you can press **Control V**, or click the button on the Event Modeler toolbar. The newly pasted rule is renamed to `Copy of its_previous_name` if there is still a rule with the same name within that state. For example, if you copy a transition or rule and then paste it back into the same state, the newly pasted one will be renamed. The transition's destination state will be preserved provided that the destination state still exists. If not, it will revert to `continue`.

Displaying global rule transitions

Global rule transitions are dotted orange lines. You can choose to have them appear in a very light shade so they do not clutter the **Event Flow** panel. At the top of the **Event Flow** panel, click **State** to display the drop-down menu.



- **All** — Displays all global rule transitions in bright orange.
- **State** — Displays in bright orange the global rule transitions for only the selected state.
- **None** — De-emphasizes all global rule transitions. They appear as a very light orange.

The current selection always appears in the **Event Flow** panel toolbar.

Working in the Rules panel

The contents of the **Rules** panel change whenever a state is selected in the **Event Flow** panel. It then lists those rules that a scenario must process when it enters the selected state. Global rules apply to two or more states; a local rule applies to only one state.

A new state does not have any rules defined in it.

Adding a rule

To add a global rule, click the ✚ button on the **Global Rules** panel toolbar. The Event Modeler adds this new rule to every state except the end state.

Local rules can be added in the following ways:

- Select the state to add the rule, and then click on the ✚ button on the **Local Rules** panel toolbar.
- In the **Event Flow** panel, in *Connect* mode, manually add a transition between two states. This creates a new local rule with that transition defined in it within the source state.

The new rule is added to the bottom of the list of local rules.

A new rule will have the default title, “`New Rule n`”, no description, an *unfinished* condition indicated by the red font of the rule name, and an action containing only a state transition statement.

You cannot add a rule to the end state. After a scenario enters its end state, nothing more can execute. If you want to do some cleanup before you terminate a scenario, add a cleanup state that comes just before the end state.

About global rules

When a state has both global and local rules, Event Modeler starts processing with the first global rule. If Event Modeler processes all of a state's global and local rules, it starts at the top, works through the global rules, and then works through the local rules.

To create a global rule, click the **Add a New Global Rule** button ✚ in the right part of the title bar of the **Global Rules** panel. This adds the new global rule to every state except the end state. If you add a new state after you create a global rule, Event Modeler automatically adds any global rules to the new state.

If you do not want a global rule to apply to a particular state, select that state, and then click the **Activate/Deactivate** button in the top right corner of the global rule. This toggles whether the selected rule is processed for the selected state. See "Activating and deactivating rules" on page 483 for more information.

To determine which states a global rule applies to, click the global rule to select it. All states that this rule applies to have dashed orange borders. If a global rule is unfinished the title of the rule appears in red italics and the titles of all states that the global rule applies to appear in red italics in the **Event Flow** pane. The **Problems** view displays information about any unfinished global rules.

There is an example of a scenario that uses a global rule in the `scenarios\samples` directory of your Apama installation directory.

Selecting rules and rule elements

To select a rule so that you can carry out operations on it, click on any empty space within it. The rule will become highlighted, with its border turning to a bold red. If the rule selected defined a state transition (that is, not `continue`) the corresponding transition will be highlighted in the **Event Flow** panel.

You can select multiple rules by holding down the **Shift** key while clicking on the rules to select.

To select a rule element, left-click it. To select multiple, contiguous rule elements, move the cursor over one of the elements, hold down the left mouse button, and drag the cursor over the other elements.

To select a rule element and display a popup selection menu for that element's position, right-click the element. This version of the selection menu also has the **Cut**/**Copy**/**Paste** options at the bottom. To display a more narrow selection menu for an element, hold down the **Shift** key and right-click the element. To select multiple, contiguous, rule elements and display a selection menu, move the cursor over one of the elements, hold down the right mouse button, and drag the cursor over the other elements.

Re-ordering rules

A rule's position in the listing of rules in the **Rules** panel is important because of the rule evaluation procedure described in "About rule evaluation" on page 454. Rules are always added to the rule queue in the top-to-bottom order shown in the **Rules** panel.

You can change a rule's position by selecting it, and then using the and icons on the **Rules** panel toolbar to move the rule upwards or downwards, respectively. You can use the **Ctrl** and **Shift** keys to select multiple rules at the same time and move them as a group.

The icons are only available when a rule is selected and their function is available for that rule. For example, you cannot move the first rule further upwards.

Deleting a rule

To delete a rule, select it and click the icon in the **Rules** panel toolbar. You can also press the **Del** key to achieve the same effect if you are not editing the rule's title or description.

If the rule has a state transition defined in its action part, the corresponding transition in the **Event Flow** panel will be deleted.

If you have multiple rules selected, any of the above variants will delete all of them in one step.

Labeling a rule

The first visual element of a rule is its title. Its function is just to assist you in visually identifying rules and is not pertinent to rule processing. The rule title is, however, included in logging information when debug mode is enabled, and therefore constitutes a very useful diagnostic tool. It is therefore recommended that you name rules. The title does not have to be unique, and by default all new rules are titled "`New Rule` *n*".

Double click with your left mouse button on the title of a rule to be able to edit it. You must press **Enter** when you are done to save the new title. If you press **Esc** your edits will be cancelled.

Changing a rule's description

The next visual element, indicated by the symbol **i**, is an optional description of the rule's purpose. You can hide or show rule descriptions by clicking in the Event Modeler toolbar, or by selecting **Scenario > Toggle Rule Comment Display** from the menu.

It is advisable to set a description that explains what condition the rule is checking, what actions it is carrying out, and its effect within the scope of the overall scenario's logic. This helps when reviewing states and rules at a later stage, more so if another person other than the scenario's author is doing the reviewing.

Minimizing and maximizing a rule

Note the two icons to the right of the rule's title: ▲ and ▼. If you click on ▲ once, the rule will be minimized to just its title, its description if it was showing, and the **When** section. If you click on it again, only the title and the rule description will be left showing. If you click to hide the comments, only the rule title appears.

You can then use ▼ to revert it back to either the title and condition, or the entire rule with title, condition and action. If necessary, click to display the rule's description.

Cutting, copying, and pasting rules

You can *Cut*, *Copy* and *Paste* rules.

To cut or copy a rule, right-click it and select the desired operation from the popup context menu. Alternatively you can press the **Control X** and **Control C** shortcut keys, or click the and buttons on the main toolbar, respectively.

To paste a rule, the **Rules** panel must be highlighted. You can do this by clicking somewhere within the **Rules** panel so that its toolbar is highlighted. You can also right-click in the **Rules** panel and select **Paste** from the popup menu. Alternatively, press **Control V**, or click the button on the Event Modeler toolbar. Note that the newly pasted rule will be renamed to `Copy of previous_name` if there is still a rule with the same name. For example, if you copy a rule and then paste it back into the same state, the newly pasted one will be renamed. The rule transition's destination state will be preserved provided that the destination state still exists. If not, it will revert to `continue`.

You can also use **Cut**/**Copy**/**Paste** with rule elements. For example, you can copy a text variable element from a "`variablechanges`" statement and paste it into a text expression element.

You can also drag and drop rule elements to copy them. To do this, first select the rule element. Then hold down the mouse button and drag the element to the location to which you want to copy it. Not all elements can be copied to every other rule element. For example, you cannot copy a number expression and paste it into a condition expression. When you drag an element over its intended target, Event Modeler highlights the target in green if the copy is allowed and in red if the copy is not allowed.

Activating and deactivating rules

A deactivated rule is excluded from the EPL code generation and deployment. The

button in the top right corner of each rule acts as a toggle to activate and deactivate the selected rule. Deactivated rules have a grey background to distinguish them from active rules which have normal white backgrounds. Also, if a rule has a transition associated with it, it will not appear on the state graph when its rule is deactivated.

An invalid rule prevents Event Modeler from exporting EPL for the scenario. If the rest of your scenario is valid and you want to export it as EPL, you can deactivate an invalid rule to generate the EPL. The EPL generator ignores deactivated rules.

Specifying conditions

In the Event Modeler **Rules** panel, the condition part of a rule is denoted by **When**. Every rule specifies a condition that must evaluate to true or false. When the condition evaluates to true, Event Modeler executes the action part of the rule, which is denoted by **Then**.

Interactive editing

As described in "How rules define scenario behavior" on page 450, there is a rich syntax available for defining conditions. Traditionally, you would expect to have to learn the language for defining conditions, specify a condition in a rule, and then have some facility that will check your input and inform you whether or not it is valid.

Event Modeler takes a different approach, in that it provides for graphical programming. With graphical programming, you assemble the condition by selecting from a number of options, gradually piecing it together. The advantage of this approach is that you do not necessarily need to know the intricacies of the language in any great detail and will be unable to make syntactic mistakes. With a little practice you can rapidly become as fast as someone who is typing in the condition.

Language elements

The interactive editing function is provided by the Condition Editor. Using the Condition Editor is very straightforward, but some terminology should be clear in order to assist with explanation.

Text in the condition part consists of a number of *elements*, which can be one of two types:

- *non-terminals* — elements that are not yet fully defined and are acting as placeholders to be replaced with further elements
- *terminals* — elements that are fully defined, and actually constitute the proper text of the condition.

An example will make the distinction clear. If it is not already open, open the Limit Order scenario as a template for exploring the Condition Editor features. See "Adding scenarios to projects" on page 468.

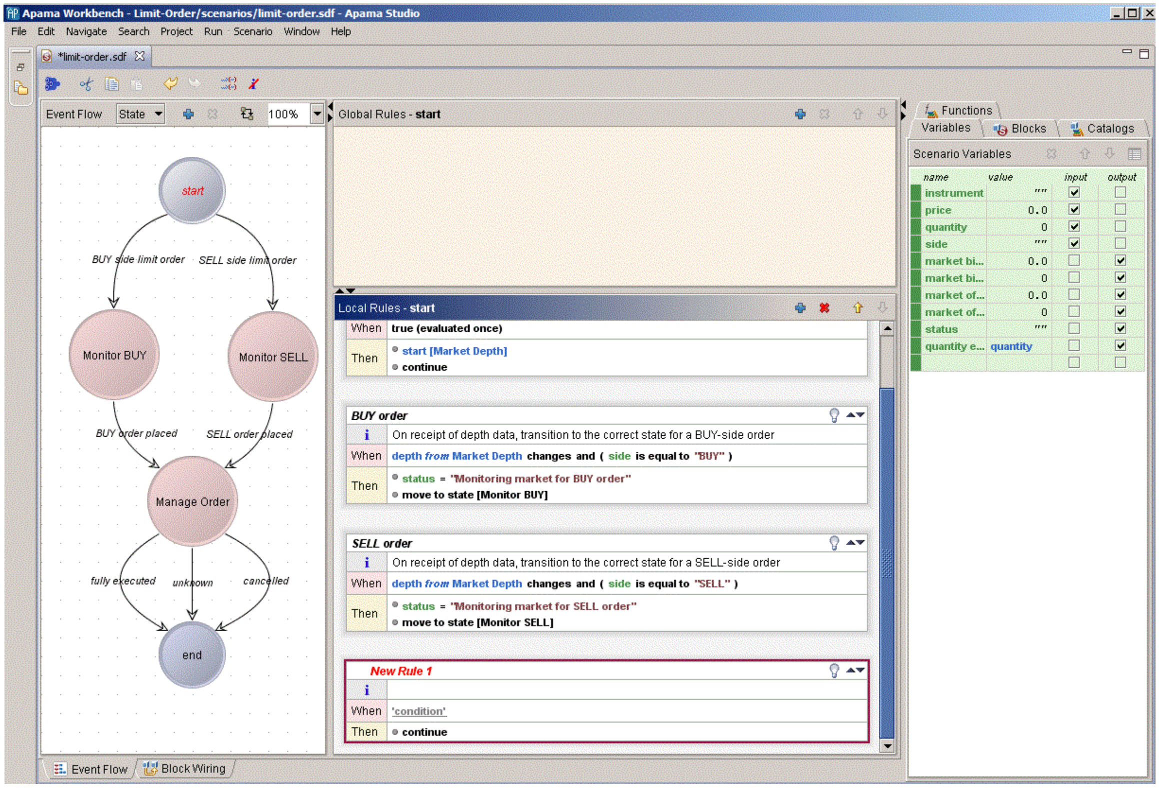
Ensure you do not save any changes as this might render the sample unusable. It is recommended that you make a backup copy of the `.sdf` file. After the scenario is open:

1. Click the **start** state to select it.
2. Click the symbol in the **Local Rules** panel toolbar to add a new rule to the **start** state.

   The new rule is added to the bottom.

A new rule starts off with the condition part containing the text `'condition'`. Note that the word `'condition'` is in quotes and also underlined. Both quotes and underlining indicate that this is a non-terminal, that is, it still needs to be replaced with more precise text for the condition to be *finished*. Because the rule is unfinished its name appears in red italics.

The Event Modeler window will look as follows:



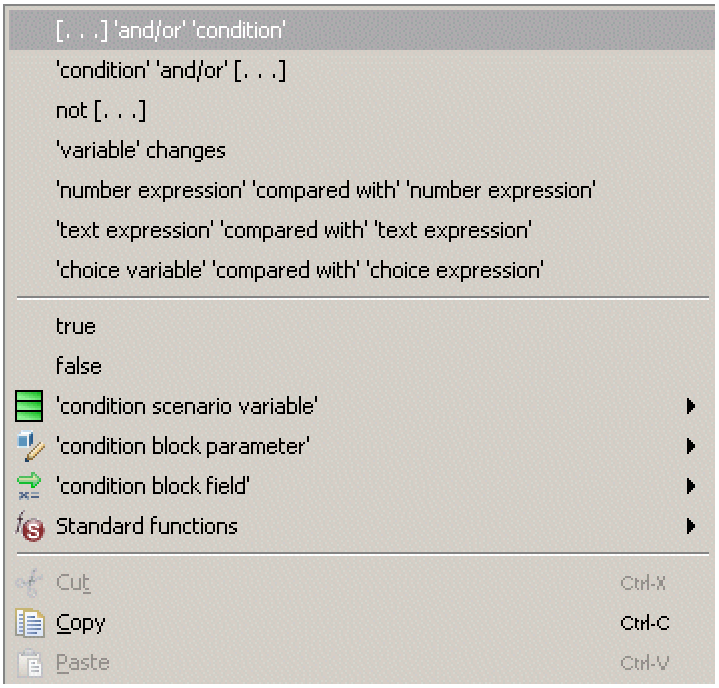
Because this condition is unfinished, the rule, the state and indeed the entire scenario are now unfinished. You can observe that a state is unfinished by the fact that its title is displayed in red italics text, as with the **start** state in this case.

Selecting and replacing elements

To select and replace elements

1. Right click on the `'condition'` non-terminal to see what it can be replaced with.

   A pop-up menu with several *alternatives* will appear.



Note that some of the alternatives themselves have elements with quotes to indicate that they are non-terminals that would need to be replaced in turn. The alternatives shown are always those with which the current *selection* can be replaced. There can be a distinction between what's selected and what's highlighted, as will be shown shortly.

2. Choose either of the first two alternatives:

   ```
   [...] 'and/or' 'condition'
   ```

   ```
   'condition' 'and/or' [...]
   ```

   The condition editor replaces `[...]` with the selected text.

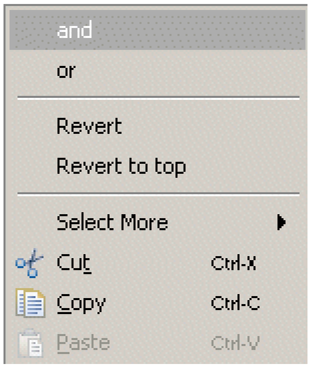
   The text inside the condition part changes from `'condition'` to `'condition' 'and/or' 'condition'`. All selections will be reset.

3. Right-click on the middle non-terminal, `'and/or'`, to see what its available alternatives are.

   They are `and` and `or`.

4. Choose `and`.

5. Now right-click on the new `and` terminal to see its alternatives.



Although it is a finished element, you can change it to `or`. Also, you can select **Revert** to set it back to what it was before the previous operation. Or, you can select **Revert to top**, which sets the value back to the value it had as far as possible in the hierarchy of changes. In this example, **Revert** and **Revert to top** have the same result.

Choosing **Select More** lets you select more of the condition statement. In this case, you can select the whole statement.

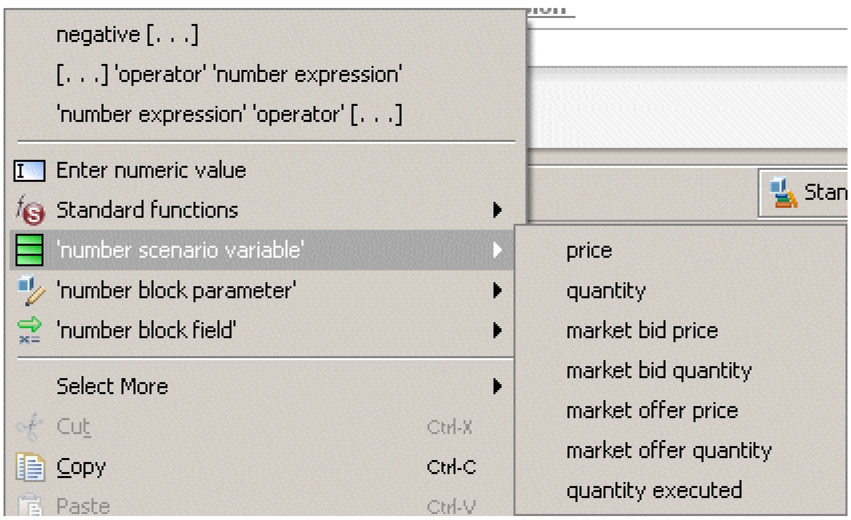
Cascading alternative menus

To fully define the condition

1. Move the cursor over either instance of `'condition'`, hold the right mouse button down and drag to select the whole condition statement. This displays a popup menu that lists the elements that can replace the selected elements.
2. Choose `'number expression' 'compared with' 'number expression'`.

   All three highlighted elements will be replaced with `'number expression' 'compared with' 'number expression'`.
3. Right-click the first `'number expression'` to display its alternatives.

   When an alternative consists of a single non-terminal, the Condition Editor looks ahead to see what it could be replaced with in turn, and provides those choices in a further cascading menu. This accelerates the process of defining a condition. This is recursive.
4. Point to `'number scenario variable'` to be shown which scenario variables of number type are available.



5. Choose `price`.
6. Right-click `'compared with'` and select `'is less than or equal to'`.
7. Right-click the remaining `'number expression'` and choose either of these alternatives:

   `[...]'operator' 'number expression'`

   `'number expression' 'operator' [...]`

   Notice how the editor has added brackets around these latest replacement elements to improve clarity when a condition starts to get complex:

   ```
   price is less than or equal to ('number expression' 'operator'
   'number expression')
   ```

8. Right-click the first `'number expression'` and select `'Enter numeric value'`.

   A dialog will appear in which you can supply a number. The dialog indicates the expected format for your locale.

9. Enter a number, like `25.36`, and click **OK** to accept it.
10. In a similar fashion replace `'operator'` with `*`.

Using functions in rules

To use a function in a rule

1. Right-click the remaining `'number expression'`, and from the alternatives in the context menu, point to `Standard functions`.

   This displays a listing of all the functions available in the Event Modeler that return a number as a result.

2. Choose `ABS ( 'number' value )`.

A function is selected slightly differently to other elements. If you click on the function name you will select the function itself, and can thus replace it. If you click on any of its parameters (if it has any), then you can replace just the parameter. Click the **Functions** tab to display information about available functions; see "Using the Functions tab" on page 506.

3. Select the `'number expression'` parameter, and replace it with the scenario variable `quantity`, by choosing `'number scenario variable', quantity`.

The condition is now complete.

There are no unfinished elements, or non-terminals, in it. No elements have quotes or are underlined.

And if you glance over at the **start** state in the **Event Flow** panel, you will notice that the name of the state is now back to regular black font.

Adding a condition to a rule

Suppose that when you have finished the condition defined in "Using functions in rules" on page 488 you realize that you only want it to evaluate to true if a condition scenario variable is also true. So you want to add an `and` with another condition clause to the end of the condition you have already specified, without having to revert it all and start all over again. You can do this as described below.

To add a condition to a rule

1. Select the entire condition by moving the cursor over the condition, holding down the right mouse button, and dragging until all elements are highlighted. This displays a popup menu of alternatives for the selected elements.

   Now, remember these two alternatives:

   ```
   [...]'and/or' 'condition'
   ```

   ```
   'condition' 'and/or' [...]
   ```

   What this means is that if you select one of those alternatives, because the selection you are replacing is already a `'condition'` in itself, it will not be thrown away but will be retained within the new replacement in place of the `[...]`.

   So, if you choose the `[...] 'and/or' 'condition'` alternative, the current selection will be retained and will replace `[...]`.

2. Do that to see this result:

   ```
   (price is less than or equal to (25.36 * ABS (quantity))) 'and/or'
   'condition'
   ```

   If you had chosen `'condition' 'and/or' [...]`, then `'condition' 'and/or'` would have been added to the front of your previous elements, not after.

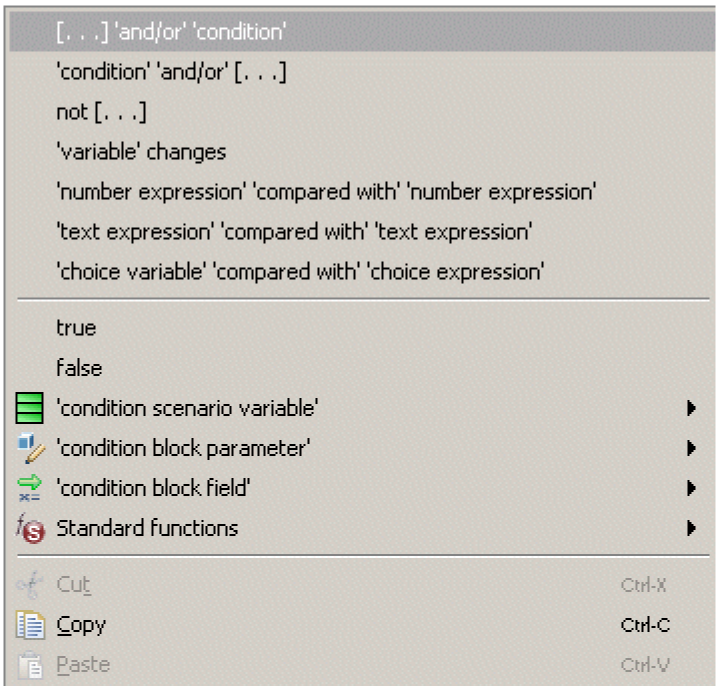
This replacement mechanism is automatically provided wherever an alternative for the current selection embeds an element of the same type as the selection itself.

Specifying variable changes in conditions

When you define a rule's condition, you can choose **'variable' changes** from the condition popup menu.

To specify variable changes in a condition

1. Add a new rule.
2. In the new rule, right-click `'condition'`, which displays this popup menu:



3. Select `'variable' changes`. This replaces `'condition'` with `'variable' changes`.
4. Right-click `'variable'`, which displays a menu of the variables you can specify. As you can see, this menu lists the scenario variables, and it then lists the blocks that the scenario uses. If you select a block, you can then select the variables in that block. The variable in the `'variable' changes` expression can be one of the following:
   - Scenario variable
   - Block output feed
   - Field in a block output feed
   - Block parameter

When you select **'variable' changes**, it can be the entire condition, or it can be an expression in a condition. Following are a few examples of specifying **'variable' changes** in a condition:

- `When  quantity changes`

- `When  quantity changes or price changes`
- `When  quantity is greater than 20 and price changes`

A **changes** expression can become true as follows:

- When the variable in the **changes** expression is a block feed, any update that causes the block to send that output feed changes the condition to true. It does not matter whether or not the values of any fields in the output feed actually change.
- When the variable in the **changes** expression is a scenario variable, a block field, or a block parameter, a change in the value of that variable causes the **'variable' changes** expression to be true. For example, if you assign the value `5` to the **quantity** scenario variable and the **quantity** scenario variable already has the value `5`, then there is no change and the **'variable' changes** expression remains false.

Suppose that a **'variable' changes** expression in a condition becomes true and the entire condition becomes true. When this happens, Event Modeler does two things:

- Executes the rule's action.
- Resets the value of the **'variable' changes** expression to false. This ensures that two rules that specify the same variable in a **changes** expression can each trigger their action as a result of the same change.

Beyond this, the behavior of a **'variable' changes** expression varies according to whether the condition appears in a global rule or a local rule.

Local rules and variable changes

When there is a transition to a state, any **'variable' changes** expressions in local rules are initially false. Any changes made in previous states do not affect any **changes** expressions in the new state. For a **changes** expression to become true, the specified change must occur in the state to which the rule, which specifies the **changes** expression, applies.

Global rules and variable changes

When there is a transition to a state, a **'variable' changes** expression in a global rule can be initially true or false.

In a global rule, the **'variable' changes** expression is initially true when all of the following are true:

- In a previous active state, the **'variable' changes** expression became true but there was a transition to another state before the associated rule was triggered.
- Since the **'variable' changes** expression became true, it has not triggered execution of an action.
- The scenario has not passed through a state for which this global rule was deactivated.

Remember that when a true **'variable' changes** expression triggers a rule, the Event Modeler resets the value of the **'variable' changes** expression to false.

In a global rule, the **'variable' changes** expression is initially false in each of the following situations:

- The active state is the first state during scenario execution for which the global rule is activated.
- The global rule was not activated in a previous state and since that state was active the variable of interest has not changed.
- The global rule was triggered in a previous state and since that state was active the variable of interest has not changed.

For example, suppose states `1`, `2`, and `3` each define global rule `X`, which specifies `price changes` as its condition. There is a transition to state `1`. Initially, the `price changes` expression is false, but while state `1` is active the `price` variable changes and the `price changes` expression becomes true. However, there is a transition to state `2` before execution triggers global rule `X`. Global rule `X` is activated for state `2` but there is a transition to state `3` before execution triggers global rule `X` in state `2`. In state `3`, the `price changes` expression is still true. Execution triggers global rule `X`, performs the associated action, and resets the `price changes` expression to false. If global rule `X` has not been activated for state `2`, or if global rule `X` has been triggered in state `2`, then the `price changes` expression would have been false when state `3` become active.

Specifying actions

The second important part of a rule is its action part.

The action part of a rule is denoted by **Then** and consists of a number of *action statements* and a *state transition statement*.

When a rule is first created it has no action statements set.

The state transition statement

The state transition statement, already introduced elsewhere, specifies whether scenario execution should transit to another state if the rule's condition is true and once its actions are fully executed.

It can be `continue`, the default setting, which specifies that no transition is to occur, or be `move to state [`*`a state`*`]`.

You can modify the state transition statement by pointing to it and right-clicking. A pop-up menu will appear listing all the possible settings for the statement.

If you select any of the states, the state transition arrow will be set to `move to state [`*`that_state`*`]`. A corresponding transition will also appear in the **Event Flow** panel.

If a state transition starts and ends within the same state, a transition will still be added from that state to itself in the **Event Flow** panel. If you ensure that the rule is highlighted, the transition will be highlighted as well, and you will then be able to change its connectors and turn it into a curve. This will make it more visible.

Note that if you click on the state transition statement, i.e. with the left mouse button, and it is set to `move to state [`*`a_state`*`]`, you will be taken to that state. That is, the target state will be selected in the **Event Flow** panel, and the **Rules** panel will change to show the rules of that state.

Adding action statements

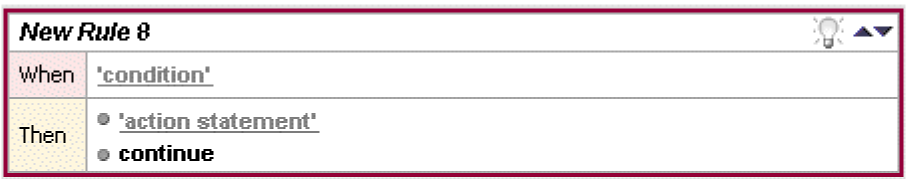
To add an action statement, you left-click the ● symbol to the left of the state transition statement.

To add an action statement

1. Click the ● symbol to add an action statement.

   New action statements consist of the text `'action statement'` preceded by a ● symbol.

   In general, when you left-click a ● symbol, Event Modeler adds an action statement before the line containing the symbol.

2. Click the ● symbol preceding the new action statement to add another action statement before it.

Deleting action statements

To delete an action statement, you right-click the ● symbol to the left of the statement you want to delete. Note that you cannot delete the transition statement.

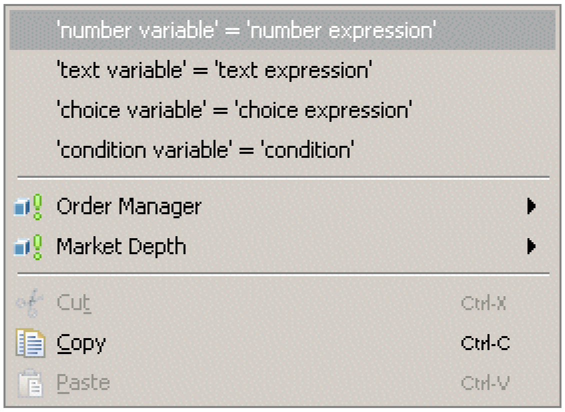
Click the ● symbol for the first action statement to delete it.

Interactive editing

Once you have added an action statement, you need to specify the desired action using the *Action Editor*.

The Action Editor works on the same principles as the Condition Editor. See "Specifying conditions" on page 483.

Right click the non-terminal `'action statement'` to see its replacement alternatives.



As you can see from the alternatives available, the main difference is that action statements can either be assignments to variables or invocations of block operations.

There is a separate Action Editor for each action statement, and like the condition, all statements need to be *finished* for the rule to be finished. Feel free to explore the language elements and replacements available in action statements.

Using the keyboard to edit rules

Instead of using the mouse, you can use the keyboard to edit rules.

Select one or more rule elements, and then press the Menu key .

This displays the menu of choices for replacing the selected element(s). Use the cursor keys to select what you want.

The following table lists the other keys you can use to edit rules. Select one or more rule elements and then press the key.

Task	Key	Description
Add action	+	Inserts a new placeholder for an action statement below the condition or action that contains the selected element.
Delete action	-	Deletes the action statement that contains the selected element(s).
Display menu	**Insert** or **Menu** key	Displays the context menu for the selected element.
Edit literal	**F2** or **Enter**	Displays a dialog in which you can edit the selected literal value.
Move to next rule	**Page Down**	Selects the first element in the next rule. If the focus is on the last rule, the focus stays

Task	Key	Description
		where it is. If the focus is on a global rule, pressing this key selects the first element in the next global rule. If the focus is on the last global rule, pressing this key does not select the first element in the first local rule. The focus stays where it is. Note: if you selected the whole rule, so that the red, rectangular outline appears around it, pressing **Page Down** does nothing.
Move to previous rule	**Page Up**	Selects the first element in the previous rule. If the focus is on the first rule, the focus stays where it is. If the focus is on a local rule, pressing this key selects the first element in the previous local rule. If the focus is on the first local rule, pressing this key does not move to the last global rule. The focus stays where it is. Note: if you selected the whole rule, so that the red, rectangular outline appears around it, pressing **Page Up** does nothing.
Move to next element	→	Selects the next element in the statement. If the last element is already selected, pressing the left arrow key does nothing.
Move to previous element	←	Selects the previous element in the statement. If the first element is already selected, pressing the right-arrow does nothing.
Move to next statement	↓	Selects the first element in the next condition or action statement. If the selected element is in the last global or local action statement, pressing this key does nothing.
Move to previous statement	↑	Selects the first element in the previous condition or action statement. If the selected element is in the first global or local condition, pressing this key does nothing.
Revert to top	**Delete**	Resets the selected element or elements as far back before any changes as possible.

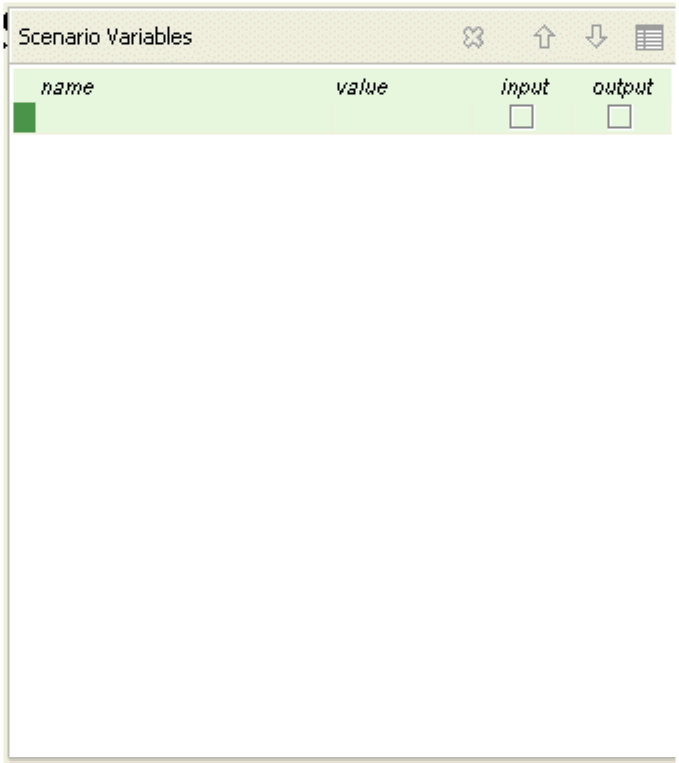
Task	Key	Description
Revert selection	**Backspace**	Resets the selected element or elements to its (their) previous value.
Select first element	**Home**	Selects the first element in the condition or action statement in which you had selected an element.
Select last element	**End**	Selects the last element in the condition or action statement in which you had selected an element.
Select multiple elements	**Shift** + →	Adds one or more subsequent elements to the selection. Event Modeler examines each subsequent element in order until it enlarges the selection to a set of elements that can be replaced as a unit. This might mean that only the next element is added to the selection, or that multiple subsequent elements are added.
	Shift + ←	Adds one or more previous elements to the selection. Event Modeler examines each previous element in order until it enlarges the selection to a set of elements that can be replaced as a unit. This might mean that only the previous element is added to the selection, or that multiple previous elements are added.

Using the Variables tab

The **Variables** tab lists and allows modification of all the variables available for use in a scenario.

In order to explore its features, create a new scenario by selecting **File > New > Scenario** from the menu.

Observe the **Variables** tab. Note the selection of buttons on its toolbar, and the fact that it contains a table, with two rows and four columns.



The first row contains column headings, while the second row appears empty. The variables table always displays a line for each variable defined, with a final empty line from which you can add new variables. In this case, no variables are yet defined, so the table only contains the final empty line.

The columns are `name`, `value`, `input` and `output`, and in addition each variable row has a dark green square to the left of it.

By default the background of these rows is green; green being used throughout the Event Modeler to denote scenario variables.

Adding a variable

To add a variable

1. Left click on the empty row in the cell under the column heading `name`. The cell will become highlighted with a border appearing around it. This means you can type in the cell.

   Alternatively you could double click on the cell, and this would display a flashing text entry cursor in the cell.

2. After selecting the name entry cell, type in a name for your new variable, like `var1`, and either click elsewhere or press **Enter**.

   Note how a new empty line is added to the bottom of the table. The name of a scenario variable must be unique within the set of a scenario's variables. A scenario variable can have the same name as a parameter of a block that the scenario uses.

3. Create a second variable by clicking on the `name` cell in the final empty row and naming it `var2`.

Renaming a variable

If you left click on the name of a variable to select its `name` cell, you can type in a new name, effectively renaming the variable.

Alternatively you can double click on the cell, and this will display a flashing text entry cursor in the cell, allowing you to edit the previous name.

Recall that variable names must be unique – if you type a name already in use it will revert to its old value on acceptance.

Selecting a variable

If you want to carry out some variable operations, like moving a variable, or viewing its properties, you first need to select it.

You can do this by clicking on the green square at the beginning of each row. This selects the entire row. Notice how the icons on the **Variables** tab change to indicate they are now available.

You can select multiple variables in one go. Select the first one normally. Then, while holding down the **Ctrl** (Control) key, select any additional variables. Alternatively, hold down the **Shift** key to select all variables from the first one selected to the current one.

Determining which states use a particular variable

Event Modeler displays a dotted green border around each state that uses the selected variable when you do either of the following:

- Highlight a row in the **Variables** tab by clicking on the green square at the beginning of the row.
- Click on a variable in a rule.

Moving a variable

Once you have selected a variable you can move it up and down in the table by using the  and  symbols.

Changing a variable's position in the **Variables** tab has no effect on scenario execution other than appearing in that order whenever the scenario is opened from disk.

You can also select multiple variables and move all of them at the same time. Hold down the **Ctrl** key when you select each variable. Or use the **Shift** key select a range of variables.

You cannot move the last empty line, and cannot move variables below it.

Deleting a variable

You can delete a variable by right-clicking its name and selecting **Cut** from the context menu.

Once you have selected a variable you can delete it by clicking on the ✖ icon on the main toolbar or by pressing **Del**.

If you have selected multiple variables, they will all be deleted.

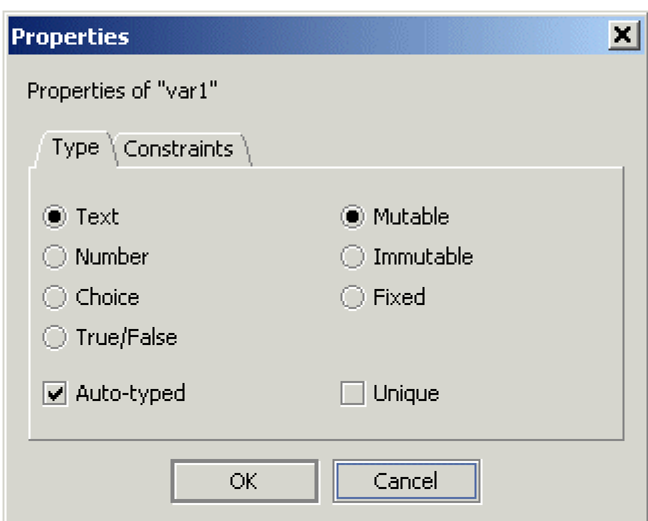
Caution: If any rules' condition or action parts refer to the variable you have removed, the references will be *reverted* back to their non-terminals. This will make those rules, and therefore the enclosing states and the scenario, unfinished.

Changing a variable's properties

Once you have selected a variable you can change its properties. To display a variable's properties, either click (again) on the green square at the left of its row, or else click on the icon in the **Variables** tab toolbar.

This will display the Properties dialog.

This dialog has two tabbed panes, **Type** and **Constraints**.



Use the **Type** pane to change the variable's type and mutability properties.

Use the **Constraints** pane to specify what values are valid for that variable.

Remember that mutability properties and value constraints only apply to an end user's interaction with the scenario through a dashboard. They do not apply when a variable is wired to another variable or a block field, or to any assignments carried out in any action part of any rule.

Note that the constraints available change according to the variable's type, so the contents of the **Constraints** pane change dynamically as you select different types on the **Type** pane.

The options available for both panes have already been described in "About scenario variables" on page 460.

Caution: When a rule's condition or action parts refer to a variable, in the majority of cases those references are type specific. For example a `'condition variable'` non-terminal can only be replaced by a scenario variable that is of type `True/False`. Therefore, if you change the type of a variable after having used it in any rule conditions or actions, the references to it will be *reverted* back to their non-terminals if they become invalid. This will make those rules, and therefore the enclosing states and the scenario, unfinished.

Setting a variable's value

Once you have created a variable you can also set its initial value. This is the value that the variable will have at the start of execution of any scenario instance before it is modified by the user or by an action in a rule.

You may have noticed that a default value is always displayed in the value cell. By default a variable is set to be `Auto-Typed`, and initially set to be of `Text` type with the empty string as its value — `""`.

You can change the initial value by clicking on the `value` cell for the particular variable, and then typing in the appropriate value, or else double clicking on the cell to get a text entry cursor. The former method over-writes any previous value; while the latter technique lets you edit the existing value.

If the variable is set to be `Auto-Typed`, you can type in any value. The variable's type will then be deduced, and may therefore be changed, by what you have typed in.

If you type any whole number (for example, `5`, `25`, `-145`) the variable will be set to `Number`, with the constraint `Whole number`. If you supply a number with a fractional part (`4.45`, `.68456`, `-23.`), the variable will be set to be a `Number` with no constraints. If you enter one of `true` or `false` (any mixture of case will work, for example, `TRUE`, `True`, `tRue`), the variable will be assumed to be of `True/False` (conditional) type. Everything else is taken to imply a `Text` variable.

If the variable is not `Auto-Typed`, you are only allowed to enter values that are valid according to the type of the variable and any constraints imposed on it. So, for example, if the variable is of `Number` type, you cannot enter “`Hello`” as a valid value. If you attempt to do so, the variable's value will be reset to the previously set value, or the default for that type if none had been set, that is `0` or `0.0`.

Variable input and output

As described in "Variable constraints" on page 461, a variable can be marked as being an input variable, or an output variable, or both. These indicators are used by the dashboard to restrict which scenario variables it should make available to the end-user. For output variables it can also auto-generate specific functionality.

By default these indicators are off for each variable. Click on the check boxes in the `input` and `output` columns to set them. The space bar also toggles this on and off.

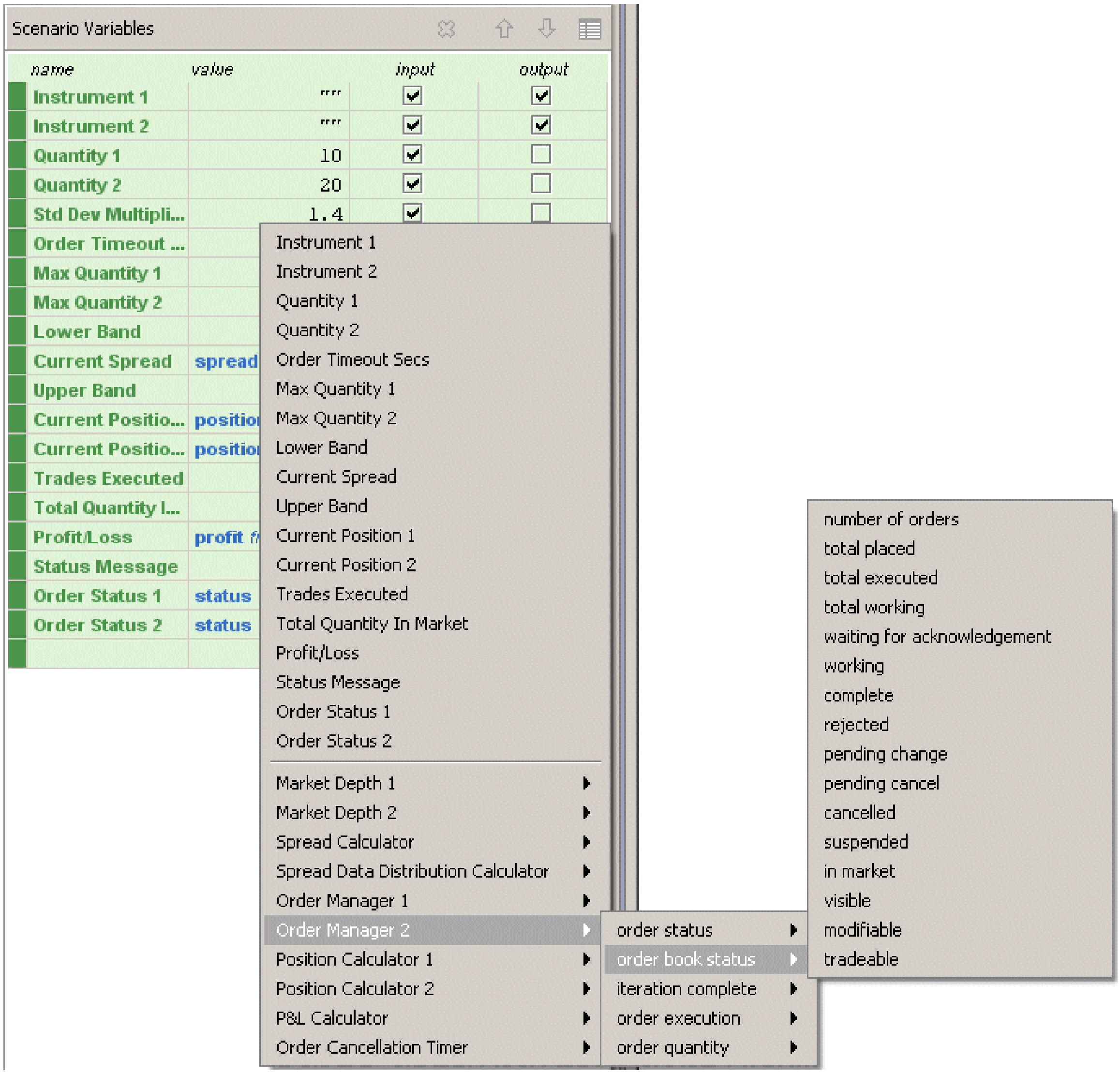
Linking a variable to a block output field

"Linking variables, block parameters, and block output fields" on page 464 described how one can set up a link between a scenario variable and another variable, or to the value of a block output field. Once this link is set up the variable will always have the same value as the source variable or the output field.

If the value of the source variable or output field changes, the destination variable's value will get updated automatically to be the same value.

You can set up such a link by right-clicking while pointing to the `value` cell for the variable to be linked. If the scenario contains any other variables or block instances with output feeds and fields, a pop-up menu will appear listing these.

Linking a variable to a block output field



When you select the output field to link with the variable, the field's name, preceded by the enclosing block instance's name, is displayed in the `value` cell.

The source variable or field chosen does not have to be of the same type as the destination variable.

If the destination variable is `Auto-Typed`, it can be wired to other variables or block output fields of any type, and will inherit their type once the wiring is carried out.

If it is not `Auto-Typed`, and it is not of the same type as the source, the source value will be converted to the destination variable's type before being copied to it. If this is not possible, a default value is set. See "Conversion rules for variable types" on page 503. For this reason, it is important to set up these links carefully.

Conversion rules for variable types

This table summarizes the conversion rules:

	Number	Number (whole)	Text	Choice	Condition
Number	Copy the value	Copy the value and round it to the nearest integer value	Copy the value as a string.	Copy the value as a string.	`false`
Number (whole)	Copy the value	Copy the value	Copy the value as a string.	Copy the value as a string.	`false`
Text	Try to convert to a valid number up to the first non-numeric character, set to 0.0 if first character is not a number.	Try to convert to a valid number up to the first non-numeric character, set to 0 if first character is not a number.	Copy the value.	Copy the value.	If the value is `true` then set to true, else false. Case is ignored.
Choice	Try to convert to a valid number up to the first non-numeric character, set to 0.0 if first character is not a number.	Try to convert to a valid number up to the first non-numeric character, set to 0 if first character is not a number.	Copy the value.	Copy the value.	If the value is `true` then set to true, else false. Case is ignored.

	Number	Number (whole)	Text	Choice	Condition
Condition	1.0 for true 0 for false	1 for true 0 for false	Copy the value as a string.	Copy the value as a string.	Copy the value.

Examples

Text Source	Number Target
`"information"`	`0` or `0.0`
`"-2.45"`	`-2.45`
`"456test"`	456

Using the Catalogs tab

The **Catalogs** tab displays catalogs of block templates that are available for use in a scenario. A catalog of block templates is a folder that contains one or more `.bdf` files, each defining a block template that the user can instantiate in a scenario. A catalog of block templates can also contain subfolders that themselves contain `.bdf` files. This hierarchical organization of a catalog appears when it is displayed in the **Catalogs** tab.

This text uses the term *block template* to refer to a block's definition on disk (within a `.bdf` file), whereas *block* is used to refer to an instance of a block template that has been added to the scenario.

The format and structure of a `.bdf` file is discussed in "File Definition Formats" on page 639.

Typically, you might want to use multiple block template catalogs to distinguish between block templates supplied by Apama, block templates that you have developed yourself, and block templates that you have obtained from third parties.

In addition, within each block template catalog, as the number of block templates available to a scenario author could be very large it is useful to organize them into categories that reflect their functionality. Furthermore, as the block templates available are enhanced and new versions released, one is likely to need access to multiple versions of the same block templates.

A block template catalog's folder structure is therefore as follows:

- A root folder that represents the block template catalog, and within it,
- One or more sub-folders that represent functional categories of block templates, and within each,

- A folder called *block_template_name* `.bdf`, which contains
- The different available versions of a block template in distinct `.bdf` files.

The default block template catalog is simply called `blocks`. In the **Catalogs** tab, it appears as **Standard Blocks**.

Adding a block template catalog

When Event Modeler is open, it automatically makes the default catalog `blocks` available. If you have another block template catalog available on your system and want to make those block templates available to your scenario, use Software AG Designer to add the block catalog to your project as described below.

To add a block template catalog

1. In the **Apama Developer** perspective, right-click the project name and select **Properties**.
2. In the Properties dialog, expand **Apama** and click **Catalogs**.
3. Click the **Blocks** tab and then **Add**.
4. In the Source Folder Selection dialog, click on **catalogs** to highlight it, and click **Create New Folder**.
5. In the **Folder name** field, enter the name of the catalog you are adding.
6. To add the complete contents of the catalog you specified, click **Finish**, and then click **OK** twice. You are done.
7. To choose particular files to add, click **Next**. Specify inclusion and/or exclusion patterns and click **Finish**. Then click **OK** twice.

Also use the **Blocks** tab in the Properties dialog when you want to remove a block template catalog.

Selecting and inspecting a block template

The **Catalogs** tab is divided horizontally into two areas.

The top area displays the available catalogs. Expand each catalog to view its contents. When you select one of the following, a description of it appears in the bottom area:

- A particular version of a block template
- A block parameter
- A block operation
- A block input feed or input field
- A block output feed or output field

Adding a block instance to the scenario

To add a block template to your scenario, first select it from the **Catalogs** tab. Open the folder it is in, select the block you want, and if there is more than one version, select the version you want. The recommendation is to use the most recent version, which is implemented in a way that delivers better performance than the older version. Also, the most recent version is parallel-aware. Older versions will be removed in a future release.

Then click on the icon in the tab's toolbar to add this block to the scenario. You will see it appearing in the **Blocks** tab.This instance of the block template in the scenario will be automatically named. The name assigned will be the block template name followed by `1`, to indicate that this is the first instance of this block.

As implied, it is possible to add multiple instances of the same block to the scenario. These will be named sequentially to differentiate between them. The unique naming of each instance is important, as all block instance feeds, fields, parameters, and operations are referred to from within rules by the enclosing block instance's name.

Using the Functions tab

The **Functions** tab presents an organized view of the functions available for use in Event Modeler. The functions are organized in a folder hierarchy.

A function catalog allows you to organize a large number of functions into a manageable set of categories that indicate their functionality. A function catalog has the following structure:

- A root folder that represents the function catalog, and within it,
- One or more sub-folders that represent functional categories of functions, and within each of the sub-folders,
- `.fdf` files that define a group of related functions.

Such a catalog is installed by the Event Modeler installer. The default function catalog is simply called `functions`. To display this catalog, click the **Functions** tab.

Adding a function catalog

When Event Modeler is open, it automatically makes the default catalog `functions` available. If you have another functions catalog available on your system and want to make those functions available to your scenario, use Software AG Designer to add the function catalog to your project as described below.

To add a function catalog

1. In the **Apama Developer** perspective, right-click the project name and select **Properties**.
2. In the Properties dialog, expand **Apama** and click **Catalogs**.
3. Click the **Functions** tab and then **Add**.

4. In the Source Folder Selection dialog, click on **catalogs** to highlight it, and click **Create New Folder**.
5. In the **Folder name** field, enter the name of the catalog you are adding.
6. To add the complete contents of the catalog you specified, click **Finish**, and then click **OK** twice. You are done.
7. To choose particular files to add, click **Next**. Specify inclusion and/or exclusion patterns and click **Finish**. Then click **OK** twice.

Also use the **Functions** tab in the Properties dialog when you want to remove a block template catalog.

You must ensure that the `function name` attribute is unique within the directory in which you save the `.fdf` file. If you save a function definition file in a function directory that has been added to Event Modeler, and your new `.fdf` file does not have a unique `function name` attribute, you receive an error message about this when you open Event Modeler. You must resolve this error condition before you try to use either of the duplicate functions. If you do not, you cannot predict which function Event Modeler will actually use when you call one of the duplicate functions.

Selecting and inspecting a function

The **Functions** tab is divided horizontally into two areas. The top area lists the categories of functions in the catalog, and within each, the available functions. You can expand each function to view its parameters and return value. When you select a function name a description of that function appears in the bottom area.

Using the Blocks tab

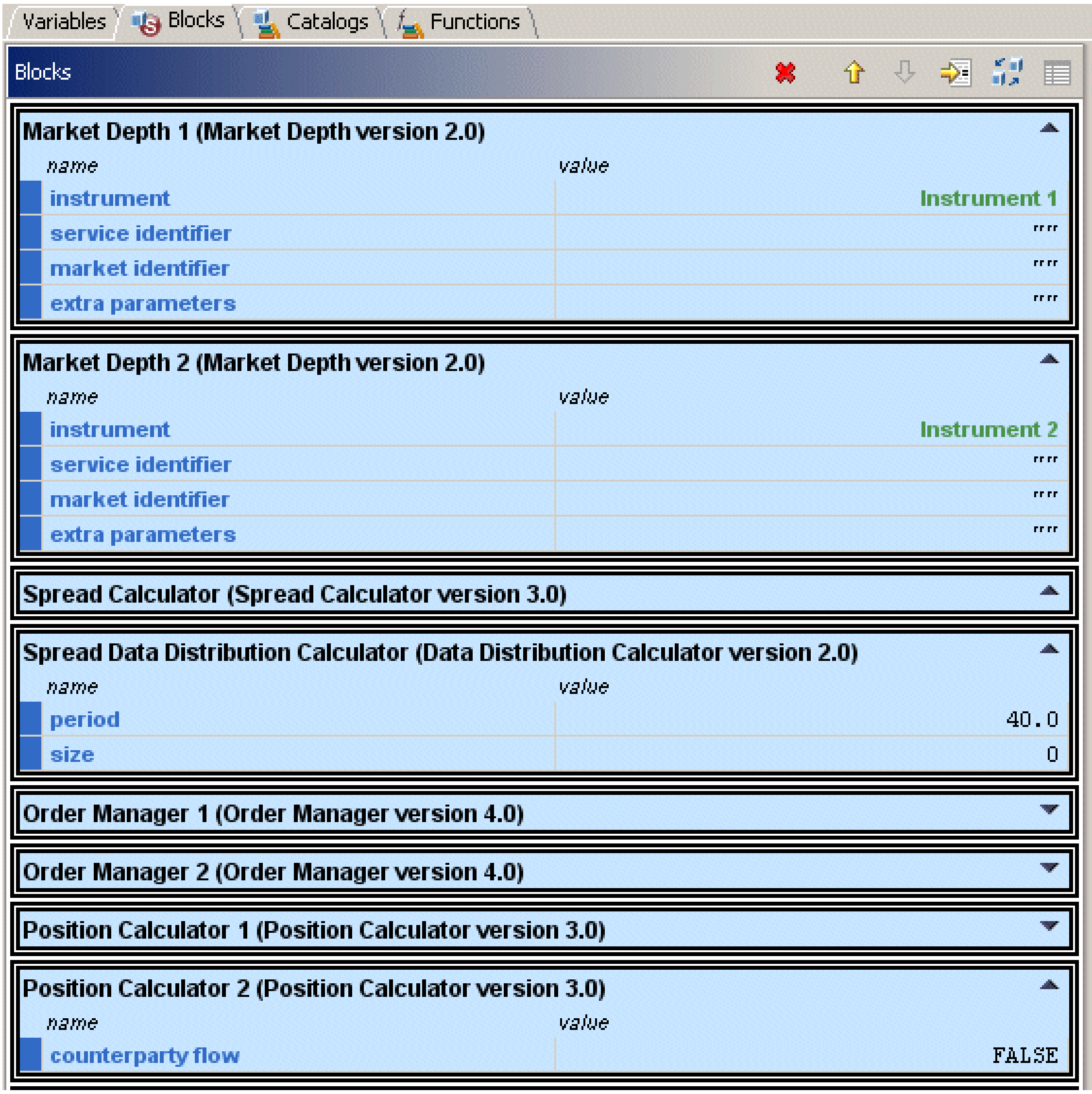
The **Blocks** tab lists all block instances that have been added to the scenario. From it you can select and delete a block, view its parameters, and link them to scenario variables or other block instances' output fields.

The **Blocks** tab is initially empty, but it then gets populated with block instances as you add these to the scenario from the **Catalogs** tab.

As you add block instances, each appears in the **Blocks** tab as a distinct element. By default, each is given a blue background, although this can be changed in the Event Modeler's preferences.

For each block instance, the representing element lists the block instance's name, and name of the block definition it was added from (this is in parenthesis), followed by a table with two columns, `name` and `value`.

Each row in the table contains a parameter, and similar to the table in the **Variables** tab, each is preceded by a solid blue square.

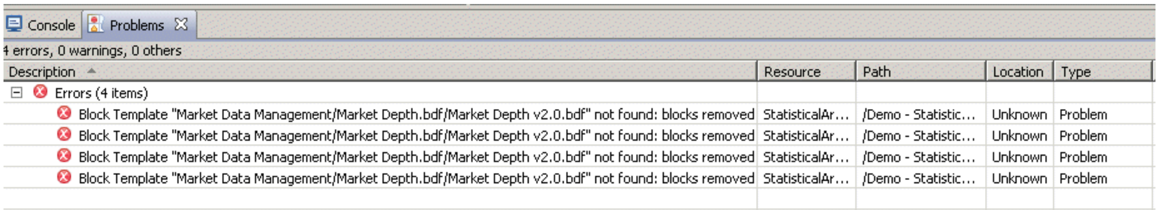


Note that a block does not have to have any parameters, and some of the standard blocks supplied by Apama are like this.

Interaction with this *parameters table* is similar to that in the **Variables** tab, with the distinction that it is not possible to add new parameters, rename them, re-order them, or change their properties. This functionality is not possible because the number, name and nature of block parameters is defined in the block's definition.

Once a block is added to the scenario, its parameters, output feeds and operations are available for interaction within rule conditions and actions. When a scenario is loaded the Event Modeler will reload that block's definition from its `.bdf` file and check that none of the referenced parameters, output feeds or operations have changed. If they have then any references will be *reverted* back to their non-terminals.

If you load a scenario and a block that you previously added to that scenario is missing Event Modeler reverts values of any variables that depended on that block's feeds to their default values. You receive a message that the block is missing when you open the scenario. Also, an entry for each missing block appears in the **Problems** view as shown in the figure below. Double-clicking on a missing block entry in the **Problems** view displays the **Block Wiring** for the scenario without the missing blocks.



Interacting with a block instance

To select a block instance you need to left click somewhere within its display element other than inside its parameters table. For example, clicking on its name or on the table's column heading will select the block instance.

Once a block is selected,

- You can delete it by pressing **Del**, or by clicking on the icon in the toolbar.

  If any rules' condition or action parts refer to any feed, field, parameter or operation of the block instance you have removed, the references will be *reverted* back to their non-terminals. This will make those rules, and therefore the enclosing states and the scenario, unfinished.

- You can move the instance's relative position in the tab by clicking on the and icons in the tab's toolbar.
- You can browse the instance's block template definition in the **Catalogs** tab by clicking on the icon in the tab's toolbar.
- You can switch all references in rules and mappings from this block to another block by clicking on the icon. This operation is described in more detail later.
- Event Modeler displays a dotted blue border around each state that uses the selected block.

Another way to see which states use a particular block is to click that block in a rule. Event Modeler displays a dotted blue outline around the states that use the selected block.

Selecting a parameter

To select a block parameter, click on the solid blue square to the left of the parameter's name.

The entire row will be highlighted with a dark red background.

Viewing a parameter's properties

Once a parameter is selected, you can view its properties. You can do this by either clicking again on the solid blue square, or else by clicking on the icon in the **Blocks** tab's toolbar.

This will display the Properties dialog. Properties for block parameters are almost identical to properties for scenario variables, with the distinction that the former cannot be modified in the Event Modeler. For this reason all settings in the Properties dialog will be grayed out. You can view them but you cannot change them.

Setting a parameter's initial value

As with scenario variables, block parameters need to have an initial value. This will be displayed in the `value` column. You can modify this initial value for each block instance's parameters by clicking on the `value` cell and typing in a new initial value. Alternatively you can double click on the `value` cell to edit the existing initial value.

Note that as with scenario variables, you are only allowed to supply an initial value that is compatible with the parameter's type and constraints (if any). If you specify an invalid value, the initial value will be reset to the default for that type.

Linking a parameter with a variable or output field

"Linking variables, block parameters, and block output fields" on page 464 described how one can set up a link between a block instance's parameter and the value of a scenario variable or block output field. Once this link is set up the block parameter will always have the same value as the source variable or block output field. If the value of the source variable or output field changes, the destination parameter's value gets updated automatically to be the same value.

You can set up such a link by right-clicking while pointing to the `value` cell for the parameter to be linked. If the scenario contains any variables or block instances, a pop-up menu will appear listing those variables, the block instances, their output feeds, and within those, their output fields.

When you select a variable or output field to link with the parameter, the variable's or field's name is displayed in the `value` cell.

The variable or field chosen does not have to be of the same type as the parameter. If it is not of the same type, its value will be changed to the parameter's type before being copied to the parameter. If this is not possible, a default value is set. See "Conversion rules for variable types" on page 503.

Since this could set the parameter to unexpected values, it is important to set up these links carefully.

Switching blocks

Consider the situation where you wish to replace a block in your scenario with another one. A common occurrence of this is if you wish to upgrade your block, for example, by replacing version 1 of a block with a newer version 2.

The problem with this is that if you delete the version 1, all references to its parameters, feeds and operations will be reverted or reset. You would then have to add the new block of the more recent version and re-establish all the references.

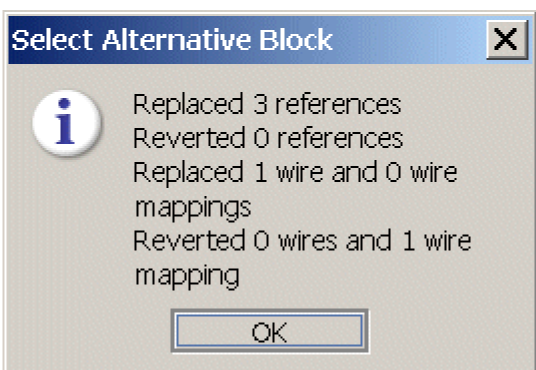
To facilitate this operation, you can *switch blocks* as described below.

To switch blocks

1. In the **Catalogs** tab, add the newer block to the scenario.
2. In the **Blocks** tab, select the block you want to replace.
3. In the **Blocks** tab's toolbar, click on  to be prompted for which block you want to use to replace the selected block.
4. Select the name of the replacement block from the choice list, and click **OK**.

Event Modeler tries to replace all references to the old block with the corresponding interface elements of the new one. Event Modeler also replaces the wiring of the old block with wiring for the new block.

At the end of the switching operation, a dialog appears that summarizes how many elements were replaced and which had to be reverted. For example:



Event Modeler can replace only those parameters, feeds and fields, and operations of the same name. If any elements do not have a corresponding element in the replacement block they will be reverted or removed, as follows:

- References are reverted to their non-terminals.
- In a wire mapping for which the source block output field has changed, the destination block input field is reverted to the default value for its type. For example, if the destination block input field is an integer, the field is reverted to `0`. The mapping itself is not removed even though it no longer has a source field.

- For a wire mapping for which the destination block input field has changed, the wire mapping is removed.

Using the Block Wiring tab

At the bottom of the **Event Flow** panel, you can click the **Block Wiring** tab to replace the **Event Flow** and **Rules** panels with the **Block Wiring** tab. The purpose of the **Block Wiring** tab is to allow you to interactively define how your scenario's block instances are to be *wired together*.

Up to this point only block parameter wiring has been discussed. Recall that a block has parameters, input feeds, output feeds and operations. Parameters are intended for initializing the block, although they can then individually be updated during the block's lifetime to modify its operation. Input feeds, on the other hand, are normally used when a block's primary role is to process or transform some regularly changing data.

For example, the `Change Notifier` block's purpose is to generate a notification when the value of a numeric input data stream changes by a given amount over a configurable moving time window. Its parameters define the time window and the amount that the monitored values must change by to trigger the notification, while the actual values being monitored would of course be an input feed.

A block might accept input data while not having an input feed. This is normally because the block's author expects their block to be used alongside, and get all its input data from, dedicated EPL such as that included with external adapters. Good examples of this are the `Market Data Management` and the `Order Management` blocks such as `Market Depth`.

In general, a block is written to have exposed input feeds if its inputs can be provided by other blocks.

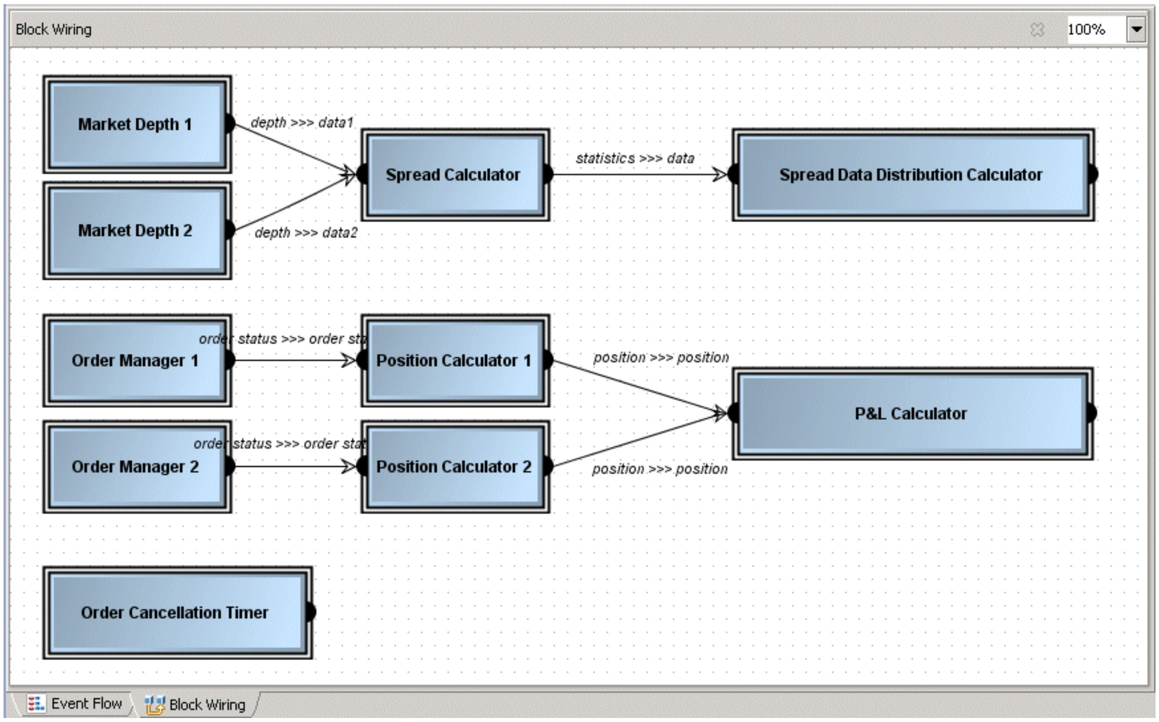
If you open a scenario and a block that was previously added to that scenario is missing you receive a pop-up error message, Event Modeler removes the block from the block wiring display, and there is an entry indicating the missing block in the **Problems** view.

Wiring block input feeds

Two block instances are said to be wired together if one block's input feed is attached to the other's output feed. Output fields from the source block's output feed then need to be mapped (that is, connected) to the destination block's input feed's input fields.

The **Block Wiring** tab displays a solid blue labeled rectangle for each of the block instances that have been added to the scenario. Unless re-organized, these will initially be displayed in a partially overlapping stack at the top-left of the tab.

If a block instance has one or more input feeds, its rectangle will have a *wiring point* on the left hand side. This is a small solid black semi-circle. Similarly, if it has one or more output feeds, its rectangle will have a wiring point on the right hand side. Blocks with both input and output feeds exhibit wiring points on both sides. The figure below shows the **Block Wiring** tab.



Selecting, resizing, and moving block instances

Interaction with the block instances in the **Block Wiring** tab is similar to that in the **Event Flow** tab.

Click on a block instance rectangle to select it. The rectangle's border will become bold red and eight drag handles will appear around the rectangle.

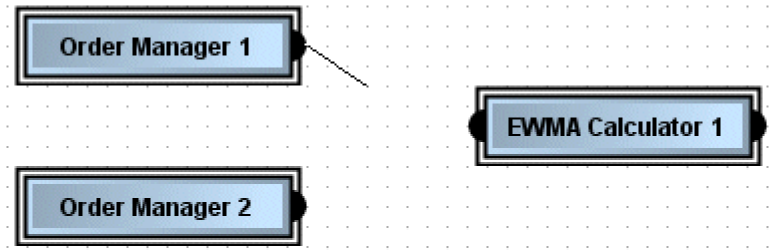
To move a rectangle simply press and hold the left mouse button while pointing to it, and drag to the desired location. Release the mouse button to confirm the new location.

You can use the drag rectangles to resize the rectangle in any of the eight coordinates. As above, point to a drag handle, press the left mouse button and hold down while dragging the handle to the desired location. If you hold down the **Shift** key while dragging, you will restore and then preserve the rectangle's aspect ratio.

Wiring two blocks together

In order to wire two blocks together, it is best to place them side by side so that the *source* block instance is displayed on the left and the *destination* instance is to the right of it.

Then point to the output wiring point on the source block. Note how the mouse cursor changes. Press the left mouse button, and while holding it down, drag to the input wiring point on the destination block. If a connection is possible the line being dragged from one wiring point to another will turn bold to indicate that you can now release the mouse button and create the wire.

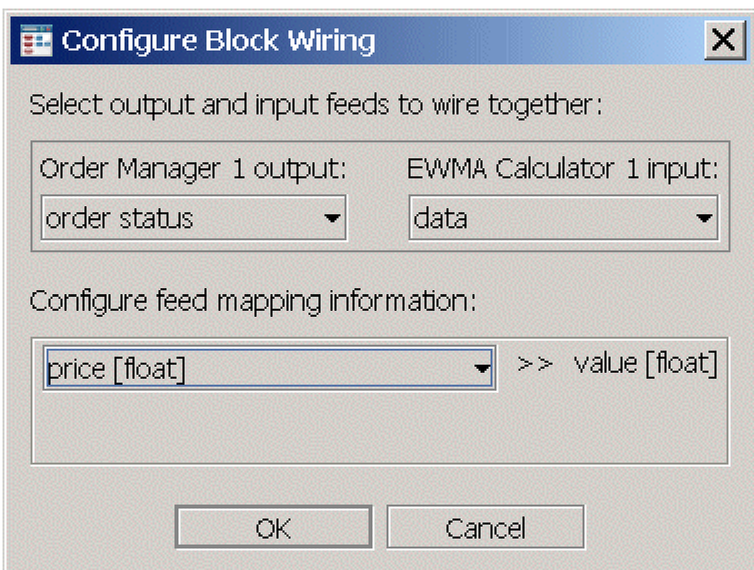


If you release the mouse button elsewhere, and when the line being dragged is not bold, then nothing will happen. You can try again.

If you release the mouse button correctly at a point where the line can be created, then the **Configure Block Wiring** dialog will appear.

Connecting feeds and specifying feed mapping

The Configure Block Wiring dialog has two main areas.



The first area is labeled "`Select output and input feeds to wire together:`". The bordered area underneath it will list all the output feeds of the source block instance on the left, and the input feeds of the destination block instance on the right.

Use the pull-down selectors for each block instance to define which feed should be mapped to which. Note that each wire corresponds to a *single* mapping of one output feed to one input feed.

Therefore once you have selected the output feed and the input feed, consider the second area of the dialog. This is labeled "`Configure feed mapping information:`".

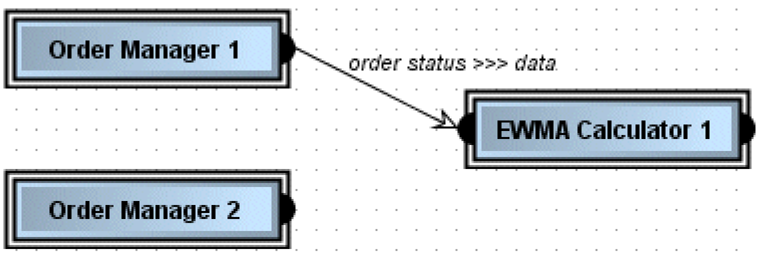
Within the bordered area underneath this label you will see a listing of all the input fields contained within the input feed selected previously. To the left of each field you need to specify the source output field that is to be connected to it. Use the pull-down selector to view the output fields available and to create the mappings.

You can map a single output field to several input fields, or create distinct mappings for each.

At runtime, the field to field mapping will ensure that the input field of the destination block instance will always be kept the same as the value of the output field of the source block instance. When the output field changes, which might be very frequently, the input field will be updated immediately.

Alternatively, you can also just type in a value instead of selecting an output field. In that case the input field will become a constant, always containing the value you set. If you select the `*` option from the selector no mapping will be made, and the input field will be set to the default value for its type.

Click on **OK** to finish the wiring operation. A line will be displayed between the two block instances, labeled to indicate which feeds are involved in the wiring.



Wiring a scenario variable to a block

You might want the value of a scenario variable to be the input for a block. To do this, use the `Variable Mapper` block. Wire the output of the `Variable Mapper` block to the input of the block that requires the scenario variable.

The `Variable Mapper` block takes the name of a scenario variable as the value of its only input parameter. When the value of the mapped variable changes, the `Variable Mapper` block sends the new value to its output feed. The output feed includes two values. The first value is the new value as a number. The second value is the new value as text. You can choose which representation you need to wire into another block.

Mapping type conversions

It is important to be aware that if the type of the source output field is not the same as the destination input field, type conversion will automatically take place.

The behavior here is the same as that already described when linking variables, parameters and output fields. That is, if the conversion cannot be carried out (such as when attempting to convert a non-numeric string to a number) then the destination field will be set to the default value for its type. See "Conversion rules for variable types" on page 503.

Editing block wiring

If you wish to edit the mapping of an existing wire just double click on the line representing the wiring.

Deleting a wiring

If you wish to delete an existing wire select the line representing the wiring by clicking on it. It will become a bold red to indicate it is selected.

You can then press **Del** to delete it, or else click on the ✖ icon in the main toolbar.

Deleting a block instance

You can delete rectangles representing block instances. However, this is the same as deleting block instances from the **Blocks** tab.

To do this, select the block instance's rectangle, and then press the **Del** button. If that block had any wiring, either as a source or a destination, it will be removed.

Caution: If any rules' condition or action parts refer to any feed, field, parameter or operation of the block instance you have removed, the references will be *reverted* back to their non-terminals. This will make those rules, and therefore the enclosing states and the scenario, unfinished.

Using older versions of blocks

Apama 4.2 modified the interface for implementing blocks. All standard blocks have been updated to use this new interface. If you use a version of a block that implements the old interface, Event Modeler indicates this in the **Block Wiring** tab by using a different color around the perimeter of the block. Deprecated blocks (blocks that use the old interface and any blocks that are deprecated in the future) have an orange border while current blocks have a black border. However, the selected block, of any type, has a red border.

You can use both deprecated and current blocks in the same scenario. However, if a scenario uses at least one deprecated block, the scenario instances cannot be run in parallel. In the **Blocks** tab and in the **Block Wiring** tab, blocks that are parallel-aware have a double-line border. Blocks that are not parallel-aware have a single-line border.

The recommendation is to update any custom blocks to the new interface. Support for the old interface will be removed in a future release. Information for converting custom blocks to the new interface is in the Apama 5.0 migration guide.

Troubleshooting invalid scenarios

Event Modeler does the following to help you troubleshoot scenario validation issues:

- An error in a scenario file causes Software AG Designer to display an error icon in the **Project Explorer** panel on the scenario name, the **scenarios** folder, and the project folder.
- Software AG Designer's **Problems** tab displays an entry for each error in a scenario.
- Double clicking a scenario error in the **Problems** tab opens the scenario that contains the error, if it is not already open, and selects the component associated with the error you clicked.
- If a global rule is incomplete (unfinished), the title of the rule appears in bright red, a red-outlined box appears around the rule definition, and the name of each state that the rule applies to also appears in bright red.
- If a local rule is incomplete the title of the rule appears in bright red, a red-outlined box appears around the rule definition, and the name of the state the rule applies to also appears in bright red.
- If a block is missing Event Modeler displays an error icon on the **Block Wiring** tab name 

, removes the block from the wiring display, and displays an error in the **Problems** tab. This error identifies the missing block. Double clicking this error displays the **Block Wiring** panel that contained the missing block. The wiring display no longer shows the block that is missing and there is no error indicator in the wiring display for the missing block.

If there is a missing block whose feeds are used to set the values of scenario variables Event Modeler reverts the value of the scenario variable to its default value. No error indication appears.

Exporting scenarios as EPL

To export one or more scenarios as EPL

1. From the Software AG Designer menu, select **File > Export**.
2. Expand **Software AG**, select **Export as MonitorScript**, and click **Next**.
3. Select the project that contains the scenario(s) you want to export.
4. Select the scenario(s) to export and whether to export them in debug mode.
5. Identify the output directory for the generated EPL.
6. Click **Finish**.

Exporting scenarios as block templates

To export a scenario as a block template

1. From the Software AG Designer menu, select **File > Export**.
2. Expand **Software AG**, select **Export as Block**, and click **Next**.

3. Select the project that contains the scenario(s) you want to export.
4. Select the scenario(s) to export and whether to export.
5. Identify the output directory for the generated block template. By default, the generated block template is put in the **Generated scenario blocks** catalog in the **catalogs** directory of the project.
6. Click **Finish**.

Event Modeler command line options

After you define a scenario, you can use a command line to generate EPL for that scenario, or to generate a block from that scenario. This might be useful for custom scripting. The Event Modeler executable is in the `bin` directory of your Apama installation directory. In addition to generating EPL or a block, you can use the command line format to obtain information about Event Modeler. Information about all `event_modeler` command line options is in the table at the end of this topic.

Scenario to EPL

The command line format for generating EPL from a scenario is as follows:

```
event_modeler -Xgenerate sdf_file_path EPL_file_path
```

Element	Description
sdf_file_path	Path of the scenario definition file for the scenario that you want to save.
EPL_file_path	Name of the new monitor.

For example:

```
event_modeler -Xgenerate c:\dev\scenario1.sdf scenario1.mon
```

This example generates the `scenario1.mon` file from the `scenario1.sdf` scenario definition file.

Scenario to block

The command line format for generating a block from a scenario is as follows:

```
event_modeler -XgenerateBlock scenario block catalog
```

Element	Description
scenario	Path of the scenario definition file for the scenario that you want to save as a block.

Element	Description
block	Name of the new block.
catalog	Path of the blocks catalog in which to save the new block.

For example:

```
event_modeler -XgenerateBlock scenario1.sdf scenario1Block.bdf C:/Apama/blocks
```

This example generates the `scenario1Block.bdf` file from the `scenario1.sdf` file and stores the new block in `C:/Apama/blocks`.

All options

The format for executing `event_modeler` is as follows:

```
event_modeler [options] [scenarioFile1.sdf scenarioFile2.sdf ...]
```

Option	Description
`-h | --help`	Displays this information.
`-v | --version`	Displays Event Modeler version information
`-c` *file* `| --conf` *file*	Path to Event Modeler configuration file. The default is `event_modeler_config.xml`.
`-l` *file* `| --logfile` *file*	Identifies the name of the Event Modeler log file.
`-V` *level* `| --loglevel` *level*	Specifies the log level.
`-f` *file* `| --file` *file*	Loads the specified scenario definition file into Event Modeler. Repeat to load multiple scenario definition files.
`-XgenerateDebug [true|false]`	Generate debug output or not (default is true).
`-Xgenerate` *scenario EPL_file*	Generate EPL from the specified scenario definition file.

Option	Description
`-XgenerateBlock` *`scenario block catalog`*	Generate a block from the specified scenario definition file and save the new block in the specified catalog.
`-XforceBlockPaths` *`path`*`[,`*`path`*` ...]`	Force Event Modeler to use the specified comma-separated block catalog paths.
`-XaddBlockPaths` *`path`*`[,`*`path`*` ...]`	Add the comma-separated block catalog paths to Event Modeler.
`-XforceFunctionPaths` *`path`*`[,`*`path`*` ...]`	Force Event Modeler to use the specified comma-separated function catalog paths.
`-XaddFunctionPaths` *`path`*`[,`*`path`*` ...]`	Add the comma-separated function catalog paths to Event Modeler.

16 Using Standard Blocks

Blocks are ready packaged modules that you can import and use in your scenarios. They can accept inputs, execute some logic of their own, and generate output. In Event Modeler, in the **Catalogs** tab, you can view and select the blocks provided with Apama.

A block is defined in a Block Definition File, or `.bdf`. This XML file describes what the block does and its implementation in Apama EPL. A block can consist of:

- *Parameters* – a block can have a number of parameters, which when set configure its behavior. Parameters differ from input fields, in that the latter are like work packages for the block to process and are expected to change all the time, while the former are typically only set to initialize the block and whenever its core behavior needs to be modified. Parameters are typed in the same way as scenario variables. Parameters are all provided at initialization time and can then be updated individually.
- *Operations* – in addition to any standard behavior that is hard-wired into it, a block can also have a number of explicit operations that can be invoked by the scenario. For example, typical operations are to start processing some data and to stop. If an operation requires any configuration information this is usually passed in through a block parameter.
- *Input feeds* – an input feed can be hooked up to a live stream of event data, like a price quote stream. Within it, an input feed will define one or more input fields, which can be mapped to data in the stream. When event data arrives, the fields' values get updated. These fields are typed in the same way as scenario variables.
- *Output feeds* – an output feed is a stream of output data that can be generated by the block. Each output feed corresponds to an event that can be generated by the block, and embeds one or more output fields. The fields are updated as a result of operations carried out by the block. These fields are typed in the same way as scenario variables.

When you add a block to a scenario, you are specifying that each instance of that scenario should create an instance of that block running within the scenario. Whether the block instance then starts executing some activity immediately or waits for some operation on it to be called depends entirely on how the block itself is written.

There is no restriction on the number of block instances that you can add to a scenario. It is possible to add multiple instances of the same block to a scenario. To ensure there is no conflict, each instance has its own operations, parameters and fields clearly tagged by its unique name.

You can save a scenario as a block, and then use that scenario block in other scenarios. In this way, you can create composite scenarios. However, you cannot create a block from a scenario that can run in parallel. Also, you cannot create a block from a non-parallel scenario and then mark that block as parallel-aware. See "Working with Blocks Created from Scenarios" on page 615.

If there is no standard block that meets your needs you can use Apama's block editor in Software AG Designer to create a custom block. You can use the block editor to define the block's parameters, operations, input feeds and output feeds, or you can use the block editor to create the block from an event definition. See "Creating Blocks" on page 591.

Notes

Only the latest version of each standard block is documented here. Except where noted otherwise, one earlier version of each standard block is included in Apama. However, use of the latest version of a standard block is recommended for the following reasons:

- It implements the block as an event type, which is faster than the previous interface.
- It is parallel-aware. You can use it in a parallel scenario.
- Support for the earlier version will be removed in a future release.

Most standard blocks are automatically available to your scenario from the **Catalogs** tab. However, some standard blocks are available only if you add a particular bundle to your project. Where this is the case, the description of the standard block notes this.

A block's lifecycle

This section describes a block's lifecycle

1. You use Software AG Designer to define a block, which is saved as a *Block Definition File* (`.bdf`). This is an XML document, and it contains the interface of the block in XML elements as well as the EPL that defines the block's functionality.

   The EPL template for a block is the `<code>` section within the block's `.bdf` file. This contains the actual implementation of the block, embedding the custom behavior that identifies the block.

2. A scenario is defined within Event Modeler. This scenario is made to import one or more instances of the block. The scenario is saved to disk in a *Scenario Definition File* (`.sdf`) which is also an XML document. This document contains a reference to the location of any imported blocks' `.bdf` files. It does not embed the blocks themselves.

   During this stage, the contents of the `<code>` section in the `.bdf` are read in and all EPL names that are tagged with `#` characters are replaced with unique names that distinguish this particular block instance from any other that the scenario imports. The modified block EPL is then added to the scenario's EPL. Because certain elements of the EPL in the `<code>` section are renamed, this section of the code is often termed an EPL *template*.

3. The scenario and the referenced blocks are converted to an EPL file (`.mon`), either explicitly with **File > Export > Software AG > Export as MonitorScript** or implicitly when running the project from Software AG Designer.

4. The EPL containing the combined scenario and block code described in Step 3 is injected into, and parsed by the correlator. Note that if the EPL supplied in the `.bdf` file is invalid, the correlator will reject the scenario at this stage. However, if the EPL is valid but does not correctly implement the block's interface, it will still inject successfully. This situation cannot be detected until the scenario does not function as expected.

5. At this point the EPL for the scenario and its embedded block(s) is now in the correlator. This means that actual instances of the scenario can be created by end users. Assume that a dashboard has been created with Dashboard Builder to go with the scenario, and that end users can therefore interact with the scenario through the Dashboard Viewer. When a user logs into the scenario's application and creates an instance (sometimes referred to as a strategy), the correlator will create a specific working instance of the scenario and of its embedded block(s). Each instance is unique and distinct. Therefore, if the scenario embedded two blocks (or even two copies of the same block), and three instances of it are created from a dashboard, there will then be three instances of the scenario and six block instances.

Therefore, when you add a block to a scenario in Event Modeler, you are effectively specifying that real instances of that scenario should each create an instance of that block running within them. Whether the block instance then starts executing some activity immediately or else waits for some operation on it to be called depends entirely on how the block itself was written.

It is possible to add multiple instances of the same block to a scenario in Event Modeler. Since their operations, parameters and fields are clearly specified by their enclosing block instance's name when invoked from the scenario there is no conflict at runtime. There is no restriction on the number of block instances that can be added to a scenario.

General analytic blocks

This section discusses Event Modeler analytic blocks.

Change Notifier v2.0

The Change Notifier block sends out a notification when its input data stream changes by a given amount over a configurable, moving time window. When a sufficiently large positive or negative change has occurred, the output feed will indicate this by setting the `changed` field to true. The output feed can be configured to automatically reset to its unchanged state a certain time after triggering by setting the `reset period` parameter.

Parameters

Parameter	Description
`period`	The maximum age of any sample that is used in the calculations, in seconds. Any samples older than this will be discarded before performing the calculation. Must be greater than zero.
`amount`	The change amount value, zero to ignore. A notification will be sent if the difference between the oldest value inside the time window and the most recent sample is greater than this amount. Absolute values are used in the calculations.

Parameter	Description
`percentage`	The change percentage value, zero to ignore. Absolute values are used as for the `amount` parameter. 100.0 means to look for a doubling of the input values.
`reset period`	Following the detection of a big enough change, the output feed will be reset to its un-triggered state after this interval. It is specified in seconds, and is ignored if less than or equal to zero.

At least one of `amount` and `percentage` should be different from 0.0, otherwise no notifications will occur.

Operations

Operation	Description
`start`	Starts checking for changes in the input data feed.
`stop`	Stops checking for changes.
`clear`	Discards all stored values.
`reset`	Resets the `changed` notification flag.

Input feeds

Feed	Field	Description
`data`	`value`	Feed of input values.

Output feeds

Feed	Fields	Description
`notify`	`percentage change`	The amount of change measured as a percentage.
	`amount change`	The amount of change.
	`changed`	Set true to indicate a sufficiently large change has occurred. Is reset to false

Feed	Fields	Description
		by calling operation `reset`, or after the specified `reset period`.

Correlation Calculator v2.0

The Correlation Calculator block calculates the correlation coefficient between two streams of data. The calculation may be performed over an unlimited set of data from each stream, or a set limited by number of samples or age of samples. The calculator only generates an output if there is at least one suitable sample from each stream.

Correlation coefficient

A correlation coefficient approaching `+1.0` shows a strong correlation between the streams, a coefficient close to `0.0` shows little or no correlation between the streams and a coefficient approaching `-1.0` shows an inverse correlation between the streams; for example, if one is increasing, the other is decreasing.

Parameters

Parameter	Description
`period`	The maximum age of any sample that is used in the calculations, in seconds. Any samples older than this will be discarded before performing the calculation.
`size`	The maximum number of sample pairs that are used in the calculation. A pair consists of a sample from one stream, and the most recent sample from the other stream. The oldest sample is replaced by the newest sample when the total number of samples has reached this limit.

One or both of the above parameters must be `0`, in which case that limit is not imposed. It is not possible to restrict the number of samples by both age and number of samples, but it is possible to not impose any limit on the number of samples (thus an infinite set of samples is kept). Note that imposing a limit after input events have been received will clear all existing samples.

Operations

Operation	Description
`start`	Starts the calculation of coefficients. Must be called before the calculator will generate any statistics.

Operation	Description
`stop`	Stops the calculation of further coefficients. Any subsequent input feeds are ignored.
`clear`	Discards all current data.

Input feeds

Feed	Fields	Description
`data1`	`value`	The first input set.
`data2`	`value`	The second input set.

Note that at least one feed from both sets needs to have been received (and if set, within `period` seconds) before an output will be generated.

Output feeds

Feed	Fields	Description
`statistics`	`correlation`	The correlation coefficient (between `-1.0` and `+1.0`).
	`samples`	The number of sample pairs used for this calculation.

Data Distribution Calculator v2.0

The Data Distribution Calculator block calculates some common statistics from a set of samples. Like the correlation block, the set of samples may be unlimited in size, or constrained by a maximum number of samples or a maximum age of samples. Note that execution of the Median and Mode Calculator block, Moving Average block or Statistics Calculator block is faster than execution of the Data Distribution Calculator block. This is because those blocks perform a subset of the processing of the Data Distribution Calculator block.

Parameters

Parameter	Description
period	The maximum age of any sample that is used in the calculations, in seconds. Any samples older than this will be discarded before performing the calculation.
size	The maximum number of samples that are used in the calculation. The oldest sample is replaced by the newest sample when the total number of samples has reached this limit.

One or both of the above parameters must be 0, in which case that limit is not imposed. It is not possible to restrict the number of samples by both age and number of samples, but it is possible to not impose any limit on the number of samples (thus an infinite set of samples is kept).

Operations

Operation	Description
start	Starts the calculation of statistics. Must be called before the calculator will generate any statistics.
stop	Stops the calculation of further statistics. Any subsequent input feeds are ignored.
clear	Discards all current data.

Input feeds

Feed	Fields	Description
data	value	The feed of values. The time of a value is taken to be the correlator's current time.

Output feeds

Feed	Fields	Description
statistics	value	The most recent value received in the input feed.

Feed	Fields	Description
	`mean`	The arithmetic mean of the distribution.
	`mode`	The most commonly occurring value, if there is one.
	`no unique mode`	`true` if there is no single mode.
	`median`	The mid point of the ordered set of data values.
	`standard deviation`	Standard deviation of the data set.
	`variance`	Variance of the distribution.
	`skew`	Degree of skewed-ness of the distribution.
	`kurtosis`	Kurtosis measure of the distribution.
	`samples`	The number of samples used for this calculation.

Median and Mode Calculator v1.0

The Median and Mode Calculator block calculates the median and the mode from the input data stream over a configurable time window and sample set size. This block performs a subset of the processing performed by the Data Distribution Calculator block. Consequently, execution of this block is slightly faster than execution of the Data Distribution Calculator block. Like the Correlation Calculation block, the set of samples may be unlimited in size, or constrained by a maximum number of samples or a maximum age of samples.

Parameters

Parameter	Description
`period`	The maximum age of any sample that is used in the calculations, in seconds. Any samples older than this will be discarded before performing the calculation.
`size`	The maximum number of samples that are used in the calculation. The oldest sample is replaced by the newest

Parameter	Description
	sample when the total number of samples has reached this limit.

One or both of the above parameters must be 0, in which case that limit is not imposed. It is not possible to restrict the number of samples by both age and number of samples, but it is possible to not impose any limit on the number of samples (thus an infinite set of samples is kept).

Operations

Operation	Description
start	Starts the calculation of statistics. Must be called before the calculator will generate any statistics.
stop	Stops the calculation of further statistics. Any subsequent input feeds are ignored.
clear	Discards all current data.

Input feeds

Feed	Fields	Description
data	value	The feed of values. The time of a value is taken to be the correlator's current time.

Output feeds

Feed	Fields	Description
statistics	value	The most recent value received on the input feed
	mode	The most commonly occurring value, if there is one.
	no unique mode	true if there is no single mode.
	median	The mid point of the ordered set of data values.

Feed	Fields	Description
	`samples`	The number of samples used for this calculation.

Moving Average v1.0

The Moving Average block calculates the moving average from the input data stream over a configurable time window and sample set size. Like the Correlation Calculation block, the set of samples may be unlimited in size, or constrained by a maximum number of samples or a maximum age of samples. The Moving Average block performs a subset of the processing performed by the Data Distribution Calculator block. Consequently, execution of the Moving Average block is considerably faster than execution of the Data Distribution Calculator block.

Parameters

Parameter	Description
`period`	The maximum age of any sample that is used in the calculations, in seconds. Any samples older than this will be discarded before performing the calculation.
`size`	The maximum number of samples that are used in the calculation. The oldest sample is replaced by the newest sample when the total number of samples has reached this limit.

One or both of the above parameters must be `0`, in which case that limit is not imposed. It is not possible to restrict the number of samples by both age and number of samples, but it is possible to not impose any limit on the number of samples (thus an infinite set of samples is kept).

Operations

Operation	Description
`start`	Starts the calculation of statistics. Must be called before the calculator will generate any statistics.
`stop`	Stops the calculation of further statistics. Any subsequent input feeds are ignored.
`clear`	Discards all current data.

Input feeds

Feed	Fields	Description
`data`	`value`	The feed of values. The time of a value is taken to be the correlator's current time.

Output feeds

Feed	Fields	Description
`statistics`	`value`	The most recent value received on the input feed.
	`mean`	The arithmetic mean of the distribution.
	`samples`	The number of samples used for this calculation.

Spread Calculator v3.0

The Spread Calculator block calculates the difference between the latest data points of two streams. The output feed also provides the time of the event. This can either be supplied in the input feed or, if no mapping is provided for the input feed, the correlator's current time is used. Note that the first result will not be generated until both input feeds have received an event.

Parameters

There are no parameters for this block.

Operations

Operation	Description
`start`	Starts the calculation of differences. Must be called before any output events are sent.
`stop`	Stops the calculation of further coefficients. Any subsequent input feeds are ignored.
`clear`	Discards all current data.

Input feeds

Feed	Fields	Description
`data1`	`value`	The first feed of values.
	`time`	The timestamp of the data point. Leave unmapped (i.e. left as `0`) to set the time as the correlator's current time.
`data2`	`value`	The second feed of values.
	`time`	The timestamp of the data point. Leave unmapped (i.e. left as `0`) to set the time as the correlator's current time.

Output feeds

Feed	Fields	Description
`statistics`	`last1`	The most recent value sent to the `data1` feed.
	`time1`	The time of the most recent value sent to the `data1` feed.
	`last2`	The most recent value sent to the `data2` feed.
	`time2`	The time of the most recent value sent to the `data2` feed.
	`spread`	Difference between `last1` and `last2`. Will be negative if `last2` is greater than `last1`.

Statistics Calculator v1.0

The Statistics Calculator block calculates running statistics from a set of samples. Like the correlation block, the set of samples may be unlimited in size, or constrained by a maximum number of samples or a maximum age of samples. The Statistics Calculator block performs a subset of the processing performed by the Data Distribution Calculator block. Consequently, execution of the Statistics Calculator block is considerably faster than execution of the Data Distribution Calculator block.

Parameters

Parameter	Description
`period`	The maximum age of any sample that is used in the calculations, in seconds. Any samples older than this will be discarded before performing the calculation.
`size`	The maximum number of samples that are used in the calculation. The oldest sample is replaced by the newest sample when the total number of samples has reached this limit.

One or both of the above parameters must be `0`, in which case that limit is not imposed. It is not possible to restrict the number of samples by both age and number of samples, but it is possible to not impose any limit on the number of samples (thus an infinite set of samples is kept).

Operations

Operation	Description
`start`	Starts the calculation of statistics. Must be called before the calculator will generate any statistics.
`stop`	Stops the calculation of further statistics. Any subsequent input feeds are ignored.
`clear`	Discards all current data.

Input feeds

Feed	Fields	Description
`data`	`value`	The feed of values. The time of a value is taken to be the correlator's current time.

Output feeds

Feed	Fields	Description
`statistics`	`value`	The most recent value received on the input feed.

Feed	Fields	Description
	mean	The arithmetic mean of the data set.
	standard deviation	Standard deviation of the data set.
	variance	Variance of the data set.
	skew	Degree of skewed-ness of the data set.
	kurtosis	Kurtosis measure of the data set.
	samples	The number of samples used for this calculation.

Velocity Calculator v2.0

Velocity calculates the rate of change (that is, change divided by the time between the changes) of the last two values of a stream. The time of incoming events is taken to be the correlator's current time. Note that the first result will not be generated until two events have been received on the input feed.

Parameters

This block has no parameters.

Operations

Operation	Description
start	Starts the calculation of velocity. Must be called before any output events are sent.
stop	Stops the calculation of velocity. Any subsequent input feeds are ignored.
clear	Discards all current data.

Input feeds

Feed	Fields	Description
data	value	The feed of values.

Output feeds

Feed	Fields	Description
velocity	value	The difference of the last two values divided by the time between the last two values. Values are assumed to arrive at no less than 0.01 seconds apart. Thus, no two events are considered to have the same timestamp, which would mean the velocity could not be computed.

The Timer blocks

Apama provides two timer blocks.

Schedule v3.0

The Schedule block sends an output feed at a given time in the future. The time is specified by any combination of weekday, month, year, hour, minute and seconds. Any of the parameters may take a negative value, which means any value is allowed. Multiple timers may be started in a single block, each one having a different timer id. This timer id is supplied in the output feed when the timer fires, so may be used to determine what to do upon the timer firing.

Parameters

Parameter	Description
timer id	A string that distinguishes this timer from other timers in this block. An empty string is valid.
month	The month of the year (1-12) or negative for any month of the year.
day	The day of the month (1-31) or negative for any day of the month.
hour	The hour of the day (0-23) or negative for any hour of the day.
minute	The minutes past the hour (0-59) or negative for any minute.

Parameter	Description
`second`	The seconds past the minute (`0-59`) or negative for any second.

Operations

Operation	Description
`start`	Starts the specified timer ID.
`cancel`	Cancels the specified timer ID.
`retrieve`	Retrieve the details of the specified timer id by setting the output feed accordingly.

Input feeds

This block has no input feeds.

Output feeds

Feed	Fields	Description
`timer`	`timer id`	A string that distinguishes this timer from other timers in this block. An empty string is valid.
	`month`	The month (`1-12`).
	`day`	The day of month (`1-31`).
	`hour`	The hour (`0-23`).
	`minute`	The minute (`0-59`).
	`seconds`	The seconds (`0-59`).
	`time up`	`true` if time is up, `false` otherwise (i.e. on retrieval).
`book`	`num timers`	The number of currently active timers known to this block.

Examples

The following tables list the values for parameters that will trigger at the times described.

Example 1 - triggered once a month, on the first of every month, at 03:00:00:

Parameter	Value
`month`	`-1`
`day`	`1`
`hour`	`3`
`minute`	`0`
`seconds`	`0`

Example 2 - triggered every hour, at 15 minutes past the hour:

Parameter	Value
`month`	`-1`
`day`	`-1`
`hour`	`-1`
`minute`	`15`
`seconds`	`0`

Note that the time and date information is simply a copy of the parameters used when starting the timer. Any field whose corresponding parameter was given a negative value will have that same value.

Example 3 - triggered every second:

Parameter	Value
`month`	`-1`
`day`	`-1`

Parameter	Value
`hour`	`-1`
`minute`	`-1`
`seconds`	`-1`

Example 4 - triggered every day at noon:

Parameter	Value
`month`	`-1`
`day`	`-1`
`hour`	`12`
`minute`	`0`
`seconds`	`0`

Example 5 - triggered once a year, at exactly 16:31:28 on 31st May:

Parameter	Value
`month`	`5`
`day`	`31`
`hour`	`16`
`minute`	`31`
`seconds`	`28`

Wait v3.0

The Wait block sends an output feed at a given time in the future. The time is specified by a number of seconds to wait from the time the start operation is called. A timer may be set to repeat. Multiple timers may be started in a single block, each one having a different timer id. This timer id is supplied in the output feed when the timer fires, so may be used to determine what to do when that happens.

Parameters

Parameter	Description
`timer id`	A string to identify this timer from others in used in this block (an empty string is valid).
`time`	The number of seconds to wait.
`repeat`	`true` if the timer should repeat, `false` if a single-shot.

Operations

Operation	Description
`start`	Starts the specified timer ID.
`cancel`	Cancels the specified timer ID.
`retrieve`	Retrieve the details of the specified timer id by setting the output feed accordingly.
`reset`	Resets the output feed. Useful for repeating timers to set the output feed's time up field to false.

Input feeds

This block has no input feeds.

Output feeds

Feed	Fields	Description
`timer`	`timer id`	The id of the timer, as supplied by the `timer id` parameter.
	`time`	The time to wait in seconds.
	`repeat`	`true` if the timer repeats.
	`time up`	`true` if time is up, `false` otherwise (i.e. on retrieval).

Feed	Fields	Description
book	num timers	The total number of timers known to this block.

The Utility blocks

Apama provides a number of utility blocks.

Dictionary v2.0

As scenarios do not support a `dictionary` type, the Dictionary block addresses this potential requirement by providing an associative map of (string) keys and values. It provides facilities for adding, accessing, removing, as well as iterating across, elements within this map.

Parameters

Parameter	Description
key	Holds the key for a `add` / `get` operation.
value	Holds the value for a `add` / `get` operation.

Operations

Operation	Description
add	Adds the name-value pair stored in `key` and `value` to the dictionary. If the key already exists, the value will be overwritten with the new value.
get	Retrieves the value for the key stored in the `key` parameter and causes a result to be sent out on the output stream.
clear	Empties the dictionary.
remove	Removes the entry with the key stored in the `key` parameter from the dictionary - fails silently if key does not exist (removed key and value will be sent out on the result output feed).
next	For iterating through the dictionary - forces the next result to be output.

Operation	Description
`reset`	Resets the iterator to the first entry in the dictionary.

Input feeds

This block has no input feeds.

Output feeds

Feed	Field	Description
`result`	`key`	The key for the entry.
	`value`	The value of the entry.
	`found`	`true` if the key was found in the dictionary, `false` otherwise.
	`size`	Number of entries in the dictionary.

File Reader v2.0

The File Reader lets a scenario read a line at a time from a specified file using the File adapter with the `JMultiFileTransport` transport layer and the `JNullCodec` codec plug-in.

For details about using the File adapter, see "Using the Apama File Adapter" in the "Using Standard Adapters" part of *Connecting Apama Applications to External Components*.

The same File Reader block can read from multiple files.

Parameters

Parameter	Description
`Transport Name`	The name of the instance of the `JMultiFileTransport` to use. This must match a transport instance name specified in the IAF configuration file.
`File Name`	The name of the file to read.
`Lines In Header`	The number of lines to skip at the beginning of the file.

Parameter	Description
`File Channel`	The name of the channel to output file events to. The various file events are defined in the `FileEvents.mon` file, and the definitions are in the `com.apama.file` package. You can find `FileEvents.mon` in the `adapters/monitors` directory of your Apama installation directory.

Operations

Operation	Description
`Open File`	Opens a file according to the current values of the `Transport Name`, `File Name`, `Lines In Header` and `File Channel` parameters.
`Close File`	Closes a file according to the current values of the `Transport Name`, `File Name` and `File Channel` parameters.
`Read Line`	Reads a line from the file. Uses the current values of the `Transport Name`, `File Name` and `File Channel` parameters.
`Get File Status`	Explicit call to update the `Status` output feed. Uses the current values of the `Transport Name`, `File Name` and `File Channel` parameters.

Input feeds

This block has no input feeds.

Output feeds

Feed	Field	Description
`line`	`file name`	The name of the file associated with the current line.
	`file transport`	The name of the transport associated with the current line.
	`line`	String that contains the current read line.

Feed	Field	Description
`error`	`file name`	The name of the file that returned the error.
	`file transport`	The name of the transport that returned the error.
	`message`	The error message returned.
`status`	`file name`	The name of the file associated with the status update.
	`file transport`	The name of the transport associated with the status update.
	`more available`	A flag that indicates whether there are currently more lines to read from the file.
	`file currently open`	A flag that indicates whether or not the file is currently open.

File Writer v2.0

The File Writer block lets a scenario write a line at a time to a specified file using the File adapter with the `JMultiFileTransport` transport plug-in and the `JNullCodec` codec plug-in. A single File Writer block can write to multiple files.

Parameters

Parameter	Description
`Transport Name`	The name of the instance of the `JMultiFileTransport` to use. This must match an instance name specified in the IAF configuration file.
`File Name`	The name of the file to write.
`Append`	A flag indicating whether to append to the end of a file, or whether to replace the contents of the existing file.
`Line`	The line to be written to the file identified by the `File Name` parameter.

Parameter	Description
`File Channel`	The name of the channel to output file events to. The various file events are defined in the `FileEvents.mon` file and they are defined in the `com.apama.file` package. You can find the `FileEvents.mon` file in the `adapters/monitors` directory of your Apama installation directory.

Operations

Operation	Description
`Open File`	Opens a file according to the current values of the `Transport Name`, `File Name`, `Append` and `File Channel` parameters.
`Close File`	Closes a file according to the current values of the `Transport Name`, `File Name` and `File Channel` parameters.
`Write Line`	Writes a line to the file identified by the current values of the `Transport Name`, `File Name`, `Line` and `File Channel` parameters.
`Get File Status`	Explicit call to update the `Status` output feed. Uses the current values of the `Transport Name`, `File Name` and `File Channel` parameters.

Input feeds

This block has no input feeds

Output feeds

Feed	Field	Description
`error`	`file name`	The name of the file that returned the error.
	`file transport`	The name of the transport that returned the error.
	`message`	The error message returned.

Feed	Field	Description
status	file name	The name of the file associated with the status update.
	file transport	The name of the transport associated with the status update.
	file currently open	A flag that indicates whether the file is currently open.

History Logger v2.0

The History Logger block maintains an ordered and (optionally) time-stamped history of text messages. This is normally used in conjunction with multi-line entries in dashboards, such as history lists, where a fixed size list is used to contain a rolling window of constantly changing information.

Parameters

Parameter	Description
entry	An entry to be added to the history.
timestamps	Index for an add, clear or retrieve operation.
most recent first	Set to true to order the history so that the most recent element is first, false for least recent first.
max size	Maximum number of entries to retain - set to 0 to retain all entries.
delimiter	String to separate history entries when output by the block. If not specified, the default is "\n" (linefeed).
time format	String format to display time-stamps, if required. A default format is used if this is not set.

Operations

Operation	Description
add	Adds the content of entry to the history - an output update will automatically be produced.
clear	Clears the history.
retrieve	Causes the latest history to be output from the block as a single, delimiter-separated string.

Input feeds

This block has no input feeds.

Output feeds

Feed	Field	Description
history	size	Number of entries in the history.
	text	Text representation of the history, where each entry is optionally time-stamped and separated by the delimiter string.

Input Merger v2.0

The Input Merger block collects a number of related field values and outputs them simultaneously.

Description

The input event is a field name/value pair. If the name in a pair matches one of the names in the `order` parameter, the corresponding value is stored for output. When all of the names in `order` have been matched at least once, the set of stored values is output. Note that multiple matches (and stores) can occur for any name. In this case, the latest store overwrites the value of the previous store, ensuring that each field has the latest value.

If the `incremental update` parameter is set, then further outputs are generated on any input that matches a field in the `order` parameter. If the `incremental update` parameter is not set, then further outputs are only sent once all fields have been received again (that is, the old input values are discarded). The `id` field increments with each output event, in either mode.

Parameters

Parameter	Description
`order`	A comma-separated list of up to 8 field names to match against names on the input stream. The order in which the names are listed is the order in which they appear on the output. Note that fields may not contain commas, but they may be repeated or be an empty string.
`incremental input`	If `true`, a change to a single field listed in the `order` parameter results in an output being generated once all input fields have been received at least once, that is, the first output is still generated only when all fields have been received.

Operations

Operation	Description
`start`	Activate merger.
`stop`	Deactivate merger.

Input feeds

Feed	Field	Description
`in`	`name`	Field name
	`value`	Field value

Output feeds

The `out` feed specifies the selected individual values from the input feed, in the order they are listed by the `order` parameter.

Feed	Field	Description
`out`	`id`	Increments each time an output event occurs, even if none of the other fields has changed from the previous output event.

Feed	Field	Description
	1	Field 1
	2	Field 2
	3	Field 3
	4	Field 4
	5	Field 5
	6	Field 6
	7	Field 7
	8	Field 8

List v2.0

As scenarios do not support a sequence type, the List block addresses this potential requirement by providing a dynamically-sized sequence of string items. It provides facilities for adding, inserting, accessing, removing, as well as iterating across, elements within this sequence.

Parameters

Parameter	Description
`item`	Holds an item for an `add` or `nextIndex` operation.
`index`	Index for an `add`, `get` or `remove` operation.

Operations

Operation	Description
`add`	Adds the value currently held in `item` to the end of the list.
`insert`	Adds the value held in `item` to the list at the position held in `index`.

Operation	Description
`get`	Retrieves the item stored at the position held in `index`.
`clear`	Empties the list.
`remove`	Removes the item at the position stored in the `index` parameter.
`next`	For iterating through the list - forces the next result to be output.
`reset`	Resets the iterator to the first entry in the list.
`nextIndex`	For iterating through the list - move the iteration position to the next instance of item stored in the item parameter and outputs the results.

Input feeds

This block has no input feeds.

Output feeds

Feed	Field	Description
`result`	`item`	Holds the item for a retrieval operation.
	`index`	Holds the index of a retrieved item.
	`found`	`true` if an item was found in the list, `false` otherwise.
	`size`	Number of entries in the list.

Scenario Terminator v2.0

The Scenario Terminator block is unusual in that it does not directly interact with the scenario through any feeds, parameters or operations. The Scenario Terminator block simply listens for special events that can be sent to the correlator, and terminates the scenario if requested to.

Description

The Scenario Terminator block depends on the `ScenarioDeleterSupport.mon` file, which is supplied in the `monitors` folder. This EPL file must be injected before a scenario containing the Scenario Terminator block can be injected.

Unlike other blocks, there is no value in including the block more than once, though doing so is not an error.

This block has no parameters, no operations, no input feeds, and no output feeds.

The Scenario Terminator block listens for the following events:

```
com.apama.scenarios.DeleteAllScenarios()
com.apama.scenarios.DeleteScenariosByUser(string owner)
```

The first deletes all scenarios with a Scenario Terminator block. The second deletes all scenarios for the given dashboard username that have a Scenario Terminator block. For example, to delete all scenarios for the user `roguetrader`, do the following:

```
com.apama.scenarios.DeleteScenariosByUser("roguetrader")
```

Status v2.0

The Status block obtains the status of an object managed by a service monitor. For example, you can use the Status block to obtain the status of a market, a connection, or some other component. The objects for which you can obtain status and the meaning of various parameters depend on the service monitor providing the status.

Usage notes

You use the Status block with the `com.apama.statusreport.*` events, which are defined in `StatusSupport.mon` in the `monitors` directory of your Apama installation directory. There are four `com.apama.statusreport` event types:

- `SubscribeStatus` events — the Status block sends a `SubscribeStatus` event to a service monitor to initiate receipt of status events from that service. A `SubscribeStatus` event identifies the ID of the service you want to receive status from, the object you want status for, the sub-service ID, if there is one, to receive status from, and the connection to use if there is a choice.

  In a `SubscribeStatus` event, when the service ID is an empty string, the Status block is initiating a status subscription with each service monitor that is listening for `SubscribeStatus` events that have an empty string for the service ID. In this case, you should expect to receive status events from more than one service.

- `UnsubscribeStatus` — the Status block sends an `UnsubscribeStatus` event to a service monitor to terminate receiving status from that service. An `UnsubscribeStatus` event identifies the same information as a `SubscribeStatus` event.

- `Status` — a subscribed service sends a `Status` event to the Status block to provide the status information. A service sends a `Status` event as the result of a new subscription and whenever there is a change in status. In addition to identifying the service that the information is from and the object that the information is for, the `Status` event contains a string that contains a status description, a sequence that contains one or more key words, a Boolean indication of whether the object is in a state in which it can be used, and a dictionary that contains any other information that the service can provide.

- `StatusError` — a subscribed service sends a `StatusError` event to the Status block when it cannot provide status information. In addition to identifying the service that the event is from and the object that the event pertains to, the `StatusError` event contains a free-form string that describes the problem, and a Boolean indication of whether the status subscription was terminated.

The Status block uses these events to interface with any service monitor that supports the `com.apama.statusreport` interface. In other words, these events form the message exchange protocol (MEP) between the Status block in your Apama application and service monitors. For example, a service monitor might be the part of your adapter that makes the features of the adapter available to your Apama application.

Parameters

Parameter	Description
`serviceID`	String that identifies the service monitor that you want to subscribe to for status information. Leave blank (empty string) to subscribe to all service monitors that are currently listening for `com.apama.statusreport.SubscribeStatus` messages.
`object`	String that identifies the object that you want status for. The service monitor defines the values that you can specify here. For example, a service monitor might provide status for `Connection` or `Market`.
`subServiceID`	For service monitors that provide sub-services, this string identifies the sub-service that you want to subscribe to for status information. If the service monitor has no sub-services, leave this parameter blank.
`connection`	For service monitors that provide status for several instances of the specified object, this string identifies the instance for which you want to obtain status information. If the service monitor provides status for only one instance, leave this parameter blank. For example, an adapter might connect to multiple sources of data. You would use this parameter to specify the data connection you are interested in. The service monitor must define the allowable values for the `connection` parameter.

Parameter	Description

`extract key 1`
`extract key 2`
`extract key 3`
	These three parameters make it convenient to obtain particular values from the `extracted parameter`*n* output fields in the Status block output feed.
	
	Each parameter is a string that specifies a key whose value you want to obtain in the status received from the service monitor. For example, when you set the `extract key 1` parameter to the value of a key defined in the service monitor, the `Status` output feed contains the specified key's value in its `extracted parameter 1` field.
	
	These fields make it easier to access particular elements in the extra parameters field of the output feed. You do not need to parse the payload string in the extra parameters field yourself.

Operations

Operation	Description
`start`	Initiates subscription to the service monitor identified by the `serviceID` parameter, for information about the component identified by the `object` parameter. If the specified service monitor has sub-services or provides information about more than one object instance, the subscription is for the sub-service and connection identified by the values that the `subServiceID` and `connection` Status block parameters have when the `start` operation is called. If the value of the `serviceID` parameter is an empty string, the `start` operation initiates a subscription to each service monitor that is listening for `SubscribeStatus` events that have an empty string in their `serviceID` field. Under the covers, the Status block routes a `SubscribeStatus` event to the correlator. This event takes its values from the current values of the Status block parameters. After a service monitor receives a `SubscribeStatus` event, it starts sending `Status` events to the subscribing scenario.
`stop`	Terminates the subscription to the service monitor identified by the `serviceID` parameter. If the value of the `serviceID` parameter is an empty string, the `stop` operation terminates the subscription to each service monitor that is listening for

Operation	Description
	UnsubscribeStatus events that have an empty string in their serviceID field. Under the covers, the Status block routes an UnsubscribeStatus event to the correlator. This event takes its values from the current values of the Status block parameters. If a scenario terminates without invoking the stop operation for a subscription, the block routes the appropriate UnsubscribeStatus events upon termination of the scenario.

Input feeds

This block has no input feeds.

Output feeds

Feed	Field	Description
Status	serviceID	String that identifies the service monitor that is providing the status.
	object	String that identifies the object that the status is for.
	subServiceID	String that identifies the sub-service that is providing the status. This is blank if the service has no sub-services.
	connection	String that identifies the object instance that status is being provided for.
	description	String that contains human-readable text that describes the status.
	summaries	One word or a series of space-separated words that describe the status. For example, Connected, Disconnected, LoginFailed. The service monitor defines and documents the words that can appear in the summaries field. While the description field is for a human reader, the summaries field contains key words that a scenario can act on. For example, suppose summaries contains Disconnected. The scenario

Feed	Field	Description
		can define a rule that specifies what to do when this service is disconnected.
	available	Boolean value that indicates whether the object is in a state where it can be used. For example, if you specify Market as the object, a value of true in the available field might mean that the market is open and accepting orders.
	extra parameters	Payload-format string that contains any other information that the service monitor provides for the object.
	extracted parameter 1 extracted parameter 2 extracted parameter 3	Each of these parameters is a string that contains the value of one of the key/value pairs that is in the extra parameters output field. The particular key value that the field contains is determined by the value that the corresponding extract key *n* block parameter had when the block's start operation was invoked. For example, suppose that the extract key 1 parameter has a value of time. The block then invokes the start operation to subscribe to a particular service monitor. When the block receives status information from that monitor, the block inserts the value of time, for example, "12:34:56" into the extracted parameter 1 field and then sends the information to its Status output feed.
	received status	Boolean value that indicates whether a Status event has been received from the specified service monitor. Initially, this field is false. When the block receives a Status event, it sets this field to true. When the block unsubscribes from the specified service monitor or when the block receives a StatusError event, the block sets the received status field to false. A value of true means that the information in the Status output feed is from the latest Status event and no error has since been signaled by the

Feed	Field	Description
		service monitor. In other words, you can trust the information in the `Status` output feed.
	`fault`	Boolean value that indicates whether there was an error obtaining status information for the specified object. When the service monitor sends a `StatusError` event, the block sets this field to true. You should consider any information from this service monitor to be stale.
	`total`	Integer that indicates the number of objects for which all of the following are true: ■ The block is receiving status information for the object. ■ The block has not received a `StatusError` event from the service monitor since the block received the previous `Status` event. ■ The object is in a state in which it can be used. That is, the value of the `available` output field is `true`. This field makes it convenient to track when a subscription is no longer providing status information. For example, if a Status block has 4 subscriptions but `total` = `3`, then the scenario can take some action such as restoring the subscription, or not using stale data.

Variable Mapper v2.0

The Variable Mapper block lets you use a scenario variable as a data source for any other block. The Variable Mapper block takes the name of a scenario variable as the value of its only input parameter. When the value of the mapped variable changes, the Variable Mapper block sends the new value to its output feed. The output feed includes two values. The first value is the new value as a number. The second value is the new value as text. You can choose which representation you need to wire into another block.

Parameters

Parameter	Description
`variable`	Name of the scenario variable whose value you want to output.

Operations

None.

Input feeds

This block has no input feeds.

Output feeds

Feed	Field	Description
`variable updates`	`number`	New value of the scenario variable as a number type.
	`text`	New value of the scenario variable as a text type.

Database functionality—storage and retrieval

The Database blocks let you store rows in a database and send queries to the database to retrieve a set of rows. They take parameters that let you specify a `database` name, a `table` name, a `user name` and `password`, and a `service identifier`. Note that any password given in the scenario or through the dashboard will be visible on screen.

The ADBC Storage block takes a list of `fields` and a list of `values` as parameters. The block places the values into their corresponding entry into the list of fields. Alternatively, the storage block takes a storage query or statement.

The ADBC Retrieval block takes a query string as a parameter. If you specify a query template, there is a parameter for specifying the query template parameters.

The format for a complete query string is service specific, typically SQL or an SQL-like language. When you specify a complete query, the block ignores the parameters that list `fields`, `values`, or a `where` clause.

The retrieval block return a number of outputs, one for each field/value pair for each row that matched the query. The scenario needs to call the `next` operation to retrieve the next field/value pair. The row number indicates when a field/value pair belongs to a different row. The row number counts from 1 upwards.

ADBC Storage v1.0

The ADBC (Apama Database Connector) Storage block uses the ADBC adapter to store data in a database. To make this block available to your scenario, add the ADBC for JDBC or ADBC for ODBC bundle to your project. Adding one of these bundles to your project automatically adds the ADBC Common bundle, which contains the ADBC blocks.

Description

The ADBC adapter is a standard adapter provided with Apama. It provides general database storage and retrieval (query) and also event capture and playback. The ADBC adapter supports both standard SQL and specialized databases. In particular, the adapter supports ODBC and JDBC. This support provides access to most commercial and open source SQL databases. ADBC provides a superset of the functionality that was available in the ODBC and JDBC Apama standard adapters.

The Storage block can also be used to perform standard SQL operations such as Delete, Update, and Rollback. To carry out an SQL operation, the value of the `statement` parameter (described below) should be set to the operation you want to carry out.

Parameters

Parameter	Description
`service identifier`	The name of the service to use.
`database`	The data source name of the database to connect to.
`user name`	The username to use when connecting to the database.
`password`	The password to use when connecting to the database (will be readable on screen).
`table`	The name of the table to store data in.
`fields`	A comma-separated list of field names.
`values`	A comma-separated list of values that will be placed in the fields list.
`statement`	If this is not empty, the correlator uses this as the storage command instead of using the `fields` and `values` parameters. This parameter can be set to an SQL operation such as `UPDATE`, `DELETE`, or `ROLLBACK`.
`autocommit`	The auto commit mode to use. The default is an empty string. Specify one of the following: ■ `OFF` indicates no auto commit mode. ■ `ADBC` indicates the ADBC adapter auto commit mode based on a time period.

Parameter	Description
	■ DATA_SOURCE indicates a data source specific auto commit mode. This might not be available for all data sources.
acknowledge store	Boolean that indicates whether the data source returns an acknowledgment to indicate success or failure for each store performed. True indicates that the data source always sends an acknowledgment. False indicates that the data source returns only store errors. The default is true. The success acknowledgment along with the current auto commit setting determine whether the data has been stored. A commit operation might also be needed.
unique connection	Boolean that indicates whether or not to create a new database connection. True indicates that you want the block to always create a new connection. False indicates that the block can use an existing connection. The default is false.
final store	If true indicates this will be the last store operation performed. Default value is false.If true the output feed field committed.final store complete will be set to true after the store operation completes (success or failure).

Operations

Operation	Description
connect	Establish a connection to the database.
store	Store in the database the data held in the block's parameters.
commit	Commit any data sent to the database.
rollback	Rollback uncommitted changes to the database.
reset	Resets the output feed.
disconnect	Close the database connection.

Input feeds

This block has no input feeds.

Output feeds

Feed	Fields	Description
result	success	true if the last update to the database was successful.
	message	A message from the last database update operation.
	connected	true if connected to the database.
committed	status	true if the last commit operation succeeds, else false.
	final store complete	true when the store operation with the final store parameter set to true has completed.
rollback	status	true if the last rollback operation succeeded; otherwise false.

ADBC Retrieval v1.0

The ADBC (Apama Database Connector) Retrieval block uses the ADBC adapter to retrieve data from a database. The ADBC adapter is a standard adapter provided with Apama. To make this block available to your scenario, add the ADBC for JDBC or ADBC for ODBC bundle to your project. Adding one of these bundles to your project automatically adds the ADBC Common bundle, which contains the ADBC blocks.

Description

The ADBC adapter is a standard adapter provided with Apama. It provides general database storage and retrieval (query) and also event capture and playback. The ADBC adapter supports both standard SQL and specialized databases. In particular, the adapter supports ODBC and JDBC. This support provides access to most commercial and open source SQL databases. ADBC provides a superset of the functionality that was available in the ODBC and JDBC Apama standard adapters.

The ADBC Retrieval block supports prepared queries, stored procedures, and query templates.

Parameters

Parameter	Description
`service identifier`	The name of the service to use, or blank for any service.
`database`	The data source name of the database to connect to.
`user name`	The username to use when connecting to the database.
`password`	The password to use when connecting to the database (will be readable on screen).
`table name`	The name of the table to retrieve data from.
`query string`	The data source specific query statement to be used. If you specify a query template name, be sure to set the `query parameters` parameter as needed for the template.
`query parameters`	If you specify a query template in the `query string` parameter, specify the parameters for the query template here. This is a comma separated list of `name:value` pairs, for example, `TABLE_NAME:Trade`, `SORT_ORDER:asc`.
`input types`	The input types of the parameters in the query template that is specified in the query. These are listed in a comma separated list of types, such as `Double, Double, Float`.
`output types`	The output types of the parameters in the query template that is specified in the query. These are listed in a comma separated list of types, such as `Double, Double, Float`.
`prepared query named id`	A `String` that uniquely identifies this prepared query.
`prepared query params`	The parameters to a prepared query in the form of a comma separated list of values.

Parameter	Description
`batch size`	Number of rows to be buffered in the block. The default is 50. The maximum is 10,000.
`disable buffering`	Boolean that indicates whether the results are streamed automatically as they are received. True indicates that they are. When set, the next `rewind` and `reset` operations have no effect since they are not needed. For use when wiring the ADBC Retrieval block's output to another block. The default is false.
`unique connection`	Boolean that indicates whether or not to create a new database connection. True indicates that you want the block to always create a new connection. False indicates that the block can use an existing connection. The default is false.

Operations

Operation	Description
`connect`	Establish a connection to the database.
`query`	Perform the query operation.
`reset`	Reset the output feed.
`next`	Look up the next field/value pair.
`rewind`	Rewind to the first result in the current buffered batch, without performing the operation again.
`stop`	Stop the query, even if not complete.
`disconnect`	Close the database connection.
`create prepared query`	Create a prepared query for use later, passing in the correct input types.
`run prepared query`	Run a previously created prepared query, passing in the relevant input parameters.
`delete prepared query`	Delete an existing prepared query.

Operation	Description
`retrieve query templates`	Retrieve a full list of named queries available, including the query template name, parameters and description.

Input feeds

This block has no input feeds.

Output feeds

Feed	Fields	Description
`schema`	`names`	The field names of the results.
	`types`	The Apama types of the fields.
	`indexable`	The names of the fields that are indexes.
`results`	`number`	The row number of the field/value pair. A number of `-1` indicates the end of data.
	`field`	The name of the field the value was taken from.
	`value`	The value of the field.
`error`	`message`	A message that describes the error if the store operation was unsuccessful.
`status`	`no more`	`true` if the current query has been completed and no more field/value pairs are available after the current pair.
	`more available`	`true` if there is more data available to be read within

Feed	Fields	Description
		the current batch and `false` otherwise.
	`connected`	`true` if connected to the database.
`prepared query`	`created`	`True` if the query is successfully created; false otherwise.
	`deleted`	`True` if the query is successfully deleted; false otherwise.
`query templates`	`retrieved`	`false` until the last query template is retrieved, at which point becomes `true`.
	`query name`	The identifying query name.
	`query parameters`	The list of parameters that the query requires.
	`query description`	A brief description of the purpose of the query.

Note that it is possible for `no more` to be false and `more available` to be false; this means that the service is waiting for more results to become available, but they have not been supplied by the database yet. The scenario should wait until `more available` becomes true before calling `next`. As with the order manager iteration, the scenario will need to re-enter the state it is in while iterating, in order to re-evaluate all of the rules in that state.

Prepared queries

To create prepared queries

1. The query string parameter should be set with the prepared query string, such as `SELECT * FROM tablename WHERE intfield < ?`.
2. The input types of the input parameters in the prepared query being created. This is a comma-separated list of types, for example `Double, Double, Float`, etc.
3. The output types of the parameters in the prepared query being created should be set to a comma-separated list of types, for example `Double, Double, Float` if calling on a stored procedure.

4. In the block's `prepared query named id` parameter specify a unique identifier in the form of a user readable name (`string`) for this prepared query. Multiple prepared queries can exist in the block at any one time, so the identifier allows you to specify which query you want to use.
5. Call the `create prepared query` operation.

   In the `prepared query` output feed, the `created` field will contain `true` if the query was successfully created.

To use prepared queries

1. In the block's `prepared query named id` specify the identifier of the prepared query you want to execute.
2. In the `prepared query params` parameter, list the values which should match, in types and number, those of the input types.
3. Call the `run prepared query` operation.
4. From this point on, the `no more` and `more available` fields and the `next` and `stop` operations behave in the same manner as they do for normal queries.

To delete prepared queries

1. To delete a prepared query, set the `prepared query named id` parameter to the identifier of the prepared query you want to delete.
2. Call the `delete prepared query` operation.

   In the `prepared query` output feed, the `deleted` field will contain `true` if the query was successfully deleted.

Stored procedures

Stored procedures must be created and deleted externally to the retrieval block, as in the case when creating a table in the database.

1. Once the stored procedure exists in the database you can create a prepared query, as described above. The syntax for using a stored procedure in a query string is in the form `{call demo_stored-procedure(?,?)}`.
2. Specify the `input types` and `output types` parameters. Use `NULL` in the list of types for padding purposes. For example, given a `Double` (input only), `Double` (both input and output), and `Float` (output only), for the `input types` parameter specify `Double, Double, NULL` and for the `output types` parameter specify `NULL, Double, Float`.
3. Set an identifier in the `prepared query named id` parameter with this prepared query for future use.
4. Call the `create prepared query` operation.

   In the `prepared query` output feed, the `created` field will contain `true` if the query was successfully created.

5. Using the prepared query associated with the stored procedure is the same as described above.

Query templates

You can retrieve the list of query templates that are associated with the project, by calling the `retrieve query templates` operation. In the `query templates` output feed, the `query name`, `query paramters`, and `query description` fields show each query template's name, parameters, and description, respectively. The `retrieved` field is `true` when all query templates have been retrieved.

To run query templates

1. Set the block's `query string` parameter to the name of the query template you want to run, such as `findEarliest`.
2. In the block's `query parameters` parameter specify the query parameters required by the query template, for example, `TABLE_NAME:tableName,TIME_COLUMN_NAME:timefield`.
3. Call the `query` operation to execute the query template, in the same way as for normal queries.

Blocks for working with scenario blocks

Apama provides blocks for working with scenario blocks.

Change Observer v2.0

The Change Observer block watches sub-scenarios for changes in the value of one of the sub-scenario variables. You specify which variable you want to watch. When the value changes, the Change Observer block sends data to its `change` output feed. The output feed indicates the old value and the new value.

Description

To use the Change Observer block, wire output fields from the scenario block to input fields of the Change Observer block. Typically, you want to map the scenario block `instance id` output field to the Change Observer `stream` input field. Then map one of the sub-scenario variables from the scenario block `output` feed to the Change Observer `watchValue` input field. When the Change Observer block detects a change in a variable value, it sends notification of this change to its output feed.

Typically, you use the sub-scenario instance ID as the key. The key's associated value is the variable whose value you want to watch.

You can specify a filter so that you obtain results from a particular set of sub-scenarios.

You can also remove keys and their associated values from the Change Observer block's internal data store. This lets you exclude certain data from calculations. One way to do this is to define a global rule that watches for sub-scenarios to terminate. When a sub-scenario terminates, you can specify its instance ID as the key and remove the data for that key from the Change Observer block's store of data.

For a detailed example of using the Change Observer block, see "Observing changes in sub-scenarios" on page 634.

Parameters

Parameter	Description
`filter`	String that indicates that you want to observe those key/value pairs for which the `input filter` field matches this field. An empty string as the value of either the `filter` parameter or the `input filter` field indicates that there is no filtering. If the value of the `filter is "not equal to"` parameter is true, and you specify a value for the `filter` parameter, the Change Observer block observes key/value pairs for which the `input filter` field does NOT match the value of the `filter` parameter.
`keyToDelete`	String that indicates a key for which you want to delete data from the Change Observer block's internal store of data. Invoke the `deleteKey` operation to delete the data associated with this key.
`filter is "not equal to"`	Boolean that indicates whether you want to match or not match the value of the `filter` parameter. When the `filter is "not equal to"` parameter is true, the Change Observer block observes key/value pairs for which the `input filter` field does NOT match the value of the `filter` parameter.

Operations

Operation	Description
`reset`	The Change Observer block stores data about the number of unique keys it has observed and their most recent associated values. This operation flushes that data; it is no longer accessible to the Change Observer block.
`deleteKey`	Deletes the key defined by the `keyToDelete` parameter. This operation deletes data from the Change Observer block's internal store of data. If the value of the `keyToDelete` parameter is an empty string, this operation does nothing.

Input feed

The Change Observer `input` input feed provides the key, the value, and possibly a filter.

Feed	Fields	Description
`input`	`stream`	String that contains the key for which you want the Change Observer block to observe changes. Typically, the key is the instance ID of a sub-scenario. The Change Observer block ignores blank keys, that is, a key that is an empty string.
	`watchValue`	String that contains the field you want to watch. Typically, this is the value of a sub-scenario variable.
	`filter`	String that contains a filter for determining the key/value pairs you are interested in.

Output feed

The Change Observer `change` output feed indicates the key, its old value, and its new value.

Feed	Fields	Description
`change`	`stream`	String that contains the key that this change is for. Typically, this is the instance ID of a sub-scenario.
	`oldValue`	String that contains the value of the variable being observed just before the value changed.
	`newValue`	String that contains the new value of the variable being observed.

Filtered Summary v2.0

The Filtered Summary block performs simple calculations across a set of sub-scenarios. This is an alternative to iterating over a set of sub-scenarios. The Filtered Summary block can operate on only floating point values.

Description

In more general terms, the Filtered Summary block performs calculations on a keyed set of floating point values. Typically, you use the sub-scenario instance ID as the key. The key's associated value is the value of a sub-scenario floating point variable that you want to use in an aggregate calculation.

You can specify filters to perform calculations on a sub-group of sub-scenarios. You can also remove keys and their associated values from the Filtered Summary block's internal datastore. This lets you exclude data from certain sub-scenarios from the calculations. One way to do this is to define a global rule that watches for sub-scenarios to terminate. When a sub-scenario terminates, you can specify its instance ID as the key and remove the data for that key from the Filtered Summary block's store of data.

To use the Filtered Summary block, wire output fields from the scenario block to input fields of the Filtered Summary block. Typically, you want to map the scenario block `instance id` output field to the Filtered Summary `key` input field. Then map a floating point sub-scenario variable from the scenario block `output` feed to the Filtered Summary `value` input field.

Parameters

Parameter	Description
`filter`	String that indicates that you want to perform calculations on only those key/value pairs for which the `input filter` field matches this field. An empty string as the value of either the `filter` parameter or the `input filter` field indicates that there is no filtering. If the value of the `filter is "not equal to"` parameter is true, and you specify a value for the `filter` parameter, the Filtered Summary block operates on key/value pairs for which the `input filter` field does NOT match the value of the `filter` parameter.
`keyToDelete`	String that indicates a key for which you want to delete data from the Filtered Summary block's internal store of data. Invoke the `deleteKey` operation to delete the data associated with this key.
`filter is "not equal to"`	Boolean that indicates whether you want to match or not match the value of the `filter` parameter. When the `filter is "not equal to"` parameter is true, the Filtered Summary block operates on key/value pairs for which the `input filter` field does NOT match the value of the `filter` parameter.

Operations

Operation	Description
reset	The Filtered Summary block stores data about the number of unique keys it has observed and their most recent associated values. This operation flushes that data; it is no longer accessible to the Filtered Summary block.
deleteKey	Deletes the key defined by the keyToDelete parameter. This operation deletes data from the Filtered Summary block's internal store of data. If the value of the keyToDelete parameter is an empty string, this operation does nothing.

Input feed

The input input feed provides the key, the value, and possibly a filter.

Feed	Fields	Description
input	key	String that contains the key under which you want the Filtered Summary block to store data in its internal datastore. Typically, the key is the instance ID of a sub-scenario. The Filtered Summary block ignores blank keys, that is, a key that is an empty string
	value	A float value that you want to operate on. Typically, this is the value of a sub-scenario variable.
	filter	String that contains a filter for determining the key/value pairs you are interested in.

Output feed

The data output feed indicates the number of keys for which data is stored, the sum of the stored values, and the average of the stored values.

Feed	Fields	Description
data	numberOfKeys	Integer that specifies the number of unique keys for which the Filtered Summary block currently stores data.

Feed	Fields	Description
	`totalValue`	Floating point value that is the sum of the values that the Filtered Summary block currently stores.
	`averageValue`	Floating point value that is the average of the values that the Filtered Summary block currently stores.

17 Using Functions in Event Modeler

In Event Modeler, when you define a rule, you can use a function to specify the value, or part of the value, of a condition or action. Event Modeler provides a number of functions that you can use. In addition, you can define your own functions.

To use a function in a rule, select **Standard Functions** from the context menu when defining a rule. Event Modeler displays only those functions that are valid for the portion of the rule you are defining.

Reference information for provided functions

Event Modeler provides a number of functions. Each function is defined in its own function definition file (`.fdf` file) in the `catalogs/functions` directory of the your Apama installation directory. A function definition file is an XML file that contains metadata about the function plus the EPL that implements the function.

The topics below describe the functions provided in Event Modeler. Your Apama Service Provider might have included additional functions that are not documented here.

Date and time functions

The following table describes the date and time functions.

Typical use

A typical use of most of these functions is something like the following:

```
ADD_YEAR(GET_CURRENT_TIME_AS_NUMBER(), 5)
```

Function name	Return value	Parameters	Description
`ADD_DAYS`	`float`	`float` *`dateTime`* `float` *`nrDays`*	Given a date plus a number of days, returns the result date in seconds since the epoch.
`ADD_HOURS`	`float`	`float` *`dateTime`* `float` *`nrHours`*	Given a date plus a number of hours, returns the result date in seconds since the epoch.
`ADD_MINUTES`	`float`	`float` *`dateTime`* `float` *`nrMins`*	Given a date plus a number of minutes, returns the result date in seconds since the epoch.

Function name	Return value	Parameters	Description
ADD_MONTHS	float	float *dateTime* float *nrMonths*	Given a date plus a number of months, returns the result date in seconds since the epoch.
ADD_WEEKS	float	float *dateTime* float *nrWeeks*	Given a date plus a number of weeks, returns the result date in seconds since the epoch.
ADD_YEARS	float	float *dateTime* float *nrYears*	Given a date plus a number of years, returns the result date in seconds since the epoch.
FORMAT_TIME	string	float *TimeInSeconds* string *TimeFormat*	Returns the specified time and date in a formatted string. For example, `FORMAT_TIME(GET_CURRENT_TIME(), "dd-MM-yyyy HH:mm:ss")`. For format options, see "Using the TimeFormat Event Library" on page 357.
GET_CURRENT_DATE	string	none	Returns the current date in a formatted string. For example, "11 June 2007".
GET_CURRENT_DATE_TIME	string	none	Returns the current date and time in a formatted string. For example, "11 June 2007 11:10:23".
GET_CURRENT_TIME	string	none	Returns the current time in a formatted string. For example, "11:10:25".
GET_CURRENT_TIME_AS_NUMBER	float	none	Returns the current time as a number of seconds since the epoch, January 1, 1970.

Function name	Return value	Parameters	Description
GET_CURRENT_TIME _FORMATTED	string	string *TimeFormat*	Returns the current time and date in a formatted string. For format options, see "Using the TimeFormat Event Library" on page 357.
GET_DAY_IN_WEEK	float	float *dateTime*	Returns the day of the week for the given date.
GET_DAY_IN_YEAR	float	float *dateTime*	Returns the day in the year for the given date.
GET_MONTH_IN_YEAR	float	float *dateTime*	Returns the month in the year for the given date.
GET_WEEK_IN_MONTH	float	float *dateTime*	Returns the week in the month for the given date.
GET_WEEK_IN_YEAR	float	float *dateTime*	Returns the week in the year for the given date.
IS_LEAP_YEAR	boolean	float *year*	Returns true if the given year is a leap year.
PARSE_TIME	float	string *TimeDate* string *TimeFormat*	Returns the specified time and date in a numeric format. For example, `PARSE_TIME (GET_CURRENT_TIME(), "H:m:s")`. For format options, see "Using the TimeFormat Event Library" on page 357.

Extended math functions on float types

The following table describes the extended math functions on `float` types.

Function name	Return value	Parameters	Description
ACOS	float	float *value*	Returns the inverse cosine of the value in radians. If the value's absolute value is greater than 1 then ACOS() returns NaN.
ACOSH	float	float *value*	Returns the inverse hyperbolic cosine of the value. If the value's absolute value is less than 1 then ACOSH() returns NaN.
ASIN	float	float *value*	Returns the inverse sine of the value in radians. If the value is NaN then ASIN() returns the value. If the value's absolute value is greater than 1 then ASIN() returns NaN.
ASINH	float	float *value*	Returns the inverse hyperbolic sine of the value.
ATAN	float	float *value*	Returns the inverse tangent of the value.
ATAN2	float	float *x* float *y*	Returns the two-parameter inverse tangent of the two values.
ATANH	float	float *value*	Returns the inverse hyperbolic tangent of the value.
CBRT	float	float *value*	Returns the cube root of the value.
COS	float	float *value*	Returns the cosine of the value. The value should be in units of radians.

Function name	Return value	Parameters	Description
COSH	float	float *value*	Returns the hyperbolic cosine of the value.
ERF	float	float *value*	Returns the error function value for the given value.
EXPONENT	float	float *value*	Returns the exponent where the given value is equal to mantissa*2^{exponent}, assuming 0.5 <= |mantissa| < 1.0.
FMOD	float	float *nominator* float *denominator*	Returns *nominator* mod *denominator* in exact arithmetic.
FRACTIONALPART	float	float *value*	Returns the fractional component of the value.
GAMMAL	float	float *value*	Returns the logarithm of the gamma function.
ILOGB	integer	float *value*	Returns the binary exponent of the specified non-zero value.
INTEGRALPART	integer	float *value*	Returns the integral part of a floating point value.
MANTISSA	float	float *value*	Returns the mantissa where the given value is equal to mantissa*2^{exponent}, assuming 0.5 <= |mantissa| < 1.0.
NEXTAFTER	float	float *x* float *y*	Returns the next machine floating point number after *x* in the direction toward *y*.

Function name	Return value	Parameters	Description
SCALBN	float	float *x* integer *n*	Returns *x**2*n*.
SIN	float	float *value*	Returns the sine of the specified value, which should be in units of radians.
SINH	float	float *value*	Returns the hyperbolic sine of the value.
TAN	float	float *value*	Returns the tan of the value, which should be in units of radians.
TANH	float	float *value*	Returns the hyperbolic tangent of the value.

IO functions

The following table describes the IO functions.

Function name	Return value	Parameters	Description
LOG	string	string *message* string *logLevel*	Logs the specified string to the correlator log.
PRINT	string	string *message*	Displays the specified string in the correlator console.

System value functions

The following table describes the system value functions.

Function name	Return value	Parameters	Description
GET_DASHBOARD_ INSTANCEID	string	None	Returns the instance ID of the current Scenario instance for use in dashboards. The apama.instanceId field contains this value.
GET_INSTANCEID	string	None	Returns the complete instance ID of the current Scenario instance. For example: "default.myScenario.1".
GET_INSTANCE_ OWNER	string	None	Returns the value of the owner attribute of the current Scenario instance. This might be, but is not necessarily, the account Id that created the Scenario. You can use the Scenario service API to create Scenario instances and set the owner attribute to a value you choose. When you use a dashboard to create Scenario instances, the owner attribute has the value of the account you logged into.
GET_NUMERIC_ INSTANCEID	float	None	Returns only the number at the end of the complete instance Id of the current Scenario instance. For example, if the complete instance Id is default.myScenario.1, this function returns 1.
GET_SCENARIO_ID	string	None	Returns the unique scenario ID of the current scenario definition. The correlator

Function name	Return value	Parameters	Description
			uses this key to create new instances of the scenario.
GET_SCENARIO_NAME	string	None	Returns the display name of the current Scenario.

Miscellaneous functions

The following table describes the miscellaneous functions.

Function name	Return value	Parameters	Description
ABS	number	number *value*	Returns the absolute value of the number supplied.
ADD_EXTRAPARAM	text	text *payload*, text *fieldname*, text *value*	This function is deprecated. Use the DICT_SET function instead. Takes an existing extraParam value and adds the specified field and value to it.
CEIL	number (whole number)	number *value*	Returns the ceiling integer value of the number passed. This is the smallest possible integer that is larger than the value supplied.
CONCAT	text	text *prefix*, text *suffix*	Concatenates two strings and returns the result as a string.
CONCAT	text	text *prefix*, choice *suffix*	Concatenates an enumeration value to a string, and returns the result as a string.

Function name	Return value	Parameters	Description
CONCAT	text	text *prefix*, number *suffix*	Concatenates a number to a string, and returns a string.
CONDITIONAL	text	condition *condition* text *true_result* text *false_result*	Functions like an IF statement. The first parameter is the expression to be evaluated, similar to a condition in an IF statement. The second and third parameters are the values to return according to the result of the condition. The second parameter represents a true result. The third parameter represents a false result. See "Example of CONDITIONAL function" on page 586.
DICT_GET	text	text *dictAsString* text *key*	Reads the dictionary specified by *dictAsString* and returns the value of the specified *key*. Specify the dictionary in dictionary<string,string>.toString() format. Returns an empty string if the key is not present or the string representation of the dictionary is "".
DICT_GETORDEFAULT	text	text *dictAsString* text *key* text *default*	Reads the dictionary specified by *dictAsString* and returns the value of the specified *key*. Specify the dictionary in

Function name	Return value	Parameters	Description
			`dictionary<string,string>.toString()` format. Returns the specified *`default`* text if the key is not present or the string representation of the dictionary is "".
`DICT_HASKEY`	`boolean`	`text` *`dictAsString`* `text` *`key`*	Reads the dictionary specified by *`dictAsString`* and returns true if the specified *`key`* exists in that dictionary. Specify the dictionary in `dictionary<string,string>.toString()` format.
`DICT_SET`	`text`	`text` *`dictAsString`* `text` *`key`* `text` *`value`*	Reads the dictionary specified by *`dictAsString`* and adds or replaces the specified *`key`*/*`value`* pair. Specify the dictionary in `dictionary<string,string>.toString()` format. An empty string for *`dictAsString`* is treated as an empty dictionary. Returns a string representation of the dictionary.
`FLOOR`	`number` (whole number)	`number` *`value`*	Returns the floor integer value of the number passed. This is the largest possible integer that is smaller than the value supplied.
`GET_EXTRAPARAM`	`text`	`text` *`payload`*,	This function is deprecated. Use the `DICT_GET` function

Function name	Return value	Parameters	Description
		text *fieldname*	instead. Returns the value from extraParam data of the specified field, else an empty string.
HAS_EXTRAPARAM	boolean	text *payload*, text *fieldname*	This function is deprecated. Use the DICT_HASKEY function instead. Returns true if the extraParam data has the specified field value.
ISFINITE	boolean	float *value*	Returns true if *value* is finite, that is, it is not infinite or NaN.
ISINFINITE	boolean	float *value*	Returns true if *value* is infinite, that is, it is positive or negative infinity.
ISNAN	boolean	float *value*	Returns true if *value* is NaN, that is, it is not a number.
MAX	number	number *value1*, number *value2*	Returns the largest of two numbers.
MIN	number	number *value1*, number *value2*	Returns the smallest of two numbers.
POW	number	number *value*, number *exponent*	Returns the value of the first parameter to the power of the second parameter.
REPLACE	text	text *value*, text *old*,	Replaces all string occurrences of *old* in *value* with *new*.

Function name	Return value	Parameters	Description
		`text` *new*	
`RND`	`number`	`number` *lower bound*, `number` *upper bound*	Returns a random number between the specified boundaries.
`ROOT`	`number`	`number` *value*, `number` *exponent*	Returns the value of the first parameter root of the second parameter.
`ROUND`	`number`	`number` *value*, `number` *decimal_places*	Rounds a float to a given number of decimal places. You can specify a negative number for *decimal_places* to round in the opposite direction. See "Example of ROUND function" on page 586.
`TO_BOOLEAN`	`condition`	`text` *value*	Converts a string to a Boolean value, and returns the Boolean value. This function is case insensitive.
`TO_NUMBER`	`number`	`choice` *value*	Converts an enumeration to a number, and returns the number.
`TO_NUMBER`	`number`	`text` *value*	Converts a string to a number, and returns the number.
`TO_TEXT`	`text`	`condition` *value*	Converts a Boolean value to a string, and returns the string.

Function name	Return value	Parameters	Description
`TO_TEXT`	`text`	`number` *`value`*	Converts a number to a string, and returns the string.

Example of CONDITIONAL function

```
side = CONDITIONAL (price is greater than 50, "BUY", "SELL")
```

If the price is greater than 50, this function returns `"BUY"`. The `side` Scenario variable is set to `BUY` or `SELL` according to whether the price variable is greater than 50.

Example of ROUND function

You can specify a negative number to round in the opposite direction. For example:

Value	Decimal places	Result
12345.6543	4	12345.6543
12345.6543	3	12345.654
12345.6543	2	12345.65
12345.6543	1	12345.7
12345.6543	0	12346.0
12345.6543	-1	12350.0
12345.6543	-2	12300.0
12345.6543	-3	12000.0
12345.6543	-4	10000.0
12345.6543	-5	0.0

About defining your own functions

You define a function in Software AG Designer. In the Apama Developer perspective, select **File > New > Scenario Function**. You are prompted for some metadata, and then a skeleton function definition file (`.fdf`) is created, which is an XML file. The skeleton file indicates where you need to add data and what kind of data you need to add.

See "Creating new scenario functions" in *Using Apama with Software AG Designer* for details about the scenario function definition file format.

The content of a function definition file must comply with the DTD in the `etc/fdf.dtd` file in the Apama installation directory.

The following topics provide additional information about using functions that you define in Event Modeler.

Related Topic

"Adding a function catalog" on page 506

Sample ABS function definition file

Following is the function definition file for the absolute value (`ABS`) function. This function returns the absolute value of the given parameter. For example, if the input is `-123`, the `ABS` function returns `123`.

Example

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE function SYSTEM "http://www.apama.com/dtd/fdf.dtd">
<!--Apama Function Definition File-->
<function name="ABS" display-string="ABS" return-type="float">
  <version>
    <id>1.0</id>
    <date>22 Nov 2004</date>
    <author>Matthew Amos</author>
    <comments>External function</comments>
  </version>
  <description>
    Return the abs value of the number passed
  </description>
  <parameters>
    <fixed-parameter name="value" type="float" />
  </parameters>
  <code><![CDATA[
    action #name#(float f) returns float {
      return f.abs();
    }
  ]]></code>
</function>
```

Notes

Notes for this function:

- The value of the `function name` attribute, ABS, is unique within the directory that contains this `.fdf` file.
- Appears as **ABS** in the Event Modeler rules menu.
- Returns a float.

- Metadata indicates who wrote the function and when the function was written.
- Description briefly describes what the function does.
- There is one parameter called `value` and it is of type `float`.
- Name of the single action is the placeholder `#name#`. This is always what you specify as the name of the function in the `code` element.
- The EPL in the `CDATA` section is standard EPL. You can use locally defined variables in addition to the function's parameters. To use a Scenario variable, assign its value to a function parameter.

Sample function definition file with imports element

Following is a function definition file that specifies the `imports` element.

Example

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE function SYSTEM "http://www.apama.com/dtd/fdf.dtd">
<!--Apama Function Definition File-->
<function name="ExtractTimeField" display-string=”ExtractTimeField"
    return-type="float">
  <version>
    <id>1.0</id>
    <date>17 May 2005</date>
    <author>Ben Spiller</author>
    <comments>External function</comments>
  </version>
  <description>
    Return the value of a single field from the specified
    time string (using the TimeFormatPlugin). Date fields
    include 'dd', 'MM' and 'yyyy'. Time fields include 'HH',
    'mm' and 'ss'.
  </description>
  <imports>
    <import library="TimeFormatPlugin" alias="timePlugin"/>
  </imports>
  <parameters>
    <fixed-parameter name="time" type="float" />
    <fixed-parameter name="field identifier" type="string" />
  </parameters>

  <code><![CDATA[
    action #name#(float time, string field_id) returns float
    {
      // If the field string is invalid, make it obvious!
      if field_identifier.length() == 0 then {
      return 0.0;
    }

      // Should return 0 if the field specifier is invalid
      return #timePlugin#.format
          (time,"%"+field_id).toFloat();
    }
  ]]></code>
</function>
```

Notes

Notes for this function:

- The value of the function name attribute, ExtractTimeField, is unique within the directory that contains this .fdf file.
- Appears as **ExtractTimeField** in the Event Modeler rules menu.
- Returns a float.
- The imports element specifies timePlugin as the alias for the plug-in, and TimeFormatPlugin as the shared library that contains the plug-in.
- The code element specifies timePlugin to refer to required plug-in.
- Takes two parameters — a float that specifies a time, and a String that specifies a field ID.
- The EPL ensures that the ID field is valid and then invokes the format function by specifying the alias for the TimeFormatPlugin library:

  ```
  return #timePlugin#.format
  ```

About function names

Functions have several different names:

- **The file name.** This is the name of the file that contains the function definition, for example, String_String_Concat.fdf.
- **The logical name.** This is the name specified by the function name attribute in the .fdf file. Event Modeler uses the logical name to distinguish each function from every other function in a particular directory. Within each directory, this value must be unique. For example, SSConcat.
- **The display name.** This is the name that appears in the Event Modeler **Functions** tab. For example, "Concat". This name also appears in the **Rules** panel context menu.

The contents of a function definition file contain something like this near the beginning:

```
<function name="SSConcat" display-string="Concat"
   return-type="string">
```

In this example, the logical name is SSConcat. The display name is Concat.

For example, it is possible to have the following three functions in the same directory:

Filename	Parameters	Display Name	Logical Name
String_String_Concat.fdf	String, String	Concat	ConcatSS
String_Integer_ Concat.fdf	String, Integer	Concat	ConcatSI

Filename	Parameters	Display Name	Logical Name
String_Integer_String_ Concat.fdf	String, Integer, String	Concat	ConcatSSS

Note that these functions have the same display name but different logical names. An exact duplicate of any of these functions can be in a directory other than the directory that already contains its duplicate.

When you select functions from the rules editor context menu, Event Modeler displays the arguments that each function takes. Consequently, if two functions have the same display name, you can distinguish them by their arguments. For example:

```
TO_NUMBER('choice' value)
```

```
TO_NUMBER ('text' value)
```

18 Creating Blocks

Apama comes with many standard blocks that you can use in your scenarios. In addition, you can use Software AG Designer to create your own blocks to implement specialized behavior. This section describes how to create custom blocks for use by scenarios in your Apama applications.

About blocks

Blocks are modules that you can import and use within your scenarios in Apama's Event Modeler. Blocks accept inputs, execute logic of their own, and generate output. Their primary purpose is to provide scenarios with access to complex functionality that can only be programmed in Apama Event Processing Language (EPL). They also provide an element of reuse. EPL is the native language of the event correlator.

For more information on writing EPL code, see "Getting Started with Apama EPL" on page 31.

Apama is distributed with a library of blocks that perform a variety of tasks such as general and financial analysis, order management, and timing. For more information on these, see "Using Standard Blocks" on page 521. If an application requires additional functionality, you can create custom blocks.

The topics below provide more introductory information about blocks.

Introduction to block definition files

A block is defined in a block definition file, which has a `.bdf` extension. This XML file describes the functionality of the block and includes its implementation in EPL. With Software AG Designer, you graphically define the block's interface, and Software AG Designer automatically generates all the XML elements of the `.bdf` file. In addition, Software AG Designer generates skeleton EPL code for the block's behavior. Software AG Designer provides a dedicated editor where you add your custom code and it validates the EPL code you add.

The block definition file actually defines an *EPL template*. The term “template” is used because the EPL in the `.bdf` is not complete EPL code. Instead of the actual block name, the `.bdf` code uses a specially encoded stand-in for the real block name. The real names are automatically generated when the combined scenario and block are converted into full EPL code when they are injected into the correlator.

Description of block interface elements

A block's interface consists of the set of parameters, input feeds, output feeds and operations it defines. You specify these items when you create a block with Software AG Designer. Software AG Designer then generates the corresponding actions.

- **Parameters.** Parameters configure the behavior of a block. You typically use parameters to initialize the block or to modify its core behavior.

- **Input feeds.** Input feeds connect live data streams to blocks. In each block input feed, you define input fields and map data in the stream to the appropriate input field. All the fields of an input feed are updated simultaneously.
- **Output feeds.** Output feeds stream output data generated by the block. Each output feed is a collection of fields that all get updated simultaneously.
- **Operations.** Operations are specific behaviors that the scenario invokes, such as starting or stopping the processing of data.

For examples, see "Using Standard Blocks" on page 521.

How scenarios communicate with their blocks

Apama implements a block as an event type. When you create a block, Software AG Designer generates the event type definition for that block. The block's event type definition includes a number of actions that are defined for you and that you can edit.

Communication from a scenario to a block instance is accomplished through calls to these actions. That is, to initialize a block, change a parameter, call an operation, and so on, a scenario calls an action on the event that contains the block instance.

Communication from the block to its host scenario is also accomplished by calling actions. In this case, the actions have been passed into the block by the scenario. For example, when a scenario initiates an operation the scenario passes in an action that the block must call to indicate that the operation has been completed.

Defining new blocks in Software AG Designer

Software AG Designer provides an integrated graphical environment for creating custom blocks that you can use to build scenarios in Event Modeler. The Apama block editor contains two tabs, the Builder tab and the Source tab.

On the Builder tab, you add the metadata for the block and specify its interface. On the Source tab, you add the EPL code that implements the block's behavior. Software AG Designer validates the EPL code you add to the block. When you save a block, it is saved as a *block definition file* with a `.bdf` extension. Block definition files are then used when you add the block to a scenario in the Event Modeler.

You can define a new block from scratch by using the block editor or you can base the new block on an existing event type definition.

See "File Definition Formats" on page 639 for detailed information on the internals of block definition files.

Specifying the block metadata

Creating a block in Software AG Designer consists of two main steps. In the first step you create the block metadata and specify its interface. In the second step you add the EPL code that implements the block's behavior.

When you create a new block, you should place it in the project's default blocks directory. This directory is found in the project's `catalogs` directory. The block directory has a name in the form *`project_name`*`\blocks`. So, for example, the default block directory of a project named `My_Project` will be `catalogs\My_Project blocks`. If you place the block in the default block directory, scenarios created in the project will automatically find them and make them available in Event Modeler when you are displaying the scenario.

You add a new block to a project by right-clicking the project and selecting **New > Block** from the pop-up context menu. Software AG Designer displays the New Block wizard where you specify whether you want to create a block from scratch or base it on an existing event type. You also specify any other information that will make up the block's metadata.

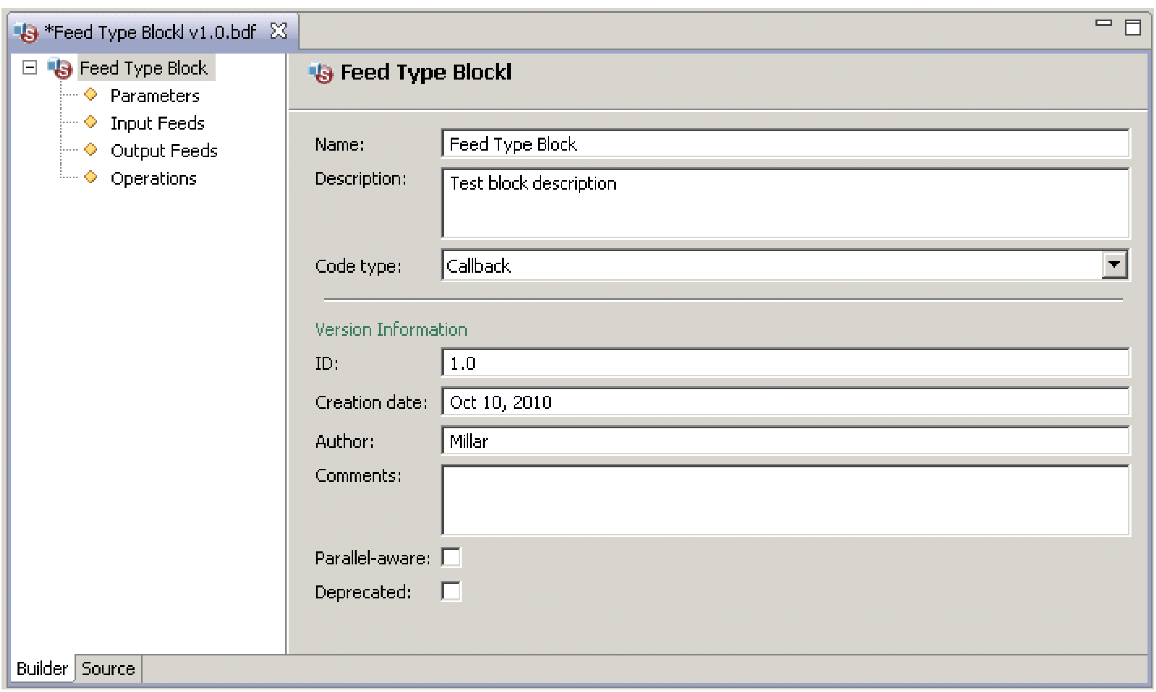
When you finish adding information in the New Block wizard, the block is added to the project and the block's metadata appears in the **Builder** tab of the block editor.

For specific steps on how to add a new block to an Apama project, see:

- *Creating a block with the block editor* in *Using Apama with Software AG Designer*
- *Creating a block from an EPL event definition* in *Using Apama with Software AG Designer*

Specifying the block interface

After you create a block, your new block is shown in the Block Editor with the **Builder** tab selected:



Initially, the name of the block is selected and general information about the block is shown. Most of the fields are self-explanatory and you can use them to help you maintain your blocks. Use the **ID** field to distinguish versions of your block. Select the

Parallel-aware checkbox if you want to be able to use this block in a parallel scenario. See "Creating parallel-aware blocks" on page 595.

The **Deprecated** checkbox indicates whether this is an older version of the block. All Apama standard blocks that use the old-style block implementation (Apama releases prior to 4.2) are deprecated. They will not be supported in a future release.

If you have any custom blocks that use the old-style implementation, you should convert them to the new implementation and mark the old-style version as deprecated. To convert a block, open it in the Block Builder editor, select Callback or Callback (DEBUG) as the code type, and click the **Source** tab. See the Apama 5.0 migration guide for details about how you must manually edit the re-generated block file to correctly use the new implementation that is generated for you. A block is never automatically converted to use the new implementation.

Event Modeler uses the setting of the **Deprecated** checkbox to determine how to display the block in the **Block Wiring** panel. Deprecated blocks have an orange border while current blocks have a black border.

Also, suppose you write a custom block that uses the new-style implementation and you then revise that block. You can select the **Deprecated** checkbox for the older version to encourage use of the new version.

At this point, if you are creating a new block based on an existing event definition, the code for the block's input and output feeds, along with the fields associated with the feeds, and the block's operations has been generated.

If you are creating a new block from scratch, the block does not contain any of the parameters, input feeds, output feeds, and operations that provide the interface of the block. When you add these elements, Software AG Designer generates the EPL code that defines the action that implements the element.

To add a parameter, input feed, output feed, or operation

1. Right-click the element you want to add and select **Add Parameter**, **Add Input Feed**, **Add Output Feed**, or **Add Operation**. The right side of the Builder tab displays the item's properties.
2. Fill in the values for the properties.
3. For input feeds and output feeds, right-click the element and select **Add Field**.
4. In the **Properties** panel for the field you added in the previous step, fill in the values for the properties and field validation specifications.

When you save a block, Software AG Designer generates the underlying code that defines the block's interface and saves it as a *block definition file* with a `.bdf` extension. To this file, you then add EPL code to implement the necessary behavior. To add code to the block, see "Adding EPL code to the block definition" on page 596.

Creating parallel-aware blocks

If you want a parallel scenario to use a block, you must mark that block as parallel-aware. You do this in the Builder tab of the block builder editor in Software AG

Designer. Select the block name. Then select the **Parallel-aware** checkbox near the bottom of the Builder tab fields.

The correlator runs each instance of a parallel scenario in a separate context. For information about contexts, see "Implementing Parallel Processing" on page 303.

When you mark a block you are creating as parallel-aware it means that you are taking responsibility for ensuring that the block functions correctly when run in multiple contexts. Blocks that do not listen for events are trivially parallel-aware since running in another context has no effect on that block. All of the block's interactions are mediated by the scenario.

Blocks that listen for events must ensure that the events they are listening for actually reach the context they are in. You can achieve this by storing a reference to the main context during the `instancePreSpawnInit()` action. Use this reference to inform services running in the main context where they should send events. Look at the Market Depth standard block for a good example of this.

Adding EPL code to the block definition

In Software AG Designer, when you click the Source tab of the block builder editor, the block's definition file is shown. Software AG Designer generates and populates all XML elements including the `<code>` element. The `<code>` element contains the EPL code that specifies the block's behavior.

Software AG Designer generates skeleton EPL with comments that indicate where to insert your code. The generated code defines the actions listed below. Each of these actions is a field in the event type that defines the block. The block's scenario will call these actions to accomplish the work of the block. For each defined action, you can add custom code that specifies the exact behavior you need.

- For each block parameter, there is an action that updates that parameter.
- For each block input feed, there is an action that takes as its arguments the fields of the feed.
- For each block operation, there is an action that performs the operation.
- For each block output feed, there is an action that takes as its arguments the fields of the feed.
- `setup` action
- `instancepreSpawnInit` action
- `instancePostSpawnInit` action
- `cleanup` action
- `start` action (for input blocks based on existing event definitions)
- `stop` action (for input blocks based on existing event definitions)
- `send` action (for output blocks based on existing event definitions)

In addition to defining these actions, Software AG Designer generates sections for adding user-defined monitors, user-defined variables, and user-defined actions. Also, the generated EPL code defines a block-level variable named `blockInstanceId$`. This variable contains the integer that uniquely identifies the instance of the block among those owned by the containing scenario and all its instances.

To add EPL code to the block

1. In Software AG Designer, in the Project Explorer view, double-click the block's `.bdf` file.
2. In the block builder editor, click the Source tab.
3. On the Source tab, enter code as needed only where there is a white background.

   Code appears either with a gray background or a white background. Code with a gray background is maintained by Apama and is not editable. The sections of code with a white background are the areas where you add your custom EPL code. Remember to remove the comment flags from lines on which you specify code.
4. Save the project.

As you add and edit code in your block, you have the full range of Apama features as described in *Editing Apama files*. You also have the full range of navigating features as described in *Navigating in Apama files*. These topics can be found in *Using Apama with Software AG Designer*.

Considerations for adding EPL code to the block definition

As you add custom code to your block, keep the following in mind:

- The `#` character denotes special names that will subsequently be assigned automatically by the code generator. Therefore, do not use the `#` character anywhere else in your EPL files, including within comments.
- You must not call `die()` anywhere in the block event type definition. Consequently you should not call `spawn()` in the block event type definition as you would have no way of terminating the new monitor instance.

In situations where you might want to spawn from within a block, use a utility monitor that is part of the block's definition instead. Insert the EPL code for a utility monitor in the `USER DEFINED MONITORS` section of your block definition file. For example, suppose your block subscribes to one or more market data feeds and you want to track data and status messages that result from each subscription. Write a utility monitor that listens for events related to the subscriptions and caches values that result from subscription operations. You can call `die()` in this monitor without affecting the block or the scenario.

- If the EPL code in your block causes a runtime error, for example you attempt a division by zero or you attempt to access an out of bounds index in a sequence or dictionary, the scenario monitor will be terminated by the correlator.

See also "Timeliness of acknowledgements" on page 604.

Details about EPL code that you can add

The following sections describe what Apama generates for you in Software AG Designer and where to add EPL code.

Actions that update parameters

Apama generates skeleton code for an action for each parameter you specify for the block. Each action updates the value of the parameter. These actions are named `update $parameter_name`, where *parameter_name* is the metadata name you specified for the parameter. Each action takes the parameter's specified name as an argument.

Each time the value of a block parameter changes in the scenario, the scenario calls the corresponding update action on the block. It is up to you to define appropriate EPL code in the body of this action to handle the block parameter update. It is bad practice to send updates to output feeds during a parameter update action because it can cause unexpected results in the running scenario.

If a parameter should not be editable, leave the body of its update action empty.

For example, if a block specifies a `string` parameter called `New Parameter 1`, Apama generates the following skeleton code:

```
    action update$new_parameter_1(string new_parameter_1) {
// BLOCKBUILDER - USER DEFINED ACTION
//
// -- insert handler for modifications to new parameter 1 --
//
// BLOCKBUILDER - END OF USER DEFINED ACTION
    }
```

If a block is based on an existing event and is an input block, the skeleton code contains additional information about the parameter. In the following example a parameter based on the event field `customerName` has been specified:

```
    action update$customerName(string customerName) {
// BLOCKBUILDER - USER DEFINED ACTION
      parameter_customerName := customerName ;
      isSet_parameter_customerName := true;
      setupNewListener();
// BLOCKBUILDER - END OF USER DEFINED ACTION
```

Actions that update input feeds

Apama generates skeleton code for an action for each input feed you specify for the block. Each action updates the values of the corresponding input feed's fields. These actions are named `input$input_feed_name`, where *input_feed_name* is the metadata name you specified for the input feed. Each action takes an argument for each field in the corresponding input feed.

It is up to you to define appropriate EPL code in the body of this action to handle the update to the input feed. For example, if a block specifies an input feed named `Input Feed 1`, Apama generates the following skeleton code:

```
   action input$new_input_feed_1(#string string_field, float float_field)
{
```

```
// BLOCKBUILDER - USER DEFINED ACTION
//
// -- insert handler for new input events on stream new input feed 1 --
//
// BLOCKBUILDER - END OF USER DEFINED ACTION
   }
```

Actions that perform operations

Apama generates skeleton code for an action for each operation that you specify in the block. Each action performs the operation. These actions are named `operation $`*operation_name* where *operation_name* is the metadata name you specified for the operation. Each action takes only an `acknowledge()` action variable argument.

It is up to you to define appropriate EPL code in the body of this action to handle the operation's invocation. You must call the `acknowledge()` action when the operation is complete. There are constraints on how long you can hold up a call to `acknowledge()`. Often, an operation updates output feeds before calling `acknowledge()`. See "Timeliness of acknowledgements" on page 604.

For example, if a block specifies an operation called `New Operation 1`, Apama generates the following skeleton code:

```
    action operation$new_operation_1(action<> acknowledge) {
// BLOCKBUILDER - USER DEFINED ACTION
//
// -- insert handler for invocations of operation new operation 1 --
//
// BLOCKBUILDER - END OF USER DEFINED ACTION
    }
```

Actions that update output feeds

Apama generates a `sendOutput` action for each output feed that you specified for the block. Each action updates the values of the corresponding output feed's fields. These actions are named `sendOutput$`*output_feed_name* where *output_feed_name* is the metadata name of the output feed. Each action takes an argument for each field in the corresponding output feed.

You do not need to add code for these actions. To output results from your block you should call one of these output feed actions. If your block uses an output feed `new_output_feed_1` with a boolean field new_field_1 and a string field new_field_2, Apama generates the following code:

```
action<boolean,string> sendOutput$new_output_feed_1;
```

setup action

Apama generates skeleton code for the `setup()` action. The scenario calls the `setup()` action once on each block instance in a scenario definition. The scenario makes this call when you inject the scenario into the correlator. Use the `setup()` action to specify any initialization that is not specific to a scenario instance. Apama generates the following skeleton code:

```
    action setup() {
// BLOCKBUILDER - USER DEFINED ACTION
//
```

```
// -- insert setup code --
//
// BLOCKBUILDER - END OF USER DEFINED ACTION
    }
```

instancePreSpawnInit action

Apama generates skeleton code for the `instancePreSpawnInit()` action. The scenario calls the `instancePreSpawnInit()` action on each scenario instance. The scenario makes this call just before it spawns the scenario instance. The scenario passes the following values into the `instancePreSpawnInit()` action:

- Scenario ID
- Dictionary of extra data
- Target context the scenario instance will run in. For a scenario that is not parallel (that is, it is a serial scenario), the target context is always the main context.

Use the `instancePreSpawnInit()` action to perform initialization in the main context. For example, the main context might need information about which context the scenario instance, and therefore the block instance(s) will run in. A block cannot generate output feed values inside the `instancePreSpawnInit()` action, but it can generate output feed values inside the `instancePostSpawnInit()` action.

When the scenario calls the `instancePreSpawnInit()` action, it passes an `acknowledgment()` action. You are responsible for ensuring that the `instancePreSpawnInit()` action calls this `acknowledgment()` action when it has completed this phase of initialization. To help you do this, Apama generates a call to `acknowledge()` when it generates the skeleton code for the block. See "Timeliness of acknowledgements" on page 604.

Apama generates the following skeleton code:

```
       action instancePreSpawnInit (
           integer blockInstanceId$,
           string scenarioId$,
           dictionary<string, string> userData$,
           context target,
           action<> acknowledge) {
       self.blockInstanceId$ := blockInstanceId$;
// BLOCKBUILDER - USER DEFINED ACTION
//
// -- insert pre-spawn initialisation code --
//
       acknowledge();
// BLOCKBUILDER - END OF USER DEFINED ACTION
    }
```

If a block is based on an existing event, the skeleton code contains additional code to specify the context.

```
   action instancePreSpawnInit(
        integer blockInstanceId$,
        string scenarioId$,
        dictionary<string, string> userData$,
        context target,
        action<> acknowledge) {
    self.blockInstanceId$ := blockInstanceId$;
// BLOCKBUILDER - USER DEFINED ACTION
```

```
//
// -- insert pre-spawn initialisation code --
//
preSpawnContext := context.current();
      acknowledge();
// BLOCKBUILDER - END OF USER DEFINED ACTION
    }
```

instancePostSpawnInit action

Apama generates skeleton code for the `instancePostSpawnInit()` action. The scenario calls the `instancePostSpawnInit()` action on each newly spawned scenario instance. The scenario makes this call right after it spawns the scenario instance. Part of this action is to pass the following to the scenario instance:

- Scenario ID
- Dictionary of extra values
- Initial values of the block's parameters
- Additional data for use by the automatically generated code.

When the scenario calls the `instancePostSpawnInit()` action, it passes an `acknowledgment()` action. You are responsible for ensuring that the `instancePostSpawnInit()` action calls this `acknowledgment()` action when it has completed this phase of initialization. To help you do this, Apama generates a call to `acknowledge()` when it generates the skeleton code for the block. See "Timeliness of acknowledgements" on page 604.

Apama generates the following skeleton code:

```
       action instancePostSpawnInit (
           integer blockInstanceId$,
           string ownerId$,
           string scenarioId$,
           dictionary<string, string> userData$,
           action<> acknowledge)
           param_type param1 //one for each parameter
           action<output_field_types> sendOutput$outfeed    {
                // one action like the above for each output feed
                // one line like the following for each output feed
       self.sendOutput$outfeed1 := sendOutput$outfeed1;
// BLOCKBUILDER - USER DEFINED ACTION
//
// -- insert post-spawn initialisation code --
//
       acknowledge();
// BLOCKBUILDER - END OF USER DEFINED ACTION
    }
```

If the block is an input block based on an existing event, the generated code looks like this:

```
   action instancePostSpawnInit(
     integer blockInstanceId$,
     string ownerId$,
     string scenarioId$,
     dictionary<string, string> userData$,
     action<> acknowledge,
     string name,
```

```
     action<string,float> sendOutput$TestEvent) {
         self.sendOutput$TestEvent := sendOutput$TestEvent;
// BLOCKBUILDER - USER DEFINED ACTION
//
// -- insert post-spawn initialisation code --
//
       enqueue TestEventForwardRequest (context.current()) to preSpawnContext;
       // Store the initial values
       parameter_name := name;
       acknowledge();
// BLOCKBUILDER - END OF USER DEFINED ACTION
   }
```

If the block is an output block based on an existing event, the generated code looks like this:

```
      action instancePostSpawnInit(
        integer blockInstanceId$,
        string ownerId$,
        string scenarioId$,
        dictionary<string, string> userData$,
        action<> acknowledge,
        string name) {
// BLOCKBUILDER - USER DEFINED ACTION
//
// -- insert post-spawn initialisation code --
//
        if (preSpawnContext.getId() = context.current().getId()) then {
           serialExecution := true;
        }
        else {
           serialExecution := false;
        }
        acknowledge();
// BLOCKBUILDER - END OF USER DEFINED ACTION
     }
```

The scenario is not in a fully created state until all blocks have acknowledged their `instancePostSpawnInit()` call. Also, updating of output feeds is not supported at any stage before `instancePostSpawnInit()` is called. If initial values for output feeds need to be generated, do this in the `instancePostSpawnInit()` action.

cleanup action

Apama generates skeleton code for the `cleanup()` action. When a block's scenario enters its end state, is deleted, or dies for some other reason, the scenario calls the block's `cleanup()` action. Even if there is a runtime error, the scenario calls the `cleanup()` action.

After the scenario calls the `cleanup()` action, the block should no longer try to update its output feeds. The block should act in every possible way as if it was dead. However, if there is any finalization work that you want to accomplish, you can add it to the body of the `cleanup()` action. Apama generates the following skeleton code:

```
    action cleanup() {
// BLOCKBUILDER - USER DEFINED ACTION
//
// -- insert finalization code --
//
// BLOCKBUILDER - END OF USER DEFINED ACTION
    }
```

start action

For blocks that are based on existing event definitions and are specified as input blocks, Apama generates code for a `start` action. Once the `start` operation is invoked the block calls a `setupNewListener` action, which creates the listener code for the event on which the block is based. If any event fields have been specified when defining the block, they are used as parameters to create filters in the listener. Apama generates the following code:

```
  action operation$start(action<> acknowledge) {
// BLOCKBUILDER - USER DEFINED ACTION
    isStarted := true;
    setupNewListener();
    acknowledge();
// BLOCKBUILDER - END OF USER DEFINED ACTION
  }
```

stop action

For blocks that are based on existing event definitions and are specified as input blocks, Apama generates code for a `stop` action. When the `stop` operation is invoked all active listeners are terminated. Apama generates the following code (where "`l`" is a `listener` defined elsewhere):

```
  action operation$stop(action<> acknowledge) {
// BLOCKBUILDER - USER DEFINED ACTION
    isStarted := false;
    l.quit();
    acknowledge();
// BLOCKBUILDER - END OF USER DEFINED ACTION
  }
```

send action

For blocks that are based on existing event definitions and are specified as output blocks, Apama generates code for a `send$event` action. When the `send` action is called, it sends the specified event on which the block is based. For example, with a specified event, `testEvent` (containing two fields, `name` and `IDnum`), Apama generates the following code:

```
    action operation$send$_testEvent(action<> acknowledge) {
// BLOCKBUILDER - USER DEFINED ACTION
//
// -- insert handler for invocations of operation send_testEvent --
//
      if (serialExecution) then{
         route  testEvent(parameter_name,parameter_IDnum);
      }
      else {
          enqueue testEvent(parameter_name,parameter_IDnum) to preSpawnContext;
      }
 acknowledge();
// BLOCKBUILDER - END OF USER DEFINED ACTION
     }
```

User-defined monitors or event types

If you need to add monitors or event types to a block, define them in the specified section of the block's generated EPL code:

```
// BLOCKBUILDER - USER DEFINED MONITORS
//
// -- insert any additional monitors you require --
//
// BLOCKBUILDER - END OF USER DEFINED MONITORS
```

For more information, see "Defining Monitors" on page 49.

User-defined variables

If you need to add variables to a block, define them in the specified section of the block's generated EPL code, which is the first section in the block's `#block#` event code:

```
event #block# {
// BLOCKBUILDER - USER DEFINED VARIABLES
//
// -- insert any additional variables you require --
//
// BLOCKBUILDER - END OF USER DEFINED VARIABLES
```

User-defined actions

In addition to the actions described above you can add any other actions that you require to implement the unique functionality of your block. Add additional actions at the end of the block definition file in the specified section:

```
// BLOCKBUILDER - USER DEFINED ACTIONS
//
// -- insert any additional actions required --
//
// BLOCKBUILDER - END OF USER DEFINED ACTIONS
```

Timeliness of acknowledgements

When a scenario calls an action that takes an `acknowledgement()` action parameter the scenario expects to receive a timely acknowledgement.

This means that the acknowledgement must be made within the chain of routed events that are currently being processed, starting with the event that is the immediate cause of the operation being performed. This constraint exists because the scenario is in a state of limbo while it is waiting for an acknowledgement. If another event comes into the scenario, either a control event or one that comes into one of its blocks, while the scenario is waiting for an acknowledgement then the scenario can get into an inconsistent state. For example, during a block operation, the scenario expects updates only from the block that the operation is called on.

This constraint is usually easily met. If an operation routes a request event that it expects a routed response to then the block can simply wait for that response before returning the acknowledgement to the scenario. Alternatively, the block can set up a `completed` listener for the request event. If the block does not expect a response with interesting data that it wants to reflect to output feeds then the block can immediately return the acknowledgement even if there are still routed events to be processed. It is especially important to ensure that all operations are acknowledged for all paths through the code because unacknowledged operations will cause the scenario to hang.

An example block

As an example, consider the Correlation Calculator Block, which is one of the standard blocks provided with Apama.

The Correlation Calculator Block calculates the correlation coefficient between two streams of data. The calculation can be performed over an unlimited set of data from each stream, or a set limited by number of samples or age of samples. The calculator generates output only if there is at least one suitable sample from each stream.

A correlation coefficient approaching +1.0 shows a strong correlation between the streams, a coefficient close to 0.0 shows little or no correlation between the streams and a coefficient approaching –1.0 shows an inverse correlation between the streams; for example, if one is increasing, the other is decreasing.

The topics below describe the Correlation Calculator block.

Description of the Correlation Calculator block interface

The Correlation Calculator block has the following parameters:

Parameter	Description
`period`	The maximum age of any sample that is used in the calculations, in seconds. Any samples older than this will be discarded before performing the calculation.
`size`	The maximum number of samples per stream that are used in the calculation.

One or both of the above parameters must be `0`, in which case that limit is not imposed. It is not possible to restrict the number of samples by both age and number of samples, but it is possible to remove the limit on the number of samples (thus an unbounded set of samples is kept). Note that imposing a limit after input events have been received will clear all existing samples.

The Correlation Calculator block has the following operations:

Operation	Description
`start`	Starts the calculation of coefficients. Must be called before the calculator will generate any statistics (output feed).

Operation	Description
`stop`	Stops the calculation of further coefficients. Any subsequent events on the input feeds are ignored.
`clear`	Discards all current data.

The Correlation Calculator block defines the following input feeds, each with one field:

Input feed	Fields	Description
`data1`	`value`	The first input set.
`data2`	`value`	The second input set.

Note that at least one value from each feed must have been received (and if set, within `period` seconds) before an output will be generated.

The Correlation Calculator block has the following output feed:

Output feed	Fields	Description
`statistics`	`correlation`	The correlation coefficient (between `-1.0` and `+1.0`).
	`samples`	The number of sample pairs used for this calculation.

The XML elements at the beginning of the Correlation Calculator's block definition file describe this interface. When you create your own block, Apama generates and populates these XML elements for you.

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE block SYSTEM "http://www.apama.com/dtd/bdf.dtd">
<!--Apama Block Definition File-->
<block name="Correlation Calculator">
  <version>
    <id>2.0</id>
    <date>7 May 2009</date>
    <author>Rune Madsen</author>
    <comments>Copyright(c) 2013 Software AG, Darmstadt, Germany and/or
      its licensors</comments>
  </version>
  <description>Calculates the correlation of two input data streams over a
    configurable time window and sample set size.</description>
  <properties parallel-aware="true" deprecated="false">
    <input-feeds>
      <feed name="data1" id="9578163894100102">
        <description>The first stream of numeric data to use in the correlation
          calculations</description>
        <field name="value" id="9578163894100103">
```

```
        <description>The numeric data value</description>
        <validation type="float" stringcase="mixed" trim="true" unique="false"
          mutability="mutable" />
      </field>
    </feed>
    <feed name="data2" id="9578163894100104">
      <description>The second stream of numeric data to use in the correlation
        calculations</description>
      <field name="value" id="9578163894100105">
        <description>The numeric data value</description>
        <validation type="float" stringcase="mixed" trim="true" unique="false"
          mutability="mutable" />
      </field>
    </feed>
  </input-feeds>
  <output-feeds>
    <feed name="statistics" id="9578163894100106">
      <description>Stream of correlation values generated every time a new
         data item arrives</description>
      <field name="correlation" id="9578163894100107">
        <description>The correlation of the samples in the data sets.
          Between -1 and +1.</description>
        <validation type="float" stringcase="mixed" trim="true" unique="false"
          mutability="mutable" />
      </field>
      <field name="samples" id="9578163894100108">
        <description>The number of sample pairs used in the correlation
          calculation</description>
        <validation type="integer" stringcase="mixed" trim="true"
          unique="false" mutability="mutable" />
      </field>
    </feed>
  </output-feeds>
  <parameters>
    <field name="period" id="9578163894100109">
      <description>The duration of the configurable time window given in
        seconds. Samples older than the period will be discarded from the
        data set. Set to zero to keep samples indefinitely, up to the
        maximum number of samples specified with the size parameter.
      </description>
      <validation type="float" stringcase="mixed" trim="true" unique="false"
        mutability="mutable" />
    </field>
    <field name="size" id="9578163894100110">
      <description>The maximum size of the sample set. The oldest sample will
        be replaced by the new sample when the total number of samples has
        reached this limit. Set to zero to keep all samples, unless period
        is set.</description>
      <validation type="integer" stringcase="mixed" trim="true" unique="false"
        mutability="mutable" />
    </field>
  </parameters>
  <operations>
    <operation name="start" id="9578163894100111">
      <description>Activate the correlation calculations</description>
    </operation>
    <operation name="stop" id="9578163894100112">
      <description>Pause the correlation calculations</description>
    </operation>
    <operation name="clear" id="9578163894100113">
      <description>Clear the existing sample data</description>
    </operation>
  </operations>
```

```
  </properties>
```

Description of the Correlation Calculator block EPL

After the XML elements that describe the block interface, there is a <code> element. The <code> element contains the EPL. The first section in which you can add custom EPL code is the user-defined monitors section. The Correlation Calculator block defines a few events here.

User-defined monitors and/or events

```
<code><![CDATA[// Apama generated code - ONLY EDIT INDICATED SECTIONS
// Generated code type: CALLBACK
// Generated code version: 1
// BLOCKBUILDER - USER DEFINED MONITORS

event CorrelationCalculator_DataPoint {
  float value1;
  float value2;
  float time;
}

event CorrelationCalculator_Incr {
  float x1;
  float y1;
  float x2;
  float y2;
  float xy;
  float N;
}

event CorrelationCalculator_InputData {
  float value;
  float time;
}

// BLOCKBUILDER - END OF USER DEFINED MONITORS
```

User-defined variables

After the section for user-defined monitors or events, Apama begins the event type definition that implements the block. The placeholder name of the event type is always #block#. When you inject a scenario that uses a block, the correlator replaces #block# with the actual name of the block plus a unique number that distinguishes the instance of the block from other instances.

The first section after the event declaration is for user-defined variables. Each variable is a field in the event type. The Correlation Calculator block defines a number of variables.

```
event #block# {
// BLOCKBUILDER - USER DEFINED VARIABLES
  sequence<CorrelationCalculator_DataPoint> dataset;
  boolean running;
  boolean infinite;
  CorrelationCalculator_Incr incr;

  integer MAX_INT;
  float MAX_FLOAT;
  float NO_CORRELATION;
```

```
  CorrelationCalculator_InputData inputdata1;
  CorrelationCalculator_InputData inputdata2;

  float period;
  integer size;

// BLOCKBUILDER - END OF USER DEFINED VARIABLES
```

Actions for updating output feeds

Following the user-defined variables are the variables that Apama automatically generates for every block. This includes an `integer` variable to contain the block instance ID and an `action` variable for each output feed in the block. For the Correlation Calculator block, these variables are defined as follows:

```
  integer blockInstanceId$;
  action<float,integer> sendOutput$statistics;
```

Actions for updating parameters

Next come the actions that update parameters. Apama defines the action and the block writer fills in the code that actually updates the parameter. For the Correlation Calculator block, the following actions update the `period` and `size` parameters:

```
  action update$period(float period) {
// BLOCKBUILDER - USER DEFINED ACTION
    self.period := period;
    updateInfinite();
// BLOCKBUILDER - END OF USER DEFINED ACTION
  }

  action update$size(integer size) {
// BLOCKBUILDER - USER DEFINED ACTION
    self.size := size;
    updateInfinite();
// BLOCKBUILDER - END OF USER DEFINED ACTION
  }
```

Actions for updating input feeds

Next come the actions that update input feeds. Again, Apama defines the action and the block writer fills in the code that actually does the update. For the Correlation Calculator block, the following actions update the `data1` and `data2` input feeds:

```
  action input$data1(float value) {
// BLOCKBUILDER - USER DEFINED ACTION
     if not running then {
       return;
     }
    self.inputdata1.value := value;
    self.inputdata1.time := currentTime;
    doStats1();
// BLOCKBUILDER - END OF USER DEFINED ACTION
  }

  action input$data2(float value) {
// BLOCKBUILDER - USER DEFINED ACTION
    if not running then {
      return;
    }
    self.inputdata2.value := value;
```

```
    self.inputdata2.time := currentTime;
    doStats2();
// BLOCKBUILDER - END OF USER DEFINED ACTION
  }
```

Actions for performing operations

The actions that perform operations come next. For the Correlation Calculator block, these actions are defined as follows:

```
  action operation$start(action<> acknowledge) {
// BLOCKBUILDER - USER DEFINED ACTION
    running := true;
    acknowledge();
// BLOCKBUILDER - END OF USER DEFINED ACTION
  }

  action operation$stop(action<> acknowledge) {
// BLOCKBUILDER - USER DEFINED ACTION
    running := false;
    acknowledge();
// BLOCKBUILDER - END OF USER DEFINED ACTION
  }

  action operation$clear(action<> acknowledge) {
// BLOCKBUILDER - USER DEFINED ACTION
    inputdata1.value := MAX_FLOAT;
    inputdata2.value := MAX_FLOAT;
    dataset.setSize(0);
    incr := new CorrelationCalculator_Incr;
    acknowledge();
// BLOCKBUILDER - END OF USER DEFINED ACTION
  }
```

Standard setup and cleanup actions

After defining the actions that implement the interface to the block, Apama defines the standard setup and cleanup actions that it defines in every block. These look like the following for the Correlation Calculator block. Notice that the `instancePreSpawnInit()` action has no user-defined code. The scenario calls this action on each new scenario instance. Since nothing other than what Apama automatically fills in is necessary, the user-defined section for the `instancePreSpawnInit()` action is empty.

```
  action setup() {
// BLOCKBUILDER - USER DEFINED ACTION
    MAX_INT := 0x7fffffffffffffff;
    MAX_FLOAT := 1.0e300;
    NO_CORRELATION := -2.0;
// BLOCKBUILDER - END OF USER DEFINED ACTION
  }

  action instancePreSpawnInit(integer blockInstanceId$,
      string scenarioId$,
      dictionary<string, string> userData$,
      context target,
      action<> acknowledge) {
    self.blockInstanceId$ := blockInstanceId$;
// BLOCKBUILDER - USER DEFINED ACTION
//
// -- insert pre-spawn initialisation code --
```

```
//
    acknowledge();
// BLOCKBUILDER - END OF USER DEFINED ACTION
  }

  action instancePostSpawnInit(integer blockInstanceId$,
      string ownerId$,
      string scenarioId$,
      dictionary<string, string> userData$,
      action<> acknowledge,
      float period,
      integer size,
      action<float,integer> $$sendOutput$statistics) {
    self.$$sendOutput$statistics := $$sendOutput$statistics;
// BLOCKBUILDER - USER DEFINED ACTION
    self.period := period;
    self.size := size;
    inputdata1.value := MAX_FLOAT;
    inputdata2.value := MAX_FLOAT;
    updateInfinite();
    acknowledge();
// BLOCKBUILDER - END OF USER DEFINED ACTION
  }

  action cleanup() {
// BLOCKBUILDER - USER DEFINED ACTION
// BLOCKBUILDER - END OF USER DEFINED ACTION
  }
```

User-defined actions

Finally, any additional user-defined actions come at the end of the block definition file. For the Correlation Calculator block, these actions contain the unique functional content of this block.

```
// BLOCKBUILDER - USER DEFINED ACTIONS
  action doStats1() {
    if inputdata2.value != MAX_FLOAT then {
      doStatsCommon(inputdata2.time);
    }
  }

  action doStats2() {
    if inputdata1.value != MAX_FLOAT then {
      doStatsCommon(inputdata1.time);
    }
  }

  action doStatsCommon(float timestamp) {
    float N;
    float Mx;
    float sum, div;
    float correlation;

    if not infinite then {
      // Remove expired samples
      removeExpiredSamples();

      // Add new pair to dataset
      dataset.append(
        CorrelationCalculator_DataPoint(inputdata1.value,
            inputdata2.value, timestamp));
    }
```

```
    incrAdd(inputdata1.value, inputdata2.value);

    // Calculate correlation
    N := incr.N;
    Mx := incr.x1 / N;
    sum := incr.xy - Mx*incr.y1;
    div := (incr.x2 - Mx*incr.x1) * (incr.y2 - incr.y1*incr.y1/N);
    if sum = 0.0 then {
      correlation := 0.0;
    } else
    if div != 0.0 then {
      correlation := sum / div.sqrt();
    } else {
      correlation := NO_CORRELATION;
    }
    sendOutput$statistics(correlation, N.floor());
  }

  action removeExpiredSamples() {
    float timeLimit := -MAX_FLOAT;
    integer sizeLimit := MAX_INT;
    if self.period > 0.0 then {
      timeLimit := currentTime - self.period;
    } else
    if self.size > 0 then {
      sizeLimit := self.size;
    }
    while (dataset.size() > 0 and dataset[0].time <= timeLimit)
      or dataset.size() >= sizeLimit {
      incrRemove(dataset[0].value1, dataset[0].value2);
      dataset.remove(0);
    }
  }

  action updateInfinite() {
    boolean wasInfinite := infinite;
    // Set infinite to true if period/size is infinite
    infinite := self.period <= 0.0 and self.size <= 0;
    if infinite then {
      dataset.setSize(0);
    } else
    if wasInfinite then {
      // Infinite has gone from true to false,
      // must reset incremental data
      incr := new CorrelationCalculator_Incr;
    }
  }

  action incrAdd(float x, float y) {
    incr.x1 := incr.x1 + x;
    incr.y1 := incr.y1 + y;
    incr.x2 := incr.x2 + x*x;
    incr.y2 := incr.y2 + y*y;
    incr.xy := incr.xy + x*y;
    incr.N  := incr.N + 1.0;
  }

  action incrRemove(float x, float y) {
    incr.x1 := incr.x1 - x;
    incr.y1 := incr.y1 - y;
    incr.x2 := incr.x2 - x*x;
    incr.y2 := incr.y2 - y*y;
    incr.xy := incr.xy - x*y;
```

```
    incr.N  := incr.N - 1.0;
  }
// BLOCKBUILDER - END OF USER DEFINED ACTIONS
}]]></code>
</block>
```

19 Working with Blocks Created from Scenarios

In the Event Modeler, you can export a scenario to create a block. You can then use this block in other scenarios. The topics below provide information and instructions for using blocks that you create from scenarios.

For a sample scenario that uses a block that was created from a scenario, open the `ScenarioAsBlockExample.sdf` file in the Event Modeler. This file is in the `samples\scenarios` directory of your Apama installation directory.

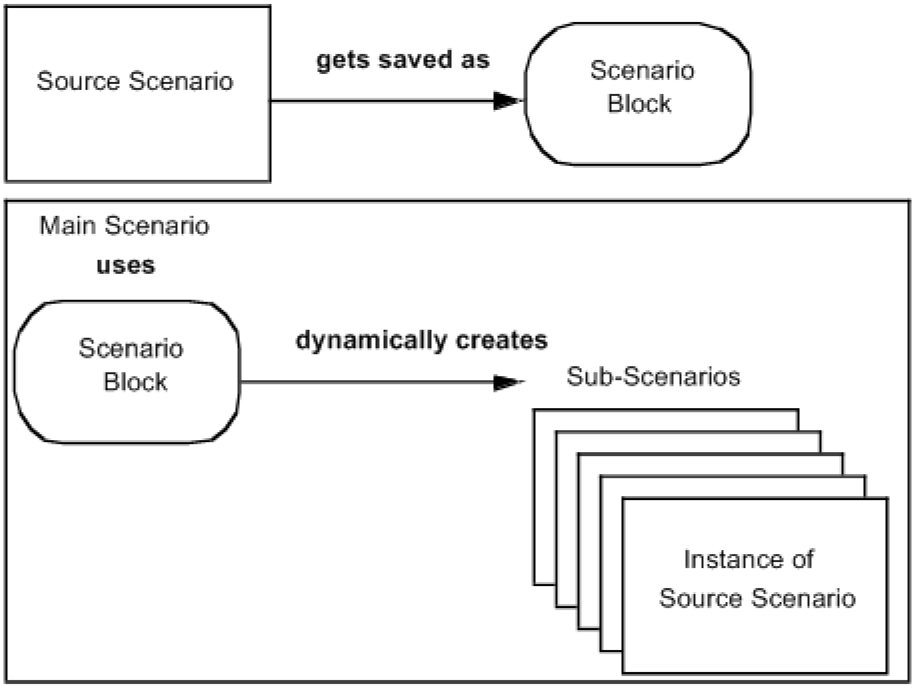
You cannot create a block from a parallel-aware scenario. Nor can you create a block from a non-parallel-aware scenario and then mark that block as parallel-aware.

Terminology for using scenario blocks

To use blocks created from scenarios, you must understand the following terms:

- **Source scenario.** A scenario block that you export to create a block.
- **Scenario block.** A block that you create from a scenario by selecting **Scenario > Generate Block** in the Software AG Designer menu and then saving and building the project. Alternatively, you can select **Software AG > Export as Block** from the **File > Export** dialog.
- **Main scenario.** A scenario that uses a scenario block.
- **Sub-scenario.** A source scenario instance that a scenario block dynamically creates. When you use a scenario block in a main scenario, the scenario block manages sub-scenarios according to the rules you define in the main scenario. The operations a scenario block can perform on a sub-scenario include `create`, `retrieve`, `commit`, `delete`, `delete all`, `iterate`, and `next`.
- **Context instance.** Also referred to as the context sub-scenario. This is the current sub-scenario. A scenario block can create any number of sub-scenarios. However, at any point in time, a main scenario can modify only the context instance. Certain operations make a particular sub-scenario the context instance. You can also set the value of the scenario block `instance id` parameter to the instance ID for a particular sub-scenario and then call the scenario block `retrieve` operation to make that sub-scenario the context instance.

The following figure shows the relationships among these items.



Benefits of scenario blocks

The benefit of using a scenario block is that you can write a scenario once and then use it any number of times without having to manually create instances of that scenario. Instead, in your main scenario, you define rules that create and manage the instances of the source scenario. When a main scenario uses a scenario block, the scenario block dynamically creates and manages instances of the source scenario according to the rules you define in the main scenario. The main scenario functions as a management tool for the sub-scenarios. This allows self-contained units of work that start and finish within the main scenario.

A main scenario can use several different scenario blocks. This lets you define multiple source scenarios, and then pull them together into a single main scenario.

Like all blocks, using scenario blocks makes propagating updates to the source scenario easier. For example, suppose you have 10 instances of a scenario. If you need to change that scenario, you must also update the 10 instances. Now suppose you have a main scenario that uses a scenario block to create 10 sub-scenarios. If you need to modify the source scenario, you only need to also update the main scenario that uses the scenario block.

Steps for using scenario blocks

The general steps for using scenario blocks are as follows:

1. Define and save the source scenario.

2. Generate a block from the source scenario to create your scenario block. This makes your new scenario block available for selection in the **Catalogs** tab.
3. Define a main scenario.
4. Add your scenario block to your main scenario.
5. In your main scenario, define rules that refer to your scenario block.
6. Deploy the source scenario. You can do this in Software AG Designer, or by injecting the `.sdf` file into the correlator with the `engine_inject` utility. If the source scenario requires any event types or other EPL to be injected before you can run it, be sure to inject those items before you try to run the main scenario.
7. Deploy the main scenario.

Background for using scenario blocks

To use scenario blocks in a main scenario, it is helpful to understand the implementation model. Consider a deck of cards with each card stacked on top of the other cards. Each card represents a sub-scenario, which is an instance of the source scenario.

When a sub-scenario generates an update event, that sub-scenario pops to the top of the stack of sub-scenarios, like you might move a card to the top of a deck. When a sub-scenario is at the top of the stack of sub-scenarios, you can access the values associated with that sub-scenario. Any time you can access the values associated with a sub-scenario, that sub-scenario is the context sub-scenario. For example, when a sub-scenario completes its processing, the scenario block sends an update event to its `output` feed. This update event makes the completed sub-scenario the context instance. Consequently, you can do something like this:

```
When  instance status from MyScenarioBlock(output) = "ENDED"
Then  quantity = quantity + subquantity from MyScenarioBlock(output)
```

If `quantity` is a variable in the main scenario, this action increases the value of the `quantity` variable upon the completion of each sub-scenario. You do not need to first retrieve a sub-scenario to obtain the value of its `subquantity` variable.

As you can see, one way to operate on a particular sub-scenario is to wait for that sub-scenario to be the context sub-scenario. Another way to operate on a particular sub-scenario is to make that sub-scenario be the context sub-scenario. You do this by specifying the context ID of the sub-scenario you want to operate on and then calling the `retrieve` operation.

A main scenario can use two or more instances of the same scenario block. Each scenario block manages only the sub-scenarios it creates. However, you can change this according to the value you specify for the scenario block `inheritExternalInstances` parameter. See "Inheriting sub-scenarios" on page 631.

Saving scenarios as block templates

To use a source scenario as a block, you must save it as a block, which creates a new block template.

To create a block template from a scenario

1. In Event Modeler, open the scenario from which you want to create a block.
2. Ensure that the scenario is complete and correct.
3. In the Event Modeler menu bar, select **Scenario** and ensure that there is a check next to **Generate Block**.

Whenever you save and/or build the project, Event Modeler generates a block template from this scenario. You can see the block template in the `Generated scenario blocks` catalog in your project's **Catalogs** tab. The name of the block template is the name of the scenario with the `.bdf` extension. If you have already saved a version of this scenario as a block, Event Modeler sets the version field to the revision level of the latest scenario block exported from this scenario.

Incrementing scenario block version numbers

To increment the version number, you export one or more scenarios as blocks as described below.

To export scenario blocks

1. From the Software AG Designer menu, select **File > Export**.
2. In the Export dialog, expand **Software AG**, click **Export as Block**, and click **Next**.
3. In the **Project:** field, select the project that contains the scenario(s) you want to export.
4. In the **Export** column, select one or more scenarios to export as blocks and click **Next**.
5. Select the folder in which you want to save your new block. By default, Event Modeler saves scenario blocks in the `catalogs\Generated scenario blocks` directory of your project directory.

   The name of the new block is always the name of the scenario with the `.bdf` extension. If you have already saved a version of this scenario as a block, Event Modeler sets the version field to the revision level of the latest scenario block exported from this scenario. To save a newer version, increment the version number.

   To create a new folder in which to store your new scenario block, click **New...**, specify the name of the new folder, and click **OK**.

   To add a new catalog in which to store your new scenario block, switch to **Apama Developer** perspective, right-click the project name, select **Properties**, and click the **Blocks** tab. Then return to the Export As Block dialog.

6. Click **Export**. Your new scenario block is immediately available for selection from the **Catalogs** tab.

You can nest a scenario block in another scenario block. In other words, you can export a main scenario as a block, and use the new scenario block in some other main scenario.

Adding a scenario block to a main scenario

You add a scenario block to a main scenario as you would add any other block to a scenario.

To add a scenario block to a main scenario

1. In the **Catalogs** tab, select the scenario block you want to use in your main scenario.
2. In the **Catalogs** tool bar, click the Add Selected Block Template button. The scenario block you selected now appears in the **Blocks** tab.

You can now use the scenario block as you would any other block.

Examining a scenario block's source scenario

After you add a scenario block to a main scenario, you might like to look at the scenario block's source scenario.

To examine the source scenario

1. Select the scenario block in the **Blocks** tab.
2. Right-click to display the context menu.
3. Select **Open Source Scenario...**.

This displays a separate copy of Event Modeler with the source scenario open.

Descriptions of scenario block parameters

A scenario block has the following parameters:

- `instance id` — This is a string that identifies a sub-scenario. An instance ID must be unique within a main scenario. In the main scenario, you set the value of the `instance id` parameter to indicate the sub-scenario that is the target of the next scenario block operation.
- `deleteChildrenOnTerminate` — Boolean that indicates whether all sub-scenarios terminate when the main scenario terminates. The default behavior is that sub-scenarios remain active if the main scenario terminates. That is, the default is false.

  If the main scenario inherits sub-scenarios from other main scenarios, the inherited sub-scenarios would also terminate when the value of the `deleteChildrenOnTerminate` parameter is true.

- `inheritExternalInstances` — Indicates whether the main scenario inherits sub-scenarios created by other main scenarios. When the main scenario inherits sub-scenarios, it means that the main scenario can operate on inherited sub-scenarios as though it had created those sub-scenarios. For details, see "Inheriting sub-scenarios" on page 631.
- *`input-variables`* — There is one parameter for each source scenario variable that is marked as input. For example, if the source scenario has a `quantity` input variable, then a scenario block created from that source scenario has a `quantity` parameter. The recommendation is that you mark a source scenario variable as input or output and not as both.

When you add a scenario block to a main scenario, the initial value of the `instance id` parameter is an empty string, `""`. When you call the `create` operation on a scenario block and the value of the `instance id` parameter is an empty string, the scenario block generates the ID that it assigns to the new sub-scenario. This ensures that the instance ID is unique within the main scenario. You can obtain the assigned instance ID from the scenario block `output` feed.

Generated instance IDs would look something like the following for a scenario block named `MyScenarioBlock`:

```
MyScenarioBlock1;1
MyScenarioBlock1;2
MyScenarioBlock1;3
```

and so on

When you want to specify the ID that the scenario block assigns to a new sub-scenario, set the value of the `instance id` parameter and then call the `create` operation. If you specify an instance ID that already exists, and call the `create` operation, the `create` operation fails.

Descriptions of scenario block operations

You can call the following operations on a scenario block:

- `create` — Creates a sub-scenario.
- `delete` — Deletes the sub-scenario identified by the value of the `instance id` parameter.
- `delete all` — Deletes all sub-scenarios that this scenario block manages. The sub-scenarios that a scenario block manages are the sub-scenarios that the scenario block created and has not yet deleted. A main scenario can use two or more instances of the same scenario block. Each scenario block manages only the sub-scenarios it creates. In a main scenario, the `A1` scenario block has no information about sub-scenarios created by the `A2` scenario block.
- `retrieve` — Retrieves the sub-scenario identified by the value of the `instance id` parameter. The retrieved sub-scenario becomes the context instance. To modify any values associated with a sub-scenario, the sub-scenario must be the context instance.

The `retrieve` operation does not modify the current values of the scenario block's parameters.

- `commit` — Changes and saves the values of the context sub-scenario's input variables that correspond to scenario block parameters whose values have changed since the previous `create`, `iterate`, `next`, `retrieve`, or `commit` operation, whichever came last.
- `iterate` — Starts an iteration through the sub-scenarios that this scenario block manages. After you call the `iterate` operation, the first sub-scenario that the block created is the context sub-scenario. You do not need to call the `next` operation to retrieve the first sub-scenario. To restart an iteration, call the `iterate` operation again.
- `next` — Moves to the next sub-scenario in the iteration and makes that sub-scenario, if there is one, the context instance. The `next` operation visits the sub-scenarios in the order in which the scenario block created them.

  Call this operation after a call to the `iterate` operation. When you call `next`, if there is a valid next instance, the scenario block sends an event to the `output` feed. You can obtain the instance ID for the new context instance from this event.

  There are no timing issues because the scenario block immediately performs the `next` operation and sends an event to the `output` feed. That is, you do not need to wait for the `next` operation to complete before you issue an action that operates on the sub-scenario that is the context instance as a result of the `next` operation.

Descriptions of scenario block feeds

Scenario blocks have no input feeds. Scenario blocks have three output feeds:

- `output` — Provides updated information about a sub-scenario. The scenario block sends output to this feed whenever the value of a sub-scenario variable changes. The main scenario that created the sub-scenario, and any other main scenarios that inherit the sub-scenario each get an `output` feed to indicate the changes.
- `iteration ended`— Indicates whether an iteration is complete.
- `group info` — Provides cumulative information about all sub-scenarios managed by this scenario block.

The following table describes the fields in each output feed.

Feed	Fields	Description
`output`	`instance id`	String that identifies the sub-scenario that changed.
	`instance owner`	Identifies the user account under which the main scenario that is using this scenario block was created.

Feed	Fields	Description
	`instance created`	Boolean value that is true after the sub-scenario is created.
	`instance ended`	Boolean value that is true after the sub-scenario stops processing. This can happen because it fails, is deleted, or ends its normal processing.
	`instance status`	Enumerated string field that indicates the status of the sub-scenario. The value is one of the following: ■ `RUNNING` — The sub-scenario has been created and has not ended, failed, or been deleted. ■ `ENDED` — The sub-scenario has ended normally; it reached its end state. ■ `FAILED` — The scenario block failed to create the sub-scenario, perhaps because of a duplicate instance ID. Or, the sub-scenario failed because something went wrong while it was running. For example, the sub-scenario tried to divide by zero. ■ `DELETED` — The main scenario called the delete operation, which removes the sub-scenario from the correlator. Or, some other external entity deleted the sub-scenario from the correlator. ■ `UNKNOWN` — The status of the sub-scenario is unknown. For example, the status is unknown after you invoke the create operation and before the scenario block actually creates the sub-scenario.
	`variables`	In the `output` feed, there is a field for each source scenario variable. Each of these fields contains the current value of the variable for the identified sub-scenario.
`iteration ended`	`complete`	Boolean value that is true when iteration through the sub-scenarios that this scenario block manages is complete. When you call the `next` operation, and there is not another sub-

Feed	Fields	Description
		scenario in the iteration, then the iteration ended feed outputs a value of true for the complete field.
group info	total created	Integer that indicates how many sub-scenarios this scenario block has created since it began processing.
	total deleted	Integer that indicates how many sub-scenarios this scenario block has deleted since it began processing.
	total loaded	Integer that indicates how many sub-scenarios created by this scenario block are loaded in the correlator. This includes sub-scenarios that are running, plus sub-scenarios that failed while they were running, plus sub-scenarios that have ended. This number does not include sub-scenarios that the scenario block tried to create and failed to create. In other words, the total loaded is equal to the total created minus the total deleted.
	number running	Integer indicating how many sub-scenarios created by this scenario block are running.
	number ended	Integer indicating how many sub-scenarios created by this scenario block are still loaded but have ended.
	number failed	Integer that indicates how many sub-scenarios created by this scenario block are still loaded but have failed.
	summary	Convenience string that summarizes the information provided by the other group info fields. For example: "Total Created: 100, Total Deleted: 40, Total Loaded: 60, Number Running: 10, Number Ended: 48, Number Failed: 2".

Inheritance affects the totals in the group info feed as follows:

- total created indicates the number of sub-scenarios that were created and that the main scenario could operate on. This number only goes up. This number includes sub-scenarios created by this main scenario as well as inherited sub-scenarios created by other main scenarios.

- `total deleted` indicates the number of sub-scenarios that were deleted while the main scenario could operate on them. This number only goes up. This number includes sub-scenarios created by this main scenario as well as inherited sub-scenarios.
- `total loaded`, `total running`, `number ended`, and `number failed` indicate the number of sub-scenarios that are currently loaded in the correlator and that the main scenario can operate on. This number goes up and down.

For example, suppose `inheritExternalInstances` is set to `Owner` for `MainScenarioA`. Now suppose `MainScenarioB`, which has the same owner as `MainScenarioA`, creates a new sub-scenario. The `total created` field for `MainScenarioA` gets incremented by 1. Now suppose that `MainScenarioC`, which has a different owner, creates the same type of sub-scenario. The `total created` field for `MainScenarioA` would not get incremented.

Following is an example of an `output` feed. Suppose the source scenario defines the following variables:

- `SYMBOL` (Input)
- `SIDE` (Input)
- `PRICE` (Output)
- `QUANTITY SOLD` (Output)

The `output` feed would have the following fields:

```
instance id
instance owner
instance created
instance ended
instance status
SYMBOL
SIDE
PRICE
QUANTITY SOLD
```

Setting parameters before creating sub-scenarios

When you add a scenario block to a main scenario, the scenario block's parameters have default values according to their types. For example, the default value of a string parameter is an empty string (`""`).

After you add a scenario block to a main scenario, you can set initial values for the scenario block's parameters in the **Blocks** tab. However, it is important to understand that the values you set are initial values and not default values. During execution of a main scenario, if you want to change the value of a parameter, you must explicitly do so. After you modify the value of a parameter, if you require the parameter to have its initial value, you must explicitly set it to its initial value.

When you call the `create` operation, the newly created instance's input variables take their values from the current values of the corresponding scenario block parameters. The current values of the parameters might or might not be the initial values; if you modified a parameter value, the parameter has the last value that was assigned to it. If you then call the `create` operation, the scenario block assigns that last value to the sub-scenario's corresponding input variable.

To create a sub-scenario that has the initial parameter values for its input variables, do one of the following:

- If the main scenario has not made any changes to the scenario block's parameter values, call the `create` operation.
- If the main scenario has made changes to parameter values, explicitly specify the value of each parameter, and then call the `create` operation. This is the safest way to ensure that you create the sub-scenario with the values you want. A common mistake is to forget that you changed the value of a parameter in the course of some work. If you then create a new sub-scenario, it has the updated value of the parameter and not the initial value.

For example, consider the following set-up: `MyScenarioBlock` has three parameters that correspond to three input variables: `Input1`, `Input2`, and `Input3`. The initial value of each parameter is `blue`. The value of the `instance id` parameter is the empty string, which means that the scenario block generates the instance IDs for you. In a rule, you can set parameter values and create sub-scenarios as follows:

`When true`
`Then Input1 = green`
`Then create [MyScenarioBlock]`
	Creates the `MyScenarioBlock1;1` instance. The values of the parameters and the values of the input variables in this instance are `green`, `blue`, and `blue`.

`Then Input2 = purple` `Then create [MyScenarioBlock]`	Creates the `MyScenarioBlock1;2` instance. The values of the parameters and the values of the input variables in this instance are `green`, `purple`, and `blue`.
`Then Input3 = white` `Then create [MyScenarioBlock]`	Creates the `MyScenarioBlock1;3` instance. The values of the parameters and the values of the input variables in this instance are `green`, `purple`, and `white`.
`Then instance id = MyScenarioBlock1;2` `Then retrieve [MyScenarioBlock]`	Makes the second created sub-scenario the context instance. The variables in this instance have the values `green`, `purple`, and `blue`. Note that this is not the same as the

	current parameter values, which are `green`, `purple`, and `white`. The `retrieve` operation does not modify the current values of the scenario block's parameters.
`Then  Input2 = gold` `Then  commit [MyScenarioBlock]`	After the `commit` operation, the values of this sub-scenario's input variables are `green`, `gold`, and `blue`. The values of the corresponding scenario block parameters are `green`, `gold`, and `white`. The `commit` operation modifies only the context instance. It does not modify any other sub-scenarios. The `commit` operation makes only those changes made since the `retrieve` operation. For example, it does not change the value of `Input3` to `white`.
`Then  create [MyScenarioBlock]`	Creates the `MyScenarioBlock1;4` instance. The values of the input variables in this instance are `green`, `gold`, and `white`, which are the current values of the corresponding parameters.

Creating sub-scenarios

The scenario block `create` operation creates a new sub-scenario with the current values of the scenario block's input-variables parameters. A sub-scenario is an instance of the source scenario. Call this operation for each sub-scenario you want to create.

You can have any number of sub-scenarios running in parallel. You do not need to wait for one sub-scenario to complete processing before you create another sub-scenario. When you invoke the `create` operation, the scenario block immediately sends an update event to its `output` feed. The fields in this event have the following values:

- `instance id` — This field provides the instance ID of the sub-scenario being created. This is either the instance ID you specified as the value of the `instance id` parameter before you called the `create` operation, or it is the instance ID generated by the scenario block if the value of the `instance id` parameter was an empty string. For the format of a generated instance ID, see "Descriptions of scenario block parameters" on page 620.
- `instance created` — This field is false because the scenario block has not yet created the new sub-scenario.

- `instance ended` — This field is also false.
- `instance status` — This field has a value of `UNKNOWN` because, again, the scenario block has not yet created the new sub-scenario.

In addition, the `output` feed contains a field for each variable that the source scenario defines.

As soon as the scenario block actually creates the new sub-scenario, it sends another event to the `output` feed. This time, if creation was successful, the `instance created` field is true, and the `instance status` field is `RUNNING`. For example, you might want to do something like this:

```
State: Step 1
When  true
Then  create [MyScenarioBlock]
Then  move to state [Step 2]
State: Step 2
When  instance created from MyScenarioBlock (output)
Then  status = "Instance created successfully"
```

When the scenario block sends the first event after you invoke the `create` operation, that event indicates that the sub-scenario you are creating is the context sub-scenario. For example, to issue two orders in sequence you can specify the following:

```
State 1
When  true
Then  Symbol from MyScenarioBlock = "APMA"
Then  create [MyScenarioBlock]
Then  continue
When  instance status from MyScenarioBlock(output) = "ENDED"
Then  Quantity = Quantity + Quantity from MyScenarioBlock(output)
Then  Symbol from MyScenarioBlock = "MSFT"
Then  create [MyScenarioBlock]
Then  move to state [State 2]
State 2
When  instance status from MyScenarioBlock(output) = "ENDED"
               (Note that this now reflects the second sub-scenario created.)
Then  Quantity = Quantity + Quantity from MyScenarioBlock(output)
```

Alternatively, you can do it this way:

```
When  true
Then  Symbol from MyScenarioBlock = "APMA"
Then  create [MyScenarioBlock]
Then  Symbol from MyScenarioBlock = "MSFT"
Then  create [MyScenarioBlock]
Then  Symbol from MyScenarioBlock = "ORCL"
Then  create [MyScenarioBlock]
```

To operate on a sub-scenario that you just created, you must wait for the value of the `instance status` field to be `RUNNING`.

Deleting sub-scenarios

To delete a sub-scenario when it reaches its end state

1. Check the `output` feed for a true value for the `instance ended` field.

2. Call the `delete` operation.

The output event that the scenario block sends to its output feed to indicate that the instance has finished processing also makes the completed instance the context instance. Consequently, you do not need to set the `instance id` parameter before you call the `delete` operation.

Unconditionally deleting a sub-scenario

To unconditionally delete a sub-scenario

1. Set the `instance id` parameter to the instance ID of the sub-scenario you want to delete.
2. Call the `retrieve` operation.
3. Call the `delete` operation.

Deleting all sub-scenarios

To delete all sub-scenarios that this scenario block created but has not yet deleted

1. Call the `delete all` operation.
2. Watch the `group info` feed's `total loaded` field for a value of `0`.

Modifying sub-scenario input variable values

To modify the value of one of a sub-scenario's input variables

1. Set the `instance id` parameter to the instance ID of the sub-scenario whose input variable you want to change.
2. Call the `retrieve` operation so that the sub-scenario you want to modify is the context instance.
3. Set the value of the scenario block's parameter that corresponds to the input variable you want to change. You can do this for each input variable you want to change.
4. Call the `commit` operation to save your changes. This does the following:
   - Updates only the sub-scenario identified by the `instance id` parameter.
   - Updates each input variable that corresponds to a scenario block parameter that you modified since the `retrieve` operation.
   - Sends output to the `output` feed to indicate the current variable values.

Iterating through sub-scenarios

To iterate through the sub-scenarios that a particular scenario block manages, you can do something like the following.

To iterate through sub-scenarios

1. In `State 1`, call the `iterate` operation to start an iteration. After you call `iterate`, the first sub-scenario that the block created becomes the context instance.
2. Move to `State 2`.
3. In `State 2`, determine whether you are done iterating through the sub-scenarios.
   a. If the value of the `complete` field in the `iteration ended` output feed is true, then you are done iterating. Move to `State 3`.
   b. If there are no sub-scenarios, the value of the `complete` field is true immediately after calling the `iterate` operation.
   c. If the value of the `complete` field in the `iteration ended` output feed is false, then you are not done iterating. Do the following:
      - Do something. For example, aggregate some quantity.
      - Call the `next` operation to make the next sub-scenario the context instance. The `iterate` operation visits the sub-scenarios in the order in which they were created.
      - Move to `State 2`.

Following are rules that perform these steps:

```
State 1
  When  true
  Then  iterate [MyScenarioBlock]
  Then  move to State 2
State 2
  When  complete from MyScenarioBlock(iteration ended)
  Then  move to State 3
  When  true
  Then  Quantity = Quantity + Quantity from MyScenarioBlock(output)
  Then  next [MyScenarioBlock]
  Then  Move to State 2
```

In your main scenario, you might want to start the iteration and perform the iteration in a single state. One way to do this is to use a Boolean variable that indicates whether an iteration is in progress. In the following example, `iterating` is a Boolean variable:

```
Iterate State
  When  not iterating
  Then  iterating = true
  Then  iterate [MyScenarioBlock]
  Then  continue
  When  complete from MyScenarioBlock(iteration ended)
  Then  iterating = false
  Then  Move to AnotherState
  When  true
  Then  Quantity = Quantity + Quantity from MyScenarioBlock(output)
  Then  next [MyScenarioBlock]
  Then  Move to Iterate State
```

There is no significant performance advantage of using one of the above iteration techniques rather than the other. Choose the simplest approach for your Scenario. To restart an iteration, call the `iterate` operation.

Note: You might find it convenient to use the Filtered Summary block instead of an iteration. The Filtered Summary block can calculate totals and averages across sub-scenarios. For any other calculations, you would need to iterate through sub-scenarios. See the "Filtered Summary v2.0" on page 568 for details.

Obtaining variable values from sub-scenarios

Because a sub-scenario is an instance of its source scenario, each sub-scenario contains the variables defined in its source scenario. To obtain the current value of a sub-scenario's variable, check the scenario block's `output` feed. The `output` feed contains a field for each source scenario variable. The scenario block updates its `output` feed whenever there is a change to the value of a sub-scenario variable.

Linking sub-scenarios with other blocks

You can share sub-scenario instance IDs with other blocks. For example, the `Wait` block supports multiple concurrent timers. You could assign an ID to each timer and then use that same ID to create a sub-scenario. You could do this multiple times. When a timer fires, you can use the ID it reports to retrieve the associated sub-scenario and perform some operation on it, such as deleting it. For example:

```
When  time up from Wait (timer)
Then  instance id from MyScenarioBlock = timer id from Wait (timer)
Then  retrieve [MyScenarioBlock]
Then  continue
When  instance status from MyScenarioBlock (output) is equal to "RUNNING"
Then  move to state[next]
```

Inheriting sub-scenarios

A scenario block has the `inheritExternalInstances` parameter, which indicates whether the main scenario inherits sub-scenarios created by other main scenarios. Inherited sub-scenarios are always

- Loaded in the correlator
- Created by the same type of scenario block as the scenario block for which you are setting the parameter.

When the main scenario inherits sub-scenarios, it means that the main scenario can operate on inherited sub-scenarios as though it had created those sub-scenarios. For example, if the main scenario iterates over its sub-scenarios, the iteration includes inherited sub-scenarios.

Description of inheritExternalInstances values

The `inheritExternalInstances` parameter has one of the following values:

- `None` — The main scenario can operate on only the sub-scenarios it creates. This is the default.
- `Owner` — The main scenario can operate on sub-scenarios that have the same owner as the main scenario.

  Every main scenario is created under a particular user account. This account is the owner of the main scenario and consequently it is also the owner of each sub-scenario that the main scenario creates. Each scenario block has an `instanceowner` output field that indicates the owner.
- `All` — The main scenario can operate on all sub-scenarios created by scenario blocks that are the same type as the scenario block for which you are setting the `inheritExternalInstances` parameter. It does not matter which main scenario created the sub-scenario or which account owns the sub-scenario.

Notes for setting the inheritExternalInstances parameter

You can change the value of the `inheritExternalInstances` parameter during Scenario execution. When you do, the new value takes effect immediately. Likewise, as other main scenarios create sub-scenarios, a main scenario might inherit those sub-scenarios if it has a value of `Owner` or `All` for its `inheritExternalInstances` parameter.

When a main scenario changes the value of the `inheritExternalInstances` parameter, the scenario block searches within the correlator for sub-scenarios that the main scenario now inherits. For each sub-scenario that the scenario block finds, it sends data to its `output` feed. For example, if the scenario block finds five sub-scenarios that the main scenario now inherits, the scenario block sends five sets of data to its `output` feed. The scenario block also sends data to its `group info` feed that includes the inherited sub-scenarios in the counts. Subsequently, if any main scenarios create or terminate sub-scenarios that another main scenario inherits, or if any inherited sub-scenarios fail, the scenario block in the inheriting main scenario sends data to its `output` feed just as if the inheriting main scenario had created the sub-scenario.

A particular main scenario does not need to create any sub-scenarios before it can inherit sub-scenarios created by other main scenarios. For example, you might define a scenario block whose only purpose is to monitor inherited sub-scenarios and perform some sort of aggregation or analysis. Or, you can define a scenario block with true as the value of the `deleteChildrenOnTerminate` parameter. When you want to terminate all instances of that type of sub-scenario you need to only terminate one main scenario.

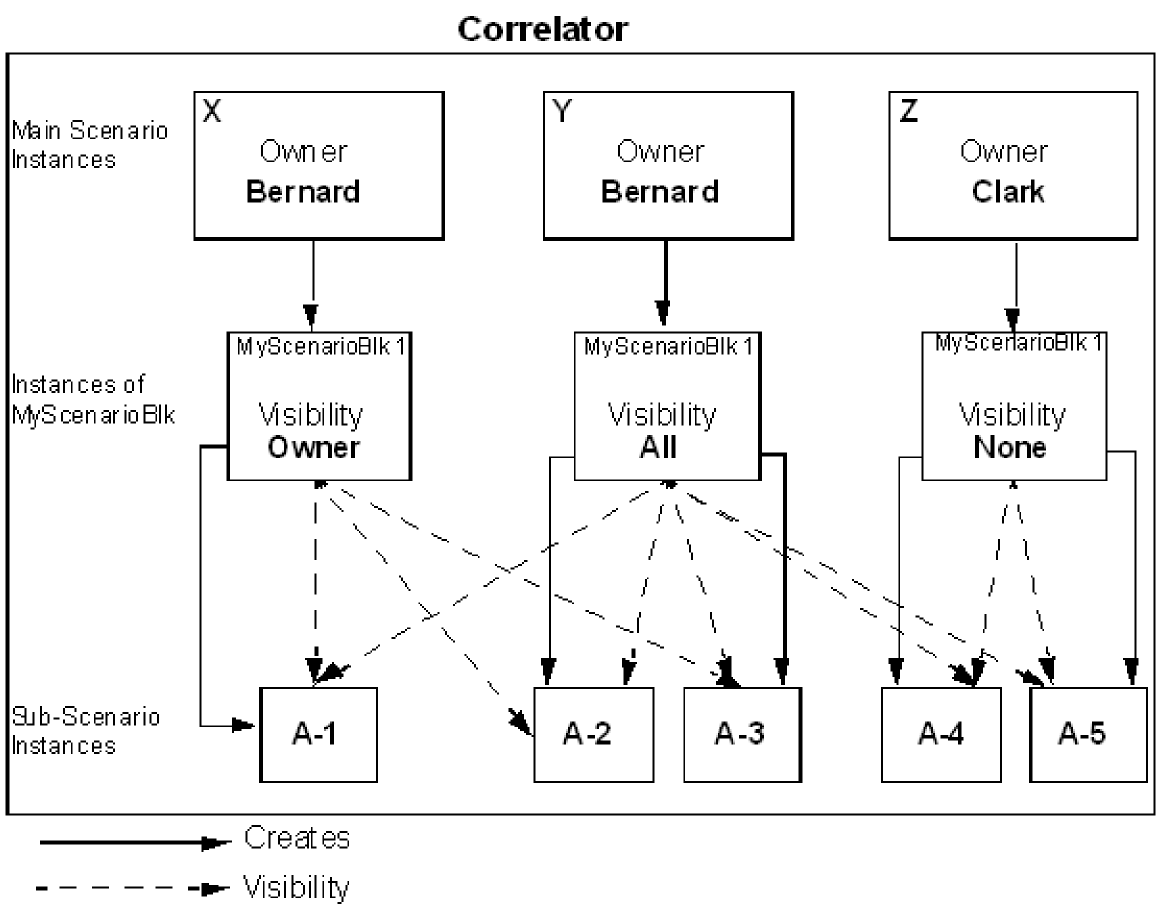
Keep in mind that inherited sub-scenarios are shared by more than one main scenario. That means that more than one main scenario can operate on the same sub-scenario. Be sure to consider this when you design your application.

Example of inheriting sub-scenarios

The following figure illustrates how the `inheritExternalInstances` parameter works. Each main scenario is owned by the user account under which it was created. When a main scenario inherits a sub-scenario, the inherited sub-scenario is visible to the main scenario.

Remember that inherited sub-scenarios are always of the same type as the scenario block for which you are setting the `inheritExternalInstances` parameter. In the following figure, the scenario blocks are each shown as `MyScenarioBlk 1`. They could of course have been shown as `MyScenarioBlk 2`, `MyScenarioBlk 3`, and `MyScenarioBlk 5`, or any other similar combination. The important point is that they are all instances of `MyScenarioBlk`. In the figure,

- Main scenario `X` can operate on sub-scenarios `A-1`, `A-2`, and `A-3`.
- Main scenario `Y` can operate on sub-scenarios `A-1`, `A-2`, `A-3`, `A-4`, and `A-5`.
- Main scenario `Z` can operate on sub-scenarios `A-4` and `A-5`.



Observing changes in sub-scenarios

The Change Observer block watches a set of sub-scenarios for changes in the value of one of the sub-scenario variables. You specify which variable you want to watch. When the value changes, the Change Observer block sends data to its `change` output feed. The output feed indicates the old value and the new value. You use one Change Observer block for each variable that you want to observe. See "Change Observer v2.0" on page 566 for details.

For example, suppose your main scenario uses the Trader scenario block and the Price Checker scenario block. The Trader scenario block output fields include:

- `instance id [string]`
- `instance owner [string]`
- `instance created [Boolean]`
- `instance ended [Boolean]`
- `instance status [UNKNOWN, RUNNING, ENDED or FAILED]`
- `trading [Boolean]`

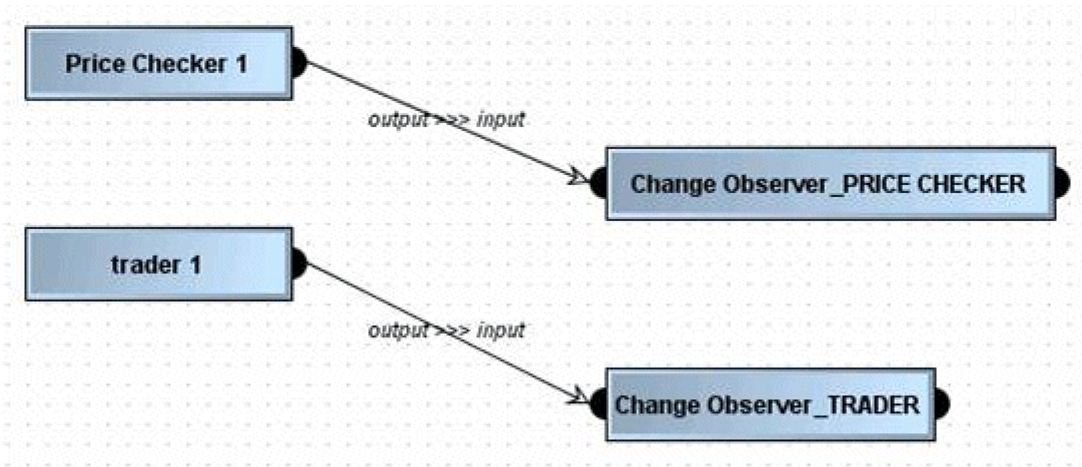
The Price Checker scenario block output fields include the following:

- `instance id [string]`
- `instance owner [string]`
- `instance created [Boolean]`
- `instance ended [Boolean]`
- `instance status [UNKNOWN, RUNNING, ENDED or FAILED]`
- `price [number]`

In your main scenario, you create several Trader sub-scenarios — each one trades in a different market. When a Trader sub-scenario finishes trading, it sends data to its output feed and this data includes `trading=false`.

You also create several Price Checker sub-scenarios — one for each type of stock symbol you are trading. When the price of a stock being checked changes, the Price Checker sub-scenario sends data to its output feed and this data includes the new price.

In your main scenario, you want to monitor changes in the Trader `trading` field and in the Price Checker `price` field. To do this, use an instance of the Change Observer block for each field. The block wiring would look like this:

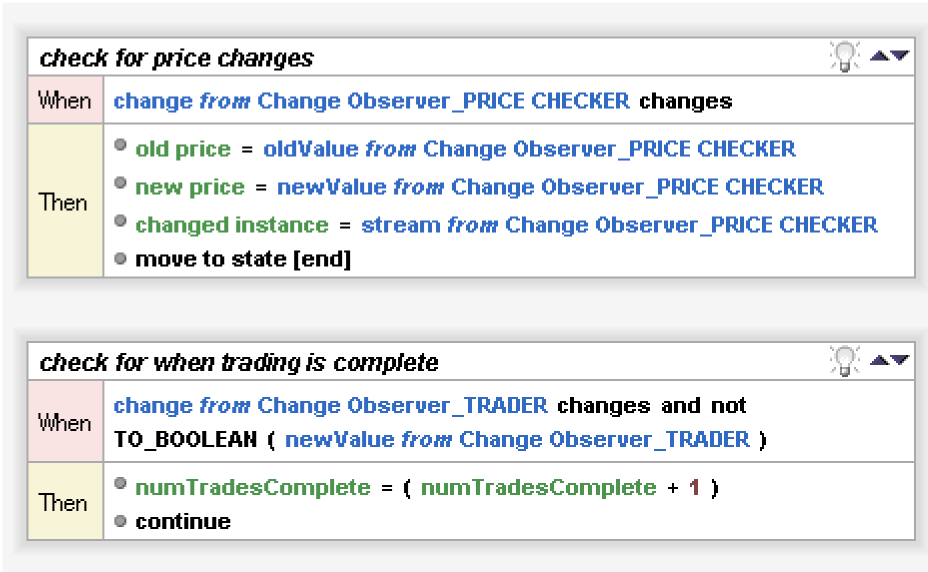


The Change Observer_PRICE CHECKER block sends an output feed whenever a Price Checker sub-scenario sends a price change to its output feed. The Change Observer_TRADER block sends an output feed whenever a Trader sub-scenario stops trading or starts trading, as indicated by the `trading` field in its output feed. You would wire their fields as follows:

Wire Price Checker 1 Output Feed	To Change Observer_PRICE CHECKER Input Feed
Output feed: `output`	Input feed: `input`
`instance id` [`string`] output field	`stream` [`string`] input field
`price` [`float`] output field	`watchValue` [`string`] input field

Wire Trader 1 Output Feed	To Change Observer_TRADER Input Feed
Output feed: `output`	Input feed: `input`
`instance id` [`string`] output field	`stream` [`string`] input field
`trading` [`boolean`] output field	`watchValue` [`string`] input field

The rules to implement this would look something like the following: (Note that the name of the Change Observer block output feed is `change`.



Performing simple calculations across sub-scenarios

The Filtered Summary block performs simple calculations across a set of sub-scenarios. This is an alternative to iterating over a set of sub-scenarios. The Filtered Summary block can operate on only floating point values. You can use this block to calculate sums and averages. See "Filtered Summary v2.0" on page 568 for details.

In more general terms, the Filtered Summary block performs calculations on a keyed set of floating point values. Typically, you use the sub-scenario instance ID as the key. The key's associated value is the value of a sub-scenario floating point variable that you want to use in an aggregate calculation.

To use the Filtered Summary block, wire output fields from the scenario block to input fields of the Filtered Summary block. Typically, you want to map the scenario block `instance id` output field to the Filtered Summary `key` input field. Then map a floating point sub-scenario variable from the scenario block `output` feed to the Filtered Summary `value` input field.

You can specify filters to perform calculations on a sub-group of sub-scenarios. For example, suppose you wanted to calculate the total number of shares purchased by sub-scenarios owned by `John`. To accomplish this, you do the following two things:

- Map the scenario block `instance owner` output field to the Filtered Summary block `filter` input field.
- Set the Filtered Summary `filter` parameter to `"John"`.

When the Filtered Summary block receives input from your scenario block, it checks whether the value of the `filter` input field is equal to the value of the `filter` parameter. If the values are equal, (in the example, they are both `"John"`) the Filtered Summary block sends output to its output feed. If the values are not equal, the Filtered Summary block sends no output.

Now suppose that you want to exclude shares purchased by John from your calculation. That is, you want to know the total number of shares purchased by everyone except John. To make this happen, you perform one step in addition to the steps already described. Set the Filtered Summary block's `filter is "not equal to"` parameter to true. Now the Filtered Summary block sends output only when the `filter` input field is not equal to `"John"`.

You can also remove keys and their associated values from the Filtered Summary block's internal datastore. This lets you exclude data from certain sub-scenarios from the calculations. You do this with the `deleteKey` operation and the `keyToDelete` parameter. One way to do this is to define a global rule that watches for sub-scenarios to terminate. When a sub-scenario terminates, you can specify its instance ID as the key and remove the data for that key from the Filtered Summary block's store of data.

20 File Definition Formats

This section describes the formats of Apama's function definition and block definition files. It is important that developers adhere strictly to these formats when developing functions and blocks to be used in Apama scenarios.

Understanding the XML format is especially important for developers creating functions, because the function editor in Software AG Designer lets you work directly on a function definition file's XML code. Function definition files have an `.fdf` extension.

On the other hand, block developers are shielded from most of a block definition file's XML code by the Apama block editor, which automatically generates the block's boilerplate code and allows input only in sections of the file where user input is appropriate. Block definition files have a `.bdf` extension.

Function definition file format

A function definition file contains metadata that describes the function plus EPL code that implements the function. The topics below describe these pieces.

Defining metadata in function definition files

The metadata in a function definition file has the following format:

```
<function name="string" display-string="string" return-type="string">
   <version>
      <id>version_number</id>
      <date>version_date</date>
      <author>version_author</author>
      <comments>internal_info_about_function</comments>
   </version>
   <description>
      description_of_what_function_does--appears_in_function_catalog
   </description>
   [<imports>
         <import library="string" alias="string"/>...
     </imports>]
   <parameters>
      [<fixed-parameter name="string" type="string"/>] ...
   </parameters>
   (EPL in a code element goes here)</function>
```

The top level `function` element must specify the following three attributes:

- `name` — Logical name of the function. To avoid function conflicts in Event Modeler, the value of this attribute must be unique across all `.fdf` files in each directory.

  When you write the EPL code that implements the function, you specify `#name#` in place of the name of the function. When you use the function in a scenario, the Event Modeler replaces `#name#` with the value you specify for the `function name` attribute. When the Event Modeler does this, it adds an identifier to the name you specify to ensure that the function name is unique.

- `display-string` — Function name that the rules editor displays. When you want to use this function in a rule, this is the name that you select from the menu of functions. You might want to give your function a short name, but specify a more descriptive name for the value of the `display-string` attribute.

- `return-type` — Type of the value returned by the function. The table below shows the values you can specify for the `return-type` attribute, and the Event Modeler types these values map to:

Value of return-type Attribute	Maps to This Event Modeler Type
`String`	`text`
`float`	`number`
`enumeration`	`choice`
`boolean`	`true/false`

Defining the version element

The `version` element must contain one of each of the following elements in the following order. Use the `version` element to maintain updates to your function. In the **Function Catalogs** panel, when you click a function, the values you specified in the `version` element (except for the contents of `comments`) appear in the middle pane.

- `id` — Identifier for this version of your function. Typically, a version number.
- `date` — Date the function was written.
- `author` — Name of the person who wrote the function.
- `comments` — Any information about the function that you want to provide. This information appears only in the `.fdf` file; it does not appear in the Event Modeler.

For example:

```
<version>
   <id>1.0</id>
   <date>7 November 2006</date>
   <author>Matthew Amos</author>
   <comments>External function</comments>
</version>
```

Defining the description element

After the `version` element, there is a `description` element that describes what the function does. The text you enter in the `description` element appears in the middle pane of the **Function Catalogs** panel. For example:

```
<description>
   Convert a string to a number, and return the number.
</description>
```

Defining the imports element

The optional `imports` element provides a place to specify any plug-ins required by your function. Any plug-ins you specify must be written in the correlator plug-in API. The `imports` element can contain any number of `import` elements. Each `import` element must contain the following attributes:

- `library` — Name of the file that contains the plug-in required by your function.
- `alias` — Name of the plug-in in the `code` element of the function definition file. When you write the EPL code that implements the function, you specify `#`*alias_value*`#` as the name of the plug-in. When you use the function in a scenario, the Event Modeler replaces `#`*alias_value*`#` with the name of the function in the specified library.

For example:

```
<imports>
   <import library="TimeFormatPlugin" alias="timePlugin"</import>
</imports>
```

In the `code` element, you would specify something like the following:

```
return #timePlugin#.formatTime
```

Defining the parameters element

After the `description` element, or `imports` element if there is one, there is a `parameters` element. The `parameters` element defines the function's parameters. A function can have

- No parameters. The `.fdf` file must still contain the `parameters` element, but it is empty. For example:

  ```
  <parameters/>
  ```

- A sequence of one or more fixed parameters. Each fixed parameter has a specified name and a specified type. In the function code, you must specify any fixed parameters in the same order in which you define them in the `parameters` element.

To define fixed parameters, specify one or more `fixed-parameter` elements. Each `fixed-parameter` element contains a `name` attribute and a `type` attribute. The value of the `name` attribute indicates the name of the fixed parameter. The value of the `type` attribute indicates the type of the fixed parameter and must be `string`, `float`, `enumeration`, or `boolean`. For example:

```
<parameters>
   <fixed-parameter name="condition" type="boolean" />
   <fixed-parameter name="true_result" type="string" />
   <fixed-parameter name="false_result" type="string" />
</parameters>
```

When you display functions in the Event Modeler `Catalogs` panel, you can click on a function and then expand **parameters** to view the parameters required by that function. When you execute the function, each fixed parameter is required.

Defining EPL code in function definition files

In a function definition file, the last element in the `function` element is the `code` element. The `code` element contains one `CDATA` section that contains EPL code that defines one action. The requirements for the EPL code are as follows:

- The parameters and types that the EPL defines must match the parameters and types specified in the `parameters` element.
- The return type specified in the EPL code must match the type specified for the `functionreturn-type` attribute.
- Specify the name of the action as `#name#`.
- Specify the name of a plug-in as `#`*alias_value*`#`.
- The function must be valid EPL code.

  For example:

  ```
  <code><![CDATA[
    action #name#(float f) returns float {
      return f.abs();
    } ] ] >
  </code>
  ```

- The function can use local variables. To use a scenario variable, assign its value to a function parameter.

Block definition file format

This section describes the format of the block definition file (`.bdf`). This is a readable XML text document. Block definition files are generated automatically by Software AG Designer. When these files are generated, Software AG Designer creates all the XML code for specifying the block's metadata and defining its interface. The task of the developer is to add the code that implements the block's behavior.

All editing of `.bdf` files should be done in the Apama block editor.

Block definition file DTD

The document must comply with the XML Document Type Definition `bdf.dtd`. This file is included in the Apama installation's `etc` directory. This description of the file format is presented for troubleshooting purposes and general background information.

When you create a new block as part of a project in Software AG Designer, the best practice is to locate it in the project's default blocks directory. This directory is found in the project's `catalogs` directory. The block directory has a name in the form *<project_name>* `blocks`. So, for example, the default block directory of a project named `My_Project` will be `catalogs\My_Project blocks`.

If you place your block in the Apama project's default block directory, scenarios created in the project will automatically find them and make them available in Event Modeler when you are displaying the scenario.

Software AG Designer assigns the name of the file as follows:

```
Block Name v version_number.bdf
```

For example, the block whose `<name>` attribute is `Database Retrieval` would be defined in the file `Database Retrieval v1.0.bdf` and stored in a folder called `Database Retrieval.bdf`. This convention makes it easy to browse multiple versions of the block within a block catalog when using the Event Modeler. Note that this naming and folder placement (and creation) is all done automatically.

Block definition file encodings

Software AG Designer and Event Modeler always read and write block definition files in UTF-8.

XML elements that define a block

Here are the list of XML element needed to define a block, arranged to show the hierarchical ordering. The elements are described in the table that follows the list:

```
<block>
  <version>
    <id> </id>
    <date> </date>
    <author> </author>
    <comments> </comments>
  </version>
  <description> </description>
  <properties parallel-aware="false" deprecated="false">
    <input-feeds>
      <feed>
        <description> </description>
        <field>
          <description> </description>
          <validation> </validation>
        </field>
      </feed>
    </input-feeds>
    <output-feeds>
definition identical to fields in input feeds
    </output-feeds>
    <parameters>
      <field>
definition identical to fields in input and output feeds
      </field>
    </parameters>
    <operations>
        <operation>
          <description> </description>
        </operation>
    </operations>
  </properties>
  <code> </code>
</block>
```

The following table lists and describes the XML elements used to define a block:

Element	Description
<block>	The root element in any .bdf file. This element has a single text (CDATA) attribute, <name>, which must define the name of the block. This element must contain the <version>, <description>, <properties>, and <code> child elements.
<version>	The block's version. This element must contain the <id>, <date>, <author>, and <comments> child elements.
<id>	From an XML point of view, this element can contain any character data (#PCDATA), but it should be set to indicate the version number of the block, for example, 1.0 or 1.1. The version number is used to distinguish different versions of the block in the catalog browser within the Event Modeler. This version number must be the same as that encoded within the .bdf filename itself. For this reason, if the block is generated by the Block Builder, the content of this element is automatically used to name the .bdf file, in conjunction with the <name> element; see the description of the <block> element. This element has no attributes.
<date>	The date when the block was authored. This information is just for the block author's future reference. This element takes any character data (#PCDATA). It has no attributes.
<author>	The block's author. This information is just for future reference. This element takes any character data (#PCDATA). It has no attributes.
<comments>	Describes any changes that have been made to the block in this version. This element takes any character data (#PCDATA). It has no attributes
<description> (child of <block>)	Can contain any character data (#PCDATA) that informatively describes the purpose of this block. As this information appears within the block catalog browser in the Event Modeler, it is useful to provide a brief summary of the block's functionality. It has no attributes.
<properties>	Describes the interface of the block. This element must contain the <input-feeds>, <output-feeds>,

Element	Description
	<parameters>, and <operations> child elements. This element can also contain the two Boolean attributes "parallel-aware" and "deprecated". When the parallel-aware attribute is set to true, the block can be used in a parallel scenario. When the deprecated attribute is set to true, the block has been deprecated.
<input-feeds>	List all the input feeds of this block. This element can include zero or more <feed> child elements within it. It has no attributes and cannot contain any text.
<feed>	Represents either an input feed or an output feed, depending on where it occurs within the XML document. <feed> has two attributes, id and name. id is optional. If supplied, it must be a unique string that distinguishes the feed from all other input or output feeds. The name attribute must also be unique, but only across input feeds or output feeds. The block definition in the EPL code defines an action type definition that corresponds to this feed and that takes an argument for each field in the feed. This element must contain the <description> and <field> child elements.
<description> (child of <feed>)	Describes the purpose and use of the feed and appears by the block catalog browser in the Event Modeler.
<field>	The <feed> element can include any number of <field> elements. Each represents a field within the feed in question. The action in the corresponding EPL code that updates according to an input feed or sends data to an output feed must accept an argument for each field in the feed. The arguments must be in the same order as the fields defined in the XML document. A <field> element has two attributes, id and name. It is highly recommended to include the id attribute, it is optional only for backwards compatibility. It must be a unique string that distinguishes the field from all other input or output fields. name, a string, must also be unique but only within the feed the field belongs to. This element must contain the <description> and <validation> child elements.

Element	Description
<description> (child of <field>)	Describes the purpose and use of the field and appears by the block catalog browser in the Event Modeler.
<validation>	Although the DTD indicates this element is optional, this is just for backwards compatibility with older blocks. This element is required, and will be added automatically with default values applied when the block is used in the Event Modeler if a <validation> is unspecified. This element defines the type of the field. If the field is of the scenario type string, float, integer or boolean, then no child elements are required within the <validation> element, whereas if the field is of type enumeration, then an <enumeration> child element should be included. Note that the first four types correspond to the types of the same name in the EPL code, whereas enumeration is really a string in the EPL code. <validation> includes nine attributes, whose relevance depends on the value entered for the first attribute, `type`. This can only take the values `string`, `float`, `integer`, `enumeration` or `boolean`, and is required. The other attributes, which are all optional, are `minlength`, `maxlength`, `minvalue`, `maxvalue`, `unique`, `mutability`, `stringcase`, and `trim`. Note that these constraints are not enforced in this version of Event Modeler and are therefore not documented.
<output-feeds>	Lists all the output feeds of this block. To do this, you can include zero or more <feed> child elements within it, in the same way as for <input-feeds>.This element has no attributes and cannot contain any text.
<parameters>	This element should list all the configuration parameters of the block. The functionality of a block should be configured primarily through parameters. Like the fields in input and output feeds, the whole set of parameters must correspond to an initialization event whose field parameters correspond to the block parameters, in the same order. Furthermore, for each parameter there must be an event which enables that parameter to be set independently of the others and after the initial configuration.

Element	Description
	This element takes no attributes and contains zero or more `<field>` child elements, one for each block parameter.
`<field>` (child of `<parameter>`)	Each `<field>` child element corresponds to an actual parameter of the block, and the XML definition is identical as that for fields in input or output feeds. As described elsewhere, each `<field>` further embeds a `<validation>` element, where the `<type>` attribute is the most relevant. The type used here must correspond to the equivalent type in the EPL code.
`<operations>`	Represents any operations implemented in the block. Operations are chunks of functionality written in EPL that could be invoked by a scenario. This element has no attributes, and contains zero or more `<operation>` child elements.
`<operation>`	Describes an operation defined in the block. There should be an instance of this element for each operation in the block. This element takes two attributes, `id` and `name`. Both attributes are XML `CDATA` elements. `id` is optional only for backwards compatibility reasons, and should be specified. If not supplied, `id` will automatically be added in a way that makes the operation element unique. `name`, the string name for the operation, should also be made unique across the set of operations. In addition, each `<operation>` element should contain a `<description>` child element. This element can contain any character data that constitutes a relevant description of the functionality that is being made available. Its description appears by the block catalog browser in the Event Modeler. Note that the XML definition of an operation consists solely of a name and a description. If you wish to pass parameters to an operation, you should use the block parameter mechanism.
`<code>`	The actual EPL template code that implements the interface and functionality of the block. For XML validation purposes, any character data can be supplied here (`#CDATA`), although the content must in fact be very carefully written. The contents of this section, which can

Element	Description
	only partly be generated by Software AG Designer, are discussed in detail in "Creating Blocks" on page 591.

III Developing Apama Applications in Java

Developing Apama Applications in Java provides information and instructions for using Apama's in-process API for Java, called JMon, to write applications that run on the event correlator. To develop an Apama application you can use the correlator's native Event Processing Language (EPL) or JMon, or Apama's Event Modeler. This document focuses exclusively on how to use JMon to write an application that runs on the correlator.

JMon reference documentation is provided in Javadoc format.

21 Overview of Apama JMon Applications

The event correlator is Apama's core event processing and correlation engine. Interfaces to the correlator let you inject monitors that

- Analyze incoming event streams to find patterns of interest
- Specify the actions to undertake when the correlator identifies such patterns

You can use the Apama JMon API to write applications that are to be deployed on the correlator.

The correlator embeds a Java Virtual Machine in which Apama JMon applications can be loaded and run.

The JMon API provides a suite of Java classes that allow a developer to build a Java application, and then inject it into the correlator. Apama JMon applications can define *listeners*, which specify patterns and sequences of events to look for and actions to carry out when the correlator detects those events.

You can develop Apama JMon applications in Software AG Designer. When you use Software AG Designer to develop an application, it can automatically generate a framework for your JMon event and JMon monitor files.

For more information on developing JMon applications in Software AG Designer, see, "Adding a new JMon application", "Adding a JMon monitor", and "Adding a JMon event" in *Using Apama with Software AG Designer*.

Note: Apama includes the in-process API for Java (JMon) and the client API for Java. In most cases, the context makes it clear which API the discussion is addressing. When this is not clear, the APIs are referred to as the JMon API or Apama client API for Java.

Introducing JMon API concepts

This section introduces the main concepts behind programming the functionality within Apama using JMon. It describes how events are modeled in JMon and how they are used to drive and trigger *listeners* within JMon *monitor* classes.

Apama is designed to fit within an event (or message) driven world. In event driven systems information is propagated through units of information termed events or messages. Conceptually, an event typically represents an occurrence of a particular item of interest at a specific time, and is usually encoded as an asynchronous network message.

Apama is designed to process thousands of these event messages per second, and to sift through them for sequences of interest based on their contents as well as their temporal relationships to each other. When writing Apama applications using JMon, the Java code you write informs the correlator of the sequences of interest and, when matching event sequences are detected, these are passed to your JMon code for handling. Apama's correlator component is capable of looking for hundreds of thousands of different event sequences concurrently.

In order to program the correlator using JMon, a developer must write their application as a set of Java classes that implement the JMon APIs. This programming model is similar to writing Enterprise JavaBeans intended for use in an application server. These Java classes then need to be loaded (or ‘injected') into the correlator, which instantiates and executes them immediately.

Almost all of the standard language functionality provided by Java and its libraries can be used in JMon applications, just as in any other Java applications. However, the power of the correlator is only truly leveraged by invoking its event matching, correlation and event generation capabilities. As streams of events are passed into a correlator, the *listeners* defined in JMon applications sift through the events looking for specific sequences of interest matching a variety of temporal constraints. Once a listener triggers, a method is invoked on a Java object, the *Match Listener* object. The developer specifies this object when the listener is created.

Three kinds of Java class objects can be loaded into the correlator; event types, monitors and match listeners.

- Event type classes serve to define the event types that the correlator can accept from external sources and carry out correlations on.
- Monitor classes program the correlator. They define what event patterns the correlator must look for and allow arbitrary Java code to be executed.
- Match listeners provide a method that is called when a specific event sequence is detected.

These three Java class types will be now be discussed in detail.

About event types

Apama events are strongly typed. Each event must be of a specific known type, henceforth called the *event type*. An event type defines the name of the event, and its particular set of parameters. Every parameter is named and can be one of a selection of types. Every event instance of a given event type is therefore identical in structure; every instance has the same set (and order) of parameters.

Before the correlator can understand and process events of a specific event type, it needs to have been provided with an *event type definition*. This allows it to understand the event messages it is passed, create optimal indexing structures, and allows listeners to be set up to look for event sequences involving events of that type.

An event type definition defines the event type's name and the name, type and order of each of its parameters. Parameters can be of any of the following types:

- Java standard types `String`, `long`, `double`, `boolean` or `Map`.
- Java arrays.
- `com.apama.jmon.Location` type — This type corresponds to either a spatial point represented by two coordinates, or a rectangular space expressed in terms of its two bounding corners.

Apama's JMon API supports Java generic maps. Apama recommends that you use these when possible instead of the `Event.getMapFieldTypes()` method. Doing so lets you gain the benefits of compile-time type safety as well as a simpler class definition.

However, while it is valid to declare a parameter to be an array of generic maps, assignment of values to the map elements is not type-safe, and will be rejected by the Java compiler. If you need a parameter that is an array of maps, use the `Event.getMapFieldTypes()` method instead of generic maps.

You can nest a plain `Map` as a value (not a key) at any depth in a parameterized `Map`. You cannot nest a parameterized `Map` in a plain `Map`. This is because you would not be able to specify the parameterized types to be returned from the `getMapFieldTypes()` method. Of course, you can nest a parameterized `Map` as a value (but not a key) in a parameterized `Map`. For example:

EPL:

```
Event BadComplexEventExample {
   Dictionary < string , dictionary < string, SimpleEvent > >  complex;
}
```

Java:

```
Import java.util.Map;
Import java.util.HashMap;
Import com.apama.jmon.Event;
Public class BadComplexEventExample extends Event {
// By using a non-parameterized map you lose the information that the field
// is a dictionary with values that are also dictionaries.
Public Map complex;

Public BadComplexEventExample() {
   This(new HashMap());
}

Public BadComplexEventExample(Map complex) {
   This.complex = complex;
}
}
```

See also the definition of `ComplexEvent` in "About event parameters that are complex types" on page 659.

An event can embed an event (potentially of a different type) as a parameter.

Simple example of an event type

An event type is defined as a Java class as per the following example,

```
/*
 * Tick.java
 *
 * Class to abstract an Apama stock tick event. A stock tick event
 * describes the trading of a stock, as described by the symbol
 * of the stock being traded, and the price at which the stock was
 * traded
 */

import com.apama.jmon.Event;
```

```
public class Tick extends Event {
   /** The stock tick symbol */
   public String name;

   /** The traded price of the stock tick */
   public double price;

   /**
    * No argument constructor
    */
   public Tick() {
      this("", 0);
   }

   /**
    * Construct a tick object and set the name and price
    * instance variables
    *
    * @param name  The stock symbol of the traded stock
    * @param price The price at which the stock was traded
    */
   public Tick(String name, double price){
      this.name = name;
      this.price = price;
   }
}
```

By Java programming conventions, the previous definition would need to be provided on its own in a stand-alone file, for example, `Tick.java`.

The definition must import the definition of the `Event` class. This is provided as part of the `com.apama.jmon` package provided with your Apama distribution. See "Developing and Deploying JMon Applications" on page 703 on installation and deployment for details of where to locate this package.

`Event` is the abstract superclass of all user classes implementing desired event types. Then we must define our new event class as a subclass of the `Event` type.

The user-defined event class must have three primary elements:

- A set of `public` variables that define the event's parameters
- A ‘no argument' constructor, whose purpose is to construct an instance of the event with the parameters set to default values
- A constructor whose parameter list corresponds (in type and order) to the event's parameters. This constructor allows creation of an instance of the event with specific parameter values.

In the above example the event is called `Tick`, and it has two parameters, `name`, of type `String`, and `price`, of type `double`. The previous definition may be considered a simple template for how to write all event definitions.

Note: Non-`public` (like `private` and `protected`) variables are not considered to be part of the event schema.

Extended example of a JMon event type

Let us now consider an extended example:

```
package test.jmon.example;

import java.util.Map;
import com.apama.jmon.*;

/*
 * TestEvent.java
 *
 * Class to abstract an Apama event whose primary purpose is to
 * showcase how to define an event class containing parameters of
 * all the allowed types, including arrays and Maps.
 */

public class TestEvent extends Event {

   // example of parameters of the basic types
   public long primitiveInteger;
   public double primitiveFloat;
   public boolean primitiveBoolean;
   public String referenceString;
   // example of parameters consisting of arrays of the basic types
   public long[] sequenceInteger;
   public double[] sequenceFloat;
   public boolean[] sequenceBoolean;
   public String[] sequenceString;

   // a nested event of type EmbeddedTestEvent
   public EmbeddedTestEvent referenceNestedTestEvent;

   // a parameter of type Location
   public Location referenceLocation;

   // a parameter of type Map
   public Map<long, String> dictionaryIntegerString;
. . .

}
```

Comparing JMon and EPL event type parameters

You might already be familiar with EPL, the Apama complex event processing scripting language through which the correlator can be programmed as an alternative to JMon. Event types defined in JMon can be used in EPL, and vice-versa. JMon event type parameters map to EPL parameter types as follows:

JMon Type	Equivalent EPL Type
`long`	`integer`
`double`	`float`

JMon Type	Equivalent EPL Type
`boolean`	`boolean`
`String`	`string`
`Location`	`location`
`array`	`sequence` (of the same type)
`Map`	`dictionary` (with the same key and value types)
`com.apama.Event` or its subclass	`event` (with the same equivalent subset of fields as defined in this table)

The correlator's performance can be optimized by *wildcarding* event type definitions where appropriate. This procedure is described in "Optimizing event types" on page 669.

About event parameters that are complex types

It is possible in both EPL and JMon to declare a field of an event definition to be a complex type. For example, the `SequenceEvent` definition below defines an event that is constructed from a sequence of `DataHolder` events, which in turn contain a string and an integer. This is defined in EPL in two events thus:

```
event DataHolder {
   string name;
   integer age;
}

event SequenceEvent {
   sequence <DataHolder> complex;
}
```

An example constructed `SequenceEvent` event is show below:

```
SequenceEvent([DataHolder("kap", 1), DataHolder("gbs", 2)])
```

The equivalent event definitions for the above in Java are defined below:

```
import com.apama.jmon.Event;

public class DataHolder extends Event {
   /** Event fields */
   public String name;
   public long age;

   /** No argument constructor
   */
   public DataHolder () {
      this("", 0);
```

```
   }
   /** Construct a DataHolder object and set the instance variables
   */
   public DataHolder (String n, long a) {
      name = n;
      age = a;
   }
}

import com.apama.jmon.Event;

public class SequenceEvent extends Event {

   /** Event field */
   public DataHolder[] people;

   /** No argument constructor
   */
   public SequenceEvent() {
      this( new DataHolder[]{} );
   }

   /** Construct a SequenceEvent object and set the instance variable
   */
   public SequenceEvent(DataHolder[] p) {
      this.people = p;
   }
}
```

Sample Java code to create and emit a `SequenceEvent` event is shown below:

```
  s = new SequenceEvent(new DataHolder[] {new DataHolder("kap", 1),
   new DataHolder("gbs", 2)} );
s.emit();
```

Events can also include `Map` types, which are equivalent to EPL `dictionary` types. When you use `Map` types, Apama recommends that you use generic maps whenever you can. For example, in EPL the following event is a dictionary of dictionaries and each internal dictionary is a sequence of `SimpleEvent` types:

```
event ComplexEvent {
  dictionary <string,
    dictionary <string, sequence<SimpleEvent> > > complex;
}
```

You can implement this in Java as follows:

```
import java.util.Map;
import java.util.HashMap;
import com.apama.jmon.Event;
import com.apama.jmon.annotation.EventType;

@EventType(description = "Event that contains a field with a complex structure")
public class ComplexEvent extends Event {

   /** Event field */
   public Map<String, Map<String, SimpleEvent[]>> complex;
   /**
   * No argument constructor
   */
   public ComplexEvent() {
      this(new HashMap<String, Map<String, SimpleEvent[]>>());
   }
```

```
   /**
   * Construct a ComplexEvent object, set the instance variable complex
   *
   * @param complex The dictionary/Map to use as the field value
   */
   public ComplexEvent(
      Map<String, Map<String, SimpleEvent[]>> complex) {
        this.complex = complex;
      }
}
```

This example is provided in its complete form as a sample. It is distributed in the folder `samples/java_monitor/complex_event/`.

Non-null values for non-primitive event field types

When the correlator creates an event to pass to the JMon code, it ensures that all fields of a non-primitive type have a non-null value. Note that this is different from the Java default, which is to allow null values for non-primitive types.

The `com.apama.jmon.Event` default constructor uses reflection to initialize non-primitive null fields with the following values:

- `sequence` — an empty array of the specified type
- `dictionary` — an empty `java.util.HashMap` object
- `string` — an empty `java.lang.String` object
- `event` — a default construction of the event, with recursive initialization for any of its non-primitive fields that have null values.

In your application, if you explicitly assign a null value to a non-primitive event field, and your application tries to emit, enqueue, or route that event, the correlator logs an error and terminates your application.

About monitors

Monitor classes configure the activity of the correlator. This is analogous to how an Enterprise JavaBean effectively defines the activity of an application server.

All monitor classes must implement the `com.apama.jmon.Monitor` interface and define an `onLoad` method. When a monitor class is loaded into the correlator, it is instantiated as an object and its `onLoad` method is executed. In Java parlance, this would be equivalent to the `static void main (args[])` method.

Most Java code (with certain limitations) can be executed within the `onLoad` method, although its primary purpose is probably to configure one or more asynchronous *listeners* for specific events or event sequences.

A monitor class must define a "no argument" constructor. The Java code within the correlator uses this when the class definition is loaded.

Below is a minimal monitor:

```
import com.apama.jmon.*;
```

```
public class Simple implements Monitor {
   /**
    * No argument constructor used by the jmon framework on
    * application loading
    */
   public Simple() {}

   /**
    * Implementation of the Monitor interface onLoad method.
    * Does nothing.
    */
   public void onLoad() {
   }
}
```

The above monitor class does nothing and is shown here as a template for how to define a monitor class.

EPL. Although there are similarities, the concept of a monitor in EPL and in JMon is not the same. The EPL monitor is a very powerful custom programming structure, whereas in JMon a monitor class is primarily a standard Java class with an entry method that gets automatically executed upon loading (as described in the topics below).

About event listeners and match listeners

For a monitor class to leverage the intrinsic features of the correlator, it must set up one or more *listeners*.

A listener is a conceptual entity whose function is to sift through all incoming event streams looking for a particular event or sequence of events. The event or sequence of events of interest is represented as an *event expression*.

The simplest way of setting up a listener is by creating an instance of an `EventExpression` and then specifying a `MatchListener` object that gets triggered when the expression becomes true, that is, when a suitable event or event sequence is detected. A more efficient alternative is to use a *prepared event expression*, which is described in "Optimizing event types" on page 669.

A match listener is a Java object that implements the `com.apama.jmon.MatchListener` interface and implements the `match` method. This method is called by the correlator when the event expression it is registered with is detected.

Example of a MatchListener

The following example illustrates this functionality:

```
import com.apama.jmon.*;
public class Simple implements Monitor, MatchListener {

   /**
    * No argument constructor used by the jmon framework on
    * application loading
    */
   public Simple() {}
   /**
    * Implementation of the Monitor interface onLoad method. Sets up
    * a single event expression looking for all Tick events
```

```
     * with a trade price of greater than 10.0. This class instance
     * is added as a match listener to the event expression.
     */
   public void onLoad() {
      EventExpression eventExpr = new EventExpression("Tick(*, >10.0)");
      eventExpr.addMatchListener(this);
   }

   /**
    * Implementation of the MatchListener interface match method.
    * Prints out
    * a message when the listener triggers
    */
   public void match(MatchEvent event) {
      System.out.println("Pattern detected");
   }
}
```

This example illustrates several new concepts.

Consider the `onLoad` method. Firstly it creates an event expression object variable. This object, of type `com.apama.jmon.EventExpression`, represents an event, or sequence of events, to look for. The constructor of an `EventExpression` is passed a string that defines the actual event expression.

As the syntax of an event expression will be illustrated in the next section it is enough to say that this event expression is specifying "the *first*`Tick` event whose *`price`* parameter is greater than the value `10.0`".

Then, a match listener is registered with the newly created event expression object. A match listener can be any object that implements the `com.apama.jmon.MatchListener` interface and defines the `match(MatchEvent event)` method. For the sake of simplicity, the `Simple` monitor class has here been written to also implement the `MatchListener` interface, and therefore the statement,

```
eventExpr.addMatchListener(this);
```

is passing `this` as the reference to a suitable `MatchListener`.

Once a match listener has been registered with an event expression the correlator creates a listener entity to start looking for the specified event expression.

Listeners are asynchronous. Hence the `match` method may be invoked at any time subsequent to the activation of the listener, but always after all Java code in the current method finishes executing. Therefore in this case all Java statements in the `onLoad` method would finish being executed before `match` is called after a match.

Defining multiple listeners

A monitor can define any number of event expressions, and create any number of listeners. The following code,

```
public void onLoad() {
   EventExpression eventExpr1 = new EventExpression("Tick(*, >10.0)");
   EventExpression eventExpr2 =
      new EventExpression("NewsItem(\"ACME\", *)");

   eventExpr1.addMatchListener(this);
   eventExpr2.addMatchListener(this);
```

```
}
```

is creating two event expressions, `eventExpr1` and `eventExpr2`. Then each is assigned a match listener, thus activating two distinct listeners. The fact that both are being assigned the same match listener object, i.e. this same object `this`, is inconsequential. It just means that the same method, the `match` method of this object, will be called when the correlator detects either of the event expressions.

As already described, creating a listener is an asynchronous operation that returns immediately. In the above code, in practice both listeners are created concurrently. It is not possible for the `eventExpr1` listener to trigger before the `eventExpr2` listener is created. However, once the enclosing method's code has completed execution, the listeners can trigger at any time, and independently of each other.

Removing listeners

A `MatchListener` instance that is no longer connected to an event expression, and to which there are no references, is garbage collected in the usual way. In some situations, you might want to be notified when the correlator removes its reference to the `MatchListener` (when it can no longer fire). For example, you might need this notification if the `MatchListener` has unmanaged resources (for example, open files) that need to be explicitly cleaned up when it is no longer needed, or your application has other references to the `MatchListener` that need to be removed when the listener can no longer fire so that it can be garbage collected. In those situations, you can define your listener so that it implements the `com.apama.jmon.RemoveListener` interface. There is no requirement to implement this interface. It is up to you to determine whether you need it.

The `RemoveListener` interface extends the MatchListener interface by providing one additional method: `removed()`. If you implement the `RemoveListener` interface, the correlator calls your implementation of the `removed()` method in the following situations:

- The application removes your listener from the event expression it is attached to.
- The event expression your listener is attached to is in a state that will never match. For example, `on A() within (10.0)` after 10 seconds have elapsed without an `A()`.

In the following example, the `removed()` method is called because the event expression dies after 10 seconds.

```
import java.util.HashMap;
import com.apama.jmon.*;

public class Test implements Monitor {
   public Test() {}
   public void onLoad() {
      EventExpression e = new EventExpression("TestEvent() within(10.0)");

      e.addMatchListener(new RemoveListener() {
         public void match(MatchEvent event) {
            System.out.println(Correlator.getCurrentTime() +
               ": Received match");
         }
      public void removed(EventExpression e) {
         System.out.println(Correlator.getCurrentTime() +
```

```
            ": Received removed");
      }
      });
   }
}
```

Description of the flow of execution in JMon applications

The flow of execution of JMon applications through the correlator at any given time is single threaded. All the listeners of JMon applications are fired in a single-threaded manner. However, during the lifetime of a JMon application, its execution may be moved among a number of threads by the correlator. This is particularly important since thread-local variables will not behave in the same way as you would expect them to in a conventional Java application.

When a number of monitor classes are loaded into the JVM within the correlator their `onLoad` methods are executed in turn, in the same order as the injected classes, and any listeners created are set up and activated.

Control then reverts to the correlator, which takes in one event from its input queue. This event is examined by each of the active listeners in turn (the order is undefined), and each one that triggers immediately calls the `match()` method in its registered `MatchListener` object.

Once all the listeners have processed the event (and hence all `match` methods terminated), control reverts to the correlator to process the next input event. Note that since events can also match listeners in EPL monitors, these would also be processed before control reverts.

However, JMon applications can create other Java threads. In such multi-threaded JMon applications, the correlator has no control of these additional Java threads. Consequently, you should never route or emit an event from a Java thread that was not the thread in which the correlator invoked the JMon application. Doing this results in unpredictable behavior. To communicate from your JMon application to other parts of the correlator, use the `enqueue()` method or preferably, the `enqueueTo()` method.

Parallel processing in JMon applications

By default, the correlator operates in a serial manner. If you want, you can implement contexts for parallel processing. You can create contexts only with EPL but you can then use those contexts from your Apama JMon code. This section provides information about how to use contexts in Apama JMon applications.

You can find a sample JMon application that implements the use of contexts in the `samples\java-monitor\context` directory of your Apama installation directory.

Overview of contexts in JMon applications

The Apama JMon API provides the `com.apama.jmon.Context` type. This class corresponds to the EPL `context` type, but with a more limited set of features:

- A JMon event definiton can contain a `Context` type field. This lets you transfer a reference to a context to and from an Apama JMon application. You cannot pass context references between the correlator and your Apama JMon application on their own.
- You can enqueue events to
  - Particular contexts:`Event.enqueueTo(Context c)`
  - A list or array of contexts:

    ```
    Event.enqueueTo(java.util.List<Context> ctxList)
    Event.enqueueTo(Context[] ctxList)
    ```

    See "Emitting, routing, and enqueuing events" on page 680.
- You can call `Context.getCurrent()` to obtain a reference to the context that a piece of code is running in. See "Obtaining context references" on page 308.
- The `Context` class provides accessor methods for context properties such as context name and context ID.

Using contexts in JMon applications

To use EPL contexts in JMon applications

1. In EPL code, create a context that you want to use in your JMon application.
2. In your JMon application, define an event type that contains a `Context` field.
3. Use this event type to obtain a reference to the context you created in EPL.
4. Use the context reference to enqueue events to that context.

For an example, see the `samples\java-monitor\context` directory in your Apama installation directory.

Using the Context class default constructor

The `com.apama.jmon.Context` class default constructor, `public Context()`, creates a dummy context that provides the same functionality as an uninitialized `context` variable in EPL. A JMon dummy context does not correspond to an actual correlator context. The JMon dummy context corresponds to the implicit context that is created in EPL for uninitialized context variables. The default constructor is provided for convenience. Use it when you want to enqueue an event to another context from a JMon application and the event happens to have a context field that contains an irrelevant value. As with other JMon types, this value cannot be null. Following is an example, beginning with the event definition:

```
import com.apama.jmon.*;

public class ContextEvent extends Event {
   public long id;
   public boolean req;
   public Context c;
   public ContextEvent(long id) {
      this.id = id;
```

```
      this.req = true;
      this.c = new Context();
   }
}
```

Here is the JMon application:

```
public class SampleJMonApp implements Monitor {
   ...
   public void onLoad() {
   ...
   ContextEvent req = new ContextEvent(service_id);
   ...
   // send requests here
   req.route();
   ...
   EventExpression cexpr =
      new EventExpression("all ContextEvent(*,false,*):ackEvt");
         cexpr.addMatchListener(new MatchListener() {
            public void match(MatchEvent event){
               ContextEvent ackEvt =
               (ContextEvent)event.getMatchingEvents().get("ackEvt");
               // extract the context here
               Context serviceContext = ackEvt.evt;
               ...
            }
         });
   }
   ...
}
```

Here is the EPL application:

```
monitor ContextFactory
{
   ...
   action onload() {
   ...
      ContextEvent req;
      on all ContextEvent(*, true, *):req {
         integer svcid;
         ...
         context serviceContext := context("svc");
         ContextEvent ack :=
            ContextEvent(svcid, false, serviceContext);
         route ack;
         ...
      }
   }
   ...
}
```

Descriptions of methods on the Context class

You can call the following methods on a `Context` object. For more information, see "context" on page 790.

- `public long getId()`

  Returns the unique identifier for the context. For a `Context` instance that would return the following `toString()` result: `"context(2,"context_name",false)"`, the `getId()` method returns the value `2`. This method returns `0` for a `Context` instance created with the default constructor.

- `public String getName()`

  Returns the name of the context. For example, suppose you create a context with the following EPL code:

  ```
  context c := context("test");
  ```

  If you transfer a reference to this context into your JMon application, a call to the `getName()` method on this context instance returns `"test"`.

  This method returns an empty string for a `Context` instance created with the default constructor.

- `public String toString()`

  Returns a string representation of the context instance. This method produces a string that is identical to the string that EPL produces. For example: `"context(2,"context_name",false)"`. The first item in the string, `2` in this example, is the context's unique identifier. The second item in the string, `"context_name"`, is the name of the context. The third item in the string is the value of the `receivesInput` boolean flag, which indicates whether the context is public or private.

  This method returns `"context(0,"",false)"` for a `Context` instance created with the default constructor.

  For details about public and private contexts, see "Implementing Parallel Processing" on page 303 and "Creating contexts" on page 306.

- `public static Context getCurrent()`

  Returns a `Context` instance that corresponds to the current correlator context. This is the context that contains the code that you are calling. Apama executes single-threaded JMon applications in the main correlator context. Consequently, this method always returns a a `Context` instance that references the main correlator context.

  During execution, JMon applications can create new Java threads. Do not confuse new threads with correlator contexts. The `Context.getCurrent()` method returns null when you call it inside newly created Java threads.

Identifying external events

In some situations, you might want to determine whether an event originated outside the correlator. To do this, call the `Event.isExternal()` method:

```
public boolean isExternal()
```

This method returns true if the event was sent to the correlator by some external process and that event was then passed into your JMon application.

Optimizing event types

"About event types" on page 655 introduced event type classes.

The correlator creates several indexing data structures for every event type. The complexity and efficiency of these data structures depends on the number of parameters an event has, and therefore ‘smaller' (with less parameters) events are processed more rapidly.

Therefore, if possible, when designing an application it is preferable to control it using a number of ‘smaller' event types rather than through a single event type with a large number of parameters.

Wildcarding parameters in event types

Alternatively, if large event types are unavoidable, you can optimize performance by reviewing the usage of these event types in JMon, specifically within event templates in event expressions.

If a parameter of an event is never matched against directly within any event expressions, that is only '`*`' (or wildcard) ever appears against it in event templates, then the event type's definition can be amended to indicate this. This tells the correlator to ignore this parameter in its internal indexing.

Consider the event type definition presented in "About event types" on page 655.

```
/*
 * Tick.java
 *
 * Class to abstract an Apama stock tick event. A stock tick event
 * describes the trading of a stock, as described by the symbol
 * of the stock being traded, and the price at which the stock was
 * traded
 *
 */
import com.apama.jmon.Event;

public class Tick extends Event {
   /** The stock tick symbol */
   public String name;

   /** The traded price of the stock tick */
   public double price;

   /**
    * No argument constructor
    */
   public Tick() {
      this("", 0);
   }

   /**
    * Construct a tick object and set the name and price
    * instance variables
    *
    * @param name  The stock symbol of the traded stock
    * @param price The price at which the stock was traded
```

```
    */
   public Tick(String name, double price){
      this.name = name;
      this.price = price;
   }
}
```

If all references to this event type in event expressions look similar to this,

```
Tick("ACME", *)
```

that is, where the second parameter `price` is always specified as a `*`, then this parameter could be *wildcarded* in the event type definition.

This can be done by annotating the field in the event type class, as shown here

```
/** The traded price of the stock tick */
@com.apama.jmon.annotation.Wildcard
public double price;
```

This definition in the `Tick` class will override the default behavior, and it lets the correlator know that it can optimize its indexing by ignoring the `price` parameter.

As many parameters as desired can be wildcarded in this way. For example, if both `price` and `name` were to be wildcarded in `Tick`, they should be defined as follows,

```
/** The stock tick symbol */
@com.apama.jmon.annotation.Wildcard
public String name;

/**The traded price of the stock tick */
@com.apama.jmon.annotation.Wildcard
public double price;
```

Of course, if you were to do this, then

```
Tick(*, *)
```

would be the only valid event template that can be expressed in JMon. Any other expression would cause a Java runtime error.

Logging in JMon applications

The logging facilities in JMon are provided by `Log4j`, a publicly available logging library for Java. These logging facilities are included in `com.apama.util.Logger`, for which reference information in `Javadoc` format is provided (`doc\javadoc\index.html` in your Apama installation directory).

Note: Full documentation for `Log4j` and the Apache Logging Service project can be found at http://logging.apache.org.

By default, the JMon classes will log at `WARN` level. The log level can be changed as described in the Javadoc for the `Logger` class. The Javadoc also provides instructions on how to get a reference to the `Logger` object in your own code so that you can produce your own logging output.

To ensure that the correlator can serialize logging behavior, specify that instances of `Logger` are static.

Using EPL keywords as identifiers in JMon applications

If you use EPL keywords as event name or field identifiers, then in the following situations you must escape such identifiers by preceding them with hash (`#`) symbols:

- You refer to the JMon identifier in EPL code — You must escape the identifier in the EPL code that contains the reference.
- You refer to the JMon identifier in a JMon event expression — You must escape the identifier in that JMon event expression.

For example, consider the following Java code:

```
class test extends Event {
   int id;
   float price;
   int integer;
}
```

Now suppose you want to write the following EPL code:

```
on all test(id=7): f {
   print f.toString();
   emit f;
}
```

No escaping is necessary. However, suppose you want to write this EPL code:

```
print f.integer.toString();
```

In this case, you must escape `integer` as follows:

```
print f.#integer.toString();
```

Likewise, you must escape `integer` in the following JMon event expression:

```
new EventExpression("all test(#integer > 5)");
```

For a list of EPL keywords, see "Keywords" on page 920.

22 Defining Event Expressions

Consider this code snippet from the previous example:

```
public void onLoad() {
   EventExpression eventExpr =
      new EventExpression("Tick(*, >10.0)");
   eventExpr.addMatchListener(this);
}
```

The highlighted code is creating an event expression, and embeds the following event expression definition string:

```
Tick(*, >10.0)
```

This is the simplest form of an event expression; specifically it contains a single *event template*.

In this case, the event expression is specifying “the first `Tick` event whose `price` parameter contains a value greater than 10.0”.

If you are already familiar with EPL, the syntax for writing JMon event expressions is the same as for EPL event expressions.

About event templates

The first part of an event template defines the event type of suitable events (in this case `Tick`), while the section in brackets describes filtering criteria that must be applied to the contents of events of the desired type for them to match.

In the example at the beginning of the chapter, the first parameter within the event template has been set to a wildcard (`*`), specifying that all `Tick` events, regardless of the value of their `name` parameter, are suitable. That is, as long as their second parameter, `price`, is greater than 10.The filtering criteria supplied are applied to the event's contents in the same order as within the event definition for that event type. This is known as *positional syntax*.

"Specifying parameter constraints in event templates" on page 676 lists all the filtering operators (like “>” above) that can be applied to the value of a parameter within an event template.

Specifying positional syntax

In positional syntax, the event template must define a value (or a wildcard) to match against for every parameter of that event's type, in the same order as the parameter's definition in the event type definition. Therefore, for the event type,

```
public class MobileUser extends Event {
   public long userID;
   public Location position;
   public String hairColour;
   public String starsign;
   public long gender;
   public long incomeBracket;
   public String preferredHairColour;
   public String preferredStarsign;
   public long preferredGender;
   // ... Constructors
```

```
}
```

a suitable event template definition might look like

```
MobileUser(*,*, "red", "Capricorn", *, *, *, *, 1)
```

This can get unwieldy when you are working with event types with a large number of parameters and very few of them are actually being used to filter on. An alternative syntax can be used that addresses this. The above can instead be expressed as:

```
MobileUser(hairColour="red", starsign="Capricorn",
  preferredGender=1)
```

This is known as *named parameter syntax* and in this style all other non-specified fields are set to wildcard.

Given the following event types:

```
public class A extends Event {
   public long a;
   public String b;

   // ... Constructors
}

public class B extends Event {
   public long a;

   // ... Constructors
}

public class C extends Event {
   public long a;
   public long b;
   public long c;

   // ... Constructors
}
```

Here are some equivalent event expressions that demonstrate how to use the two syntaxes:

	Positional Syntax	Name/Value Syntax
Using constants and literals	`on A(3,"string")` `on A(=3,="string")`	`on A(a=3,b="string")` `on A(b="string",a=3)`
Relational comparisons	`on B(>3)`	`on B(a>3)`
Ranges	`on B([2:3])`	`on B(a in [2:3])`
Wildcards	`on C(*,4,*)` `on C(*,*,*)`	`on C(b=4)` `on C(a=*,b=4,c=*)`

Positional Syntax	Name/Value Syntax
	`on C()`

More details about the operators and expressions possible within event templates are given in the next section.

Note that it is possible to mix the two styles as long as you specify positional parameters before named ones. There cannot be any positional parameters after named ones. Therefore the following syntax is legal:

```
D(3,>4,i in [2:4])
```

while the following is not:

```
E(k=9,"error")
```

Specifying completed event templates

In some situations, you want to ensure that the correlator completes all work related to a particular event before your application performs some other work. In your event template, specify the `completed` keyword to accomplish this. For example:

```
on all completed A(f < 10.0) {}
```

When an event that matches the template comes into the correlator, the correlator

1. Runs all of the event's normal and unmatched listeners.
2. Processes all routed events that result from those listeners.
3. Calls the `completed` listeners.

Specifying parameter constraints in event templates

The first part of an event template defines the event type of the event the listener is to match against, while the section in brackets describes further filtering criteria that must be satisfied by the contents of events of that type for a match.

Event template parameter operators specify constraints that define what values, or range of values, are acceptable for a successful event match.

Operator	Meaning
`[`*`value1`*` : `*`value2`*`]`	Specifies a range of values that can match. The values themselves are included in the range to match against. For example: `stockPrice(*, [0 : 10])` This event template will match a `stockPrice` event where the price is between 0 and 10 inclusive. This

Operator	Meaning
	range operator can only be applied to `double` and `long` types.
`[`*`value1`*` : `*`value2`*`)`	Specifies a range of values that can match. The first value itself is included while the second is excluded from the range to match against. For example: `stockPrice(*, [0 : 10))` This example will match a `stockPrice` event where the price is between 0 and 9 inclusive (assuming the parameter was of `long` type). This range operator can only be applied to `double` and `long` types.
`(`*`value1`*` : `*`value2`*`]`	Specifies a range of values that can match. The first value itself is excluded from while the second is included in the range to match against. For example: `stockPrice(*, (0 : 10])` This example will match a `stockPrice` event where the price is between 1 and 10 inclusive (assuming the parameter was of `long` type). This operator can only be applied to `double` and `long` types.
`(`*`value1`*` : `*`value2`*`)`	Specifies a range of values that can match. The values themselves are excluded in the range to match against. For example: `stockPrice(*, (0 : 10))` This example will match if a `stockPrice` event where the price is between 1 and 9 inclusive (assuming the parameter was of `long` type). This operator can only be applied to `double` and `long` types.
`>` *`value`*	All values greater than the value supplied will satisfy the condition and match. This operator can only be applied to `double` and `long` types.

Operator	Meaning
`< value`	All values less than the value supplied will satisfy the condition and match.This operator can only be applied to `double` and `long` types.
`>= value`	All values greater than or equal to the value supplied will satisfy the condition and match. This operator can only be applied to `double` and `long` types.
`<= value`	All values less than or equal to the value supplied will satisfy the condition and match. This operator can only be applied to `double` and `long` types.
`value`	Only a value equivalent to the value supplied will satisfy the condition and match. A `String` value must be enclosed in double quotes (" "), and therefore these need to be preceded with an escape character inside event expression definitions in an `EventExpression` constructor (\") A `Location` value must consist of a structure with four `double`s representing the coordinates of the corners of the rectangular space being represented.
`*`	Any value for this parameter will satisfy the condition and match.

Obtaining matching events

An event template provides a definition against which several event instances could match. Once a listener triggers, sometimes it is necessary to get hold of the *actual* event that matched the template.

This can be achieved through *event tagging*.

EPL - If you are familiar with EPL, event tagging in JMon is similar in principle to variable coassignment in EPL. For this reason the term *coassigned* is sometimes used to refer to event tagging.

Consider this revised `Simple` monitor:

```
import com.apama.jmon.*;

public class Simple implements Monitor, MatchListener {
```

```
   /**
    * No argument constructor used by the jmon framework on
    * application loading
    */
   public Simple() {}

   /**
    * Implementation of the Monitor interface onLoad method. Sets up
    * a single event expression looking for all stock trade events
    * with a trade price of greater than 10.0. This class instantiation
    * is added as a match listener to the event expression.
    */
   public void onLoad() {
      EventExpression eventExpr = new EventExpression("Tick(*, >10.0):t");
      eventExpr.addMatchListener(this);
   }

   /**
    * Implementation of the MatchListener interface match method.
    * Extracts the tick event that caused the event expression to
    * trigger and emits the event onto the default channel
    */
   public void match(MatchEvent event) {
      Tick tick = (Tick)event.getMatchingEvents().get("t");
      System.out.println("Event details: "  + tick.name
         + " "   + tick.price);
      tick.emit();
   }
}
```

Note the revised event expression

```
Tick(*, >10.0):t
```

This specifies that when a suitable `Tick` event is detected, it must be recorded with the `t` tag. This allows a developer to get hold of the actual event that matched the event expression within the registered match listener's `match` method.

Once the `eventExpr` listener detects a suitable event it will trigger and call `match`, passing to it a `MatchEvent` object. This object embeds within it all the individual event instances that together caused the event expression to be satisfied and were tagged.

In this example our event expression still consists of a single event template, and since this is tagged, then the `MatchEvent` object will contain the single `Tick` event that triggered the `eventExpr` listener. This will be tagged as `t`.

A `MatchEvent` object has two methods:

- `HashMap getMatchingEvents()` - Get the set of tagged `Event`s that caused the match. This method returns a `Map` of the tagged `Event` objects that hold the values that matched the source `EventExpression`.
- `Event getMatchingEvent(String key)` - Get one of the tagged `Event`s that caused the match. This method returns the tagged Event object that matched in the source `EventExpression`.

Refer to the reference documentation provided in Javadoc format for complete class and method signatures (`doc\javadoc\index.html` in your Apama installation directory).

The lines:

```
Tick tick = (Tick)event.getMatchingEvents().get("t");
```

or

```
Tick tick = event.getMatchingEvent("t");
```

show how the tagged event can be extracted by using the tag as a key.

Emitting, routing, and enqueuing events

Once the event has been extracted it can also be *emitted*, *routed*, or *enqueued*.

This functionality is provided by the following methods of the `Event` class:

- `route()` — Route this event internally within the correlator.
- `emit()` — Emit this event from the correlator onto the default channel.
- `emit(String channel)` — Emit this event from the correlator onto the named channel.
- `enqueue()` — Route this event internally within the correlator to a special queue just for enqueued events.
- `enqueueTo()` — Route this event internally within the correlator to the input queue of the specified context or contexts.

The `route` method generates a new event that is dispatched back into the correlator. Any active listeners seeking that event then receive this. There is no difference between an externally sourced event (passed in through a live message feed) and an event that was issued internally through a `route` method, other than that internally routed events are placed at the front of the input queue, although in the same order as they are routed within an action.

The `emit` method dispatches events to external registered event receivers, i.e. sends them out from the correlator. Active listeners will not receive events that are emitted.

Events are emitted onto named *channels*. For an application to receive events from the correlator it must register itself as an event receiver and *subscribe* to one or more channels. Then if events are emitted to those channels they will be forwarded to it.

Channels effectively allow both *point-to-point* message delivery as well as through *publish-subscribe*. Channels can be set up to represent topics. External applications can then subscribe to event messages of the relevant topics. Otherwise a channel can be set up purely to indicate a destination and have only one application connected to it.

The `enqueue()` method generates an event and places the event on a special queue just for events generated by the `enqueue()` method. A separate thread moves each enqueued event to the input queue of each public context. This arrangement ensures that that if a public context's input queue is full, the event generated by `enqueue()` still arrives on its special queue, and is moved to that context's input queue when there is a room. Active listeners will eventually receive events that are `enqueue`'d, once those events make their way to the head of the context's input queue alongside normal events.

Use the `enqueue()` method when you want to ensure that the correlator processes the generated event after it processes all routed events. This means that you want the correlator to finish processing the current external event. Completion of processing the current external event means that all routed events that resulted from that external event have been processed.

In a parallel application, you can enqueue an event to a particular context by calling the following method on an instance of `com.apama.jmon.Event`:

```
public void enqueueTo(Context ctx)
```

This method provides the same functionality provided by the EPL `enqueue ... to` statement. See "Sending an event to a particular context" on page 312.

However, it is important to mention that when you enqueue an event to a particular context the event goes on that context's input queue and not on the special queue for enqueued events. Consequently, when you call this method from an application thread that was created from the main JMon application and the destination context's input queue is full, this method blocks until the queue is able to accept the event.

Call the following method to enqueue an event to a array of contexts:

```
public void enqueueTo(Context[] ctxArray)
```

Call the following method to enqueue an event to a list of contexts:

```
public void enqueueTo(List < Context> ctxList)
```

Specifying temporal sequencing

If you want to search for a temporal sequence of two events, for example, “locate the sequence of a `NewsItem` event followed by a `Tick` event”, there are two ways you can proceed in JMon.

Chaining listeners

You can *chain* listeners, as follows:

```
// Code within the monitor class

public void onLoad() {
   EventExpression eventExpr = new EventExpression("NewsItem(*, *)");
   eventExpr.addMatchListener(matchListener1);
}

// Code within the first Match Listener class - matchListener1
public void match(MatchEvent event) {

   // Arbitrary additional code …
   EventExpression eventExpr = new EventExpression("Tick(*, *)");
   eventExpr.addMatchListener(matchListener2);
}

// Code within the second Match Listener class - matchListener2

public void match(MatchEvent event) {
   System.out.println("Detected a NewsItem followed"
      + " by a Tick event, both regarding any company.");
}
```

The Java code above shows how to set up a listener to seek the first event, and then once that is located, start searching for the second. This programming style is particularly appropriate when further actions need to be taken at each stage of the event detection, in this case between detecting the `NewsItem` and seeking the `Tick`.

It is also the only way in which the event templates can be ‘linked' together. If the desired effect was to locate ‘any' first `NewsItem` and then seek a `Tick` specifically for the same company mentioned in the `NewsItem`, you could amend the example as follows,

```
// Code within the monitor class
public void onLoad() {
   EventExpression eventExpr
      = new EventExpression("NewsItem(*, *):n");
   eventExpr.addMatchListener(matchListener1);
}

// Code within the first Match Listener class - matchListener1
public void match(MatchEvent event) {

   NewsItem newsItem = (NewsItem)event.getMatchingEvents().get("n");
   EventExpression eventExpr
      = new EventExpression("Tick(\"" + newsItem.name + "\", *)");
   eventExpr.addMatchListener(matchListener2);
}

// Code within the second Match Listener class - matchListener2
public void match(MatchEvent event) {
   System.out.println("Detected a NewsItem, followed"
      + " by an Tick event regarding the same company.");
}
```

Note how the above code seeks out a `NewsItem` on any company, but then extracts the actual `NewsItem` event detected, and uses its `name` parameter to create the event template for seeking the `Tick` event.

Using temporal operators

Let us return to how to express searching for a temporal sequence. If there is no requirement to execute any arbitrary code in between events and there is no requirement to link searches as illustrated above, then you can embed a temporal event expression within a single listener.

The first code excerpt could be re-written as follows,

```
// Code within the monitor class
   public void onLoad() {
      EventExpression eventExpr
         = new EventExpression("NewsItem(*,*) -> Tick(*,*)");
      eventExpr.addMatchListener(matchListener1);
  }

// Code within the first (and only) Match Listener class - matchListener1
   public void match(MatchEvent event) {
      System.out.println("Detected a NewsItem followed"
         + " by a Tick event, both regarding any company.");
  }
```

The event expression definition for `eventExpr` no longer consists of a single event template. It now has multiple clauses and contains a temporal operator.

In this case, the operator used is `->`, or the *followed-by* operator. This is the primary temporal operator for use in event expressions. It allows a developer to express a sequence of events to match against within a single listener, with the listener triggering once the whole sequence is encountered.

In Java, an event sequence does not imply that the events have to occur right after each other, or that no other events are allowed to occur in the meantime.

For the sake of brevity, let `A, B, C` and `D` represent event templates, and `A'`,`B'`,`C'` and `D'` be individual events that match those templates, respectively. If a listener is created to seek the event expression `(A -> B)`, the event feed {`A'`,`C'`,`B'`,`D'`} would result in a match once the `B'` is received by the correlator.

Followed-by operators can be chained to express longer sequences. Therefore you could write,

```
A -> B -> C -> D
```

within an event expression definition.

The next section focuses on the use of temporal operators in event expressions.

Defining advanced event expressions

An event template is the simplest form of an event expression. All event expression operators, including `->`, can themselves take entire event expressions as operands.

It is useful to think of event expressions as being Boolean expressions. Each clause in an event expression can be true or false, and the whole event expression must evaluate to true before the listener triggers and calls the match listener's `match` method.

As before, for the sake of brevity, let us use the letters `A, B, C` and `D` to represent event templates, and `A'`,`B'`,`C'` and `D'` to represent individual events that match those templates, respectively.

Once more, consider this representation of an event expression,

```
A -> B -> C -> D
```

When the listener is first activated it is helpful to consider the expression as starting off by being false. When an event that satisfies the `A` clause occurs, the `A` clause becomes true. Once `B` is satisfied, `A -> B` becomes true in turn, and evaluation progresses in a similar manner until eventually all `A -> B -> C -> D` evaluates to true. Only then does the listener trigger and call the associated match listener's `match` method. Of course, this event expression might never become true in its entirety (as the events required might never occur) since no time constraint (see "Specifying the timer operators" on page 691) has been applied to any part of the event expression.

Specifying other temporal operators

For a listener to trigger on an event sequence, the event expression defining what to match against must evaluate to `true`.

The `or` operator allows you to specify event expressions where a variety of event sequences could lead to a successful match. It effectively evaluates two event templates (or entire nested event expressions) simultaneously and returns true when either of them become true.

For example,

```
A or B
```

means that either `A` or `B` need to be detected to match. That is, the occurrence of one of the operand expressions (an `A` or a `B`) is enough to satisfy the listener.

The `and` operator specifies an event sequence that might occur in any temporal order. It evaluates two event templates (or nested event expressions) simultaneously but only returns true when they are both true.

```
A and B
```

will seek 'an `A` followed by a `B`' or 'a `B` followed by an `A`'. Both are valid matching sequences, and the listener will seek both concurrently. However, the first to occur will terminate all monitoring and trigger the listener.

The following example code snippets indicate a few patterns that can be expressed using the three operators presented so far.

Example	Meaning
`A -> (B or C)`	Match on an `A` followed by either a `B` or a `C`.
`(A -> B) or C`	Match on either the sequence `A` followed by a `B`, or just a `C` on its own.
`A -> ((B -> C) or (C -> D))`	Find an `A` first, and then seek for either the sequence `B` followed by a `C` or `C` followed by a `D`. The latter sequences will be looked for concurrently, but the monitor will match upon the first complete sequence that occurs. This is because the `or` operator treats its operands atomically, i.e. in this case it is looking for the sequences themselves rather than their constituent events.
`(A -> B) and (C -> D)`	Find the sequence `A` followed by a `B` (`A -> B`) followed by the sequence `C -> D`, or else the sequence `C -> D` followed by the sequence `A -> B`. The `and` operator treats its operands

Example	Meaning
	atomically—that is, in this case it is looking for the sequences themselves and the order of their occurrence, rather than their constituent events. It does not matter when a sequence starts but it occurs when the last event in it is matched. Therefore {A',C',B',D'} would match the specification, because it contains an A -> B followed by a C -> D. In fact the specification would match against either of the following sequences of event instances; {A',C',B',D'}, {C',A',B',D'}, {A',B',C',D'}, {C',A',D',B'}, {A',C',D',B'}, and {C',D',A',B'}.

The not operator is unary and acts to invert the truth value of the event expression it is applied to.

```
A -> B and not C
```

therefore means that the correlator will match only if it encounters an A followed by a B without a C occurring at any time before the B is encountered.

Note: The not operator can cause an event expression to reach a state where it can never evaluate to true any more, that is, it will become *permanently false*.

Consider this listener event sequence:

```
on (A -> B) and not C
```

The listener will start seeking both A -> B and not C concurrently. If an event matching C is received at any time before one matching B, the C clause will evaluate to true, and hence not C will become false. This will mean that (A -> B) and not C will never be able to evaluate to true, and hence this listener will never trigger. In practice the correlator cleans out these *zombie* listeners periodically.

Note: It is possible to write an event expression that always evaluates to true immediately, without any events occurring.

Consider this listener:

```
on (A -> B) or not C
```

Assuming that A, B, and C represent event templates, their value will start off as being false. However, that means that not C will become true immediately, and hence the whole expression will become true right away. This listener will therefore trigger immediately as soon as it is instantiated. If any of A, B or C were nested event expressions the same logic would apply for their own evaluation.

Specifying a perpetual listener for repeated matching

So far all the examples given have created listeners that will trigger on the first occurrence of an event (or sequence of events) that satisfies the supplied event expression.

For example,

```
public void onLoad() {
   EventExpression eventExpr = new EventExpression("Tick(*, >10.0)");
   eventExpr.addMatchListener(this);
}
```

locates the *first* occurrence of a `Tick` event that satisfies the `Tick(*, >10.0)` event template. This first suitable event triggers the listener and calls the `match` method of the registered match listener object.

However, you might want to detect *all*`Tick` events that satisfy the above event template (or event expression). To do this you must create a *perpetual* listener, that is, one that does not terminate on the first suitable occurrence, but instead stays alive and triggers repeatedly on every subsequent occurrence.

This effect can be achieved through use of the `all` event expression operator.

If the above is rewritten as follows,

```
public void onLoad() {
   EventExpression eventExpr =
      new EventExpression("all Tick(*, >10.0)");
   eventExpr.addMatchListener(this);
}
```

the listener created will now seek the first `Tick` event whose price is greater than 10. Upon detecting such an event it will trigger and call the `match` method. It will then return to monitoring the incoming event streams to look for the next suitable occurrence. This behavior will be repeated indefinitely until the listener is explicitly deactivated. This means that potentially the `match` method could be invoked multiple times.

Deactivating a listener

A listener whose event expression embeds an `all` operator will stay active indefinitely and trigger repeatedly. It will continue doing this until it is explicitly deactivated. This can be done using the `removeMatchListener` method on the `EventExpression` object.

Refer to the Apama API for Java (JMon) reference information provided in Javadoc format for complete class and method signatures (`doc\javadoc\index.html` in your Apama installation directory).

Temporal contexts

Imagine that we have seven event templates defined, which for the sake of brevity are represented by the letters `A`, `B`, `C`, `D`, `E`, `F` and `G` in the following text. Now, consider a stream of incoming events, where `Xn` indicates an event instance that matches the event template `X`. Likewise, `Xn+1` indicates another event instance that matches against `X`, but which need not necessarily be identical to `Xn`.

Consider the following sequence of incoming events:

```
C1 A1 F1 A2 C2 B1 D1 E1 B2 A3 G1 B3
```

Given the above event sequence, what should the event expression

```
A -> B
```

match upon?

In theory the combinations of events that correspond to “an `A` followed by a `B`” are:

```
{A1, B1}, {A1, B2}, {A1, B3}, {A2, B1}, {A2, B2}, {A2, B3}, {A3, B3}
```

In practice it is unlikely that a developer wanted their monitor to match seven times on the above example sequence, and it is uncommon for all the combinations to be useful.

In fact, consistent with the truth-value based matching behavior already described, the event expression `A -> B` will only match on the first event sequence that matches the expression. Given the above event sequence the listener will trigger only on {`A1`, `B1`}, call the associated `match` method, and then terminate.

If a developer wishes to alter this behavior, and have the monitor match on more of the combinations, they can use the `all` operator within the event expression.

If the listener's specification was rewritten to read:

```
all A -> B
```

the listener would match on ‘every `A`' and the first `B` that follows it.

The way this works is that upon encountering an `A`, a second *child* listener (or *sub-listener*) is created to seek for the next `A`. Both listeners would continue looking for a `B` to successfully match the sequence specified. If more `A`'s are encountered the procedure is repeated; this behavior continues until the *master* listener is explicitly deactivated.

Therefore `all A -> B` would match on {`A1`, `B1`}, {`A2`, `B1`} and {`A3`, `B3`}.

Note that `all` is a unary operator and has higher precedence than `->`, `or` and `and`. Therefore `all A -> B` is the same as `(all A) -> B` or `( ( all A ) -> B )`.

The following table illustrates how the execution of `on all A -> B` proceeds over time as the above sequence of input events is processed by the correlator. The timeline is from left to right, and each stage is labeled with a time `tn`, where `tn+1` occurs after `tn`. To the left are listed the listeners, and next to each one (after the `?`) is shown what event template that listener is looking for at that point in time. In the example, assuming `L` was the initial listener, `L'`, `L''` and `L'''` are other sub-listeners that are created as a result of the `all` operator.

Guide to the symbols used:

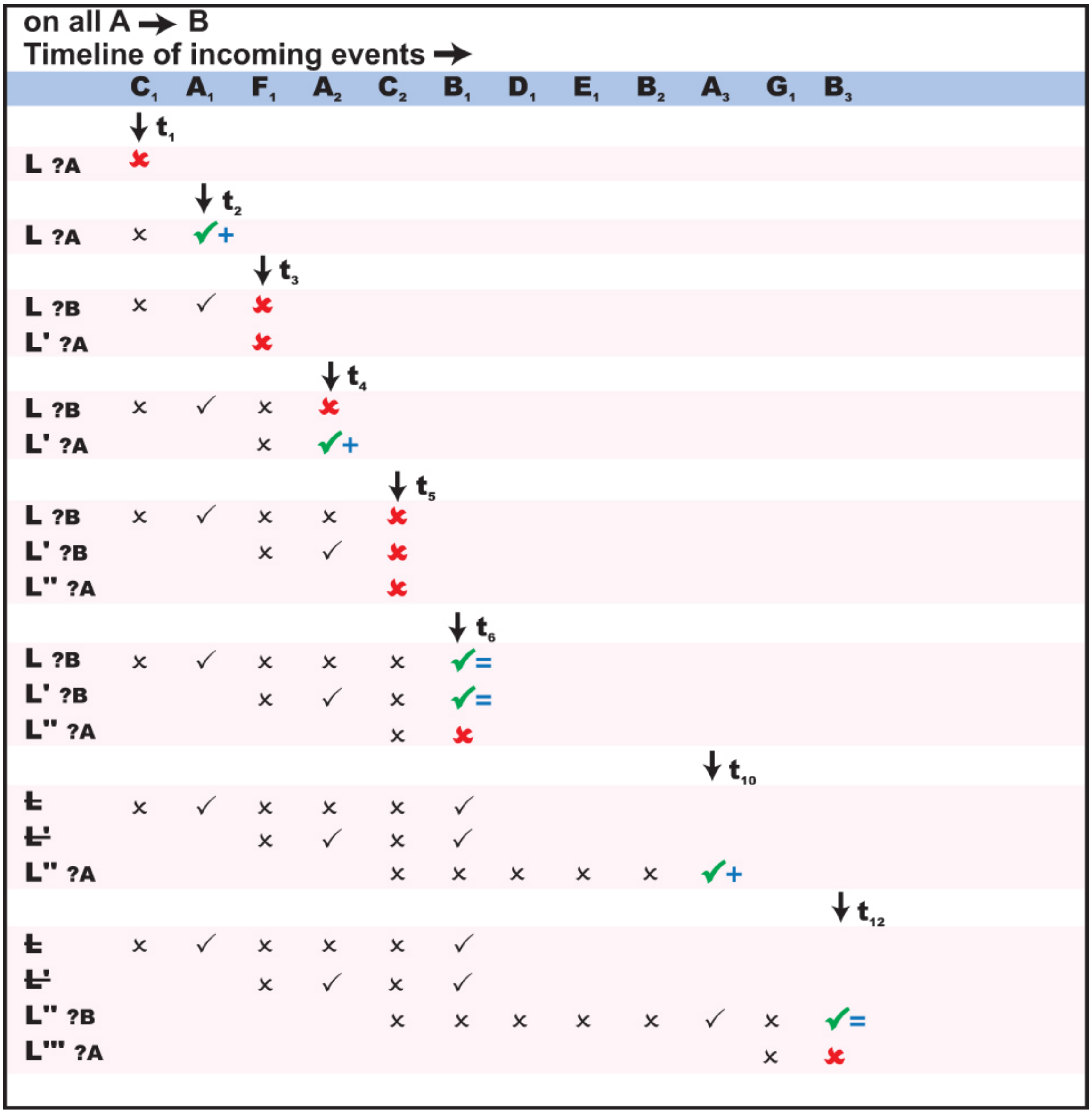
 indicates a specific point in time when a particular event is received

 indicates that at that time no match was found

✓ indicates that the listener has successfully located an event that matches its current active template

= is used to indicate that a listener has successfully triggered

\+ indicates that a new listener is going to be created.



The master listener denoted by `all A -> B` will never terminate as there will always be a sub-listener active looking for an `A`.

If, on the other hand, the specification is written as,

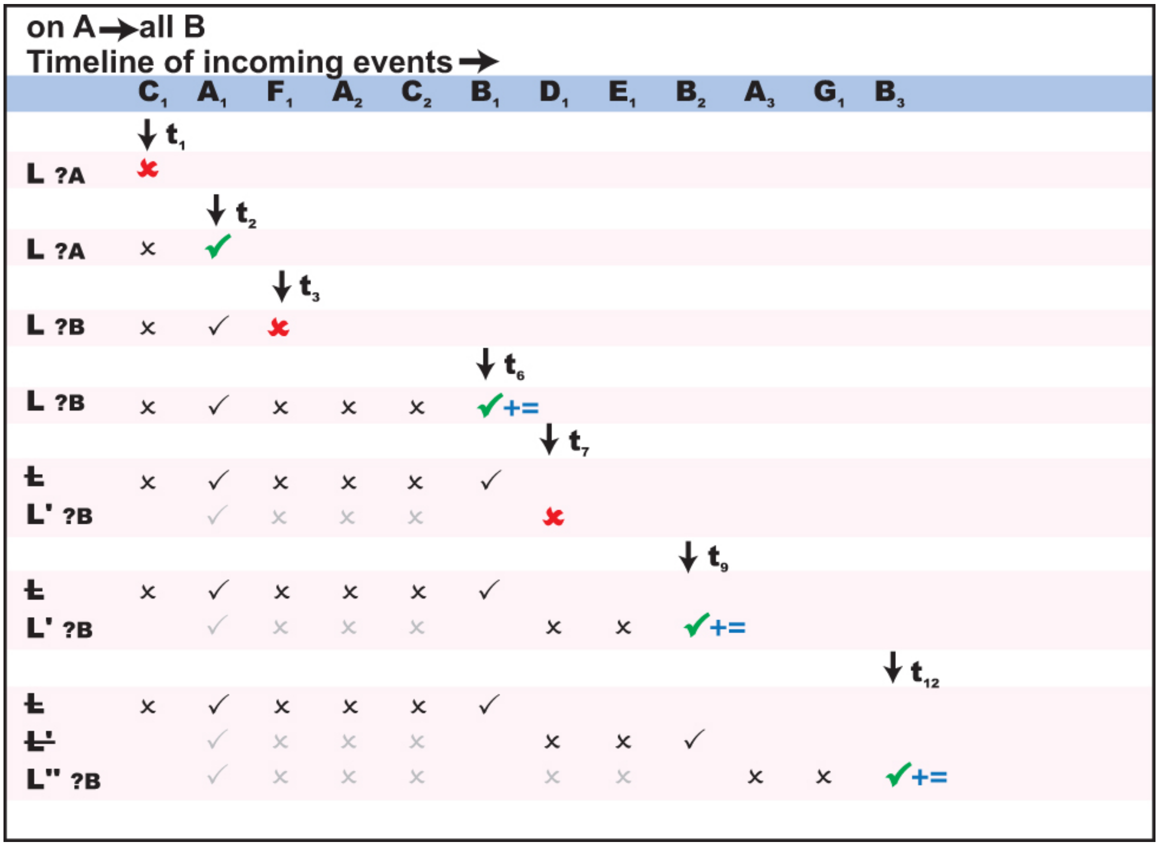
```
A -> all B
```

the listener would now match on all the sequences consisting of the first `A` and each possible following `B`.

The way this works is by creating a second listener upon matching a `B` that then goes on to search for an additional `B`, and so on repeatedly until the listener is explicitly killed.

Therefore `A -> all B` would match {`A1`, `B1`}, {`A1`, `B2`} and {`A1`, `B3`}.

Graphically this would now look as follows:



The table shows the early states of `L'` and `L''` in light color because those listeners actually never really went through those states themselves. However, since they were created as a clone of another listener, it is as though they were.

The master listener denoted by `A -> all B` will never terminate, as there will always be a sub-listener looking for a `B`.

The final permutation is to write the monitor as,

```
all A -> all B
```

Now the listener would match on an `A` and create another listener to look for further `A`'s. Each of these listeners will go on to search for a `B` after it encounters an `A`. However, in this instance all listeners are duplicated once more after matching against a `B`.

The effect of this would be that `all A -> all B` would match {`A1`, `B1`}, {`A1`, `B2`}, {`A1`, `B3`}, {`A2`, `B1`}, {`A2`, `B2`}, {`A2`, `B3`} and {`A3`, `B3`}, i.e. all the possible permutations. This could cause a very large number of sub-listeners to be created.

Note: The `all` operator must be used with caution as it can create a very large number of sub-listeners, all looking for concurrent patterns. This is particularly applicable if multiple `all` operators are nested within each other. This can have an adverse impact on performance.

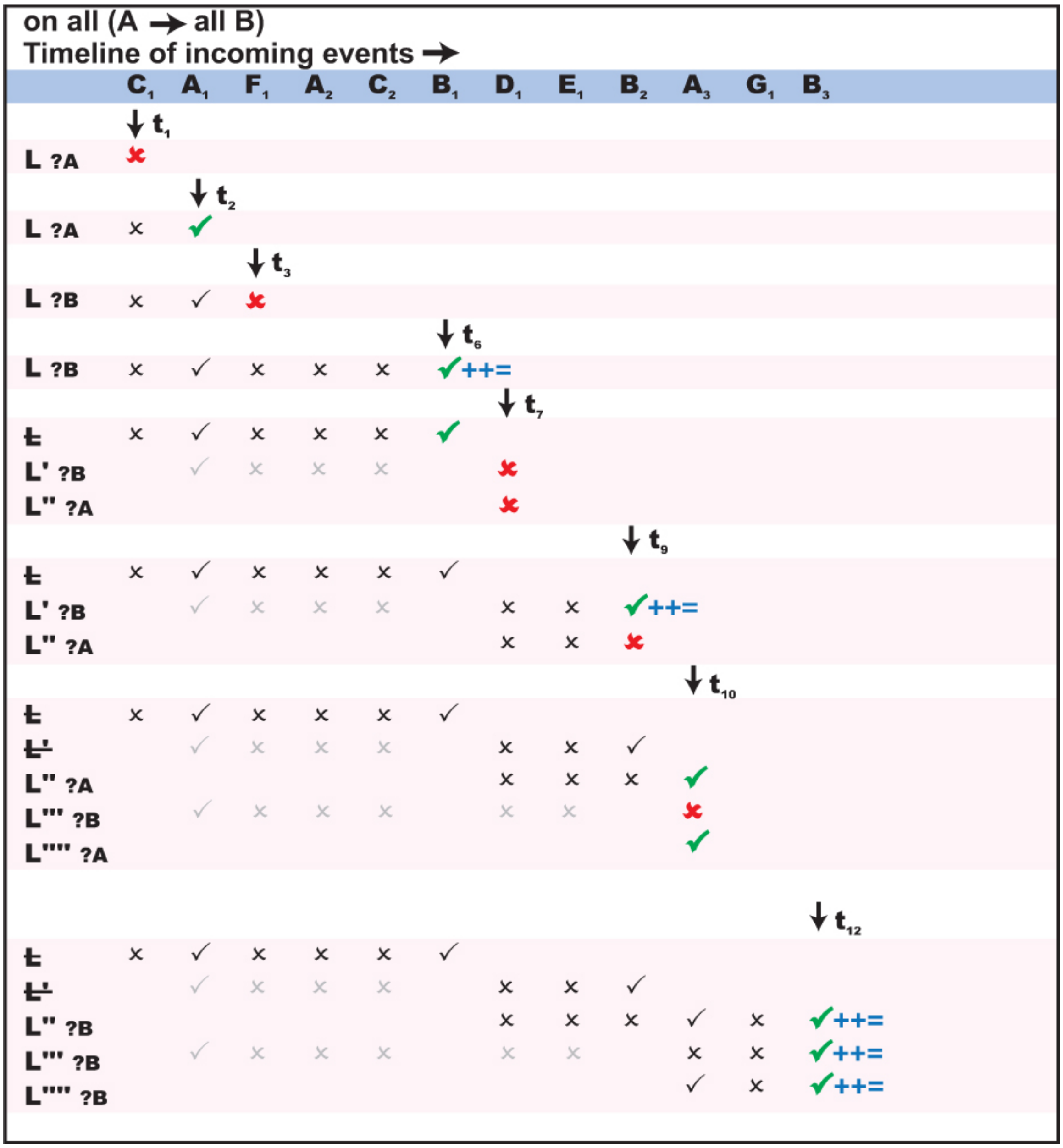
As with all other event expression operators, the `all` operator can be used within nested event expressions, and be nested within the operating context of another `all` operator. This can have a dramatic effect on the number of sub-listeners created.

Consider the example,

```
all (A -> all B)
```

This will match the first `A` followed by all subsequent `B`'s. However, as on every match of an `A` followed by `B`, `(A -> all B)` becomes true, then a new search for the 'next' `A` followed by all subsequent `B`'s will start. This will repeat itself recursively, and eventually there could be several concurrent sub-listeners that might match on the same sequences, thus causing duplicate triggering.

On the same event sequence as previously, graphically, this would be evaluated as follows:



Thus matching against {A1, B1}, {A1, B2}, {A1, B3}, and twice against {A3, B3}. Notice how the number of active listeners is progressively increasing, until after t12 there would actually be six active listeners, three looking for a B and three looking for an A.

Specifying the timer operators

So far we have shown how to use event expressions to define interesting sequences of events to look for, where the events of interest depend not only on their type and content, but also on their temporal relationship to (whether they occur before or after) other events.

Being able to define temporal relationships can be useful, but typically it also needs to be constrained over some temporal interval.

Looking for event sequences within a set time

Consider this earlier example:

```
// Code within the monitor class
public void onLoad() {
   EventExpression eventExpr = new EventExpression(
      "NewsItem(\"ACME\",*) -> Tick(\"ACME\",*)");
   eventExpr.addMatchListener(matchListener1);
}

// Code within the first (and only) Match Listener
// class - matchListener1

   public void match(MatchEvent event) {
      System.out.println("Detected a NewsItem followed"
         + " by an Tick event, both regarding the ACME company.");
   }
```

This will look for the event sequence of a news item about a company followed by a stock price tick about that company. Once improved this could be used to detect the beginning of a rise (or fall) in the value of shares of a company following the release of a relevant news headline.

However, unless a temporal constraint is put in place, the monitor is not going to be that pertinent, as it might trigger on an event sequence where the price change occurs weeks after the news item. That would clearly not be so useful to a trader, as the two events were most likely unrelated and hence not indicative of a possible trend.

If the event expression above is rewritten as follows,

```
EventExpression eventExpr = new EventExpression(
   "NewsItem(\"ACME\",*) -> Tick(\"ACME\",*) within(30.0)");
```

the `Tick` event would now need to occur within 30 seconds of `NewsItem` for the listener to trigger.

The `within(`*float* `)` operator is a postfix unary operator that can be applied to an event expression (the `Tick` event template in the above example). Think of it like a stopwatch. The clock starts ticking as soon as the event expression it is attached to becomes active, i.e. when the listener actually starts looking for it. If the stopwatch reaches the specified figure before the event expression evaluates to `true` the event expression becomes permanently `false`.

In the above code, the timer is only activated once a suitable `NewsItem` is encountered. Unless an adequate `StockTick` then occurs within 30 seconds and makes the expression evaluate to true, the timer will fire and fail the whole listener.

As already specified, the `within` operator can be applied to any event expression, hence `A within(x)`, where `A` represents just an event template and `x` is a float value specifying a number in seconds, is perfectly valid.

Waiting within a listener

The second timer operator available for use within event expressions is `wait(`*float*`)`.

`wait` allows you to insert a ‘temporal pause' within an event expression. Once activated, a `wait` expression becomes true automatically once a set amount of time passes. For example,

```
A -> wait(x seconds) -> C
```

will proceed as follows; activate the listener and look for the `A` event expression or template, then once `A` becomes true pause (i.e. wait) for `x` seconds, then finally start looking for the `C` event expression or template.

In addition to being part of an event expression, `wait` can also be used on its own,

```
wait(20.0)
```

is a valid event expression in its own right. When its listener activates it just waits for the number of seconds specified (here being `20`), then it evaluates to true and calls any registered `match` methods.

Therefore a `wait` clause starts off being false, and then turns to true once its time period expires. This behavior can be inverted through use of `not`. The expression

```
not wait(20.0)
```

would start off being true, and stay true for 20 seconds before becoming false.

The following,

```
B and not wait(20.0)
```

is an interesting example. It effectively means that this listener will trigger only if a `B` occurs within 20 seconds of its activation. After that the `not wait(20)` clause would become false and prevent the listener from ever triggering.

By using `all` with `wait`, you can easily implement a periodic repeating timer,

```
all wait(5.0)
```

This listener will trigger every 5 seconds and calls any registered `match` methods.

Working with absolute time

The final temporal operator is the `at` operator. This operator allows you to express temporal activity with regards to absolute time.

The `at` operator allows triggering of a timer:

- At a specific time; for example, at 12:30pm on April, 5th.
- Repeatedly with regards to the calendar when used in conjunction with the `all` operator, across seconds, minutes, hours, days of the week, days of the month, and months; for example, on every hour, or on the first day of the month, or every 10 minutes past and 40 minutes past.

The syntax is as follows:

```
at(minutes , hours , days_of_the_month , month , days_of_the_week
```

```
  [ , seconds ])
```

where the last operand, `seconds`, is optional.

Valid values for each operand are as follows:

Timer operand	Values
minutes	`0` to `59`, indicating minutes past the hour.
hours	`0` to `23`, indicating the hours of the day.
days_of_the_month	`1` to `31`, indicating days of the month. For some months only `1` to `28`, `1` to `29` or `1` to `30` are valid ranges.
month	`1` to `12`, indicating months of the year, with `1` corresponding to January
days_of_the_week	`0` to `6`, indicating days of the week, where `0` corresponds to Sunday.
seconds	`0` to `59`, indicating seconds past the minute.

The operator can be embedded within an event expression in a manner similar to the `wait` operator. If used outside the scope of an `all` operator it will trigger only once, at the *next* valid time as expressed within its elements. In conjunction with an `all` operator, it will trigger at *every* valid time.

The wildcard symbol (`*`) can be specified to indicate that all values are valid, i.e.

```
at(5, *, *, *, *)
```

would trigger at the next “five minutes past the hour”, while

```
all at(5, *, *, *, *)
```

would trigger at five minutes past each hour (i.e. every day, every month).

Whereas,

```
all at(5, 9, *, *, *)
```

would trigger at 9:05am every day.

However,

```
all at(5, 9, *, *, 1)
```

would trigger at 9:05am only on Mondays, and never on any other weekday. This is because the effect of the wildcard operator is different when applied to the *`days of the week`* and the *`days of the month`* elements. This is due to the fact that both specify the same entity. The rule is therefore as follows:

- As long as both elements are set to wildcard, then each day is valid.

- If either of the `days of the week` or the `days of the month` elements is not a wildcard, then only the days that match that element will be valid. The wildcard in the other element is effectively ignored.
- If both the `days of the week` and the `days of the month` elements are not a wildcard, then the days valid will be the days which match either. That is, the two criteria are *or*''ed, not and'ed.

A range operator (`:`) can be used with each element to define a range of valid values. For example

```
all at(5:15, *, *, *, *)
```

would trigger every minute from 5 minutes past the hour till 15 minutes past the hour.

A divisor operator (`/x`) can be used to specify that every `x`'th value is valid. Therefore

```
all at(*/10, *, *, *, *)
```

would trigger every ten minutes, that is, at 0, 10, 20, 30, 40 and 50 minutes past every hour.

If you wish to specify a combination of the above operators you must enclose the element in square brackets (`[]`), and separate the value definitions with a comma (`,`). For example,

```
all at([*/10,30:35,22], *, *, *, *)
```

indicates as following values for minutes to trigger on; 0,10, 20, 22, 30, 31, 32, 33, 34, 35, 40 and 50.

A further example,

```
all at(*/30,9:17,[*/2,1],*,*)
```

would trigger every 30 minutes from 9am to 5pm on even numbered days of the month as well as specifically the first day of the month.

Optimizing event expressions

When a developer creates an event expression, a substantial percentage of the computational overhead goes into parsing the event expression itself.

If you need to create several instances of an event expression where only literal values in event templates vary, this repeated parsing cost can be removed through the use of a *prepared* event expression.

Instead of writing,

```
EventExpression eventExpr1 = new EventExpression(
   "NewsItem(\"ACME\",*) -> Tick(\"ACME\",*)");
EventExpression eventExpr2 = new EventExpression(
   "NewsItem(\"EMCA\",*) -> Tick(\"EMCA\",*)");
eventExpr1.addMatchListener(matchListener1);
eventExpr2.addMatchListener(matchListener2);
```

you could write,

```
PreparedEventExpressionTemplate et
```

```
   = new PreparedEventExpressionTemplate(
      "NewsItem(?,*) -> Tick(?,*)");

PreparedEventExpression pex1=et.getInstance();
pex1.setString(0, "ACME");
pex1.setString(1, "ACME");

PreparedEventExpression pex2=et.getInstance();
pex2.setString(0, "EMCA");
pex2.setString(1, "EMCA");

pex1.addMatchListener(matchListener1);
pex2.addMatchListener(matchListener2);
```

The above example shows how instead of creating two very similar event expressions you can create a single prepared event expression template, and then customize multiple instances of it. The main advantage of the latter approach is the fact that the event expression was parsed in Java only once. With an example as simple as the ones above this would in fact hardly make any difference, but in Java code with hundreds of such event expressions the difference in performance can be significant.

As shown in the code snippet above, the procedure for creating listeners with prepared event expressions is slightly different from that of normal event expressions.

You must create a `PreparedEventExpressionTemplate` and define within that the event expression. The syntax for event expression definitions is the same as previously with the exception of the `?` operator. This can be used instead of any literal value. The next step is to get an instance of a `PreparedEventExpression`, and then to set values for any literals replaced by `?` in the prepared event expression template. Finally, you can create listeners on the `PreparedEventExpression` instances just as with normal event expressions.

Validation of event expressions

When an `EventExpression` or `PreparedEventExpressionTemplate` is created or when `addMatchListener()` is called on an event expression within a JMon monitor the event expression is not validated immediately. It is queued for processing later when the JMon monitor yields control back to the correlator. This means that a badly formed event expression does not cause an exception to be thrown from the constructor. Instead, the correlator logs an error message later when it tries to validate the event expression.

23 Concept of Time in the Correlator

An understanding of how the correlator handles time is essential to writing Apama applications. The topics below discuss time in the correlator.

See also "Disabling the correlator's internal clock" on page 197 in *Developing Apama Application in EPL*.

Correlator timestamps and real time

When the correlator receives an event, it gives the event a timestamp that indicates the time that the correlator received the event. The correlator then places the event on the input queue of each public context. The correlator processes events in the order in which they appear on input queues.

An input queue can grow considerably. In extreme cases, this might mean that a few seconds pass between the time an event arrives and the time the correlator processes it. As you can imagine, this has implications for whether the correlator triggers listeners. However, the correlator uses event timestamps, and not real time, to determine when to trigger listeners.

As an extreme example, suppose a monitor is looking for `A -> B within(2.0)`. The correlator receives event `A`. However, the queue has grown to a huge size and the correlator processes event `A` three seconds after event `A` arrives. The correlator receives event `B` one second after it receives event `A`. Some events in the queue before event `B` cause a lot of computation in the correlator. The result is that the correlator processes event `B` five seconds after event `B` arrives. In short, event `B` arrives one second after event `A`, but the correlator processes event `B` three seconds after it processes event `A`.

If the correlator used real time, `A -> B within(2.0)` would not be triggered by this pattern. This is because the correlator processes event `B` more than two seconds after processing event `A`. However, the correlator uses the timestamp to determine whether to trigger actions. Consequently, `A -> B within(2.0)` does trigger, because the correlator received event `B` one second after event `A`, and so their timestamps are within 2 seconds of each other.

As you can see, the number of events on an input queue never affects temporal comparisons.

Event arrival time

As mentioned before, when an event arrives, the correlator assigns a timestamp to the event. The timestamp indicates the time that the event arrived at the correlator. If you coassign an event to a variable, the correlator sets the timestamp of the event to the current time in the context in which the coassignment occurs. For JMon applications, this is always the current time in the main context.

The correlator uses clock ticks to specify the value of each timestamp. The correlator generates a clock tick every tenth of a second. The value of an event's timestamp is the value of the last clock tick before the event arrived.

When you start the correlator, you can specify the `--frequency` *hz* option if you want the correlator to generate clock ticks at an interval other than every tenth of a second. Instead, the correlator generates clock ticks at a frequency of *hz* per second. Be aware that there is no value in increasing *hz* above the rate at which your operating system can generate its own clock ticks internally. On UNIX and some Windows machines, this is 100 Hz and on other Windows machines it is 64 Hz.

When you start the correlator, you can specify the `-Xclock` option to disable the correlator's internal clock and replace it with externally generated time events. See "Externally generating events that keep time (&TIME events)" on page 197.

Getting the current time

In the correlator, the current time is the time indicated by the most recent clock tick. There are two exceptions to this:

- If you specify the `-Xclock` option when you start the correlator, the correlator does not generate clock ticks. Instead, you must send time events (`&TIME`) to the correlator. The current time is the time indicated by the most recent externally generated time event. See "Externally generating events that keep time (&TIME events)" on page 197.
- When the correlator is firing a timer, the current time is the timer's trigger time. See "About timers and their trigger times" on page 700.

The information in the remainder of this topic assumes that the current time is the time indicated by the most recent clock tick.

Use the static method `double com.apama.jmon.Correlator.getCurrentTime()` to obtain the current time. The value returned by the `getCurrentTime()` method is the current time represented as seconds since the epoch, January 1st, 1970 in UTC.

In the correlator, the current time is never the same as the current system time. In most circumstances it is a few milliseconds behind the system time. This difference increases when public context input queues grow.

When a listener triggers, it causes a call to the listener's `match()` method. The correlator executes the entire method before the correlator starts to process another event. Consequently, while the listener is executing a method, time and the value returned by the `getCurrentTime()` method do not change.

Consider the following code snippet,

```
double a;
void checkTime() {
   a = Correlator.getCurrentTime();
}

// A listener calls the following method some time later
void logTime() {
   System.out.println("a: "+a );
      // The time when checkTime() was called

   System.out.println("current time: "+Correlator.getCurrentTime() );
   // The time now
```

```
}
```

In this code, a method sets `double` variable `a` to the value of `getCurrentTime()`, which is the time indicated by the most recent clock tick. Some time later, a different listener prints the value of `a` and the value of `getCurrentTime()`. The values logged might not be the same. This is because the first use of `getCurrentTime()` might return a value that is different from the second. If the two listeners have processed the same event, the logged values are the same. If the two listeners have processed different events, the logged values are different.

About timers and their trigger times

In an event expression, when you specify the `within`, `wait`, or `at` operator you are specifying a timer. Every timer has a trigger time. The trigger time is when you want the timer to fire.

- When you use the `within` operator, the trigger time is when the specified length of time elapses. If a `within` timer fires, the listener fails. In the following listener, the trigger time is 30 seconds after `A` becomes true.

  ```
  A -> B within(30.0)
  ```

  If `B` becomes true within 30 seconds, the trigger time for the timer is not reached, the timer does not fire, the listener triggers, and the monitor calls any attached JMon listeners. If `B` does not become true within 30 seconds, the trigger time is reached, the timer fires, and the listener fails. The monitor does not call the `MatchListener`.

- When you use the `wait` operator, the trigger time is when the specified pause during processing of the event expression has elaspsed. When a `wait` timer fires, processing continues. In the following expression, the trigger time is 20 seconds after `A` becomes true. When the trigger time is reached, the timer fires. The listener then starts watching for `B`. When `B` is true, the monitor calls any attached listeners.

  ```
  A -> wait(20.0) -> B
  ```

- When you use the `at` operator, the trigger time is one or more specific times. An `at` timer fires at the specified times. In the following expression, the trigger time is five minutes past each hour every day. This timer fires 24 times each day. When the timer fires, the monitor calls any attached JMon listeners.

  ```
  all at(5, *, *, *, *)
  ```

At each clock tick, the correlator evaluates each timer to determine whether that timer's trigger time has been reached. If a timer's trigger time has been reached, the correlator fires that timer. When a timer's trigger time is exactly at the same time as a clock tick, the timer fires at its exact trigger time. When a timer's trigger time is not exactly at the same time as a clock tick, the timer fires at the next clock tick. This means that if a timer's trigger time is .01 seconds after a clock tick, that timer does not fire until .09 seconds later.

When a timer fires, the current time is always the trigger time of the timer. This is regardless of whether the timer fired at its trigger time or at the first clock tick after its trigger time.

A single clock tick can make a repeating timer fire multiple times. For example, if you specify `all wait(0.01)`, this timer fires 10 times every tenth of a second.

Because of rounding constraints,

- A timer such as `all wait(0.1)` drifts away from firing every tenth of a second. The drift is of the order of milliseconds per century, but you can notice the drift if you convert the value of the current time to a string.
- Two timers that you might expect to fire at the same instant might fire at different, though very close, times.

  The rounding constraint is that you cannot accurately express `0.1` seconds as a float because you cannot represent it in binary notation. For example, the `on wait(0.1)` listener waits for `0.1000000000000000555` seconds.

To specify a timer that fires exactly 10 times per second, calculate the length of time to wait by using a method that does not accumulate rounding errors. For example, calculate a whole part and a fractional part:

```
@Application(author="Tim Berners", company="Apama",
description="Demonstrate tenth of second timers", name="Tenth",
version="1.0")
@MonitorType
public class TenthOfSecond implements Monitor {

   private static final Logger LOGGER =
      Logger.getLogger(TenthOfSecond.class);
   private static final NumberFormat formatter =
      NumberFormat.getInstance();
   static { formatter.setGroupingUsed(false); }

   double startTime;
   double fraction;

   public void onLoad() {
      startTime = Math.ceil( Correlator.getCurrentTime() );
      fraction = Math.ceil(
         (Correlator.getCurrentTime() - startTime) * 10.0);
      setupTimeListener();
   }
   void setupTimeListener() {
      fraction++;
      if (10.0 <= fraction) {
         fraction = 0.0;
         startTime++;
      }
      EventExpression ee = new EventExpression("wait("+ ((startTime +
         (fraction / 10.0))-Correlator.getCurrentTime()) +")");
      ee.addMatchListener(new MatchListener() {
         public void match(MatchEvent evt) {
            LOGGER.info(formatter.format(Correlator.getCurrentTime()));
            // System.out.println(Correlator.getCurrentTime());
            // This would go to STDOUT, and isn't as pretty
            new TestEvent(Correlator.getCurrentTime()).emit();
            setupTimeListener();
         }
      });
   }
}
```

```
// TenthOfSecond
```

When a timer fires, the correlator processes items in the following order. The correlator

1. Triggers all listeners that trigger at the same time.
2. Routes any events, and routes any events that those events route, and so on.
3. Fires any timers at the next trigger time.

24 Developing and Deploying JMon Applications

This section describes the steps required to develop and deploy a JMon application. You can develop JMon applications with Apama in Software AG Designer or manually, outside Software AG Designer. When you use Software AG Designer, some development steps are performed automatically for you. This section describes all development steps and notes which steps Software AG Designer automatically performs.

For more information on developing JMon applications, see "Working with projects" in *Using Apama with Software AG Designer*.

See also "Writing Correlator Plug-ins in Java" on page 751 which describes how it is possible to call out to code written in Java even when the main application logic is written in EPL rather than JMon.

Steps for developing JMon applications in Software AG Designer

To develop JMon applications in Software AG Designer

1. Add Java support to a project.

   See "Adding Java support to an Apama project" in *Using Apama with Software AG Designer*.

2. Create your application's source files.

   Select **File** > **New** > **Java Event** or select **File** > **New** > **Java Monitor**.

   Or, in the **Project Explorer**, right-click your project and select **New** > **Java Event** or select **New** > **Java Monitor**.

   A wizard appears that lets you specify the event or monitor's name, the package, a description, the Java source folder and Java package. Software AG Designer automatically adds an entry for the event or monitor to the `jmon-jar.xml` deployment descriptor file and regenerates the JMon `JAR` file to include the new event or monitor.

   If you want to build your `JAR` files manually, right-click your project and select **Apama** > **Build JAR Files**. This is useful if you unselected the **Build jar files automatically** option in the `apama_java.xml` file, which is in the `config` directory of your project. One reason you might not want to build the `JAR` files automatically is that the build takes too long. When **Build jar files automatically** is selected, Software AG Designer builds the `JAR` files every time you modify a JMon file.

   If there are events that you defined in JMon and you refer to those events, or listen for those events in EPL code, then you must define those events in EPL as well as JMon. If you do not also define the events in EPL, Software AG Designer flags EPL references to those events as errors.

   See also "Creating new files for JMon applications" in *Using Apama with Software AG Designer*.

3. Create your application's launch configuration.

Software AG Designer adds all JMon JAR files to the correlator initialization list and all non-JMon JAR files to the correlator class path.

If you want to build your project's files outside Software AG Designer and Eclipse, right-click your project and select **Apama** > **Generate Ant Buildfiles**. Software AG Designer generates an ant build file (with the name `build-`*`project-name`*`.xml`), which you can use only to build your project's JMon JAR files outside of the Eclipse environment. Note that this is unrelated to the Software AG Designer feature for exporting an Ant build file that you can use for deployment.

See "Defining custom launch configurations" in *Using Apama with Software AG Designer*.

4. Run and test your application.

   See "Launching Projects" in *Using Apama with Software AG Designer*.

5. Debug your application.

   See "Debugging JMon Applications" in *Using Apama with Software AG Designer*.

6. Deploy your application.

   See "Deploying JMon applications" on page 706.

   Software AG Designer generates your application's JMon JAR file in the *`jmon_config_name`* `java application files` folder of your project's directory. By default, *`jmon_config_name`* is the project name.

   You can manage the content of the JMon JAR file and `jmon-jar.xml` file by using the editor in Software AG Designer to update the `apama_java.xml` file, which is located in the project's `config` folder. You can use this editor to do the following:

   - Set JMon metadata.
   - Set the injection order of the events and monitors.
   - Add non-JMon Java classes to the JMon JAR files.
   - Add JMon classes that were not created by the Apama wizards in Software AG Designer to the JMon JAR file.

Java prerequisites for using Apama's JMon API

When you install Apama, the installation script installs the JMon API as `ap-correlator-extension-api.jar` in the Apama `lib` directory.

Software AG Designer includes the required Java compiler for running your application.

Steps for developing JMon applications manually

To develop JMon applications outside Software AG Designer

1. Ensure that `ap-correlator-extension-api.jar` is in your Java `CLASSPATH` environment variable.
2. Create a folder in which to develop your application.
3. In this development folder, define one `.java` file for each event type and one `.java` file for each monitor class.
4. Ensure that there is a deployment descriptor file named `jmon-jar.xml`. See "Creating deployment descriptor files" on page 707.
5. In your development folder, compile all your Java source code.

   ```
   javac *.java
   ```

   If `ap-correlator-extension-api.jar` is not already in your `CLASSPATH` environment variable, you can specify the `-classpath` command-line option to point to `ap-correlator-extension-api.jar`.
6. In your development folder, create a `JAR` file that contains the deployment descriptor and all class files. The command line format is as follows:

   ```
   jar -cf application_name.jar META-INF/jmon-jar.xml *.class
   ```

   Replace *`application_name`* with a name you choose for your application. On Windows, use backslashes "`\`" instead of forward slashes "`/`".

   If your application uses an event type definition class that is also used by another JMon application, you must include the event type definition class in the `JAR` file of each application that uses it. If you do not include a shared event type definition class in your application's `JAR` file, injection fails with an `ApplicationVerificationException`.

   You cannot specify the location of a shared event type definition class in your `CLASSPATH` environment variable. The correlator uses a separate classloader for each application, and it cannot use the system classloader for event type definition classes.
7. If any of your application's `.class` files are in your `CLASSPATH` environment variable, remove them. If the JRE can resolve a class path by using either your application's `JAR` file or your `CLASSPATH` environment variable, Apama fails to load your application.

Deploying JMon applications

To deploy and run your application outside Software AG Designer

1. Start a correlator with Java enabled:

   ```
   correlator -j other_options
   ```

2. Inject the application JAR file:

```
engine_inject -j application_name.jar
```

Apama creates an object instance of each monitor class defined in the deployment descriptor file and executes its onLoad method. If there are multiple monitor classes, they are injected in the order in which they are specified in the jmon-jar.xml file.

The classes in the application's JAR file cannot also exist (have the same packaging and name) anywhere else on the classpath. If they do, it causes the application to fail to load.

When you start the correlator, you can pass properties and options to the embedded JVM with the -J option. Specify the -J option with each property or option you want to specify.

For example, you can use this mechanism to specify a global classpath for the JVM with: -J-Djava.class.path=*path*. Apama prepends its own internal classpath .jar files to the path you specify. If you specify both the CLASSPATH environment variable and a classpath on the correlator start-up command line the classpath specified on the command line takes precedence. See also "Specifying classpath in deployment descriptor files" on page 709 for information about specifying the classpath for each individual application.

Removing JMon applications from the correlator

To stop and delete a running JMon application, execute the engine_delete operation:

```
engine_delete [options_to_identify_correlator]application_name
```

If the application you want to delete is not running on the local host on the default correlator port, be sure to specify options that indicate the correlator that is running the application you want to delete.

Replace *application_name* with the name of the application as specified in the deployment descriptor. This is not necessarily the same as the name of the application's JAR file.

Deleting a JMon application does the following:

- Terminates the application's active listeners.
- Deletes the application's monitor classes.
- Leaves the event type definitions loaded in the correlator. To remove the event type definitions, execute engine_delete and specify the files that contain the event type definitions.

Creating deployment descriptor files

The JMon application's JAR file must contain a deployment descriptor file. Inside the correlator, the JVM processes the application's deployment descriptor file and uses it as a guide to the event types and monitor classes to load. The name of the deployment descriptor file must be `jmon-jar.xml`.

When you use the Java support in Software AG Designer to develop your JMon application, the deployment descriptor file is generated for you. If you develop your JMon application outside Software AG Designer, there are two ways to create a deployment descriptor file:

- Manually write the deployment descriptor XML file. Use your favorite editor to create this XML file according to the "Format for deployment descriptor files" on page 708.
- Insert Java annotations in your source files and run a utility to generate the deployment descriptor file. The annotations you can insert are defined in the `java.apama.jmon.annotation` package.

Of course, you can use the utility to generate the deployment descriptor file and then manually edit the result. If you then run the utility again, you would lose any manual changes you had made.

The technique you use is largely a matter of personal preference — hand-coded or machine-generated. If you have a very large application with many event types and monitors, you might prefer to insert the annotations and generate the deployment descriptor file. If you have a small application, you might find it easier to write the deployment descriptor file.

Format for deployment descriptor files

The format of the deployment descriptor file must be compliant with the XML defined by the following XML Document Type Definition (DTD):

```
http://www.apama.com/dtd/jmon-jar_1_2.dtd
```

You should become familiar with this DTD to understand the exact definition of the deployment descriptor file. However, the normal structure of the file is as follows. In the following format, all text inside XML element tags, *which is in italic typeface*, indicates placeholders for which you would supply an actual value.

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE jmon-jar PUBLIC "-//Apama, Inc.//DTD Java Monitors 1.2//EN"
  "http://www.apama.com/dtd/jmon-jar_1_2.dtd">

<jmon-jar>

  <name>Application Name in the Correlator</name>
  <version>Version Number</version>
  <author>Author</author>
  <company>Company Name</company>
  <description>Description of this application</description>
  <classpath>${sys:MY_THIRD_PARTY_DIR}/lib/foo.jar;
             ${sys:MY_THIRD_PARTY_DIR}/lib/bar.jar</classpath>
  <application-classes>

    <event>
      <event-name>Event Type name in the Correlator</event-name>
      <event-class>Event Type's class location</event-class>
      <description>Description of Event Type</description>
    </event>
```

```
    <monitor>
      <monitor-name>Monitor's name in the Correlator</monitor-name>
      <monitor-class>Monitor's class location</monitor-class>
      <description>Description of Monitor class</description>
    </monitor>
  </application-classes>
</jmon-jar>
```

The most important part of the deployment descriptor file is the `application-classes` element. This element must contain an `event` element for each event type your JMon application defines. It must also contain a `monitor` element for each monitor your JMon application defines.

The application name that you specify in the `name` element is important because it defines the JMon application's name in the correlator. The `engine_inspect` management tool displays this name when it lists data for your application. If you want to delete your application, you specify this name. The application name must be unique across all currently loaded applications. If the application name is not unique, injection fails.

Specifying classpath in deployment descriptor files

Each JMon or Java plug-in jar is loaded in its own dedicated Java classloader, which by default has access only to its own classes, and those available globally in the correlator's system classloader.

Note: The correlator's system classloader includes some standard Apama libraries such as the `ap-correlator-extension-api.jar` and `ap-util.jar` jar files plus any additional jars the user chooses to specify on the correlator command line using `-J-Djava.class.path=`*path*.

It is also possible to specify additional jars for use by a specific JMon application or Java plug-in, to provide access to any third party libraries that the jar requires. This approach is more self-contained than adding to the correlator's global classloader.

The classpath string for a JMon application or Java plug-in is specified in its deployment descriptor XML file as follows:

- If you are manually writing the deployment descriptor XML, add the optional *classpath* element just after the *description* element, e.g.

  ```
  ...
  <description>Description of this application</description>
  <classpath>${sys:MY_THIRD_PARTY_DIR}/lib/foo.jar;
             ${sys:MY_THIRD_PARTY_DIR}/lib/bar.jar</classpath>
  ...
  ```

  Note that the *classpath* element is only available in the 1.2 (and greater) versions of the JMon XML DTD (`jmon-jar_1_2.dtd`), so it may be necessary to update the DOCTYPE of the deployment descriptor to specify this DTD version if it does not already.

- If you are generating the deployment descriptor automatically using Java annotations then use the optional *classpath* attribute in the `@Application` annotation:

```
@Application(
   name = "Simple",
   author = "My Name",
   version = "1.0",
   company = "Apama",
   description = "My simple JMon application or Java plug-in",
   classpath = "${sys:MY_THIRD_PARTY_DIR}/lib/foo.jar;
                ${sys:MY_THIRD_PARTY_DIR}/lib/bar.jar"
   )
```

- If you are using Software AG Designer to generate the .jar and deployment descriptor, use the `@Application` annotation approach to specify the classpath.

In both cases, the classpath string consists of any number of classpath entries, delimited by semi-colon characters (`;`). Note that semi-colon must be used even on platforms that typically use a colon or other character to separate path entries, and also that forward slashes (/) should be used instead of backslashes (\), in order to ensure that the application works in the same way regardless of the platform it is deployed on.

Avoid using absolute paths in the classpath, as this makes it difficult to use the application jar on different machines. Instead, use `${...}` placeholders to identify the first part of each path, for example the installation directory of a third party whose libraries you wish to use. Currently two types of placeholder are supported:

- `${sys:`*`MY_SYS_PROP_NAME`*`}` is replaced by a Java system property called *`MY_SYS_PROP_NAME`*
- `${env:`*`MY_ENV_VAR_NAME`*`}` is replaced by an environment variable called *`MY_ENV_VAR_NAME`*

The values for system property placeholders can be specified on the correlator command line using: `-J-D`*`MY_SYS_PROP_NAME=path`*.

The correlator will log a warning for any path that cannot be found, but will fail to inject the application entirely if the classpath includes any ${...} placeholders that are not defined.

Defining event types in deployment descriptor files

The deployment descriptor file must define an `event` element for each event type class in your JMon application's `JAR` file. Each `event` element must contain the following two elements:

- `event-name` — The name by which this event type is to be defined within the correlator. The correlator has a single namespace. Consequently, this name must be unique across *all* applications. For example, `Tick` or `SimpleApp.Tick`. If you specify a package qualified name, it is the qualified name that must be unique.
- `event-class` — The name of the Java class in which this event type is defined. This must correspond to the fully qualified name of the class, for example, `Tick` if the event type class is defined within the default Java package, or `com.apama.example.types.Tick` if the event type class is defined in the `com.apama.example.types` package. The file, for example, `Tick.java`, is expected to be located within a folder structure that maps to the packaging, as per standard Java convention.

The `event` element can optionally contain a third element. This is the `description` element. Specify a description of the event type. For example:

```
<event>
   <event-name>Tick</event-name>
   <event-class>Tick</event-class>
   <description>Event that signals a stock trade</description>
</event>
```

JMon and EPL share a single namespace for event types. After an event type is loaded into the correlator, using either JMon or EPL, it is available for use in either environment. However, within a JMon application, you cannot instantiate variables of an event type defined in EPL.

When you try to inject an event type definition that has the same name as a loaded event type, the correlator checks whether the two definitions are duplicates. If they are, the correlator ignores the duplicate you are trying to load. If the definitions are different, the correlator generates an injection error.

Defining monitor classes in deployment descriptor files

The deployment descriptor file must define a `monitor` element for each monitor class in your JMon application's `JAR` file. Each `monitor` element must contain the following two elements:

- `monitor-name` — The name by which this monitor is to be defined within the correlator. The correlator has a single namespace. Consequently, this name must be unique across *all* applications. For example, `SimpleMon` or `SimpleApp.SimpleMon`. If you specify a package qualified name, it is the qualified name that must be unique.
- `monitor-class` — The name of the Java class in which this monitor is defined. This must correspond to the fully qualified name of the class, for example, `SimpleMon` if the monitor class is defined within the default Java package, or `com.apama.example.monitors.SimpleMon` if the monitor class is defined in the `com.apama.example.monitors` package. The file, for example, `SimpleMon.java`, is expected to be located within a folder structure that maps to the packaging, as per standard Java convention.

The `monitor` element can optionally contain a third element. This is the `description` element. Specify a description of the monitor. For example:

```
<monitor>
   <monitor-name>Simple</monitor-name>
   <monitor-class>Simple</monitor-class>
   <description>A simple JMon monitor, used to show functionality of
      a new installation.</description>
</monitor>
```

Inserting annotations for deployment descriptor files

In your JMon source files, you can specify the following annotations:

- `@Application` — This annotation indicates the name of the application, as well as the author, version, company, and description of the application. Insert this annotation in any one, and only one, of your JMon source files. Each value is required. This annotation must be after any `import` statements and before the class definition statement. For example:

```
@Application(
   name = "Simple",
   author = "Moray Grieve",
   version = "1.0",
   company = "Apama",
   description = "Deployment descriptor for a simple JMon monitor",
   classpath = "${sys:MY_THIRD_PARTY_DIR}/lib/foo.jar;
                ${sys:MY_THIRD_PARTY_DIR}/lib/bar.jar"
   )
```

- `@MonitorType` — This annotation indicates the definition of a monitor. In each monitor class, insert this annotation immediately before the monitor class definition statement. You can specify a name and a description for the monitor. The name is the fully qualified EPL name for the monitor. If you do not specify a name, the name defaults to the fully qualified JMon class name of the class you are annotating.

```
@MonitorType(description = "A simple JMon monitor, used to show
     functionality of a new installation.")
```

- `@EventType` — This annotation indicates the definition of an event type. In each event type definition class, insert this annotation immediately before the definition statement for the event type. You can specify a name and a description for the event. The name is the fully qualified EPL name for the event. If you do not specify a name, the name defaults to the fully qualified JMon class name of the class you are annotating. For example:

```
@EventType(description = "Event that signals a stock trade")
```

- `@Wildcard` — This annotation indicates a wildcard event field. Insert it immediately before the field definition statement. You must have specified the `@EventType` annotation for the event type that defines this field. For example:

```
import com.apama.jmon.*
import com.apama.jmon.annotation.*

@EventType
public class EventWithWildcard extends Event {
   public long indexedField;
   @Wildcard
   public long wildcardField;
   public EventWithWildcard() {
      this(0, 0);
}
public EventWithWildcard(long iField, long wField) {
   this.indexedField = iField;
   this.wildcardField = wField;
}
```

Sample source files with annotations

Following are two sample source files with annotations. These are the source files for the `simple` sample application provided with Apama. The lines with the annotations are in bold typeface for your convenience.

Here is the `Simple.java` file with comments removed:

```
import com.apama.jmon.*;
```

```
import com.apama.jmon.annotation.*;

@Application(name = "Simple",
    author = "Moray Grieve",
    version = "1.0",
    company = "Apama",
    description = "Deployment descriptor for the Simple JMon monitor",
    classpath = ""
    )

@MonitorType(description = "A simple JMon monitor, used to show
    functionality of a new installation.")
public class Simple implements Monitor, MatchListener {

   public Simple() {}

   public void onLoad() {
      EventExpression eventExpr = new EventExpression(
         "all Tick(*, >10.0):t");
      eventExpr.addMatchListener(this);
   }
   public void match(MatchEvent event) {
      Tick tick = (Tick)event.getMatchingEvents().get("t");
      tick.emit();
   }
}
```

Here is the `Tick.java` file with comments removed:

```
import com.apama.jmon.Event;
import com.apama.jmon.annotation.*;

@EventType(description = "Event which signals a stock trade")
public class Tick extends Event {

   public String name;
   public double price;
   public Tick() {
      this("", 0);
   }

   public Tick(String name, double price){
      this.name = name;
      this.price = price;
   }
}
```

Generating deployment descriptor files from annotations

There are two utilities that you can use to generate the deployment descriptor file from annotations in your source files:

- `com.apama.jmon.annotation.DirectoryProcessor` — This utility processes a directory and generates the deployment descriptor file, which you must add to your application's `JAR` file.
- `com.apama.jmon.annotation.JarProcessor` — This utility processes an application's `JAR` file and adds the deployment descriptor file to that `JAR` file.

You can execute these utilities from the command line or from a Java build file.

The `DirectoryProcessor` utility takes three optional arguments:

- `-r` indicates that you want to recursively process the `.class` files in each directory and subdirectory in the specified directory. The default is that the utility processes only the `.class` files that are in the specified directory.
- `-d` specifies the directory that contains the `.class` files you want to process. The default is that the utility processes any `.class` files in the current working directory.
- `-o` specifies the file in which to store the output. The default is that output goes to `stdout`. In the JMon application `JAR` file, the name of the deployment descriptor file must always be `jmon-jar.xml`.

After you generate the deployment descriptor file, you must place it in the `META-INF` directory of your development directory. For example, you can execute the `DirectoryProcessor` utility from the command line as follows:

```
cd src
javac -classpath
$APAMA_CORRELATOR_HOME/lib/ap-correlator-extension-api.jar
*.java
java -DAPAMA_LOG_LEVEL=WARN -classpath
$APAMA_CORRELATOR_HOME/lib/ap-correlator-extension-api.jar
com.apama.jmon.annotation.DirectoryProcessor -r -d ./src -o
./src/META-INF/jmon-jar.xml
jar -cf ../simple-jmon.jar META-INF/jmon-jar.xml *.class
```

The `JarProcessor` utility takes one required argument, which is the name of the `JAR` file to operate on. To execute the `JarProcessor` utility from a Java build file, you can define something like the following:

```
<!--Target to process the annotations in the JMon application classes
    to produce jmon-jar.xml -- the deployment descriptor file.
-->
<target name="process-jar" depends="jar">
  <echo message=
    "Process annotations in jar file: ${process-jar-file}" />
  <java jvm="java"
    classname="com.apama.jmon.annotation.JarProcessor" dir="."
    fork="yes">
    <classpath>
      <fileset dir="${lib-dir}">
        <patternset refid="libs" />
      </fileset>
    </classpath>
    <jvmarg value="-DAPAMA_LOG_LEVEL=WARN" />
    <arg value="${process-jar-file}" />
  </java>
</target>

<target name="process" depends="jar">
  <antcall target="process-jar">
    <param name="process-jar-file" value="${jar-file}" />
  </antcall>
</target>
```

Package names and namespaces in JMon applications

There is no correlation between the correlator namespace defined for a named JMon event or monitor, and the Java package structure of the class file in which that event or monitor is implemented. Event expressions are based on the correlator namespace, not on the Java package of the implementation.

Consider the following example. An event type defined in a Java class `a.b.c.MyEvent` that is given the correlator name `x.MyEvent`. Also a monitor defined in a Java class `a.b.c.MyListener` that is given the correlator name `y.MyListener`. Now, although the two classes are in the same Java package and need not use import statements to see each other, their correlator names are in different namespaces. This means that an event expression in `y.MyMonitor` will need to use the fully qualified name `x.MyEvent` to refer the event.

Sample JMon applications

The Apama distribution includes a number of complete sample applications. These applications are in the `samples` folder under `java_monitor`, and are called `simple`, `stockwatch`, `vwap`, `dos`, `context` and `complex`.

See the `README.txt` file included with each sample for complete instructions for how to compile and run the sample application.

IV Developing Correlator Plug-ins

Although the correlator's native programming language, the Apama Event Processing Language (EPL), has most of the functionality of modern programming languages, its primary purpose is enabling the detection of, correlation across, and triggering on complex event patterns.

In most cases existing code could be ported and rewritten in EPL, but in practice this might not be feasible. For example, an application might need to carry out advanced arithmetic operations and a significant programming library of such functions might already be available. Porting such complex code to EPL would be a lengthy, expensive and error prone task, and is unnecessary.

The following topics describe Apama's EPL Plug-in APIs and illustrate how to use them.

25 Introduction to Correlator Plug-ins

In order to incorporate existing specialized functionality, developers can write what is termed an *event correlator plug-in*. A correlator plug-in consists of an appropriately formatted library of C or C++ functions, which can be called from within EPL code. In the case of a plug-in written in Java, the Java classes that are called from an application's EPL code are contained in a `jar` file. The event correlator does not need to be modified to enable or to integrate with a plug-in, as the plug-in loading process is transparent and occurs dynamically when required.

Custom correlator plug-ins can be developed using Apama's EPL Plug-in APIs for C, C ++, and Java. Once a plug-in is developed, a developer can call the functions it contains directly from EPL code, passing EPL variables and literals as parameters, and getting return values that can be manipulated.

Note: It is very important that strict plug-in development guidelines are followed when developing a plug-in. The functions provided must be adequately debugged prior to their integration within a plug-in. This is because when the event correlator loads a plug-in it is dynamically linked with the correlator's runtime process. If any code within the plug-in causes a runtime error the correlator might fail and terminate.

For this reason, Apama customers who experience problems with correlator stability while using plug-ins will be asked by Apama Technical Support to remove the plug-in and reproduce the problem prior to being offered further technical help. Apama Technical Support will only lift this restriction if the plug-ins have had prior certification by Apama.

"Writing a Plug-in in C or C++" on page 723 illustrates the plug-in development process through exploration of a simple example. "Advanced Plug-in Functionality in C++ and C" on page 731 takes this further with a more comprehensive example, while "The EPL Plug-in APIs for C and C++" on page 747 provides a more complete overview of the functionality of the EPL Plug-in C API and the EPL Plug-in C++ API. "Writing Correlator Plug-ins in Java" on page 751 describes the EPL Plug-in for Java.

26 Providing an EPL event wrapper for a plug-in

When creating a plug-in, it is considered best practice to provide an EPL event wrapper to access all methods of the plug-in. This provides type safety at runtime with respect to EPL objects of type `chunk`, that is, opaque objects whose contents cannot be seen or directly manipulated in EPL.

An example of this is the `TimeFormat` event which is provided as a wrapper for the Time Format plug-in (see also "Using the TimeFormat Event Library" on page 357). Using the plug-in directly, you can write code such as the following:

```
monitor UsePlugin {
  import "TimeFormatPlugin" as timeMgr;
  chunk pattern;
  action onload() {
      pattern := timeMgr.compilePattern("EEE MMM dd HH:mm:ss yyyy");
      float stateTimestampSec :=
         timeMgr.parseTimeFromPattern(pattern, "1996.07.10 AD at 15:08:56");
  }
}
```

Of course there is nothing to prevent someone passing a chunk from another plug-in as the parameter to the `parseTimeFromPattern` method. You can forestall this possibility and enforce type safety by using an event wrapper instead to hide the `chunk` type as in the following example:

```
using com.apama.correlator.timeformat.TimeFormat;
using com.apama.correlator.timeformat.CompiledPattern;
monitor UseEventWrapper {
  CompiledPattern pattern;
  action onload() {
    TimeFormat timeFormat := TimeFormat();
    pattern := timeFormat.compilePattern("EEE MMM dd HH:mm:ss yyyy");
    float stateTimestampSec := pattern.parseTime("1996.07.10 AD at 15:08:56");
  }
}
```

The event definitions for the `TimeFormat` and `CompiledPattern` events can be found in the TimeFormatEvents.mon file, which is located in the monitors directory of your Apama installation. Note how the `CompiledPattern` event wraps a chunk object, and the `parseTime` method on the `CompiledPattern` event uses the chunk in the `CompiledPattern` object and the string parameter passed in to the action.

This approach gives a more object-oriented feel to using the plug-in and can be used to emulate calling methods on Java or C++ objects. The signatures of actions on event definitions are also available to Apama in Software AG Designer, so they can be viewed there and benefit from completion proposals and type checking. (Software AG Designer does not know about the actions exposed by plug-ins, so it cannot provide type checking for them.)

27 Writing a Plug-in in C or C++

The Apama EPL Plug-in APIs for C and a C++ make it possible for developers to write event correlator plug-ins either in C or in C++.

As long as certain conventions are followed, writing a plug-in is very straightforward. In essence, a plug-in consists of a set of static C or C++ functions (representing the functionality that the developer wishes to invoke from within EPL code) and some necessary initialization functions.

C++ compilers vary extensively in their support for the ISO C++ standard and in how they support linking. For this reason, Apama supports the writing of C++ plug-ins only with specific compilers. For a list of the supported C++ compilers, see Software AG's Knowledge Center in Empower at https://empower.softwareag.com.

On the other-hand, C has been standardized for many years, and for this reason the C API should work with the majority of modern C/C++ compilers on all platforms.

The EPL Plug-in APIs are versioned. For a correlator plug-in to be compatible with an event correlator they both need to support the same plug-in interface version. Plug-ins built with earlier versions of the APIs need to be re-compiled and re-linked. Note that the API version number is separate from the product version number and only increases when the plug-in API is changed.

The APIs comprise the relevant header files, `correlator_plugin.hpp` and `correlator_plugin.h`, and are accompanied by a set of sample applications.

To configure the build for a correlator plug-in:

- On Linux, copying and customizing an Apama makefile from a sample application is the easiest method.
- On Windows, you might find it easiest to copy an Apama sample project. If you prefer to use a project you already have, be sure to add `$(APAMA_HOME)\include` as an include directory. To do this in Visual Studio, select your project and then select **Project Properties** > **C/C++** > **General** > **Additional Include Directories**.

A simple plug-in in C++

As an example, this topic describes the development of a simple plug-in called, appropriately, `simple_plugin`. It has only one function, called `test`, which takes a string as its sole parameter, makes some alterations to it, prints it out, and passes back another string as the result.

Let us first consider a C++ example using the C++ API. The first requirement is to include the header file `correlator_plugin.hpp`. This header file contains the definitions for the C++ API. The file is located in the Apama installation's `include` directory.

The C++ method that implements this plug-in function must be defined as follows:

```
class SimplePlugin {
  public:
  static void AP_PLUGIN_CALL test(
    const AP_Context& ctx,
    const AP_TypeList& args,
    AP_Type& rval,
```

```
    AP_TypeDiscriminator rtype);
}
```

The definition for all plug-in functions must be as for `SimplePlugin::test` above. In essence only the method name and the enclosing class name should vary as far as the definition is concerned. This is important, since it is the Correlator's Plug-in Support Mechanism that will be calling this C++ method and filling in its parameters.

- The `ctx` parameter is known as the execution context and is used internally by the event correlator to make the call to the plug-in function. The developer normally need not be concerned with it in the function's implementation.
- `args` is an array of parameters; in effect the parameters that the EPL writer will have to supply when calling `test`.
- `rval` denotes the return value. Plug-in function implementations must pass out any return value through this parameter, although as will be shown, in EPL the function will appear to return a result in the traditional way. The return value can be a `float`, `boolean`, `string`, `integer` or `chunk`, and the expected return type is indicated by `rval.discriminator()`. It is not possible to return sequences or other correlator types.
- `rtype` is the expected return type, identical to the result of calling `rval.discriminator()` and is retained for backwards compatability.

The next important step is to define exactly what type of parameters the above plug-in function should expect and accept, what it should return, and under what name it should appear within EPL.

```
/** Parameter types for the 'test' function */
static const char8* testParamTypes[1] = {"string"};
/** Declare functions provided by this plugin */
static AP_Function Functions[1] = {
  {"test", &SimplePlugin::test, 1, &testParamTypes[0], "string"}
};
```

The static array of `AP_Functions` structures needs to be defined in every plug-in to describe which functions that plug-in is exporting to the event correlator. In this case the C++ method `SimplePlugin::test` has been mapped to appear as the external plug-in function "test", to take a single parameter, with the latter being of the EPL type `string` (as defined within `testParamTypes`), and return a value of EPL type `string`. If a particular function returns nothing, the return type should be specified as `void`.

All that is left is to implement the "C" plug-in initialization method:

```
AP_PLUGIN_DLL_SYM AP_ErrorCode AP_PLUGIN_CALL
  AP_INIT_FUNCTION_NAME (
    const AP_Context& ctx,
    uint32& version,
    uint32& nFunctions,
    AP_Function*& functions
);
```

the "C" plug-in shutdown method:

```
AP_PLUGIN_DLL_SYM AP_ErrorCode AP_PLUGIN_CALL
  AP_SHUTDOWN_FUNCTION_NAME (const AP_Context& ctx);
```

and the "C" plug-in library version check:

```
AP_PLUGIN_DLL_SYM AP_ErrorCode AP_PLUGIN_CALL
  AP_LIBRARY_VERSION_FUNCTION_NAME(const AP_Context& ctx,
 uint32& version);
```

The names of the functions are macros defined in `correlator_plugin.hpp`.

Linking limitations require that these three functions be defined as “C” functions. Both should at least implement the code as indicated in the `simple_plugin.cpp` example that can be found in the `samples\correlator_plugin\cpp` directory of your Apama installation. For most situations, it is recommended that the developer re-deploy the initialization and shutdown methods provided unchanged, although more complex plug-ins may include plug-in-specific startup and shutdown code in these functions. Note that the initialization and shutdown functions are invoked each time the library is loaded or unloaded, so these functions must be re-entrant and able to be safely invoked multiple times.

Going back to the implementation of the test method, through use of the extensive library of helper functions available on the `AP_Type` class, the developer can manipulate the values passed through by the EPL code.

For example, this code displays an integer argument passed to a function:

```
cout << args[0].integerValue();
```

while this call increments the second element of a `sequence` argument:

```
AP_Type &element = args[0][2];
element.integerValue(element.integerValue()+1);
```

Note that this is relevant since sequences and chunks are passed by reference. So, if the EPL code calling it was:

```
sequence<integer> mySeq := [0,10,20,30];
myPlugin.exampleFunction(mySeq);
print mySeq;
```

then after the call `mySeq` is [0,10,21,30].

Note that this is modifying the `sequence` to which `mySeq` refers, not altering the value of `mySeq` itself. A plug-in function cannot do the equivalent of `mySeq := otherSeq;`.

Similarly, it is not possible to modify primitives passed to a plug-in as arguments. Strings, while strictly speaking a reference type, are immutable and so cannot be modified either.

The complete code base of this simple example can be found in the `simple_plugin.cpp` file which is located in the `samples\correlator_plugin\cpp\` directory of your Apama installation. A makefile (for use with GNU Make) and a batch file (for Microsoft's Visual Studio) are provided in this directory to assist with compiling plug-ins on UNIX and Windows platforms respectively. A `README.txt` file in the directory describes how to build the example.

Calling the test function from EPL

Compiling `simple_plugin.cpp` produces the plug-in file `libsimple_plugin.so` (on UNIX) or `simple_plugin.dll` (on Windows).

Note: The plug-in needs to be placed in a location where it can be picked up by the event correlator.

This means that on Windows you either need to copy the .dll into the lib sub-directory of your Apama work directory, or else place it somewhere which is on your path, that is, a location that is referenced by the PATH environment variable.

On Linux or Solaris, you either need to copy the .so into the lib sub-directory of your Apama work directory, or else place it somewhere which is on your library path, that is, a directory that is referenced by the LD_LIBRARY_PATH environment variable.

The next step is to write some EPL code that imports the simple_plugin plug-in and calls the method test.

Some example EPL code to achieve this is as follows:

```
monitor SimplePluginTest {

  // Load the plugin
  import "simple_plugin" as simple;

  // To hold the return value
  string ret;
  string arg;
  action onload() {

    // Call plugin function
    arg := "Hello, Simple Plugin";
    ret := simple.test(arg);

    // Print out return value
    log "simple.test = " + ret;
    log "arg = " + arg;
  }
}
```

Firstly, simple_plugin must effectively be located and loaded. This is the first purpose of the import statement. Secondly, it must be assigned an alias name, in this case simple.

This then allows the plug-in's test method to be invoked as simple.test(), taking an EPL string as parameter, and returning an EPL code string as its result.

The above EPL code is provided as simple_plugin.mon in the Apama installation's samples\correlator_plugin\cpp directory.

A simple C plug-in

The C version of the above example, simple_plugin.c, is very similar. The first difference is the use of the C version of the API, which is correlator_plugin.h. This can be located in the include directory of the Apama installation.

As before, there is only one function, called `test`, which takes a string as its sole parameter, makes some alterations to it, prints it out, and passes back another string as the result.

The C method that implements this plug-in function must be defined as follows:

```
static void AP_PLUGIN_CALL simplePluginTest(
  const AP_PluginContext* ctx,
  const AP_PluginTypeList* args,
  AP_PluginType* rval,
  AP_TypeDiscriminator rtype)
```

The rest of the example is very similar to the C++ example. The complete code base can be found in the file `simple_plugin.c` which is located in the `samples\correlator_plugin\c` directory of your Apama installation. A makefile (for use with GNU Make) and a batch file (for Microsoft's Visual Studio) are provided in this directory to assist with compiling plug-ins on UNIX and Windows platforms respectively. A `README.txt` file in the directory describes how to build the plug-in.

Parameter-less plug-in functions

Occasionally, it is useful to invoke a function or method within a plug-in which requires, and returns, no parameters. This is simply achieved by having the function/method ignore the function/method parameters and defining a function which takes no parameters and returns `void` in the function table. Examples are given below.

In C++ the method is defined as:

```
void AP_PLUGIN_CALL Analytic::SilentInitialisation (
  const AP_Context& ctx,
  const AP_TypeList& args,
  AP_Type& rval,
  AP_TypeDiscriminator rtype) {
  // Custom Code Here
  // Ignoring the args, rval and rtype parameters
}
```

And, in C as:

```
static void AP_PLUGIN_CALL SilentInitialisation (
  const AP_PluginContext* ctx,
  const AP_PluginTypeList* args,
  AP_PluginType* rval,
  AP_TypeDiscriminator rtype)  {
    // Custom Code Here
    // Ignoring the args, rval and rtype parameters
}
```

Then the function table would appear thus, in C++:

```
Static AP_Function Functions[1] = {
  {
    "SilentInit", &Analytics:: SilentInitialisation, 0, NULL,
    "void" },
};
```

And as below in C:

```
Static AP_Function Functions[1] = {
  { "SilentInit", &SilentInitialisation, 0, NULL, "void" },
```

```
};
```

In EPL, the plug-in function/method is then invoked as:

```
import "analytics" as a;
action onload() {
  a.SilentInit();
  // Custom Code Here
}
```

Each call to a plug-in function returns a single value. Occasionally, it is necessary for an operation to return multiple values; there are various techniques that can be used to achieve this:

- Provide multiple functions which are called in turn, each of which returns one of the values.
- Return a `chunk` expressing the composite value, and provide functions that interrogate the `chunk` to extract each individual value.
- Return a `string` that can be parsed as an event that expresses the composite value.
- Enqueue an event that expresses the composite value.
- Pass the function a `sequence` and modify the elements.

See "The chunk type" on page 733 for details of how chunks are used and "Asynchronous plug-ins" on page 739 for how to enqueue an event from a plug-in.

28 Advanced Plug-in Functionality in C++ and C

This topic uses the `simple_plugin` example described in "Writing a Plug-in in C or C++" on page 723. This section extends the example and illustrates more advanced use of the APIs.

Introducing complex_plugin

Appropriately, this extended C++ example is called `complex_plugin.cpp`, and it is also available in the `samples\correlator_plugin\cpp` directory of the Apama installation. A `README.txt` file in the directory describes how to build the example plug-in.

This time, the C++ example has three plug-in C++ methods defined:

```
class ComplexPlugin {
  public:

    static void AP_PLUGIN_CALL test1(
      const AP_Context& ctx,
      const AP_TypeList& args,
      AP_Type& rval,
      AP_TypeDiscriminator);

    static void AP_PLUGIN_CALL test3(
      const AP_Context& ctx,
      const AP_TypeList& args,
      AP_Type& rval,
      AP_TypeDiscriminator);

    static void AP_PLUGIN_CALL test4(
      const AP_Context& ctx,
      const AP_TypeList& args,
      AP_Type& rval,
      AP_TypeDiscriminator);
}
```

`ComplexPlugin::test1` dynamically decodes and displays its arguments, and then modifies the contents of any sequences that are passed to it. `ComplexPlugin::test3` allocates and returns an `ExampleChunk` *opaque object* (see "The chunk type" on page 733 for more information on opaque objects). `ComplexPlugin::test4` uses an `ExampleChunk` object as created by `ComplexPlugin::test3`, modifies and prints its contents, and then returns it.

You may have noticed that no `test2` was defined. This is intentional and the reason will become evident shortly.

In order to map the above C++ methods to plug-in functions, you must define the `Functions` static array. This time this looks as follows:

```
static const char8* test1ParamTypes[4] =
  {"integer", "float", "boolean", "string"};

static const char8* test2ParamTypes[4] =
  {"sequence<integer>", "sequence<float>", "sequence<boolean>",
   "sequence<string>"};

static const char8* test3ParamTypes[1] = {"integer"};
static const char8* test4ParamTypes[1] = {"chunk"};

static AP_Function Functions[4] = {
```

```
  {"test1",&ComplexPlugin::test1,4,&test1ParamTypes[0],"string"},
  {"test2",&ComplexPlugin::test1,4,&test2ParamTypes[0],"float"},
  {"test3",&ComplexPlugin::test3,1,&test3ParamTypes[0],"chunk"},
  {"test4",&ComplexPlugin::test4,1,&test4ParamTypes[0],"void"}
};
```

This definition highlights some of the powerful capabilities available to plug-in developers.

- First of all it maps `ComplexPlugin::test1` to the plug-in method `test1`, indicates that it takes four EPL parameters, sets these to be an `integer`, a `float`, a `boolean` and a `string` respectively, and sets the return type to be a `string`.
- It then maps `ComplexPlugin::test1` (again!) to the plug-in method `test2`, this time indicating that it will take four EPL parameters, and sets these to be a `sequence` of `integer`, a `sequence` of `float`, a `sequence` of `boolean` and a `sequence` of `string`, respectively. It then sets the return type to be a `float`. It is important to note that this multiple mapping of the same C++ method can only be carried out if the method is written with no assumptions regarding the type of its parameters or result. In fact, if you examine the full source code for this example, as provided below, you will see that this method examines the parameters' types before manipulating them.
- `ComplexPlugin::test3` is mapped to `test3` and set to take a single `integer`. Interestingly though, it is set to return a `chunk` type. This is a special purpose *opaque type*. For an explanation of this type, "The chunk type" on page 733.
- `ComplexPlugin::test4` is mapped to `test4`, and accepts a `chunk` type. Its implementation is designed to work on the `chunk` result produced by `ComplexPlugin::test3`. It does not return a value.

The chunk type

Apama's Plug-in Support Mechanism assumes that the functions called are stateless, that is they do not retain state between calls. However, it is recognized that in some circumstances a developer might need to retain complex state in between function calls and in order to assist in this, the opaque type `chunk` is provided. Furthermore, the `chunk` type allows data to be referenced from EPL that has no equivalent EPL type.

It is not possible to perform operations on data of type `chunk` from EPL code directly; it exists purely to allow "pass-through" of data output by one external plug-in function to another function. The event correlator does not modify the internal structure of `chunk` values in any way, so as long as a receiving function expects the same type as that output by the original function, any complex data structure can be passed around using this mechanism.

Note: Chunks cannot be routed, emitted or enqueued. Also note that passing a chunk created by one plug-in to a second plug-in in the same monitor is not permitted. If one plug-in returns a chunk and a second plug-in tries to read it, a C++ exception will be thrown within the second plug-in and, unless it is caught, the exception will terminate the correlator instance.

To use chunks with plug-ins first requires declaring a variable of type `chunk`. It can then be assigned the return value from an external function or used as a parameter in the function call.

The following example illustrates this. Monitor `printTime` prints out the current time when it is loaded. To generate `timeString` the monitor uses an external time plug-in. In this plug-in, the `time()` function returns a `float` representing the time in seconds; `localtime()` returns a structure containing year, month, day and time data which the `asctime()` function formats into a `string` of the form: “`Friday February 1 15:00:07 GMT 2002`”.

```
import "apama_time" as time;

monitor printTime {
  float millis;
  chunk timeData;
  string timeString;

  action onload() {
    millis := time.time();
    timeData := time.localtime(millis);
    timeString := time.asctime(timeData);
    print "The time is " + timeString;
  }
}
```

It can be seen that the `timeDatachunk` is used to store output from `localtime()` and pass it to `asctime()`; the value is not inspected from EPL code directly.

Although the `chunk` type was designed to support unknown data types, it is also a useful mechanism to improve performance. Where data returned by external library functions does not need to be accessed from the EPL code, using a `chunk` can cut down on unnecessary type conversion. For example, in the above example the output of `localtime()` is actually a 9-element array of `float`. The fact that the value is never accessed by the EPL code means that it can be declared as a `chunk` and an unnecessary conversion from native array to an EPL `sequence` and back again is removed.

Working with chunk in C++

A `chunk` object points to an instance of a class derived from the class `AP_Chunk`.

In this example `ComplexPlugin::test3` and `ComplexPlugin::test4` communicate state through the use of the same `chunk`, with this being of the type `ExampleChunk`. The `ExampleChunk` class is defined as follows:

```
/**
 * Simple 'chunk' class demonstrating how opaque, plugin-private data
 * may be passed between plugin functions by MonitorScript. Note that
 * every chunk class must be derived from AP_Chunk.
 */
class ExampleChunk : public AP_Chunk {
public:
 /**
  * Construct an ExampleChunk containing the specified number of
  * floating-point values.
  */
 explicit ExampleChunk(size_t size=2048);
```

```
 /**
  * Note that we can rely on the default copy constructor and
  * destructor
  */

 /**
  * Copy method creates a new ExampleChunk that is an exact duplicate
  * of the current object. This method must be provided by every chunk
  * class, so that the Engine can assign to and from chunk objects.
  */
 AP_Chunk* copy(const AP_Context& ctx) const;

 /**
  * Print out the contents of the chunk
  */
 void print() const;

 /** The contents of this chunk */
 std::vector<float64> data;
};
```

For every chunk sub-class, you need to define the copy (or cloning) method `copy()`. When the chunk is no longer needed by the correlator, it is deleted. As for any other C ++ class, it is important to ensure that the destructor releases any resources or memory owned by the instance, though best practice is for the class's members to manage their own resources, as with `std::vector<float64> data` in `ExampleChunk`. In the `correlator_plugin.hpp` header file these are defined as:

```
/**
 * Pure virtual destructor.  It is *essential* that every AP_Chunk
 * derived class implements this method to free any resources
 * allocated by the derived class.  The Engine will arrange for the
 * destructor to be called when the associated MonitorScript chunk
 * object is deleted.
 *
 * The correlator interface may not be used from a chunk's destructor.
 *
 * Also, correlator interface calls on another thread may
 * block until the chunk's destructor returns. Chunk
 * destructors that can block should therefore be careful to
 * avoid deadlocking against such a thread.
 */
 virtual ~AP_Chunk() {}

/**
 * Chunk cloning method (typically calls a copy constructor in the
 * derived class).  As with the destructor, it is essential for
 * AP_Chunk derived classes to implement this method, to ensure that
 * MonitorScript assignments to/from chunk objects work correctly.
 *
 * @param ctx Execution context for the copy operation.
 *
 * @return Pointer to a copy of this AP_Chunk object.
 */
virtual AP_Chunk* copy(const AP_Context& ctx) const = 0;
```

The contents of these methods depend on what the `chunk` is intended to contain. In this example the `chunk` is intended to store `data`, a vector of `float` values. Because `std::vector`, and therefore also `ExampleChunk`, is copy-constructible, returning `new ExampleChunk(*this);` suffices. Only if the type is not copy-constructible will `copy()`

need to do anything more elaborate. The destructor needs to adequately de-allocate the memory assigned to this structure. Both methods are used implicitly by EPL: the event correlator will invoke the destructor when the `chunk` object is no longer accessible to the EPL code, and will call the `copy()` method as necessary to handle EPL assignments.

It is important to note that if plug-in function code invokes the `chunk` destructor itself, it should first call `chunkValue(NULL)` on the associated `AP_Type` object, to prevent the event correlator from attempting to delete the same object again.

The `size` member is then being used to keep track of the size of the `data` member. Two constructors and a utility `print()` method have also been provided in this case.

Working with chunk in C

In C, working with chunks is similar. Functions that carry out the functionality that would otherwise be defined within the class methods need to be implemented. There are two specific rules that must be followed.

First a callback function table must be supplied with every user `chunk` that is created. Here's an example:

```
const struct AP_PluginChunk_Callbacks exampleChunkCallbacks = {
  exampleChunkFreeUserData,
  exampleChunkCopyUserData,
};
```

This specifies the functions that represent the "destroy" and "copy" functions described in the above C++ sections.

The other rule is that the user must implement a `chunk` "constructor" like method. Its contents or name do not matter, but it must return a specific structure that is obtained through calling the `createChunk` function. Here's an example constructor:

```
AP_PluginChunk* exampleChunkConstructor(
  const AP_PluginContext *ctx, unsigned size)
{
  struct ExampleChunk* data;

  data = (struct ExampleChunk*)malloc(
    sizeof(struct ExampleChunk));
  data->size = size;
  data->data = (double *)malloc(sizeof(double) * size);
  printf(
    "ExampleChunk constructor called with size = %u\n",size);
  return ctx->functions
    ->createChunk(ctx,&exampleChunkCallbacks,data);
}
```

Working with sequences

Sequences are the most complex type currently supported in the API. The C++ API defines `AP_Type` functions and operators to:

- Get the number of elements in a `sequence`.
- Get the type of the `sequence` elements.

- Set the length of an existing `sequence`.

  Invoking `setSequenceLength()` is not permitted while the plug-in has unreleased `sequenceElements` arrays. After a call to `setSequenceLength()`, any references to members returned from `sequenceElement()` or `operator[]` calls will become invalid.

- Extract a single element from the `sequence`, as an `AP_Type`.
- Create a sequence in an uninitialized (empty) `AP_Type` object.

  The sequence can contain the type you specify, which can be `integer`, `float`, `boolean`, `string`, or `chunk`. For example:

  ```
  rval->createSequence(AP_INTEGER_TYPE);
  ```

  Populate the sequence by setting the length and assigning content to members.

See the content of the `correlator_plugin.hpp` file for details. This file is located in the Apama installation's `include` directory.

In the C API, similar functions are provided by the `AP_PluginType_Functions` class.

The `DumpAP_Type()` function in the following example demonstrates some sequence operations and functions.

```
cout << "sequence type = " << arg.sequenceType() << endl;
cout << "sequence size = " << arg.sequenceLength() << endl;
for (uint32 i = 0; i < arg.sequenceLength(); i++) {
  cout << "sequence element[" << i << "]: ";
  DumpAP_Type(arg[i]);
  ModifyAP_Type(arg[i]);
}
```

It is also possible to map some or all of the `sequence` elements onto traditional C/C++ arrays, consisting either of `AP_Type` objects encapsulating the individual elements of the `sequence`, or of the “native” objects stored in each element. For example, the elements of an EPL `sequence<integer>` object can be mapped onto a native `int64` array like this:

```
int64 * intArray = arg.integerSequenceElements();
for (uint32 i = 0; i < arg.sequenceLength(); i++) {
  cout << intArray[i] << endl;
}
```

Alternatively, a “slice” containing a range of elements from the `sequence` can be mapped. The example below maps elements 20 through 59 of the `sequence` onto a native `int64` array of length 40. Note that an exception will be thrown if the specified slice lies outside the bounds of the `sequence`.

```
int64* intSlice = arg.integerSequenceElements(20, 40);
for (uint32 i = 0; i < 40; i++) {
  cout << intSlice[i] << endl;
}
```

Mapping `sequence` elements in this way may be relatively inefficient. An EPL `sequence` is not necessarily stored as a native object array internally, so it may be necessary to copy the element data into the native array when performing the mapping. Likewise, the EPL `sequence` must be updated to reflect any changes to the elements made by the plug-in function, before returning to EPL. This latter operation is achieved by the family of release<*type*>SequenceElements() functions. For the integer sequence in the example above, it is necessary to call

```
sequence.releaseIntegerSequenceElements();
```

before returning from the plug-in function. Note that this will immediately invalidate the arrays returned by *all* calls to integerSequenceElements() made by the plug-in function, so it should typically only be used once per function invocation, once the function is finished with any mapped sequence data.

Any necessary release<*type*>SequenceElements() calls will in fact be made automatically when a plug-in function terminates. These functions are provided to plug-in writers so that mapped data can be released early if it is necessary to make memory available. It is also possible to access elements of a sequence using the visitor idiom by calling visitSequenceElements with an appropriate functor. Although less convenient than other sequence element accessors, it is more efficient as it entails no memory allocation.

The complete example

The file complex_plugin.cpp in the samples/correlator_plugin/cpp directory of your Apama installation contains the implementation of the ComplexPlugin:: methods and the ExampleChunk class. The implementation of ComplexPlugin::test1 is particularly interesting as it demonstrates how to use the functionality provided by the EPL Plug-in C++ API to examine the type of a parameter and act accordingly.

The equivalent C example is supplied in the installation as complex_plugin.c in the samples/correlator_plugin/c folder of your Apama installation.

The Plug-in initialization and shutdown methods are as used within simple_plugin.

Using complex_plugin from the event correlator

Example EPL code that imports this plug-in and uses its functionality is provided in the file complex_plugin.mon, which is located in the samples\correlator_plugin\cpp folder of your Apama installation.

Once more the monitor starts by importing complex_plugin, this time mapping it to the alias complex.

After defining a number of variables, it calls complex.test1. This function displays the number of arguments and then displays them. It also returns the string value “Hello, World”, which is then stored in ret1.

The call to complex.test2 requires setting up the sequences it takes as parameters. As the implementation of test2 within complex_plugin is effectively the same as test1, this does the same; it displays the number of arguments and then displays each one, in this case printing out the contents of every sequence. The float value 2.71828 is returned instead.

For complex.test3 the monitor is creating a chunk. The test3 method will create a chunk with a numeric array of the specified size 20, which it initializes with the numbers

1 to 20. It then prints the contents out and returns the `chunk` to the event correlator for retaining in `myChunk`.

The event correlator cannot examine or manipulate `myChunk`, but `myChunk` can be passed in to other plug-in methods that expect a `chunk` of the same type. Note that the type of a `chunk`, in this case the C++ class `ExampleChunk`, is not visible in EPL, so it is up to the developer to ensure the `chunks` are compatible across plug-in methods. This broadly applies to all plug-in methods irrespective of parameter and return types. The developer must ensure that the parameters passed are of the correct types as otherwise failure might occur.

The `complex.test4` method is called with `myChunk`. This traverses the array of floating point numbers contained within and takes the square root of each one. It then prints out the revised numbers. It does not return anything.

Asynchronous plug-ins

It is possible to write a plug-in that can send events asynchronously to the event correlator. This is not a recommended technique as multiple correlator processes or external processes connected via the client API are preferred approaches to scaling Apama deployments. However, an example of how to implement asynchronous plug-ins is available in the `samples\correlator_plugin\cpp` directory of the Apama installation, and is called `async_plugin.cpp`.

This is a simple example which uses the `getCorrelator()` method of `AP_Context` to get a reference to an `AP_CorrelatorInterface`.

The single public method of `AP_CorrelatorInterface` is declared as follows:

```
/**
* Send an event to the correlator
*
* @param event the event to send.  The event is represented as a string
* using the format described in Deploying and Managing Apama Apps.
* See the correlator utilities section, Event File Format.
*/
virtual void sendEvent(const char* event) const = 0;
```

The event correlator implements this method by using the same event queuing and asynchronous processing mechanism as is used for the EPL `enqueue` keyword.

In this sample, the plug-in has one function exposed that is also called `sendEvent`. This function demonstrates the feature by simply sending the data it was given back to the event correlator. A more elaborate use of this mechanism might use its own background processing thread to occasionally send events to the event correlator.

Examples of using the `sendEvent` method include:

```
ctx.getCorrelator()->sendEvent("SimpleCounter(1)");
```

This will dispatch the event of type SimpleCounter with a single integer field set to 1.

Also, in the sample discussed above it is used thus:

```
ctx.getCorrelator()->sendEvent(args[0].stringValue());
```

Here the event provided by the first argument is the complete event to be dispatched.

There is one area where extra caution is required when building asynchronous plug-ins, which is the lifetime of variables within the plug-in. When a plug-in function is called with an `AP_Context` argument, that context is valid only for the duration of the call (and only on that thread). However, the `AP_CorrelatorInterface` remains valid for the lifetime of the plug-in. References to it may be retained and used at any time on any thread. This information is important to anyone writing a plug-in that may be holding references to an `AP_CorrelatorInterface`, for example, in another thread. The plug-in author must ensure that when the plug-in is shutdown these references are cleaned up, since attempts to use these references after the plug-in has been shutdown may cause instability of the event correlator.

Writing correlator plug-ins for parallel processing applications

For a plug-in created before Apama 9.9 to work with Apama 9.9, you must re-compile it.

Beginning with release 5.0, all plug-ins are required to be thread-safe. Beginning with release 4.2, the interface is more accurate with respect to the use of `const`, so minor code changes may be required.

Plug-ins created before Apama 4.2 run in a single operating system thread at a time. The correlator assumes that such plug-ins are not thread-safe. For each call to such a plug-in, the correlator acquires a mutex to ensure that multiple correlator contexts cannot use the plug-in at the same time.

When multiple contexts need to concurrently use a plug-in, you must ensure that the plug-in is thread safe. A plug-in can export a function that returns the capabilities of the plug-in. See the `AP_PluginCommon.h` header file in the `include` directory of your Apama installation for the definition of `AP_PLUGIN_GET_CAPABILITIES_FUNCTION_NAME`. The correlator calls this function before it calls the plug-in's `init()` function. The return value is a bit-wise `OR` of capabilities, as defined in the `AP_PluginCommon.h` header file. If the return value indicates that the plug-in is thread-safe, multiple contexts can make concurrent calls to the plug-in. When multiple contexts need to concurrently use a plug-in, you must ensure that the plug-in is thread-safe.

A plug-in can use a context's ID to send events to a particular context. Use the `AP_Context.getContextId()` method to obtain the context ID. The correlator passes an `AP_Context` object to each plug-in. This object has a `getCorrelator()` method that returns an interface that defines a `sendEventTo()` method, which has the following signature:

```
sendEventTo(const char *event, AP_uint64 targetContextId,
  const AP_Context &source)
```

The `sendEventTo()` method takes three arguments:

- `event` — For the event to send, specify a string in the format described in *Event file format* in *Deploying and Managing Apama Applications*.
- `targetContextId` — Specify the ID of the context you want to send the event to.

- `&source` — Specify the context that this plug-in call is running in. This is the `AP_Context` object that was passed to the plug-in method or event handler method. If this method is called from a background thread then that thread passes an `AP_Context::NoContext()` object to this method. Specify that object as the source context.

  You can obtain the current context ID with a call to `AP_Context.getContextId()`, which might be useful for sending or passing events to other threads. However, you should not use the returned object as the value for the `&source` argument.

The following overloading of the `sendEventTo()` method is deprecated and will be removed in a future release. Use the previously described overloading instead.

```
sendEventTo(const char *event, AP_uint64 targetContextId,
  AP_uint64 sourceContextId)
```

Note: The class `AP_Context`, which you use for correlator plug-in development, is completely different and unrelated to contexts that you define in EPL for parallel processing.

Working with blocking behavior in C++ plug-ins

When the behavior of a C++ plug-in is that it never blocks or does not usually block you can declare the plug-in to be non-blocking. Even if one or more methods defined in a plug-in might block, you can declare the plug-in to be non-blocking and override the non-blocking designation for just the methods that might block. The benefit of declaring a plug-in to be non-blocking is that the correlator refrains from creating unneeded processing threads.

By default, the correlator assumes that any plug-in method or handler it calls might block for an arbitrary amount of time. Consequently, the correlator creates additional threads to continue processing other contexts. If the plug-in method/handler does not block, these extra threads represent an expense that could be avoided.

Declaring a plug-in as non-blocking

To declare a plug-in as non-blocking, define an `AP_PLUGIN_GET_CAPABILITIES_FUNCTION_NAME` function that returns `AP_CAPABILITIES_NON_BLOCKING`. See the `AP_PluginCommon.h` header file in the `include` directory of your Apama installation directory for the definition of `AP_PLUGIN_GET_CAPABILITIES_FUNCTION_NAME`. The correlator calls this function before it calls the plug-in's `init()` function. The return value is an `AP_Capabilities` object that contains a bit-wise `OR` of capabilities, as defined in the `AP_PluginCommon.h` header file.

When you declare a plug-in to be non-blocking the correlator lets plug-in methods and any plug-in event handlers process to completion without spawning new threads.

You must ensure that a plug-in declared to be non-blocking does not block. If a non-blocking plug-in does block it can cause a correlator deadlock. To avoid this, for each plug-in method that might block, be sure to override the non-blocking designation. For example, consider a method that accesses a local cache. Normally, this method would not block. However, if the method uses a remote process when the needed object is not in the local cache then the method might block. You must override the non-blocking designation for a method such as this one.

Overriding the non-blocking designation for particular methods

A plug-in that you declare as non-blocking can have one or more methods that might block. In each method that might block, you must call the `pluginMethodBlocking()` function on either an `AP_Context` object or an `AP_CorrelatorInterface` object. The signature for the `pluginMethodBlocking()` function is as follows for each type of object:

```
void pluginMethodBlocking();
```

Calling `pluginMethodBlocking()` is idempotent. A call to `pluginMethodBlocking()` informs the correlator that the containing method might block and that the correlator should start additional threads to compensate.

Working with channels in C++ plug-ins

In a C++ correlator plug-in, you can send an event to a particular channel, subscribe to receive events sent to particular channels, receive events sent on subscribed channels, and unsubscribe from subscribed channels.

There is currently no support for channels in correlator plug-ins written in C.

Sending events to particular channels

To send an event to a particular channel, call the `AP_CorrelatorInterface.sendEventTo()`method:

```
virtual void sendEventTo(const char *event, const char *targetChannel,
             const AP_Context &source)
```

- `event` — For the event to send, specify a string in the format described in *Event file format* in *Deploying and Managing Apama Applications*.
- `targetChannel` — Specify the name of the channel you want to send the event to.
- `&source` — Specify the context that this plug-in call is running in. This is the `AP_Context` object that was passed to the plug-in method or event handler method. If this method is called from a background thread then that thread passes an `AP_Context::NoContext()` object to this method. Specify that object as the source context.

An event that is passed to the `sendEventTo()` method is delivered to any contexts, receivers, and plug-in event handlers that are subscribed to the specified channel.

Defining an event handler class for receiving events

To receive events sent to channels, derive an event handler class from `AP_EventHandlerInterface` and implement the `handleEvent()` method:

```
virtual void handleEvent(const AP_BlockingAwareContext &ctx,
```

```
              const char *event, const char *channel)
```

`ctx` — Context in which this execution of the event handler is happening.

`event` — An event being received. The event must be represented as a string in the format described in *Event file format* in *Deploying and Managing Apama Applications*.

`channel` — The channel on which the event was received.

Store each reference to an event handler instance in the `AP_EventHandlerInterface::ptr_t` smart pointer. When the last reference to a particular event handler is dropped then that instance is deleted.

Subscribing event handlers to channels

After you create an event handler class, you use event handler objects to subscribe to receive events sent on one or more channels. Each event handler object can receive events from multiple channels and you can specify the same event handler in multiple subscriptions. If you subscribe to receive events from the same channel more than once the duplicate subscriptions are ignored. When an event handler is subscribed to one or more channels its `handleEvent()` method is called once for each event that is sent to any subscribed channel.

There are several overloadings of the `AP_CorrelatorInterface.subscribe()` method:

- To use an initializer list to subscribe an event handler object to one or more channels:

  ```
  void subscribe(const AP_EventHandlerInterface::ptr_t &handler,
  std::initializer_list<const char *> channels);
  ```

  This overloading is not supported on SUSE Linux Enterprise Server 11.

  This overloading uses smart pointers for reference counting. Use the following format to call it:

  ```
  correlator->subscribe(AP_EventHandlerInterface::ptr_t(new MyHandlerType()),
  { "channel one", "channel two" });
  ```

  `handler` — Specify the handler to subscribe.

  `channels` — Specify one or more channels that you want to receive events from.

- To use an iterator pair or an array of `char*` values to subscribe an event handler object to one or more channels:

  ```
  template<typename ITER>
  void subscribe(const AP_EventHandlerInterface::ptr_t &handler,
  const ITER &start, const ITER &end);
  ```

  This overloading uses smart pointers for reference counting. Use the following format to call it:

  ```
  correlator->subscribe(AP_EventHandlerInterface::ptr_t(new
  MyHandlerType()), channels.begin(), channels.end());
  ```

  `handler` — Specify the handler to subscribe.

  `start` — The iterator to start from.

  `end` — The iterator to end at.

The iterators must resolve to values that can be cast to `const char*` values. Alternatively, you can use an array of `char*` values in place of the iterators.

- To subscribe an event handler object to a single channel:

```
template<typename T>
void unsubscribe(const AP_EventHandlerInterface::ptr_t &handler,
      const T &channel);
```

  This overloading uses smart pointers for reference counting. Use the following format to call this method:

```
correlator->subscribe(AP_EventHandlerInterface::ptr_t(new
MyHandlerType()), "channel one");
```

  `handler` — Specify the handler to subscribe.

  `channel` — Specify the channel to subscribe to. The value you specify must be a value that can be cast to `char*`.

Unsubscribing event handlers from channels

Several overloadings of the `AP_CorrelatorInterface.unsubscribe()` method let you cancel one, multiple, or all channel subscriptions. If the result of an `unsubscribe()` method is that the event handler has no subscriptions, and if there are no references to that event handler, then the event handler object is deleted.

- To use an initializer list to unsubscribe an event handler object from one or more channels:

```
void unsubscribe(const AP_EventHandlerInterface::ptr_t &handler,
std::initializer_list<const char *> channels);
```

  This overloading is not supported on SUSE Linux Enterprise Server 11.

  This overloading uses smart pointers for reference counting. Use the following format to call it:

```
correlator->unsubscribe(my_handler, { "channel one", "channel two" });
```

  `handler` — Specify the handler to unsubscribe.

  `channels` — Specify a list of channels for which to cancel subscriptions.

- To use an iterator pair or an array of `char*` values to unsubscribe an event handler object from one or more channels:

```
template<typename ITER>
void unsubscribe(const AP_EventHandlerInterface::ptr_t &handler,
const ITER &start, const ITER &end);
```

  This overloading uses smart pointers for reference counting. Use the following format to it:

```
correlator->unsubscribe(my_handler, channels.begin(), channels.end());
```

  `handler` — Specify the handler to unsubscribe.

  `start` — The iterator to start from.

  `end` — The iterator to end at.

The iterators must resolve to values that can be cast to `const char*` values. Alternatively, you can use an array of `char*` values in place of the iterators.

- To unsubscribe an event handler object from a single channel:

```
template<typename T>
void unsubscribe(const AP_EventHandlerInterface::ptr_t &handler,
       const T &channel);
```

`handler` — Specify the handler to unsubscribe.

`channels` — Specify the channel to unsubscribe from. The value you specify must be a value that can be cast to `char*`.

- To unsubscribe an event handler object from all channels it is subscribed to:

```
virtual void unsubscribe(const AP_EventHandlerInterface::ptr_t &handler);
```

`handler` — Specify the handler to unsubscribe. If there are no other references to this event handler, it is deleted.

Notes for writing C++ plug-ins that use channels

- **Ordering**

  When an event is sent to some contexts and some plug-ins the order the order in which those contexts and plug-ins process the event is unpredictable.

  Events sent on a particular channel maintain their order on the event handler that receives them. However, there is no ordering with regard to other components that might be subscribed to the same channel and so receive and operate on the same events.

  There is no ordering of events sent on different channels and received by the same event handler.

- **Blocking**

  As with plug-in method calls, methods on event handlers may be blocking or nonblocking. If a plug-in is declared as nonblocking then the correlator will assume that all its event handlers are also nonblocking. You can call the `AP_BlockingAwareContext.pluginMethodBlocking()` method to declare that an event handler is actually blocking, despite the overall plug-in nonblocking setting. Event handlers must not perform any potentially blocking operations if the plug-in is nonblocking without calling `pluginMethodBlocking()`. See "Working with blocking behavior in C++ plug-ins" on page 741.

- **Exceptions**

  If a handler throws an exception it is reported in the correlator log file and then discarded.

- **Plug-in lifetime**

  If all monitors that reference a plug-in have terminated or have been removed by the `engine_delete` utility, then the plug-in and any event handlers that belong to the plug-in are removed from the correlator. If an event handler callback is in progress, then the delete operation blocks until the event handler has completed. At that point, references to the handler are dropped so that the plug-in can be unloaded.

C++ plug-in samples that use channels

C++ code samples that use channels in plug-ins are in the `subscribe_plugin` file in the `samples\correlator_plugin\cpp` directory of your Apama installation.

29 The EPL Plug-in APIs for C and C++

The correlator_plugin.hpp header file provides the functionality of the EPL Plug-in C++ API. The file is located in the include folder of your Apama installation. The file is extensively documented and is recommended as a reference to the functionality available within the definitions of the classes listed below.

The equivalent header file for the EPL Plug-in C API is correlator_plugin.h. This will not explicitly be covered here, as it is broadly identical in functionality to the C++ header file. The only difference is that the functionality presented as class methods in the C++ API is presented as C functions in the C API. This file is also located in the include folder.

The C++ header defines several types. First it defines two enumerations:

- AP_TypeDiscriminator - Identifies the type of the data item encapsulated by an AP_Type “smart union” object. Its values map to EPL types.
- AP_ErrorCode – Specifies the error codes that can be returned by plug-in functions that do not throw exceptions. In this release of the API these are just the C-linkage initialization and destructor functions.

Then it defines a number of exceptions. All exception classes inherit from AP_PluginException, and they are AP_TypeException, AP_UnimplementedException, AP_BoundsException and AP_SerialisationException.

Primary class types

The primary class types follow:

- AP_Chunk – This is the base class for all chunk values. Plug-ins need to inherit from this class and add suitable data and function members in the derived class to manage their private data structures in memory allocated by the plug-in itself. AP_Chunk instances are passed in and out of plug-in functions as the “chunk value” of AP_Type objects, and referenced in EPL code via variables of type chunk.
- AP_Type – This is a type-safe encapsulation of an EPL object for passing arguments and return values into and out of plug-in functions. The implementation of the AP_Type member functions is internal to the event correlator. One consequence of this is that plug-ins *cannot* create a useful instance of this class themselves; the only valid AP_Type objects are those passed to a plug-in function by the event correlator. AP_Type is a “smart union” object; each instance holds a single value of one of the supported types and only allows access to data of that type. Note that integer, float, and boolean values are passed by value, while the “complex” types — sequence and chunk — are passed by reference, so changes made to the contents of these objects by a plug-in will be seen by the invoking EPL code. Strings are treated slightly differently: though EPL string objects themselves are immutable, the plug-in API allows return values and the values in a sequence of strings to be modified. When this is done, a new EPL string object is created containing the specified text. As of version 5.0 it is no longer possible to modify a string argument to a plug-in function.

- `AP_TypeList` – A container class for an ordered list of `AP_Type` objects, typically used to hold the argument list for a plug-in function call.
- `AP_Context` – The execution context for a plug-in function call. Holds per-call correlator-internal data and provides various utility functions to plug-ins. Note that the implementation of the `AP_Context` member functions is internal to the event correlator. One consequence of this is that plug-ins *cannot* create a useful instance of this class themselves; the only valid `AP_Context` objects are those passed in to a plug-in function by the event correlator.
- `AP_Function` – A plug-in function descriptor. The argument and return types in this structure are strings (not `AP_TypeDiscriminator` objects) that use the same syntax as EPL declarations. For example, if one declares a function argument as a `sequence` of `integer`s, the corresponding element of the `paramTypes` array would contain `sequence<integer>`.
- `AP_CorrelatorInterface` – An abstraction of the interface for calling back into the event correlator. There is a single method provided that enables a plug-in to send events to the event correlator. An instance of this class is acquired by requesting it via a method on the `AP_Context`.

The header file also defines pointers to the plug-in initialization and destructor (or shutdown) functions, as well as version checking. Each plug-in must export these two functions with these signatures, named using specific macros and with "C" linkage. The first is called immediately upon loading of the plug-in by the library whereas the other is called immediately before unloading.

If the plug-in's functions can safely be called simultaneously from multiple EPL contexts, a get-capabilities function should be defined that announces the plug-in as thread-safe.

Some plug-ins may need to keep thread-specific data in order to work correctly; in which case a thread-ended function should also be defined. This function will be called on the thread so that resources can be freed if the thread is ending before the plug-in is shut down. When the shutdown function is called it is responsible for freeing resources related to any threads that are still running.

30 Writing Correlator Plug-ins in Java

EPL plug-ins can be written in Java. Java plug-in classes are automatically analyzed by the correlator and any suitable methods exposed as methods that can be called from EPL.

EPL plug-ins written in Java are packaged and deployed in the same way as JMon applications. See "Developing and Deploying JMon Applications" on page 703 for more information.

Creating a plug-in using Java

To create a Java class to use as a correlator plug-in

1. In the Java class used as a plug-in, you need to have one or more public static methods that match the permitted signatures, which are described in "Permitted signatures for methods" on page 753.

   All calls from an Apama application will be made to these static methods from all contexts.

   As the plug-in author you are responsible for any concurrency concerns.

2. Correlator plug-ins in Java are deployed using a JMon application and are packaged in a jar file. You need to create a JMon deployment descriptor file in the application's `META-INF/jmon-jar.xml` file. For the plug-in you need to add a `<plugin>` to the `<application-classes>` element.

   For more information on Apama deployment descriptor files, see "Creating deployment descriptor files" on page 707.

   An example plug-in stanza looks like this:

```
<plugin>
  <plugin-name>TestPlugin</plugin-name>
  <plugin-class>test.TestPlugin</plugin-class>
  <description>A test plugin</description>
</plugin>
```

   - `plugin-name` defines the name visible to EPL.
   - `plugin-class` indicates the class to load from the jar for this plugin.
   - `description` is a simple textual description that appears in log messages.

   Instead of writing a deployment descriptor file manually, if you are using Software AG Designer to create the plug-in you can annotate the plug-in class and have Software AG Designer automatically generate the descriptor file. Here is an example annotation:

```
@com.apama.epl.plugin.annotation.EPLPlugin(name="TestPlugin",
                                          description="A test plugin")
class testplugin
{
   ...
}
```

3. Create a jar file for deploying the plug-in and add the Java class file and the deployment descriptor file `META-INF/jmon-jar.xml` to it. In Software AG Designer when you create a JMon application, this is done automatically.

For applications that you plan to inject into a correlator, the recommendation is to create separate jar files for:

- Correlator plug-ins written in Java
- JMon applications

Although the mechanism for creating these jars and describing their meta-data is similar, the interactions of these two different uses of injected jars mean that they will often need to be injected into the correlator separately. The creation of separate jar files ensures that you can inject your application components in the correct order, which is typically:

1. Correlator plug-ins written in Java
2. EPL monitors and events
3. JMon applications

Permitted signatures for methods

For a method to be exposed to EPL it must be public, must be static and every argument plus the return type must be one of the following:

Java Entry	EPL Type	Notes
`int`	`integer`	Truncated when passed in, for compatibility.
`long`	`integer`	
`String`	`string`	Copy in / copy out.
`boolean`	`boolean`	
`double`	`float`	
`java.math.BigDecimal`	`decimal`	Passing in either NaN or infinity throws an exception that kills the monitor instance if not caught.

Java Entry	EPL Type	Notes
com.apama.epl.plugin.Context	context	New type defined for plug-ins.
com.apama.epl.plugin.Channel	com.apama.Channel	New type defined for plug-ins.
Object	chunk	Any Java object can be held in EPL via a chunk.
TYPE[]	sequence<TYPE>	Any above type except int can be passed in as an arbitrary-depth nested array->sequence. The sequence is strictly copy-in, non-modifiable, but can be returned as copy-out.
void	N/A	Permitted as a return type only.

Any method not matching this signature is ignored and logged at DEBUG.

Overloaded functions

Any function with multiple overloads is ignored (none of them are exposed) and this is logged once at WARN and once per method at DEBUG.

Using Java plug-ins

After you create a correlator plug-in in Java, it must be injected into a Java-enabled correlator before it is available for use in Apama applications. Applications that will use the plug-in also need to import the plug-in by name, as is done with correlator plug-ins written in C or C++.

Injecting

The .jar file containing the correlator plug-in must be injected into a correlator that has been started with the --java option, which enables support for JMon applications.

When using the Apama engine_inject utility to inject the .jar file, you also need to use the --java option.

Importing

Once a Java plug-in has been injected it is available for import using the plugin-name defined in the deployment descriptor file. The correlator will automatically introspect the class and make available any suitable, public methods that can be called directly from EPL. For example, the following code imports a plug-in named TestPlugin and calls its dosomething method:

```
monitor m {
   import "TestPlugin" as test;
   action onload()
   {
      test.dosomething();
   }
}
```

Note, if the plug-in .jar has been incorrectly injected, the correlator will try to load the plug-in as a C/C++ plug-in and may give an error such as `Error opening plug-in library libfoo.so: libfoo.so: cannot open shared object file: No such file or directory`. If this happens and you were trying to load a plug-in written in Java, then check that the .jar file was created and injected correctly before your EPL file was injected.

Classpath

Each JMon or Java plugin application is loaded into its own separate classloader. This means that they have no access to any classes loaded in other .jar files. If your plug-in requires any other Java libraries they must be listed in the classpath element of the deployment descriptor, included in the correlator's global classpath, or injected in the same application .jar as the plug-in. See "Specifying classpath in deployment descriptor files" on page 709 for more details.

Deleting

A correlator plug-in can be explicitly deleted by calling engine_delete with the application name defined in the deployment descriptor, as with JMon applications. Monitors using the plug-in depend on the plug-in type in the normal fashion. The plug-in will not be deleted until the application and all dependent monitors are deleted.

As each plugin is loaded in its own classloader, once the application has been deleted, the plug-in can be re-injected and it will be loaded into a new classloader.

Interacting with contexts

Correlator plug-ins can be passed context objects using the com.apama.epl.plugin.Context type. The Context object is defined as:

```
package com.apama.epl.plugin;
public class Context
{
  public String toString();
  public Context();
  public String getName();
```

```
  public int hashCode();
  public boolean isPublic();
  public boolean equals(Context other);
  public static native Context getCurrent();
}
```

The `getCurrent` method returns the context that this method was called from.

Interacting with the correlator

Correlator plug-ins can use the `com.apama.epl.plugin.Correlator` class to send an event, subscribe to a channel, or to specify blocking behavior. The `Correlator` class is defined as:

```
package com.apama.epl.plugin;
public class Correlator
{
  public static native void sendTo(String evt, String chan);
  public static native void sendTo(String evt, Context ctx);
  public static native void sendTo(String evt, Context[] ctxs);
  public static native void sendTo(String evt, Channel c);

  public static native void subscribe(EventHandler handler, String[] channels);
  public static native void unsubscribe(EventHandler handler, String[] channels);
  public static native void unsubscribe(EventHandler handler);

  public static native void enqueue(String evt);
  public static native void enqueueTo(String evt, Context c);

  public static native void pluginMethodBlocking();
}
```

The `Correlator` methods are:

- `sendTo(String, String)` – Sends the event represented in the first `String` to the channel specified in the second `String`. Any contexts and external receivers that are subscribed to the specified channel receive the event. If there are no subscribers the event is discarded.
- `sendTo(String, Context)` – Sends the event represented in `String` to the context referred to by the `com.apama.epl.plugin.Context` argument. An exception is thrown if the context reference is invalid.
- `sendTo(String, Context[])` – Sends the event represented in `String` to the array of contexts referred to by the `com.apama.epl.plugin.Context[]` argument. If one context reference is invalid an exception is thrown and the event is not sent to any context.
- `sendTo(String, Channel)` — Sends the event represented in `String`. If the specified `com.apama.epl.plugin.Channel` object contains a string then the event is sent to the channel that has that name. If `Channel` contains a context then the event is sent to that context.
- `subscribe(EventHandler, String[])` – Subscribes the handler object to the channels listed in the string array. If the handler is already subscribed to some channels then the channels listed in the array are added to the list of existing subscriptions. Subscribing to the same channel multiple times results in a single subscription. However, to completely remove a channel subscription that has been

added multiple times you must unsubscribe from that channel the same number of times that it was subscribed to.

- `unsubscribe(EventHandler, String[])` – For the channels specified in the string array, this method removes the subscriptions from the specified handler. It is possible for the result of this method to be that the handler is not subscribed to any channels. Unsubscription from a channel that the handler is not subscribed is ignored.
- `unsubscribe(EventHandler)` – Removes all subscriptions from the specified handler. If this handler is not subscribed to any channels the method is ignored.
- `enqueue(String)` – Adds the event represented in `String` to the back of the input queue of all public contexts. This method is expected to be deprecated and then removed in future releases. Use a `sendTo()` method instead.
- `enqueueTo(String, Context)` – Adds the event represented in `String` to the back of the input queue of the specified context. This method is expected to be deprecated and then removed in future releases. Use a `sendTo()` method instead.
- `pluginMethodBlocking()` – Informs the correlator that the plug-in is potentially blocking for the rest of this call and the correlator is free to spin up additional threads on which to run other contexts.

For more information on `com.apama.epl.plugin.Context` and `com.apama.epl.plugin.Correlator`, see the Javadoc reference material available at `doc\javadoc\index.html` in your Apama installation directory.

Receiving events from named channels

A Java plug-in can register callbacks to receive events that are sent to named channels. This is similar to the `monitor.subscribe()` method in EPL. Events are delivered in string form by means of a method on a known interface.

To register a callback, the plug-in must define a class that implements the `com.apama.epl.plugin.EventHandler` interface:

```
public interface EventHandler
{
   void handleEvent(String event, String channel);
}
```

The `handleEvent()` method is called once for each event sent to a channel that this handler is subscribed to, with the channel on which it was received. To manage `EventHandler` object channel subscriptions, use the `subscribe()` and `unsubscribe()` methods on `com.apama.epl.plugin.Correlator`. When a handler is unsubscribed from all channels any in-progress callbacks will complete, but no further callbacks will be made to that handler.

Working with Channel objects

Similar to context objects, you can pass EPL `com.apama.Channel` objects into a Java plug-in. The equivalent Java class is `com.apama.epl.plugin.Channel` and you can use objects of this class to send events to channels. Like the EPL `Channel` type, the Java `Channel` class has three constructors:

```
Channel (String name)
Channel (com.apama.epl.plugin.Context c)
Channel ()
```

A `Channel` object can contain a string that is the name of a channel or it can contain a context. The no-argument constructor creates a `Channel` object that contains an empty context. If you try to send an event to an empty context the `sendTo()` method throws an exception.

You can call the `empty()` method on a Java `Channel` object. It returns true only if the object contains an empty context.

Exceptions

If a method throws an exception, that exception is passed up to the calling EPL and can be caught by the calling monitor. If an exception is not caught it will terminate the monitor instance. Details on catching exceptions in EPL can be found in "Catching exceptions" on page 293.

If a Java plug-in throws a `java.lang.RuntimeException`, or subclass, which is in the `java.` namespace (for example, `java.lang.NullPointerException`) then it will be logged at ERROR with a stacktrace before being rethrown. Unchecked exceptions from other sources (for example client exception types) will not be logged.

Persistence

No Java plug-ins are persistent and they are not permitted in a persistent monitor, but they are permitted in non-persistent monitors in a persistent correlator.

Load, unload, and shutdown hooks

If a plug-in needs to run anything when it is loaded, you can do this in a static initializer:

```
public class Plugin
{
   static {
      ... // initialization code here
   }
}
```

It is not natively possible for a plug-in to run anything when it is unloaded. If you need this functionality you can declare a method to be called when the plug-in is unloaded using annotations:

```
public class Plugin
{
   @com.apama.epl.plugin.annotation.Callback(
      type=com.apama.epl.plugin.annotation.Callback.CBType.SHUTDOWN)
   public static void shutdown()
   {
      ... // shutdown code here
   }
}
```

The method must be a public static function which takes no arguments and returns void. Currently, Apama does not support callbacks other than `SHUTDOWN`.

Non-blocking plug-ins and methods

In a correlator some threads have the potential to block and others do not. If a thread might block, the correlator starts new threads if it has additional runnable contexts. By default the correlator assumes that a plug-in call may block and will start additional threads on which to run other contexts. In situations where the plug-in call can never block, the additional overhead of starting new threads when all CPUs are busy is unnecessary. If you know that a plug-in or an individual method is non-blocking, you can improve efficiency by annotating either entire plug-ins or individual methods as non-blocking.

Note, however, if a method declared as non-blocking does block, the correlator can block all threads waiting for them to finish, resulting in a deadlocked correlator. For methods that are normally non-blocking, but may block in predictable situations, see "Sometimes-blocking functions", below.

- **Annotations.** You can apply the annotation `com.apama.epl.plugin.annotation.NoBlock` with no arguments to either a plug-in class, or to a method on a class:

  ```
  @com.apama.epl.plugin.annotation.NoBlock()
  public class Plugin
  {
    ...
  }
  ```

  When applied to a class, the annotation indicates that no method on the plug-in can ever block.

  ```
  public class Plugin
  {
    @com.apama.epl.plugin.annotation.NoBlock()
    public static String getValue() { ... }
  }
  ```

  When applied to a method, the annotation indicates that this method will never block, but other methods may block.

- **Sometimes-blocking functions.** If you have a function that usually will not block, but under some known conditions may block, then the method can be declared as `NoBlock` as long as it then uses a callback to indicate when it is starting the potentially-blocking behavior. The callback is a static method on `com.apama.epl.plugin.Correlator` called `pluginMethodBlocking`. This function takes no arguments, returns no value and is idempotent. When it is called, the correlator will then assume that the plug-in is potentially blocking for the rest of this call and is free to spin up additional threads on which to run other contexts.

  ```
  public class Plugin
  {
     @com.apama.epl.plugin.annotation.NoBlock()
     public static String getValue()
     {
        if (null != localValue) return localValue;
        else {
  ```

```
            com.apama.epl.plugin.Correlator.pluginMethodBlocking();
            localValue = getRemoteValue();
            return localValue;
         }
      }
   }
```

Logging

Correlator plug-ins written in Java can log to the correlator's log file. This is done via the `com.apama.util.Logger` class. Each plug-in must create a static instance of the `Logger` using the static `getLogger` method. This instance provides `debug(...)`, `info(...)`, `warn(...)` and `error(...)` methods, which log a string at that log level in the correlator log file. The level is configured either by means of the correlator command line and management commands or using a log4j configuration file.

For more information on using the `Logger` class, including how to override the default log level, see the Javadoc reference material, available starting with `doc\javadoc\index.html` in your Apama installation directory.

The following is an example of logging in a correlator plug-in:

```
package test;
import com.apama.util.Logger;
public class Plugin
{
   private static final Logger logger = Logger.getLogger(Plugin.class);
   public static void foo()
   {
      logger.info("A string that's logged at INFO");
   }
}
```

This will produce entries in the correlator log file like this:

```
2013-06-11 15:14:21.974 INFO [1167792448:processing] - <test.Plugin> A
string that's logged at INFO
```

Sample plug-ins in Java

Apama provides sample correlator plug-ins written in Java, located in the `samples\correlator_plugin\java` directory of your Apama installation. The samples are:

- `SimplePlugin` – a basic plug-in with one method that takes a string, and returns another string.
- `ComplexPlugin` – a plug-in that has several methods and handles more complex types.
- `SendPlugin` – a plug-in that demonstrates passing contexts around and sending events.
- `SubscribePlugin` – a plug-in that shows how to subscribe to receive events sent on a particular channel.

The `samples\correlator_plugin\java` directory contains the Java code for the samples, the EPL code for the Apama applications that call each of the plug-ins, the deployment descriptor files, and an Ant `build.xml` file for building all of the samples. The directory also contains a `README.txt` that describes how to build and run the samples as well as text files that depict what the output of the samples should be like.

A simple plug-in in Java

The simple plug-in sample in the `samples\correlator_plugin\java` directory of your Apama installation is comparable to the similar C and C++ simple plug-in samples.

The Java code for the `SimplePlugin` class contains the public static `test` method. (Methods that will be called from EPL code need to be public and static.)

```
public class SimplePlugin
{
  public static final String TEST_STRING = "Hello, World";
  public static String test(String arg)
  {
    System.out.println("SimplePlugin function test called");
    System.out.println("arg = "+arg);
    System.out.println("return value = "+TEST_STRING);
    return TEST_STRING;
  }
}
```

The `SimplePlugin.xml` file is the deployment descriptor and contains the following `<plugin>` stanza that illustrates how to specify the plug-in.

```
  <application-classes>
    <plugin>
      <plugin-name>SimplePlugin</plugin-name>
      <plugin-class>SimplePlugin</plugin-class>
      <description>A test plugin</description>
    </plugin>
  </application-classes>
```

The `SimplePlugin.mon` file contains the EPL code. It imports the plug-in and calls the `test` method.

```
monitor SimplePluginTest {
  // Load the plugin
  import "SimplePlugin" as simple;
// To hold the return value
  string ret;
  string arg;
  action onload() {
    // Call plugin function
    arg := "Hello, Simple Plugin";
    ret := simple.test(arg);
    // Print out return value
    log "simple.test = " + ret at INFO;
    log "arg = " + arg at INFO;
  }
}
```

A more complex plug-in in Java

The complex plug-in sample in the `samples\correlator_plugin\java` directory of your Apama installation is comparable to the corresponding C and C++ complex plug-in samples.

The Java code for the `ComplexPlugin` class contains the public static methods: `test1`, `test2`, `test3`, and `test4`. It also contains an object, `ComplexChunk` that represents a complex type.

The `complex_plugin.xml` file is the plug-in's deployment descriptor and contains the `<plugin>` stanza that specifies the name, class, and description for the plug-in.

The sample's `ComplexPlugin.mon` file contains the EPL code for the Apama application. It imports the plug-in and calls the various `test`*`x`* methods.

A plug-in in Java that sends events

The `SendPlugin.java` file in the `samples\correlator_plugin\java` directory of your Apama installation is a sample plug-in that shows how to pass contexts around and how to send events to specific contexts.

The Java class for the plug-in imports `com.apama.epl.plugin.Context` and `com.apama.epl.plugin.Correlator` and it declares a public method that sends an event to a channel and another public method that sends an event to a particular context.

The `SendPlugin.xml` deployment descriptor file contains the name, class, and description of the plug-in in the `<plugin>` stanza.

The Apama application `SendPlugin.mon` first imports the plug-in and then calls the plug-in's `sendEventToChannel()` method as well as its `sendEventTo()` method with a variety of contexts.

A plug-in in Java that subscribes to receive events

The `SubscribePlugin.java` file in the `samples\correlator_plugin\java` directory of your Apama installation is a sample that shows how a plug-in subscribes to receive events sent on a particular channel. This sample is comparable to the similar C and C++ subscription plug-in samples.

The Java code for the `SubscribePlugin` class contains the public static `createHandler` method. (Methods that will be called from EPL code need to be public and static.)

The deployment descriptor file `SubscribePlugin.xml` contains the `<plugin>` stanza that illustrates how to specify the plug-in.

The EPL code in the file `SubscribePlugin.mon` imports the plug-in and calls the `createHandler()` method.

V EPL Reference

Apama Event Processing Language (EPL) is the native language of the Apama event correlator. You use EPL to write programs that process events in the correlator. This *EPL Reference* is a companion to the Apama EPL tutorials in Software AG Designer and "Developing Apama Applications in EPL" on page 29, which you can use to learn how to write programs in EPL. Use this *EPL Reference* to answer questions and obtain complete details about a particular construct.

Note: MonitorScript is the old name for EPL. You might still see the old name in the product documentation.

31 Introduction

EPL is a flexible and powerful curly-brace, domain-specific, language designed for writing programs that process events.

In EPL, an event is a data object that contains a notification of something that has happened, such as a customer order was shipped, a shipment was delivered, a sensor state change occurred, a stock trade took place, or myriad other things. Each kind of event has an event type name and one or more data elements (called event fields) associated with it. External events are received by one or more adapters, which receive events from an event source and translate them from a source-specific format into Apama's internal canonical format. Derived events can be created as needed by EPL programs.

Hello World example

Though it contains many of the familiar constructs and features found in general-purpose programming languages like Python or Java, EPL also has special features to make it easy to aggregate, filter, correlate, transform, act on, and create events in a concise manner. Here is the canonical "hello world" example written in EPL:

```
monitor HelloWorld
{
   action onload()
   {
      print "Hello world!";
   }
}
```

The Apama event processor, called the correlator, receives events of various types from external sources and routes them to one or more active EPL programs, called monitors or queries.

- Monitors have registered event handlers, called listeners, for events of particular types with specific combinations of data values or ranges of values. When the correlator detects an event of interest, it calls the appropriate event handlers. If there are no handlers for an event, the correlator discards it or passes it to an event handler specifically for events that have no handler.

  Event handlers in EPL are conceptually similar to methods or functions used for handling user-interface events in other languages, such as Java Swing or SWT applications. In EPL, code is executed only in response to events. Except, that is, for the special EPL `onload()`, `ondie()`, and `onunload()` actions. See "Monitor lifecycle" on page 846 for information about these actions.

- Queries define particular event types as input and then partition incoming events of those types according to a specified key. For example, a query might partition bank transactions according to their account numbers. Like a monitor, a query watches for an event pattern of interest, but it does this in each partition independently of every other partition.

  When the correlator finds a match, it executes the procedural code specified in the query.

32 Types

EPL has primitive types and reference types. Data in the primitive types are simple scalar values. Reference types (also called complex types or object types) have values that are more complicated and some, like the `dictionary` type, have multiple values and have definitions that involve more than one type.

When values are passed as parameters in action and method invocations, primitive types are passed by value, and reference types are passed by reference. When a parameter is passed by value, the called action or method receives a copy of the value and has no direct way to change the variable that the value may have been derived from. When a parameter is passed by reference, the called action or method receives a reference instead of a copy and if the called action changes the value, the caller also sees the change.

Note that there is no type equivalent to a memory address or pointer.

Primitive and string types

Apama supports these primitive types: `boolean`, `decimal`, `float`, and `integer` which are discussed in this section.

In addition, this section also discusses `string` which is technically a reference type. However, strings are immutable. Therefore, `string` behaves more like a primitive type than a reference type.

boolean

The boolean type has two possible values: `true` or `false`.

Operators

The table below lists the EPL operators that you can use with Boolean values.

Operator	Description	Result Type
`=`	Equal comparison	`boolean`
`!=`	Not equal comparison	`boolean`
`or`	Boolean (logical) or	`boolean`
`and`	Boolean (logical) and	`boolean`
`xor`	Boolean (logical) exclusive or	`boolean`
`not`	Boolean (logical) inverse	`boolean`

False sorts before true.

Methods

The following methods may be called on variables of `boolean` type:

- `canParse()` — returns `true` if the string argument can be successfully parsed.
- `parse()` — method that returns the `boolean` instance represented by the `string` argument. You can call this method on the `boolean` type or on an instance of a `boolean` type. The more typical use is to call `parse()` directly on the `boolean` type.

  The `parse()` method takes a single string as its argument. This string must be the string form of a `boolean` object. The string must adhere to the format described in *Deploying and Managing Apama Applications*, "Event file format". For example:

  ```
  boolean a;
  a := boolean.parse("true");
  ```

  You can specify the `parse()` method after an expression or type name. If the correlator is unable to parse the string, it is a runtime error and the monitor instance that the EPL is running in terminates.
- `toString()` – returns a `string` representation of the `boolean`. The return value is "`true`" if the referenced Boolean's value is `true`. The return value is "`false`" if the referenced Boolean's value is `false`.

decimal

A signed decimal floating point number. Either a decimal point (.) or an exponent symbol (e) must be present within the number for it to be a valid `decimal`, plus a decimal suffix (`d`) to distinguish it from a `float`.

When perfect accuracy of base-10 numbers is a requirement, use the `decimal` type in place of the `float` type. When extremely small floating point variations are acceptable, you might choose to use the `float` type to obtain better performance.

Values

Values of the `decimal` type are a finite-precision approximation of the mathematical real numbers, encoded as 64-bit decimal floating-point values consisting of sign, significand, and exponent, as defined by the *IEEE Standard for Floating-Point Arithmetic, ANSI/IEEE Standard 754 -2008 (IEEE, New York)*. Values of the `decimal` type have a precision of exactly 16 decimal digits.

The largest positive decimal floating point value that can be stored in a variable of type `decimal` is $9.999999999999999 * 10^{384}$ and the smallest nonzero positive value that can be stored is 10^{-398}.

In addition to the usual positive and negative numbers, the IEEE standard also defines positive and negative zeros, positive and negative infinities, and Not-a-Number values. For information about how the correlator handles these values, see "Support for IEEE 754 special values" on page 822.

Because decimal values are of finite precision, they cannot accurately represent all values, for example, recurring decimals or irrational numbers. However, decimals have the advantage over floats in that provided a decimal literal does not exceed the 16-place precision, it will be represented exactly within the correlator. The following program illustrates the difference between `decimal` and `float` types in this regard:

```
monitor foo
{
   action onload()
   {
      float f;
      decimal d;
      f := 0.1;
      d := 0.1d;
      print f.formatFixed(18);
      print d.formatFixed(18);
   }
}
```

This program produces the output below. Note the small error in the least significant digit in the `float`, versus the `decimal`.

```
0.100000000000000006
0.100000000000000000
```

There are a number of `decimal` constants provided in EPL. See "Support for IEEE 754 special values" on page 822.

Operators

The EPL operators that you can use with `decimal` types are the same operators that you can use with `float` types. For information on these operators, see "float" on page 770.

Methods

The methods that you can call on `decimal` types are the same methods that you can call on `float` types. For information on these methods, see "float" on page 770. There are a few differences according to whether the method is called on a `decimal` or `float` type and these are noted in the descriptions.

float

A signed floating point number. Either a decimal point (`.`) or an exponent symbol (`e`) must be present within the number for it to be a valid `float`.

When perfect accuracy is a requirement, use the `decimal` type in place of the `float` type. When extremely small floating point variations are acceptable, you might choose to use the `float` type to obtain better performance.

Values

Values of the `float` type are a finite-precision approximation of the mathematical real numbers, encoded as 64-bit binary floating-point values consisting of sign, significand, and exponent, as defined by the *IEEE Standard for Binary Floating-Point Arithmetic, ANSI/*

IEEE Standard 754 -1985 (IEEE, New York). Values of the `float` type have a precision of approximately 16 decimal digits. (The binary significand is 52 bits wide.)

The largest positive floating point value that can be stored in a variable of type `float` is `1.7976931348623157 * 10`^{308} and the smallest nonzero positive value that can be stored is `2.2250738585072014 * 10`$^{-308}$.

In addition to the usual positive and negative numbers, the IEEE standard also defines positive and negative zeros, positive and negative infinities, and Not-a-Number values. For information about how the correlator handles these values, see "Support for IEEE 754 special values" on page 822.

Because float values are of finite precision and binary encoded, they cannot accurately represent all values. In particular, when a floating point literal expressed in decimal notation is converted to its binary floating-point representation, there can be a slight loss of accuracy. This occurs because most decimal fractions cannot be represented precisely in binary. So the fraction `0.1` or `1/10` in base 10 becomes the infinitely repeating fraction `0.0001100110011001100110011...` when it is converted to base 2. Similarly, conversions from floating point values to integral or string types will sometimes be inexact. The following program illustrates the effects of finite precision and conversions between base 10 and base 2:

```
monitor foo
{
   action onload()
   {
      float f;
      f := 0.1;
      print f.formatFixed(18);
   }
}
```

This program produces the output `0.100000000000000006`. Note the small error in the least significant digit.

There are a number of `float` constants provided in EPL. See "Support for IEEE 754 special values" on page 822.

Operators

The following table lists the EPL operators available for use with floating point values, that is `decimal` or `float` types.

Operator	Description	Result Type
`<`	Less-than comparison	`boolean`
`<=`	Less-than or equal comparison	`boolean`
`=`	Equal comparison	`boolean`
`!=`	Not equal comparison	`boolean`

Operator	Description	Result Type
>=	Greater-than or equal comparison	boolean
>	Greater-than comparison	boolean
+	Unary floating point identity	decimal or float
-	Unary floating point additive inverse	decimal or float
+	Floating point addition	decimal or float
-	Floating point subtraction	decimal or float
*	Floating point multiplication	decimal or float
/	Floating point division	decimal or float

Overflows and underflows are ignored by the EPL runtime.

The correlator compares floating point values as follows:

- Finite `float` and `decimal` types compare in the obvious way.
- `-Inf` is equal to `-Inf` and is less than any finite number or `+Inf`.
- `+Inf` is equal to `+Inf` and is greater than any finite number or `-Inf`.
- `NaN` is not equal to anything, including another `NaN`.
- If you try to use `NaN` for keying or sorting the correlator terminates the monitor instance.

Methods

The following inbuilt methods may be called on variables of `decimal` or `float` type. Unless noted otherwise, if you call a method on a `decimal` type the return value is a `decimal`, and if you call the method on a `float` type, the return value is a `float`. In all method descriptions, *x* represents the value that the method is called on.

- `abs()` — returns `|x|`, the absolute value of *x*.
- `acos()` — returns the inverse cosine of *x* in radians. Special case: `x.acos()` = `NaN`, if `|x| > 1`.
- `acosh()` — returns the inverse hyperbolic cosine of *x*. Special case: `x.acosh()` = `NaN`, if `x < 1`.
- `asin()` — returns the inverse sine of *x* in radians. Special cases:
  - `(NaN).asin() = NaN`

  - `x.asin() = NaN`, if `|x| > 1`
- `asinh()` — returns the inverse hyperbolic sine of *x*.
- `atan()` — returns the inverse tangent of *x*.
- `atan2(y)` — returns the two-parameter inverse tangent of *x* and *y*. Special cases:
  - `(anything).atan2(NaN) = NaN`
  - `(NaN).atan2(anything) = NaN`
  - `(±0).atan2(anything except NaN) = ±0`
  - `(±0).atan2(-anything except NaN) = ±pi`
  - `(anything except 0 and NaN).atan2(0) = ±pi/2`
  - `(anything except ±Infinity and NaN).atan2(+Infinity) = ±0`
  - `(anything except ±Infinity and NaN).atan2(-Infinity) = ±pi`
  - `(±Infinity).atan2(+Infinity) = ±pi/4`
  - `(±Infinity).atan2(-Infinity ) = ±3pi/4`
  - `(±Infinity).atan2(anything except 0, NaN and ±Infinity) = ±pi/2`
- `atanh()` — returns the inverse hyperbolic tangent of *x*. Special cases:
  - `x.atanh() = NaN`, if `|x| > 1`
  - `(NaN).atanh() = NaN`
  - `(±1).atanh() = ±Infinity`
- `bitEquals(decimal)` or `bitEquals(float)` — returns true if the value it is called on and the value passed as an argument to the method are the same. The value the method is called on and the argument to the method must both be `decimal` types or must both be `float` types. The method performs a bitwise comparison. This is useful because `bitEquals()` returns true for `NaN.bitEquals(NaN)` for `NaN`s that are bitwise identical whereas `NaN = NaN` is always false even if the `NaN`s have identical representations.
- `canParse(string)` — returns `true` if the string argument can be successfully parsed.
- `cbrt()` — returns the cube root of *x*.
- `ceil()` — returns the smallest possible integer that is greater than or equal to the value the method is called on. Special cases:
  - `(+Infinity).ceil() = integer.MAX`
  - `(-Infinity).ceil() = integer.MIN`
  - `(NaN).ceil()` causes a runtime error; the correlator terminates the monitor
- `cos()` — returns the cosine of *x*. See also the note at the end of this list.

- `cosh()` — returns the hyperbolic cosine of *x*. Special case: `(±Infinity or NaN).cosh() = |x|`
- `erf()` — returns the error function of *x*. The formula is as follows:

$$\mathrm{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt.$$

- `exp()` — returns `e` to the power *x* or `ex`, where *x* is the value of the `decimal` or `float` and where `e` is approximately 2.71828183. Special cases:
  - `exp(NaN) = NaN`
  - `exp(+Infinity) = +Infinity`
  - `exp(-Infinity) = 0`
- `exponent()` — When called on a `float` value, this method returns the integer that is the exponent where *x* = `mantissa*2`^{exponent} assuming `0.5 <= |mantissa| < 1.0`. When called on a `decimal` value, this method returns the exponent where `x = mantissa*10`^{exponent} assuming `0.1 <= |mantissa| < 1.0`. Special cases:
  - `(0.0).exponent() = 0`
  - `(±Infinity or NaN).exponent()` terminates the monitor instance that contains the method call.
- `floor()` — returns the largest possible integer that is less than or equal to the value the method is called on. Special cases:
  - `(+Infinity).floor() = integer.MAX`
  - `(-Infinity).floor() = integer.MIN`
  - `(NaN).floor()` causes a runtime error; the correlator terminates the monitor.
- `fmod(y)` — returns `x mod y` in exact arithmetic.
- `formatFixed(integer)` — returns a string representation of the value the method is called on where the value is rounded to the number of decimal places specified in the argument. This method can operate on the IEEE special values.
- `formatScientific(integer)` — returns a string representation of the value the method is called on where the value is truncated to the number of significant figures specified in the argument and formatted in Scientific Notation. This method can operate on the IEEE special values.
- `fractionalPart()` — returns the fractional component of *x*.
- `gammal()` — returns the logarithm of the gamma function.
- `ilogb()` — returns an `integer` that is the binary exponent of non-zero *x*. Special case: throws exception for `ilogb(NaN)`.
- `integralPart()` — returns an `integer` that is the integral part of a floating point value. Similar to `floor()`, which rounds down, and `ceil()`, which rounds

up. `integralPart()` rounds towards zero. Special case: throws exception for `integralPart(NaN)`.

- `isFinite()` — returns true if and only if the value it is called on is not `±Infinity` or `NaN`.
- `isInfinite()` — returns true if and only if the value it is called on is `±Infinity`.
- `isNaN()` — returns true if and only if the value it is called on is `NaN`.
- `ln()` — returns the natural log of the value the method is called on. Special cases:
  - `(0).ln() = -Infinity`
  - `(-`*`anything`*`).ln() = NaN`
- `log10()` — returns the log to base 10 of the value the method is called on. Special cases:
  - `(0).log10() = -Infinity`
  - `(-`*`anything`*`).log10() = NaN`
- `mantissa()` — When called on a `float` value, this method returns a mantissa where *`x`* `= mantissa*2`$^{\text{exponent}}$ assuming that `0.5 <= |mantissa| < 1.0`. When called on a `decimal` value, this method returns a mantissa where *`x`* `= mantissa*10`$^{\text{exponent}}$ assuming that `0.1 <= |mantissa| < 1.0`. Special cases:
  - `(0.0).mantissa() = 0.0`
  - `(Infinity or NaN).mantissa()` terminates the monitor instance that contains the method call
- `max(`*`decimal`*`, `*`decimal`*`)` or `max(`*`float`*`, `*`float`*`)` — returns the value of the larger operand. You can call this method on the `decimal` or `float` type or on an instance of a `decimal` or `float` type.
- `min(`*`decimal`*`, `*`decimal`*`)` or `min(`*`float`*`, `*`float`*`)` — returns the value of the smaller operand. You can call this method on the `decimal` or `float` type or on an instance of a `decimal` or `float` type.
- `nextafter(`*`y`*`)` — returns the next distinct floating-point number after *`x`* that is representable in the underlying type in the direction toward *`y`*.
- `parse(`*`string`*`)` – method that returns the `decimal` or `float` instance represented by the `string` argument. You can call this method on the `decimal` or `float` type or on an instance of a `decimal` or `float` type. The more typical use is to call `parse()` directly on a `decimal` or `float` type.

  The `parse()` method takes a single string as its argument. This string must be the string form of an `event` object. The string must adhere to the format described in *Deploying and Managing Apama Applications*, "Event file format". For example:

  ```
  float a;
  a := float.parse("123.456");
  ```

You can specify the `parse()` method after an expression or type name. If the correlator is unable to parse the string, it is a runtime error and the monitor instance that the EPL is running in terminates.

A call to `decimal.parse()` can include or exclude the appended `d`. In other words, `decimal.parse("1.0")` and `decimal.parse("1.0d")` both work.

The `parse()` method can operate on the string form of the IEEE special values.

- `pow(`*`decimal`*`)` or `pow(`*`float`*`)` — returns *x* to the power *y* (where *y* is the argument) or *xy*. See also "Special cases of pow()" on page 824.
- `rand()` — returns a random value from 0.0 up to (but not including) the value the method was invoked on. If the value was negative, then the random value will be from the value (but not including it) up to 0.0. When you are calling the `rand()` method on a variable, the method behaves correctly if the variable value is zero, for example, `(0.0).rand()` returns `0.0`.

  Special case: `(±Infinity or NaN).rand()` causes a runtime error; the correlator terminates the monitor.

  > **Caution:** This random number generator is not verified to be cryptographically strong. Therefore, it should not be used for purposes where a strong random number is required.

- `round()` – rounds to the nearest integer. Uses banker's rounding, which means the round-to-even method, to break ties. For example, it rounds both `3.5` and `4.5` to `4`. Special cases:
  - `(+Infinity).round() = integer.MAX`
  - `(-Infinity).round() = integer.MIN`
  - `(NaN).round()` causes a runtime error; the correlator terminates the monitor.
- `scalbn(`*`n`*`)` — When called on a `float` value, this method returns $x*2^n$, where *n* is of `integer` type. When called on a `decimal` value, this method returns $x*10^n$, where *n* is of `integer` type.
- `sin()` — returns the sine of *x*. See also the note at the end of this list.
- `sinh()` — returns the hyperbolic sine of *x*. Special case: `(±Infinity or NaN).sinh() = |`*`x`*`|`
- `sqrt()` — returns the positive square root of the value it is called on. Special cases:
  - `(-`*`anything`*`).sqrt() = NaN`
  - `(`*`+Infinity`*`).sqrt() = +Infinity`
- `tan()` — returns the tangent of *x*. See also the note at the end of this list.
- `tanh()` — returns the hyperbolic tangent of *x*. Special case: `NaN.tanh() = NaN`
- `toDecimal()` — returns a `decimal` representation of the `float`. This method can operate on the IEEE special values.

- `toFloat()` — returns a `float` representation of the `decimal`. This method can operate on the IEEE special values.
- `toString()` — returns a `string` representation of the `float` or `decimal` it is called on. This method can operate on the IEEE special values. A call to `decimal.toString()` does not include a `d` suffix.

Note: Let `trig` be any of `sin`, `cos`, or `tan`. The argument to these functions is in units of Radian. Also `(±Infinity or NaN).trig() = NaN`.

integer

Values of the `integer` type are negative, zero, and positive integers encoded as 64-bit signed two's complement binary integers. The lowest negative value that can be stored in a variable of type integer is `-9223372036854775808` (or -2^{63}) and the highest positive value that can be stored is `9223372036854775807` (or $2^{63} - 1$).

There are a few `integer` constants provided in EPL. See "Support for IEEE 754 special values" on page 822.

Operators

The following table describes the EPL operators available for use with `integer` values.

Operator	Description	Result Type
<	Less-than comparison	`boolean`
<=	Less-than or equal comparison	`boolean`
=	Equal comparison	`boolean`
!=	Not equal comparison	`boolean`
>=	Greater-than or equal comparison	`boolean`
>	Greater-than comparison	`boolean`
+	Unary integral identity	`integer`
-	Unary integral additive inverse	`integer`
+	Integral addition	`integer`
-	Integral subtraction	`integer`

Operator	Description	Result Type
`*`	Integral multiplication	`integer`
`/`	Integral division	`integer`
`%`	Integral remainder	`integer`
`or`	Bitwise or	`integer`
`and`	Bitwise and	`integer`
`xor`	Bitwise exclusive or	`integer`
`not`	Unary bitwise inverse	`integer`
`>>`	Bitwise shift right	`integer`
`<<`	Bitwise shift left	`integer`

An attempt to divide by zero (0) or to compute a remainder of zero raises an error. Overflows and underflows in arithmetic are ignored by the EPL runtime.

When you use the shift operators, the sign of a result value can differ from that of the operand value being shifted. When you use `not` the sign of the result value will be the opposite of that of its operand.

Methods

The following methods may be called on variables of `integer` type:

- `abs()` – returns as an `integer` the absolute value of i or `|i|`, where i is the value of the integer.
- `canParse()` — returns `true` if the string argument can be successfully parsed.
- `getUnique()` – method that generates a unique integer in the scope of the correlator. This is a type method as well as an instance method. It returns an `integer` that is unique for the correlator session's lifetime. When the correlator is shut down and restarted, then the integers returned might be the same as some or all of the values produced in the earlier session.

  When correlator persistence is enabled the state of this method is preserved across shutdown and recovery. In other words, as long as you use the same recovery datastore, it does not matter how many times you restart the correlator. The result of invoking `getUnique()` will always be a unique number across all restarts.

This method starts by generating 0, 1, 2, 3, and so on. However, you cannot assume that you will receive the integer you might expect. The returned numbers are 64-bit signed integers.

For example, the following statement prints a different number every time the correlator executes it:

```
print integer.getUnique().toString();
```

Following are more examples:

```
monitor M {
   action onload() {
      integer i;
      i := integer.getUnique(); // called on type
      i := i.getUnique();       // called on instance
    }
}
```

- `max(`*`integer`*`, `*`integer`*`)` – returns as an `integer` the value of the larger operand. You can call this method on the `integer` type or on an instance of an `integer` type.
- `min(`*`integer`*`, `*`integer`*`)` – returns as an `integer` the value of the smaller operand. You can call this method on the `integer` type or on an instance of an `integer` type.
- `parse()` – method that returns the `integer` instance represented by the `string` argument. You can call this method on the `integer` type or on an instance of an `integer` type. The more typical use is to call `parse()` directly on the `integer` type.

  The `parse()` method takes a single string as its argument. This string must be the string form of an `integer` object. The string must adhere to the format described in *Deploying and Managing Apama Applications*, "Event file format". For example:

  ```
  integer a;
  a := integer.parse("20080116");
  ```

  You can specify the `parse()` method after an expression or type name. If the correlator is unable to parse the string, it is a runtime error and the monitor instance that the EPL is running in terminates.

- `pow(`*`integer`*`)` – returns as an `integer` the value of the operand to the power *x* (where *x* is the argument) or *x* , where *i* is the value of the operand. Note that negative values of *x* are not allowed, as these would generate floating point results.
- `rand()` – returns a random `integer` value from `0` up to (but not including) the value of the variable the method was invoked on. The following snippet of code would set `B` to a random value from `0` to `19`:

  ```
  integer A;
  integer B;
  A := 20;
  B := A.rand();
  ```

  while the next snippet would set `B` to a random value from `-14` and `0`:

  ```
  integer A;
  integer B;
  A := -15;
  B := A.rand();
  ```

When you are calling the `rand()` method on a variable, the method behaves correctly if the variable value is zero, that is `(0).rand()` returns `0`.

> **Caution:** This random number generator is not verified to be cryptographically strong. Therefore, it should not be used for purposes where a strong random number is required.

- `toDecimal()` – returns a `decimal` representation of the `integer`.
- `toFloat()` – returns a `float` representation of the `integer`.
- `toString()` – returns a `string` representation of the `integer`.

string

A text string.

Usage

Enclose string literals in double quotes. Values of the `string` type are sequences of non-null Unicode characters encoded in UTF-8 format. Note that UTF-8 is a variable-width encoding and a character can occupy from 1 to 4 bytes of storage. The characters in the 7-bit ASCII character set are a subset of UTF-8 and occupy a single byte each.

Although `string` types are discussed as though they are primitive types, they are actually reference types. However, EPL's `string` objects are immutable. For example, a statement such as `s:=s+" suffix";` creates a new string object and changes the variable `s` to refer to that new string object. Any other references to the old value continue to point to the old value.

Operations that can return a different string value, such as concatenation, case folding, or trimming white space, always create new strings rather than modifying the existing value in place. The previous value's storage is recovered later by the EPL runtime garbage collector.

The length of a string is limited by the memory available at runtime, which can be multiple gigabytes. In practice, you are unlikely to exceed the limit in a single string.

Use the `\` to enter special characters in string literals:

To enter this...	Insert this...
`"` (double quote)	`\"`
`\` (backslash)	`\\`
newline character	`\n`
tab character	`\t`

Operators

The table below lists the EPL operators available for use with string values.

Operator	Description	Result Type
<	Less-than string comparison	`boolean`
<=	Less-than or equal string comparison	`boolean`
=	Equal string comparison	`boolean`
!=	Not equal string comparison	`boolean`
>=	Greater-than or equal string comparison	`boolean`
>	Greater-than string comparison	`boolean`
+	String concatenation	`string`

When you compare two strings for equality, the result is `true` if the strings are the same length and each character in one string is identical to the corresponding character at the same position in the other string.

When you compare two strings for less than or greater than, the characters in the strings are compared pairwise according to the numerical values of their Unicode code points. The comparison is case-sensitive so capital letters are not equal to their lower case equivalents. Characters earlier in the character set sort before characters later in the character set. To order two unequal strings, the earliest difference is considered. For example, `"abcXdef"` sorts earlier than `"abcYdef"`, `"abc"` sorts earlier than `"abcXYZ"`; the empty string sorts earliest of all.

Methods

The following methods may be called on values of `string` type:

- `canParse()` — returns `true` if the string argument can be successfully parsed.
- `clone(`*`string`*`)` — returns a reference to the specified string. When called on a `string`, the `clone()` method does not make a copy of the string since strings are immutable.
- `find(`*`substring`*`)` — returns an `integer` indicating the index position of the substring passed as parameter to the method. If the string parameter does not exist as a substring within the string, the method returns `-1`. Note that in EPL string indices (the position of a character within the string) count upwards from `0`.
- `findFrom(`*`substring, fromIndex`*`)` — behaves like the `find()` method, but starts searching for the specified substring with the character indicated by *`fromIndex`*. For

example, if the value of *fromIndex* is 7, the search begins with the character that has an index of 7.

- intern() — marks the string it is called on as interned. Subsequent incoming events that contain a string that is identical to an interned string use the same string object. The intern() method takes no arguments and returns the interned version of the string it is called on. For example:

```
print "hello world";
print "hello world".intern();
```

  Both statements print:

```
hello world
```

  The benefit of using the intern() method is that it reduces the amount of memory used and the amount of work the garbage collector must do. A disadvantage is that you cannot free memory used for an interned string.

  If there are a limited number of strings that will be used many times then calling intern() on these strings speeds the handling of events that use them. You might want to call intern() on the names of products or stock symbols, which are all used frequently. For example, invoking "APMA".intern() might make sense if you are expecting a large number of incoming events of the form Tick("APMA", ...). You would not want to call intern() on order IDs, because there are so many and each one is likely to be unique.

  Calling intern() on a string is a global operation. That is, all contexts can then use the same string object. Any strings already in use by the correlator are not affected, even if they match the string intern() is called on.

  If you use correlator persistence, details of which strings have been interned are not stored in the recovery datastore. If the correlator shuts down and restarts, you must call intern() again on the pertinent strings.

- join(sequence<string> *s*) — concatenates the strings in *s* using the string it is called on as a separator. The single parameter must be a sequence type that contains strings. You cannot specify a variable number of string parameters. For example:

```
sequence<string> s :=
   ["Something", "Completely", "Different"];
print ", ".join(s);
```

  This prints the following:

```
Something, Completely, Different
```

- length() — returns an integer indicating the length of the string.

- ltrim() — returns a string where all white space characters at the beginning have been removed. White space characters are space, new line and tab characters.

- parse() — method that returns the string value represented by the string argument without enclosing that value in quotation marks. You can call this method on the string type or on an instance of a string type. The more typical use is to call parse() directly on the string type.

The `parse()` method takes a single string as its argument. The string must adhere to the format described in *Deploying and Managing Apama Applications*, "Event file format".

Use the following format to specify the string you want to parse:

```
"your_string_with_escape_characters"
```

Use a backslash to escape each quotation mark or backslash in your string, including quotation marks that enclose your string. For example, to parse `"Hello World"`, specify it as `"\"Hello World\""`. In other words, if you are writing literal strings in EPL, you must precede all backslashes and quotation marks with a backslash. For example:

```
string a := "\".\\\\.\"";
string b := string.parse(a);
print a;
print b;
```

This prints the following:

```
".\\."
.\.
```

The `string.parse()` method is useful when you have a string that contains backslash escape characters and you want to obtain a string without them.

More examples:

```
string a := string.parse("\"Hello World\"");
string b := string.parse("\"\\\"\"");
print a;
print b;
```

This prints the following:

```
Hello World
"
```

You can specify the `parse()` method after an expression or type name. If the correlator is unable to parse the string, it is a runtime error and the monitor instance that the EPL is running in terminates. For example, the following is an error and causes the correlator to terminate:

```
a := string.parse("Hello World");
```

The `parse()` method cannot parse the result of a `toString()` method. This is because the `toString()` method does not enclose its result in quotation marks, nor does it escape any special characters. For example, the following is false:

```
   x = string.parse(x.toString())
```

If a string contains no special characters (for example, " or \) then the following equality does hold true:

```
   x = string.parse("\""+x.toString()+"\"")
```

- `replaceAll(`*`string`*`, `*`string`*`)` — takes two `string` arguments, *`string1`* and *`string2`*. For the `string` the method is called on, the `replaceAll()` method makes a copy of that string, replaces instances of *`string1`* with instances of *`string2`* and returns the revised string. For example:

```
string x := "XYZ";
print x.replaceAll("Y","y");
print x;
```

This prints the following:

```
XyZ
XYZ
```

Notice that `x` itself is unchanged. If *`string1`* is an empty string then the monitor instance dies. If instances of *`string1`* overlap then the method replaces only the first instance in the overlapping instances.

- `rtrim()` — returns a string where all *whitespace* characters at the end have been removed. Whitespace characters are space, new line and tab characters.
- `split(string` *`input`*`)` — returns a sequence of the strings that result from splitting the *input* string on every occurrence of the delimiter string that the method is called on. The size of the returned sequence is always one more than the total number of occurrences of the delimiter string. Consecutive delimiters in the input string result in empty strings in the returned sequence. The `split()` method is useful for separating a string that contains newline characters into individual lines or for dividing comma-separated values in a single string into multiple strings. For example:

Method Call	Returned Sequence
`",".split("x,y,z")`	`["x","y","z"]`
`",".split("")`	`[""]`
`",".split(",x,,y")`	`["","x","","y"]`
`"\r\n".split("line1\r\nline2\r\n\r\n")`	`["line1","line2", "", ""]`

This method performs the inverse of `join(sequence<string>)`. See also the `tokenize(string)` method which is related but has slightly different behavior.

- `substring(`*`integer`*`, `*`integer`*`)` — returns the substring indicated by the `integer` parameters. The parameters indicate the position of the first and last characters of the substring, the first being inclusive, while the second is exclusive. If a parameter is a positive value it is taken to be the position of a character going from left to right counting upwards from `0`. If a parameter is a negative value it is taken to be the position of a character going from right to left counting downwards from `-1`. Therefore if

```
string s;
s := "goodbye";
```

then

```
s.substring(0, 0) is ""
s.substring(0, 2) is "go"
```

```
s.substring(2, 4) is "od"
s.substring(0, 7) is "goodbye"
s.substring(0, -1) is "goodby"
s.substring(-4, -1) is "dby"
s.substring(-7, -1) is "goodby"
s.substring(-7, 7) is "goodbye"
```

- `toBoolean()` — returns true if the string is `"true"` and false in all other cases. This method is case sensitive.
- `toDecimal()` — returns a `decimal` representation of the string, if the string starts with one or more numeric characters. The numeric characters can optionally have amongst them a decimal point or mantissa symbol. Returns `0.0` if there are no such characters.
- `toFloat()` — returns a `float` representation of the string, if the string starts with one or more numeric characters. The numeric characters can optionally have amongst them a decimal point or mantissa symbol. Returns `0.0` if there are no such characters.
- `toInteger()` — returns an `integer` representation of the string, if the string starts with one or more numeric characters. Returns `0` if there are no such characters.
- `toLower()` — returns an all-lowercase `string` representation of the string.
- `toUpper()` — returns an all-uppercase `string` representation of the string.
- `tokenize(string` *`input`*`)` — returns a sequence of all the non-empty strings (tokens) that result from splitting the *input* string on occurrences of any character from the string that the method is called on. The returned sequence never contains any empty strings, and will have no elements if the input string is empty or contains only delimiters. The `tokenize()` method is useful for extracting words from whitespace. For example:

  ```
  string s := "     This   is\na test!  See? ")
  print " ".tokenize(s).toString();
  print " .,:;!?\n\t".tokenize(s).toString();
  ```

  This prints the following:

  ```
  ["This","is\na","test!","See?"]
  ["This","is","a","test","See"]
  ```

  See also the `split(string)` method which is related but has slightly different behavior.
- `toString()` — returns the contents of the string value, exactly the same as using the string directly.

Reference types

In addition to the primitive types, EPL provides for a number of object types. These types are manipulated by reference as opposed to by value (in the same way as complex types are handled in Java). These are the reference types which are discussed in this section.

When a variable of reference type is assigned to another one of the same type, the latter will reference the same object as the former, and should one be changed, the other one would reflect the change as well.

If you require a variable of reference type to contain a copy of another one of the same type, that is a completely distinct but identical copy, then you should use the `clone()` method as described below. This returns a deep copy of the variable, that is, it copies it and all its contents (and their contents in turn) recursively.

The `string` type is technically a reference type, but unlike all other reference types, the `string` type is immutable; its value cannot change. The `clone()` method has no effect on strings, as they cannot be changed. Therefore, `string` is discussed with the primitive types.

Note that you cannot use an object type for matching in an event template. For example, suppose you have the following event types:

```
InnerEvent
{
   float f;
}

WrapperEvent
{
   string s;
   InnerEvent anInnerEvent;
}
```

The following statement is correct:

```
on all WrapperEvent(s = "some_string")
```

However, the following statement is not allowed:

```
on all WrapperEvent(anInnerEvent.f = 5.5)
```

More than one variable can have a reference to the same underlying data value. For example, consider the following code:

```
sequence <integer> s1;
sequence <integer> s2;
s1 := [12, 55, 42];
s2 := s1;
print s1[1].toString; // print second element of s1
s2[1] := 99; // change the second element
print s1[1].toString; // print second element of s1 again
```

Both `s1` and `s2` refer to the same array, so whichever variable you use, there is only one copy of the data values. So the program's output is:

```
55
99
```

action

In addition to defining an action, you can define a variable whose type is `action`. This lets you assign an action to an `action` variable of the same `action` type. An action is of the same type as an `action` variable if they have the same argument list (the same types in the same order) and return type (if any).

Usage

Defining `action` type variables is useful for invoking an action and for passing an action to another action.

You can use an `action` variable anywhere that you can use a `sequence` or `dictionary` variable. For example, you can

- Pass an action as a parameter to another action.
- Return an action from execution of an action.
- Store an action in a local variable, global variable, event field, `sequence`, or `dictionary`.

You must initialize an `action` variable before you try to invoke it.

You cannot send, route, emit, or enqueue an event that contains an `action` type member.

When an action variable is a member of an event the behavior of the action depends on the instance of the event that the action is called on. Consequently, it can be handy to bind an action variable member with a particular event instance. This is referred to as creating a closure. For details, see "Using action type variables" on page 276.

An `action` variable is a potentially-cyclic type — a type that directly or indirectly refers to itself. For details about the behavior of such objects, see "Potentially cyclic types" on page 819.

When the correlator clones a value that contains an action variable, or copies a value that contains an action variable into a new monitor because of a spawn operation, the correlator preserves the structure inside the value. This means that if two things are references to the same object in the original value, they will be references to the same object in the copy. This includes objects referred to by closures that have been assigned to action variables.

When you call `toString()` on an object that contains an action variable, the result is the name of the method or action in the action variable. If the action variable contains a closure, the `toString()` method outputs the bound value followed by the name of the action or method being called on the value. For example:

```
"E(42).f"
"12.0.rand"
```

See "String form of potentially cyclic types" on page 820.

When the `toString()` method encounters an empty action variable the output is `new` followed by the type. Following are two examples:

- `"new action<>"`
- `"new action<sequence<string>,float> returns boolean"`

Methods

The only operation that you can perform on an `action` variable is to call it. You do this in the normal way by passing a set of parameters in parentheses after an expression that evaluates to the `action` variable. For an example and additional details, see "Using action type variables" on page 276.

Channel

Values of the `Channel` type are objects that hold either a string, which is a channel name, or a context object depending on how you construct it.

Usage

The `Channel` type is defined in the `com.apama` namespace. Typically, to easily refer to `Channel` objects, you specify:

```
using com.apama.Channel
```

The `Channel` type lets you send an event to a channel or context. If the `Channel` object contains a string then the event is sent to the channel with that name. If the `Channel` object contains a context then the event is sent to that context.

A Channel object has three constructors:

```
Channel(string)
Channel(context)
new Channel
```

The third constructor creates a `Channel` object that contains an empty context object. The contained empty context is the same result you would get from `new context`. It is a runtime error to send an event to an empty context. Likewise, it is a runtime error to send an event to a `Channel` object that contains an empty context.

For example, the following two lines have the same result:

```
send e to "MyChannel";
send e to Channel("MyChannel");
```

Similarly, the following two lines have the same result when `c` is a variable of the `context` type:

```
send e to c;
send e to Channel(c);
```

The benefit of using a `Channel` object rather than a `string` or `context` object is that the `Channel` object is polymorphic. For example, by using a `Channel` object to represent the source of a request, you could write a service monitor so that the same code sends a response to a service request. You would not need to have code for sending responses to channels and separate code for sending responses to contexts.

You cannot send an event to a sequence of `Channel` objects. You cannot route a `Channel` object, but a routable object can have a `Channel` object as a member.

Methods

The following methods may be called on values of `Channel` type:

- `canParse()` — returns `true` if the string argument can be successfully parsed to create a `Channel` object. You cannot parse a string representation of a `Channel` object that contains a context. For more information about the parseable type property, see the table in "Type properties summary" on page 811.

- `clone()` — returns a new `Channel` that is an exact copy of the `Channel` the `clone()` method is called on. The original `Channel`'s content is copied into the new `Channel`.
- `empty()` – returns true if the `Channel` object contains an empty context. This lets you distinguish between an object that contains a default initialization value and an object that has been explicitly populated.
- `parse()` – returns the `Channel` instance represented by the `string` argument. You can call this method on the `Channel` type or on an instance of a `Channel` type. The more typical use is to call `parse()` directly on the `Channel` type.

  The `parse()` method takes a single string as its argument. This string must be the string form of a `Channel` object. The string must adhere to the format described in *Deploying and Managing Apama Applications*, "Event file format". For example:

  ```
  Channel a;
  a := Channel.parse(com.apama.Channel("channelName");
  Channel b;
  b := Channel.parse(com.apama.Channel(context(3, "contextName", true) );
  ```

  You can specify the `parse()` method after an expression or type name. If the correlator is unable to parse the string, it is a runtime error and the monitor instance that the EPL is running in terminates.
- `toString()` — returns a string that contains the channel name or the name of the contained context.

chunk

Values of the `chunk` type are references to dynamically allocated opaque objects whose contents cannot be seen or directly manipulated in EPL. They are used by correlator plug-ins to store state information across multiple plug-in method calls.

In EPL, `chunk` reference values can be held in variables of the type `chunk` and passed as parameters to plug-ins when they are called. The `chunk` type lets you reference data that has no equivalent EPL type.

It is not possible to perform operations on data of type `chunk` from EPL directly; the `chunk` type exists purely to allow data output by one external library function to pass through to another function. Apama does not modify the internal structure of `chunk` values in any way. As long as a receiving function expects the same type as that output by the original function, any complex data structure can be passed around using this mechanism.

To use `chunks` with plug-ins, you must first declare a variable of type `chunk`. You can then assign the chunk to the return value of an external function or use the chunk as the value of the *`out`* parameter in the function call.

The following example illustrates this. The `complex.test4()` method prints output to `stdout`. Apama provides the source code for `complex_plugin`. You can find it in the Apama `samples\correlator_plugin\cpp` directory.

```
monitor ComplexPluginTest {
```

```
   // Load the plugin
   import "complex_plugin" as complex;
   // Opaque chunk value
   chunk myChunk;
   action onload() {
      // Generate a new chunk
      myChunk := complex.test3(20);
      // Do some computation on the chunk
      complex.test4(myChunk);
   }
}
```

Although the `chunk` type was designed to support unknown data types, it is also a useful mechanism to improve performance. Where data returned by external plug-in functions does not need to be accessed from EPL, using a `chunk` can cut down on unnecessary type conversion. For example, suppose the output of a `localtime()` method is a 9-element array of type `float`. While you could declare this output to be of type `sequence<float>`, there is no need to do so because the EPL never accesses the value. Consequently, you can declare the output to be of type `chunk` and avoid an unnecessary conversion from native array to EPL `sequence` and back again.

An event can contain a field of type `chunk`, however you cannot send, emit, route, or enqueue an event that has a `chunk` type field.

Methods

The following methods may be called on variables of `chunk` type.

- `clone()` – requests that the plug-in return a new `chunk` that is an exact copy of the `chunk` that `clone()` was called on. `The clone()` method calls the `copy()` C++ virtual member function on the existing `AP_Chunk` object.

  See "Working with chunk in C++" on page 734.

- `empty()` – returns true if the chunk is empty. This lets you distinguish between a chunk that contains a default initialization value and a chunk that has been explicitly populated by a correlator plug-in. You can also get an empty chunk as a result of a `new chunk` expression.

- `getOwner()` – returns a string that contains the name of the correlator plug-in that the chunk belongs to. The name returned is the name you specify as the first argument in the `import` statement that loads the correlator plug-in. For example:

  ```
  import "TimeFormatPlugin" as tfp;
  ```

  The `getOwner()` method on a chunk from that plug-in returns `"TimeFormatPlugin"` and not `"tfp"`.

  The `getOwner()` method returns an empty string if the chunk is empty.

context

Values of the `context` type are references to contexts. A context lets EPL applications organize work into threads that the correlator can concurrently execute.

Usage

A context is subscribed to the union of the channels each of the monitor instances in that context is subscribed to. This is a property of the monitor instances running in a context and is not accessible by means of the context reference object.

Use one of the following constructors to create a `context` reference:

```
context(string name)
context(string name, boolean receivesInput)
```

The optional `receivesInput` Boolean flag controls whether the context is public or private:

- `true` — A public context can receive external events on the default channel, which is the empty string (`""`). There is no requirement for a monitor instance in this context to subscribe to the default channel.
- `false` — A private context does not receive external events on the default channel. This is the default.

Methods

The following methods may be called on variables of `context` type:

- `current()` — Returns a context object that is a reference to the current context. The current context is the context that contains the monitor instance or event instance that is calling this method.
- `getId()` — Returns an integer that is the ID of the context.
- `getName()` — Returns a string that is the name of the context.
- `isPublic()` — Returns a Boolean that indicates whether the context is public. If the context was created as a public context then the return value is true.
- `toString()` — Returns a string that contains the properties of the context. For example, for a public context whose name is `test`, the content of the returned string would be something like this:

  ```
  context(1, "test", true)
  ```

See also "Contexts" on page 850.

dictionary

A `dictionary` is a means of storing and retrieving data based on an entry key. This enables, for example, a user's name to be retrieved from a unique user ID.

The syntax of a `dictionary` definition is:

```
dictionary < key , item > varname
```

Dictionaries are dynamic and new entries can be added and existing entries deleted as desired.

The dictionary *key* must be a comparable type. See "Comparable types" on page 817.

The *item* can be any Apama type.

Two dictionaries are equal only if they contain the same keys and the same value for each key. When dictionaries are not equal they are ordered as though they were sequences of key-value pairs, sorted in key order.

Example

```
// A simple stock dictionary, each stock's name is gained and
// stored from a numerical key
//
dictionary< integer, string > stockdict;

// A dictionary that can be used to store the number of times
// that a given event is received
//
dictionary< StockChoice, integer > stockCounterDict;
```

Note that a `dictionary` of sequences or dictionaries is supported. Care must be taken in how these are specified by separating trailing > characters with whitespace, to distinguish them from the right-shift operator >>. For example:

```
// A correctly specified dictionary containing sequence elements
   dictionary< integer, sequence<float> > willWork;

// An incorrectly specified dictionary containing sequence elements
// dictionary< integer, sequence<float>> willNotWork;
```

A global variable of type `dictionary` is initialized by default to an empty instance of the type defined. On the other hand, a local variable must be explicitly initialized using the `new` operator, as follows:

```
dictionary<integer, string> stockdict;
stockdict := new dictionary <integer, string>;
```

It is also possible to both declare and populate a variable of type `dictionary` as a single statement, regardless of the scope in which the variable is declared, as follows:

```
dictionary<integer, string> stockdict := {1:"IBM", 2:"MSFT", 3:"ORCL"};
```

using `{}` to delimit the dictionary, a comma (`,`) to delimit individual entries, and a colon (`:`) to separate keys and values.

Dictionary types do not allow duplicate keys. Ensure that you do not specify duplicate keys when initializing a dictionary or in a string that will be parsed to produce a dictionary.

A `dictionary` variable can be a potentially cyclic type — a type that directly or indirectly refers to itself. For details about the behavior of such objects, see "Potentially cyclic types" on page 819.

Methods

The methods available on the `dictionary` data structure are:

- `add(`*`key, item`*`)` – add an entry to the dictionary. The first parameter is an expression whose type is the same type as the dictionary's key type and which becomes the entry's key. The second parameter is an expression whose type is the same type as the dictionary's item type and whose value becomes the entry's item value. The key expression is evaluated first, then the item expression. There is no return value. For example:

```
stockdict.add(71, "ACME");
```

When you are adding an entry and the key you specify already exists in the dictionary, the correlator replaces the item already in the dictionary with the new item.

- `canParse()` — this method is available only on dictionaries where the item type is parseable. Returns `true` if the string argument can be successfully parsed to create a dictionary object. For more information about the parseable type property, see the table in "Type properties summary" on page 811.
- `clear()` – sets the size of the dictionary to 0, deleting all entries. Takes no parameters. Returns no value.
- `clone()` – returns a new `dictionary` that is an exact copy of the `dictionary`. All the `dictionary`'s contents (both keys and items) are cloned into the new `dictionary`, and if the items were complex types themselves, their contents are cloned as well.

  When the dictionary you are cloning is a potentially cyclic type, the correlator preserves multiple references, if they exist, to the same object. That is, the correlator does not create a separate copy of the object to correspond to each reference. See also "Potentially cyclic types" on page 819.
- `getDefault(`*`key`*`, `*`item`*`)` – Before Apama 5.0, the `getOr()` method was called `getDefault()`. You should not use the `getDefault()` method. It remains only for backwards compatibility, it is deprecated, and it will be removed in a future release. Use the `getOr()` method instead.
- `getOr(`*`key`*`, `*`alternative`*`)` – returns the item that corresponds to the specified key. If the specified key is not in the dictionary, the `getOr()` method returns *`alternative`*. The benefit of calling this method is that if you were to call `dictionary[key]` instead of `dictionary.getOr()` and the key you were trying to look up did not exist, the correlator would terminate the monitor instance.

  The `getOr()` method lets you avoid a call to the `hasKey()` method before you look up a key.

  For example, suppose you have the following dictionary:

```
dictionary<integer,string> integerSqrts := {
   1:"one", 4:"two", 9:"three", 16:"four", 25:"five", 36:"six",
   49:"seven", 64:"eight", 81:"nine", 100:"ten" };
```

  Now suppose you call the following method:

```
integerSqrts.getOr(key, "irrational")
```

  Assume that you specify a key that is in the range of 1 - 100. If the value of the key is a square of an integer, `getOr()` returns the written form of the key's square root. For any other key value, `getOr()` returns `"irrational"`.

- `getOrDefault(key)` – retrieves an existing item by its key or returns a default instance of the dictionary's item type if the dictionary does not contain the specified key.

  The `getOrDefault()` method lets you avoid a call to the `hasKey()` method before you look up a key.

- `getOrAdd(key, alternative)` – retrieves an existing item by its key or adds the specified key to the dictionary with *`alternative`* as its value if it is not already present and also returns the specified alternative.

  The `getOrAdd()` method lets you avoid a call to the `hasKey()` method before you look up a key. If the item type is complex, a call to the `getOrAdd()` method can be more efficient than a call to the `getOr()` method, because it will not construct a default item unless necessary.

- `getOrAddDefault(key)` – retrieves an existing item by its key or, if it is not already present, adds the specified key with a default instance of the dictionary's item type and returns that instance.

  For example, suppose you want to maintain a record of which client companies each sales representative handles. You might write:

  ```
  dictionary<string, sequence<string> > representing := {};
      representing.getOrAddDefault("Sue").append("We-Haul");
      representing.getOrAddDefault("Joe").append("McDonuts");
      representing.getOrAddDefault("Sue").append("ACME");
  ```

  The first time `getOrAddDefault()` is called with key `"Sue"`, that key does not exist yet, so it is added with an empty sequence as the item. That empty sequence is then returned, so `"We-Haul"` can be appended to it. The second time `getOrAddDefault()` is called with key `"Sue"`, the existing sequence (containing `"We-Haul"`) is returned, so `"ACME"` can be appended to it.

  This idiom is considerably simpler and more efficient than testing `hasKey()` and then either adding or retrieving.

- `hasKey(key)` – returns `true` if a key exists within the dictionary, `false` otherwise. Takes one parameter, which is an expression whose type is the same as the referenced dictionary's key type and whose value is the key value whose presence in the dictionary is tested.

  For example: `stockdict.hasKey(71)`

- `keys()` – returns a `sequence` of the dictionary's keys sorted in ascending order. This will be a `sequence` of the same type as the key type of the dictionary. The primary purpose of this method is to enable one to iterate over a dictionary's contents by looping through the sequence of its keys, as follows:

  ```
  integer k;
  for k in stockdict.keys() {
    myString := stockdict[k];
  }
  ```

  The `keys()` method performs a deep copy (like the `clone()` method) of the dictionary keys into a `sequence`; that is by value as opposed to by reference. This behavior ensures that the result of `keys()` is a consistent view of the dictionary's keys at the time `keys()` was called, regardless of whether entries were added to or removed from the dictionary while examining the result of `keys()`. This also ensures that the dictionary keys themselves cannot be modified by changing the sequence.

- `parse()` – this method is available only on dictionaries where the item type is parseable. Returns the `dictionary` object represented by the `string` argument. For more information about the parseable type property, see the table in "Type properties summary" on page 811. You can call this method on the `dictionary` type or on an instance of a `dictionary` type. The more typical use is to call `parse()` directly on the `dictionary` type.

  The `parse()` method takes a single string as its argument. This string must be the string form of a `dictionary` object. The string must adhere to the format described in *Deploying and Managing Apama Applications*, "Event file format". For example:

```
dictionary<string, integer> d := {};
d := dictionary<string, integer>.parse("{\"foo\":1, \"bar\":2}");
```

  You can specify the `parse()` method after an expression or type name. If the correlator is unable to parse the string, it is a runtime error and the monitor instance that the EPL is running in terminates.

  When a dictionary is a potentially cyclic type , the behavior of the `parse()` method is more advanced. See "Potentially cyclic types" on page 819.

- `remove(key)` – remove an entry by key. Takes one parameter, which is an expression whose type is the same as the referenced dictionary's `key` type and whose value is the value of the key of the entry to be removed. The `remove()` method does not return a value. If the `key` value is not present in the referenced dictionary, a runtime error is raised.

  For example: `stockdict.remove(71);`

- `size()` – returns as an `integer` the number of elements in the dictionary. Takes no parameters.

- `toString()` – converts the entire dictionary in ascending order of key values to a `string`. This will create a string that contains all the elements enclosed within curly braces, `{ }`, separated by commas (`,`), with each element consisting of the key followed by an item, the two being separated by a colon (`:`). That is:

```
{key1:item1, ... ,keyn:<itemn>}
```

  The string is constructed by concatenating the string representation of each of the referenced dictionary's key/value pairs.

  When a dictionary is a potentially cyclic type, the behavior of the `toString()` method is different. See "Potentially cyclic types" on page 819.

- `values()` – returns a `sequence` of the dictionary's items sorted in ascending order of keys. The order of the items in the returned sequence is the order returned by the dictionary's `keys()` method. The `sequence` contains items that are the same type as the item type in the dictionary. The primary purpose of this method is to let you iterate over a dictionary's contents by looping through the sequence of its item values, as follows;

```
string v;
for v in stockdict.values() {
   myString := v;
}
```

The `values()` method performs a shallow copy of the dictionary items, that is, if the items are of a reference type the returned `sequence` contains references to the dictionary's items rather than clones of them. This behavior ensures that a change to an object in the dictionary is reflected in the returned `sequence` and a change to an object in the sequence is reflected in the dictionary.

- `[key]` – retrieve or overwrite an existing item by its key, or create a new item. For example:

  ```
  stockdict[71] := "XRX";
  ```

  If you are using `[key]` to write and if an item with the key `key` does not exist, the correlator creates it. If you are using `[key]` to retrieve and if an item with the key `key` does not exist, it is a runtime error.

event

Values of the `event` type are data objects that can represent notifications of something happening, such as a customer order, shipment delivery, sensor state change, stock trade, or myriad other things. Event objects can also be used as a container or structure for holding several related data values.

Usage

Each kind of event has a type name and one or more data elements, called event fields, associated with it. An event can also have blocks of executable code, called actions, associated with it.

A field in an event can be any Apama type. If an event contains a field of type `action`, `chunk`, `listener`, or `stream`, you cannot specify that event in an event template, and you cannot send, emit, route or enqueue that event.

Two events are equal if corresponding members are equal. If corresponding members are not equal then the events are ordered according to the first member that differs.

The correlator orders events by considering the event's fields in order.

An `event` variable can be a potentially cyclic type, a type that directly or indirectly refers to itself. For details about the behavior of such objects, see "Potentially cyclic types" on page 819.

See also "Defining event types " on page 40.

Methods

The following methods may be called on variables of `event` type and on `event` types:

- `canParse()` — this method is available only on events that are parseable. Returns `true` if the string argument can be successfully parsed to create an event object. For more information about the parseable type property, see the table in "Type properties summary" on page 811.

- `clone()` — returns a new `event` that is an exact copy of the `event`. All the `event`'s contents are cloned into the new `event`, and if they were complex types themselves, their contents are cloned as well. Takes no parameters.

  When the event you are cloning is a potentially cyclic type, the correlator preserves multiple references, if they exist, to the same object. That is, the correlator does not create a copy of the object to correspond to each reference. See also "Potentially cyclic types" on page 819.

- `getFieldNames()` — returns a `sequence` of strings that contain the field names of an event type. This method takes no parameters. The return value is of type `sequence <string>`. You can call this method on an event type or on an instance of an `event` type. For example:

```
event Foo {
   string bar;
   integer count;
}

monitor m {
   action onload() {
    print Foo.getFieldNames().toString();
    }
}
```

  The above code prints the following:

```
["bar","count"]
```

- `getFieldTypes()` — returns a sequence of strings that contain the type names of an event type's fields. This method takes no parameters. The return value is of type `sequence <string>`. You can call this method on an event type or on an instance of an `event` type. For example:

```
event Foo {
   string bar;
   integer count;
}

monitor m {
   action onload() {
   print Foo.getFieldTypes().toString();
   }
}
```

  The above code prints the following:

```
["string","integer"]
```

- `getFieldValues()` — returns a sequence of strings that contains the string version of the event's field values. This method takes no parameters. The return value is of type `sequence <string>`. For `string` type fields, there is no quoting or escaping. You can call this method only on an event instance. For example:

```
event Foo {
```

```
   string bar;
   integer count;
}

monitor m {
   action onload() {
   Foo f:=Foo("Hello",1);
   print f.getFieldValues().toString();
   }
}
```

The above code prints the following:

```
["Hello","1"]
```

- `getName()` — returns a `string` whose value is an event's type name. This method takes no parameters. You can call this method on an event type or on an instance of an `event` type. For example:

```
event Foo {
   string bar;
   integer count;
}

monitor m {
   action onload() {
   print Foo.getName();
   }
}
```

The above code prints the following:

```
Foo
```

- `getTime()` — returns a `float` that indicates a time expressed in seconds since the epoch, January 1st, 1970. The particular time returned is as follows:
  - If the correlator created this event, the `getTime()` method returns the time that the correlator created the event. This is the creation time in the context in which the correlator created the event.
  - Coassignment sets the timestamp of an event. A call to `getTime()` on a coassigned event returns the time that the correlator performed the coassignment. This is the context's time at the point at which the correlator performed the coassignment or added the event to a query window. Events that are routed, sent or enqueued will have their time updated to be the receiving context's current time when the event was processed (and thus coassigned) by that context.

    An event's timestamp might not match the time when an event listener for that event fires. For example, consider the following:

```
on A():a and B():b {
...
}
```

    Suppose that `currentTime` is `1` when the correlator processes `A` and `currentTime` is `2` when the correlator processes `B`. A call to `a.getTime()` returns `1`, while a call to `b.getTime()` returns `2`. Of course, the event listener fires only after processing `B`.

> **Caution:** In the Software AG Designer code editor, you might notice the `setTimeDeep()` method, which can be invoked on `event` type variables. This method is for internal use only. You should not invoke this method without assistance from Software AG Global Support.
> If you will be sending `&TIME` events to externally control time in the correlator then use the `&SETTIME` event to specify the start time. See "Setting the time in the correlator (&SETTIME event)" on page 199.

- `isExternal()` — returns a `boolean` that indicates whether the event was generated by an external source. Typically, such an event came from an external event sender, triggered an event listener, and was coassigned to a monitor instance variable. A return value of `true` indicates an event that was generated by an external source.

  When a monitor instance uses `enqueue` to send an event, then that event is considered to be generated by an external source. When a monitor uses `route`, `send..to` or `enqueue..to`, the `isExternal()` property of the event does not change. If an external event is received and then sent to another context using `send..to`, it will still be external (unless the event is copied with `clone`; see below).

  When the correlator spawns a monitor instance, it preserves the value that the `isExternal()` method returns. In other words, if you coassign an external event in a monitor instance, and then spawn that monitor instance, the `isExternal()` method returns true in the spawned monitor instance.

  This method takes no parameters.

  The `isExternal()` method returns `false` when a monitor instance

  - creates an event inside the correlator
  - clones an event

  This method is useful when you need to determine whether an event came from outside or was in some way derived inside the correlator. Although this distinction is often clear from the event type, that is not always the case.

- `parse()` — this method is available only on events that are parseable. Returns the `event` object represented by the `string` argument. For more information about the parseable type property, see the table in "Type properties summary" on page 811. You can call this method on an event type or on an instance of an `event` type. The more typical use is to call `parse()` directly on the event type.

  The `parse()` method takes a single string as its argument. This string must be the string form of an `event` object. The string must adhere to the format described in "Event file format" in *Deploying and Managing Apama Applications*. For example:

  ```
  A a := new A;
  a := A.parse("A(10, \"foo\")");
  ```

  You can specify the `parse()` method after an expression or type name. If the correlator is unable to parse the string, it is a runtime error and the monitor instance that the EPL is running in terminates.

When an event is a potentially cyclic type, the behavior of the `parse()` method is different. See "Potentially cyclic types" on page 819.

- `toString()` — returns a `string` representation of the event. Takes no parameters. The return value is constructed by concatenating the string representation of the referenced event's fields.

  When you define an event type inside a monitor it has a fully qualified name. For example:

```
monitor Test
{
   event Example{}
}
```

  The fully qualified name for the `Example` event type is `Test.Example` and the `toString()` output for the event name is `"Test.Example()"`.

  When an event is a potentially cyclic type, the behavior of the `toString()` method is different. See "Potentially cyclic types" on page 819.

Also, you can define your own actions on events.

Exception

Values of `Exception` type are objects that contain information about runtime errors.

Usage

The `Exception` type is defined in the `com.apama.exceptions` namespace. Typically, you specify `using com.apama.exceptions.Exception` so you can easily refer to `Exception` objects.

An `Exception` object has methods for accessing an error message, an error type, and a `sequence` of `com.apama.exceptions.StackTraceElement` objects that show where the exception occurred and what the calls were that led to the exception.

You cannot route an `Exception` object, but a routable object can have an `Exception` object as a member.

Methods

The following methods may be called on values of `Exception` type:

- `getMessage()` — returns a string that contains the exception message.
- `getStackTrace()` — returns a `sequence` of `StackTraceElement` objects that represent the stack trace for when the exception was first thrown. The sequence is empty if the exception has not been thrown.
- `getType()` — returns a string that contains the exception type, which is one of the following:

Exception Type	Description	Example
`ArithmeticException`	Illegal arithmetic operations	Attempt to divide by 0, call to the `ceil()` method on `NaN`, call to the `exponent()` method on infinity, specifying `NaN` as all or part of an ordered key, call to the `rand()` method on an illegal `float` value such as `Infinity`

`DefaultContextException`	Spawning, sending or enqueuing to a context and specifying a `context` variable that has been declared but the context has not yet been created	`monitor m {`
		`   context c;`
		`   action onload()`
		`   {`
		`      send A() to c;`
		`   }`
		`}`

`IndexOutOfBoundsException`	Invalid index in a sequence or string operation	`sequence.insert(-1, x)`
`IllegalArgumentException`	Illegal argument value in an expression	`"".split()`
`IllegalStateException`	Calling an action when it is illegal to do so	`spawn` statement in `ondie()` or `onunload()`
`MemoryAllocationException`	Unable to fulfill memory allocation request	An invalid size is passed to the `sequencesetCapacity()` method

`NullPointerException`	Attempt to call an `action` variable when that variable	`event E {`
		`  action<string> x;`
		`}`
		`monitor m {`
		`  E e;`
		`  action onload() {`
		`    e.x("This will fail!");`

Exception Type	Description	Example
	has not been initialized	`}` `}`
`OtherInternalException`	An internal error occurred	`parse("two")` on an integer
`ParseException`	Error that occurs while parsing	
`PluginException`	An exception thrown by a correlator plug-in. See the note that follows this table.	
`StackOverflowException`	Attempt to use more space than is available on the stack	

In C++ correlator plug-ins, you can customize exception types so that the type returned has this format:

```
PluginException:user_defined_type
```

See `AP_UserPluginException` in the `correlator_plugin.hpp` file in the `include` folder of your Apama installation.

In Java plug-ins, the exception type returned has this format:

```
PluginException:class_name
```

For example:

```
import "MyJavaPlugin" as myjavaplugin;
...
  action myAction() {
    try {
      myjavaplugin.processfile("config.txt");
    } catch (Exception e) {
      log "Exception of type "
        + e.getType() at WARN;
    }
  }
...
```

Returns something like:

```
Exception of type
PluginException:java.io.FileNotFoundException
```

- `toString()` — returns a string that contains the exception message and the exception type.
- `toStringWithStackTrace()` — returns a string that contains the exception message, the exception type, and the stack trace elements.

listener

A handle to a listener.

Usage

A `listener` variable can be instantiated only by assigning to it the outcome of an `on` statement, a `from` statement, or by assigning to it the value of another `listener` variable. Values of `listener` type are references to `listener` objects created with the `on` statement or `from` statement. The main use of `listener` variables is, in combination with the `listener` type's inbuilt `quit` method, to terminate an active listener when it is no longer needed.

An event can contain a field of type `listener`, however you cannot send, emit, route, or enqueue an event that has a `listener` type field. Also, you cannot specify an event with a `listener` field in an event template.

Methods

The following method may be called on variables of `listener` type:

- `quit()` – causes the listener to terminate immediately.

  If the listener is invalid or has already been quit, then the `quit()` method does nothing and does not raise an error.

  The `quit()` method takes no parameters and does not return a result.

location

Values of the `location` type describe rectangular areas in a two-dimensional unitless Cartesian coordinate plane. Locations are defined by the `float` coordinates of two points `x1`, `y1` and `x2`, `y2` at diagonally opposite corners of an enclosing boundary rectangle.

The format of a `location` type is as follows:

```
location(x1 , y1 , x2 , y2)
```

An example of a valid location therefore looks as follows:

```
location(15.23, 24.234, 19.1232, 28.873)
```

A point can be represented simply as a rectangle with both corners being the same point. You can access the data members of a `location` type in the same way that you access the fields of an event. For example:

```
location l := location(1.0, 2.0, 3.0, 4.0);
print l.x1.toString();
```

This prints `1.0`. You can use a `location` type to describe a rectangular area but you can also use it to describe various other quantities, such as line segments connecting two endpoints, circles, vectors, or points in a four-dimensional space. However, certain inbuilt methods, such as the `inside()` method, give correct results only for boundary rectangles.

A listener that is watching for a particular value for a `location` field matches when it finds a `location` field that intersects with the `location` value specified by the listener. In the following example, the listener matches each `A` event whose `loc` field specifies a location that intersects with the square defined by `(0.0, 0.0, 1.0, 1.0)`. When the limits specified for a `location` type are out of order, the correlator correctly orders them before performing a comparison. When locations touch it is considered to be an intersection.

```
location l := location(0.0, 0.0, 1.0, 1.0);
on all A(loc = l) ...
```

Methods

The following methods may be called on variables of `location` type:

- `canParse()` – returns `true` if the string argument can be successfully parsed.
- `clone()` – returns a new `location` that is an exact copy of the `location`.
- `expand(`*`float`*`)` – returns a new `location` expanded by the value of the `float` parameter in each direction. For example:

  ```
  location l := location(0.0, 0.0, 0.0, 0.0);
  on all A(loc = l.expand(0.5)) ...
  ```

  This event listener watches for `A` events whose `loc` field specifies a location that intersects with `(-0.5, -0.5, 0.5, 0.5)`.
- `inside(`*`location`*`)` – returns `true` if the location is entirely enclosed by the space defined by the `location` parameter, `false` otherwise. Note that if the two locations are exactly equal, the result of calling the `inside()` method is `false`.
- `parse()` – method that returns the `location` instance represented by the `string` argument. You can call this method on the `location` type or on an instance of a `location` type. The more typical use is to call `parse()` directly on the `location` type.

  The `parse()` method takes a single string as its argument. This string must be the string form of a `location` object. The string must adhere to the format described in *Deploying and Managing Apama Applications*, "Event file format". For example:

  ```
  location a;
  a := location.parse("(15.23, 24.234, 19.1232, 28.873)");
  ```

  You can specify the `parse()` method after an expression or type name. If the correlator is unable to parse the string, it is a runtime error and the monitor instance that the EPL is running in terminates.
- `toString()` – returns a `string` representation of the `location`.

sequence

Values of the `sequence` type are finite ordered sets or arrays of entries whose values are all of the same primitive or reference type. The type can be any Apama type.

Usage

Sequences are indexed by nonnegative integers from 0 to one less than the number of entries given by their `size` inbuilt method. Sequences are dynamic and new entries can be added and existing entries deleted as needed.

The individual elements of a sequence can be referenced in several ways.

- With subscripts — use the `[ ]` operators in combination with an integral expression, to reference sequence elements as an array. For example, `aSequence[3]` refers to the fourth element of a sequence. The first element is `aSequence[0]`. The last, for a sequence with `n` elements is `aSequence[n -1]`
- With the `for` loop — use the `for` loop to iterate over the individual elements of the sequence from first to last. See "The for statement" on page 885.
- With instance methods — you can use the `indexOf`, `insert`, `delete` (and others) methods to operate on individual elements.

Two sequences are equal if they are the same length and corresponding elements are equal. Otherwise, they sort according to the earliest difference. For example:

- `"abc"` sorts earlier than `"abcXYZ"`
- `[1,2,3]` sorts earlier than `[1,3,0]`
- `[1,2,3]` sorts earlier than `[1,2,3,77,88,99]`

The empty sequence sorts earliest of all.

Syntax

The syntax for `sequence` is:

```
sequence< type > varname
```

For example:

```
// A sequence to hold the names and volume of all my stocks
// (assuming the StockNameAndPrice event type includes a string
// for stock name and float for the volume)
sequence<StockNameAndPrice> MyPortfolio;

// A sequence to hold a list of prices
sequence<float> myPrices;
```

Note that sequences of sequences (and so on) are also supported. Care must be taken in how these are specified by separating trailing > characters with white space, to distinguish them from the right-shift operator >>. For example:

```
// A correctly specified sequence containing sequence elements
sequence< sequence<float> > willWork;
```

```
// An incorrectly specified sequence containing sequence elements
sequence<sequence<float>> willnotWork;
```

A global variable of type `sequence` is initialized by default to an empty instance of the type defined. On the other hand, you must explicitly initialize a local variable using the `new` operator, as follows

```
sequence<integer> someNumbers;
someNumbers := new sequence<integer>;
```

It is also possible to both declare and populate a variable of type `sequence` as a single statement, regardless of the scope in which the variable is declared, as follows:

```
sequence<integer> someNumbers := [0, 1, 2, 3, 4, 5, 6, 7, 8, 9];
```

Use `[]` to delimit the sequence and a comma (`,`) to delimit individual elements.

A `sequence` variable can be a potentially cyclic type — a type that directly or indirectly refers to itself. For details about the behavior of such objects, see "Potentially cyclic types" on page 819.

Methods

The methods available to the `sequence` data structure are:

- `append(`*`item`*`)` – appends the item to the end of the sequence.

  For example: `myPrices.append(55.20);`

- `appendSequence(`*`sequence`*`)` – appends the *`sequence`* to the end of the sequence that this method is called on. The appended sequence must be the same type as the sequence this method is called on.

- `canParse()` — this method is available only on sequences where the item type is parseable. Returns `true` if the string argument can be successfully parsed to create a sequence object. For more information about the parseable type property, see the table in "Type properties summary" on page 811.

- `clear()` – sets the size of the sequence to 0, deleting all entries.

- `clone()` – returns a new `sequence` that is an exact copy of the `sequence`. All the `sequence`'s contents are cloned into the new `sequence`, and if they were complex types themselves, their contents are cloned as well.

  When the sequence you are cloning is a potentially cyclic type, the correlator preserves multiple references, if they exist, to the same object. That is, the correlator does not create a copy of the object to correspond to each reference. See also "Potentially cyclic types" on page 819.

- `indexOf(`*`item`*`)` – return as an `integer` the location of the first matching item within the sequence. This method is available only if the item type is a comparable type. For details about whether a type is comparable and, if so, how the comparison is done, see "Comparable types" on page 817. The value returned by `indexOf()` will be from `0` to `size() - 1` if the item is found, or `-1` if the item is not a member of the sequence. A call to `indexOf()` to find the index of a `NaN` value in a sequence of `decimal` or `float` values returns `-1` because `NaN` values cannot be compared for equality by using the standard operator.

- `insert(item, integer)` – insert the item specified into the location indicated by the second parameter. The location must be a valid index within the sequence, or the next index due to be filled. That means that the only valid values are from `0` to `size()`, inclusive. An invalid value will cause a runtime error, which will terminate the enclosing monitor instance.
- `parse()` – this method is available only on sequences where the item type is parseable. Returns the `sequence` object represented by the `string` argument. For more information about the parseable type property, see the table in "Type properties summary" on page 811. You can call this method on the `sequence` type or on an instance of a `sequence` type. The more typical use is to call `parse()` directly on the `sequence` type.

  The `parse()` method takes a single string as its argument. This string must be the string form of a `sequence` object. The string must adhere to the format described in *Deploying and Managing Apama Applications*, "Event file format". For example:

  ```
  sequence<float> s := [];
  s := sequence<float>.parse("[1.0, 4.0, 9.0, 16.0, 25.0]");
  ```

  You can specify the `parse()` method after an expression or type name. If the correlator is unable to parse the string, it is a runtime error and the monitor instance that the EPL is running in terminates.

  When a sequence is a potentially cyclic type , the behavior of the `parse()` method is different. See "Potentially cyclic types" on page 819.
- `remove(`*`integer`*`)` – remove the n^{th} element in the sequence, moving all the elements above it down and reducing the size by 1. Note that in EPL sequence elements are indexed from `0`, i.e. the first element is at location `0`.

  For example: `myPrices.remove(1);`
- `reverse()` – modifies the sequence by reversing the order of the items in the sequence. For example, if the sequence contains `1`, `2`, `3`, `4`, then after execution of `reverse()` the updated sequence contains `4`, `3`, `2`, `1`. There is no return value; the method modifies the sequence in place and does not create a new sequence nor does it create any new items.
- `setCapacity(`*`integer`*`)` – sets the amount of memory initially allocated for the sequence. Note that this does not limit the amount of memory the sequence can use. By default, as you add more elements to a sequence, the correlator allocates more memory. Calling `sequence.setCapacity()` can improve performance because it removes the need to add more memory repeatedly as you add elements to the sequence. For example, consider a sequence that you intend to populate with 1000 elements. A call to `setCapacity(1000)` removes the need to allocate additional memory unless more than 1000 elements are added. A call to this method does not change the behavior of your code.
- `setSize(`*`integer`*`)` – sets the number of elements in the sequence to the specified integer, either deleting entries from the end or adding initialized (using default values of variables) entries to the end.

For example: `myPrices.setSize(10);`

- `size()` – returns as an `integer` the number of elements in the sequence.
- `sort()` – Sorts the sequence it is called on in ascending order. The type of the sequence items must be comparable. See "Comparable types" on page 817. There is no return value; the method modifies the sequence in place and does not create a new sequence nor does it create any new items. A sequence of `decimal` or `float` values that contains `NaN` values cannot be sorted and will result in termination of the monitor instance that contains the method call.

  For example:

```
sequence<integer> s := [4,2,3,1];
s.sort();
```

  After that, `s` is `[1,2,3,4]`.

- `toString()` – convert the entire sequence to a `string`. This will create a string containing all the elements enclosed within square brackets `[ ]`, separated by commas (`,`). That is, `[<item1> , ... , <itemn> ]`

  When a sequence is a potentially cyclic type, the behavior of the `toString()` method is different. See "Potentially cyclic types" on page 819.

- `[integer]` – retrieve or overwrite an existing entry from the sequence, specifically the one located at the index specified. Note that in EPL sequence elements are indexed from `0`, that is, the first element is number `0`. The index specified must be valid, that is it must be between `0` and `size() - 1`, inclusive, as otherwise a runtime error will occur and the monitor instance will terminate.

  For example: `totalCost := myPrices[1] + myPrices[2];`

Iterating over sequence elements

You can iterate over a sequence both on the elements and on the indices. The indices are numbered from `0` to `size() - 1`, inclusive. For example:

```
sequence<string> seq := ["zero", "one", "two"];

// sequence elements
string s;
for s in seq {
   print s;
}

// sequence indices
integer i := 0;
while i < seq.size() {
   print seq[i];
   i := i + 1;
}
```

Loops are discussed in "Compound statements" on page 885.

StackTraceElement

A `StackTraceElement` type value is an object that contains information about one entry in the stack trace.

Usage

A `com.apama.exceptions.Exception` object contains a `sequence` of `StackTrackElement` objects, which indicate where an exception occurred. The correlator generates this sequence. You should not need to create `StackTraceElement` objects yourself. The first object in the sequence points to the line of code that caused the exception. The next object points to the action that contains the code that caused the exception. The next object points to the action that called that action, and so on.

The `StackTraceElement` type is defined in the `com.apama.exceptions` namespace. Typically, you specify `using com.apama.exceptions.StackTraceElement` so you can easily refer to `StackTraceElement` objects.

It is permissible to parse an event that contains a `StackTraceElement` object or a sequence of `StackTraceElement` objects.

Methods

The following methods may be called on values of `StackTraceElement` type:

- `getActionName()` — returns a string that contains the name of the action in which the exception occurred.
- `getFilename()` — returns a string that contains the name of the file that contains the code in which the exception occurred.
- `getLineNumber()` — returns an integer that indicates the line number of the code in which the exception occurred.
- `getTypeName()` — returns a string that indicates the type (event, aggregate, monitor) that contains the action in which the exception occurred.
- `toString()` — returns a string whose format is "*typeName*.*actionName*() *filename*:*linenumber*".

stream

A value of `stream` type refers to a stream. Each stream is a conduit or channel through which items flow. The item types that can flow through streams are `event`, `location`, `boolean`, `decimal`, `float`, `integer`, or `string`. A stream transports items of only one type. Streams are internal to a monitor.

Usage

An event can contain a field of type `stream`, however you cannot send, emit, route, or enqueue an event that has a `stream` type field. Also, you cannot specify an event that has a `stream` field in an event template.

Syntax

The syntax for declaring a `stream` variable is:

```
stream< type > varname
```

Replace *type* with the type of the items in the stream. This can be an event type, or `location`, `boolean`, `decimal`, `float`, `integer`, or `string`.

Replace *varname* with an identifier for the stream. For example:

```
stream<Tick> ticks;
```

Methods

The methods available to the `stream` type are:

- `clone()` – returns the original stream. It does not clone it.
- `quit()` – causes a stream listener to terminate.

  If the referenced listener's value is an inert stream, then the `quit()` method does nothing and does not raise an error.

  The `quit()` method takes no parameters and does not return a result.

monitor pseudo-type

The use of the `monitor` keyword as a pseudo-type is limited to invocation of the `subscribe()` and `unsubscribe()` methods.

Usage

Use the following formats:

```
monitor.subscribe(channel_name);
monitor.unsubscribe(channel_name);
```

Replace *channel_name* with a string expression that resolves to the name of the channel you want to subscribe to or unsubscribe from. In a monitor instance, call these methods from inside an action.

It is not possible to use instances of the `monitor` type. For example, there cannot be variables or event members of type `monitor`. You cannot specify a `com.apama.Channel` object as the argument to `subscribe()` or `unsubscribe()` method.

Methods

- `subscribe()` — Subscribes the calling context to the specified channel. All listeners in the same context as the calling monitor instance can process events sent to the specified channel. The calling monitor instance owns the subscription. If the calling monitor instance terminates the subscription ends.

Multiple monitor instances in the same context can subscribe to the same channel. Each event is delivered once as long as any of the subscriptions are active. An event is not delivered once for each subscription.

- `unsubscribe()` — Unsubscribes the calling context from the specified channel. If this was the only subscription in the context to the specified channel then the context no longer processes events sent to the unsubscribed channel.

Type properties summary

Apama type properties include the following:

- Indexable — An indexable type can be referred to by a qualifier in an event template.
- Parseable — A parseable type can be parsed and has `canParse()` and `parse()` methods. The type can be received by the correlator.
- Routable — A routable type can be a field in an event that is
  - Sent by the `route` statement
  - Sent by the `send...to` or `enqueue...to` statement
  - Sent by the `enqueue` statement
  - Sent outside the correlator with the `emit` statement
- Comparable — A comparable type can be used as follows:
  - Dictionary key
  - Item in a sequence on which you can call `sort()` or `indexOf()`
  - Stream query partition key
  - Stream query group key
  - Stream query window `with-unique` key
  - Stream query equijoin key
- Potentially cyclic — A potentially cyclic type uses the `@n` notation when it is parsed or converted to a string. When a potentially cyclic type is cloned, the correlator uses an algorithm that preserves aliases. See "Potentially cyclic types" on page 819
- Acyclic — An acyclic type is a type that is not potentially cyclic.
- `E`-free — `E`-free types cannot contain references to instances of a particular event type `E`. This property is used only to determine whether `E` is acyclic.

The following table shows the properties of each Apama type.

Type	Indexable	Parseable	Routable	Comparabl	Acyclic	`E`-free
`boolean`	✔	✔	✔	✔	✔	✔

Type	Indexable	Parseable	Routable	Comparabl	Acyclic	`E`-free
`decimal`	✓	✓	✓	✓[1]	✓	✓
`float`	✓	✓	✓	✓[1]	✓	✓
`integer`	✓	✓	✓	✓	✓	✓
`string`	✓	✓	✓	✓	✓	✓
`location`	✓	✓	✓	✓	✓	✓
`Channel`	✗	✓[2]	✓	✓	✓	✓
`Exception`	✗	✓	✓	✓	✓	✓
`context`	✗	✗	✓[3]	✓	✓	✓
`listener`	✗	✗	✗	✗	✓	✓
`chunk`	✗	✗	✗	✗	✓	✓
`stream`	✗	✗	✗	✗	✓	✓
`action`	✗	✗	✗	✗	✗	✗
`sequence`	✗	⚠	⚠	★	⚠	⚠
`dictionary`	✗	⚠	⚠	★	⚠	⚠
event `E`	✗	⚠[4]	⚠[4]	★	★ (blue)	✗

Legend:

Symbol	Description
	Yes. This type has the corresponding property. [1] Attempts to use a `NaN` in a key terminates the monitor instance. [2] A `Channel` object is parseable only when it contains a string. [3] Although a context can be enqueued, it is not parseable, so the correlator will reject it from the input queue with a warning.
	No. This type does not have the corresponding property.
	This type inherits the corresponding property from its constituent types, that is, the item type in a sequence, the key and item types in a dictionary, the types of fields in an event. The type has the corresponding property only when all its constituent types have that property. [4] An event defined inside a monitor cannot be received from an external source nor emitted from that correlator. An event defined inside a monitor can be sent or enqueued only within the same correlator.
	The type is comparable only when all its constituent types are both comparable and acyclic.
	An event `E` is acyclic only when all its constituent types are both acyclic and `E`-free.

Examples

The following code provides examples of event type definitions and their properties.

```
// You can do everything with "Tick", including index both its fields.
   event Tick {
       string symbol;
       float price;
   }
// You can do everything with "Order", except refer to its target or
// properties fields in an event template.
   event Order {
       string customer;
       Tick target;
       string symbol;
       float quantity;
       dictionary<string,string> properties;
   }
// The correlator cannot receive the next event as an external event and
// you cannot usefully enqueue it, but you can send it, route it, or
// enqueue it to a context.
    event SubscriptionRequest {
```

```
        string channel;
        context recipient;
    }
// You can do very little with this event except access its members and
// methods. It cannot be routed, you cannot sort sequence<TimeParse>,
// trying to group a stream query by TimeParse is illegal, and so on.
     event TimeParse {
         import "TimeFormatPlugin" as TF;
         string pattern;
         chunk compiledPattern;
     }
// This has all the same restrictions as TimeParse, but is also
// potentially cyclic, so will use the @n format when parsed or
// converted to a string.
     event Room {
         string roomName;
         float squareFeet;
         sequence<Room> adjacentRooms;
         sequence<Employee> occupants;
     }
```

Timestamps, dates, and times

Although EPL does not have time, date, or datetime types, timestamp (a date and time) values can still be represented and manipulated because EPL uses the `float` type for storing timestamps. See "currentTime" on page 912.

Timestamp values are encoded as the number of seconds and fractional seconds (to a resolution of milliseconds) elapsed since midnight, January 1, 1970 UTC and do not have a time zone associated with them. Although the resolution is to milliseconds, the accuracy can be plus or minus 10 milliseconds, or some other value depending on the operating system.

If you have two float variables that both contain timestamp values, subtracting one from the other gives you the difference in seconds.

You can add or subtract a time interval from a timestamp by adding or subtracting the appropriate number of seconds (60.0 for 1 minute, 3600.0 for 1 hour, 86,400.0 for 1 day, and so forth).

See also:

- `event.getTime()` for information about when the correlator assigns timestamps to events (see the description of the reference type "event" on page 796).
- "Using the TimeFormat Event Library" on page 357 for information about formatting timestamps.

Type methods and instance methods

There are two kinds of inbuilt methods: type methods and instance methods. Type methods are associated with types. Instance methods are associated with values.

Type methods

To call a type method, you specify the name of the type followed by a period, followed by the method name with its parameters enclosed in parentheses. Some methods do not have parameters and for them you must supply an empty parameter list.

Examples:

```
event someEvent;
{
   integer n;
}
integer i;
i:=integer.getUnique();
print someEvent.getName();
```

Instance methods

Each type (except `action`), whether primitive or reference, has a number of instance methods that provide a number of useful functions and operations on instance variables of that type. These methods are quite similar to actions except that they are predefined and associated with variables, not monitors or events.

To call an instance method, you specify an expression followed by a period and the name of the method, followed by a parenthesized list of actual parameters or arguments to be passed to the method when it is called. Some methods do not have parameters and for them you must supply an empty parameter list.

Examples:

```
integer i := 642;
float f;
f := i.toFloat ();
print f.formatFixed (5);
```

See Also

See the information in the following sections for the methods you can call on types and instances:

- "Primitive and string types" on page 768
- "Reference types" on page 785

Type conversion

EPL requires strict type conformance in expressions, assignment and other statements, parameters in action and method calls, and most other constructs. This means that

- The left and right operands of most binary operators must be of the same type.
- An actual parameter passed in a method or action invocation must be of the same type as the type of the corresponding formal parameter in the action or method definition.

- The expression result type on the right side of an assignment statement must be the same type as that of the target variable.
- The expression result type in a variable initializer must be the same type as that of the variable.
- The expression result type in a subscript expression must be integer.
- The expression result type in a `return` statement must be the same type as that specified in the action's `returns` clause.

EPL does not allow implicit or explicit casting to perform type conversions. Instead, the inbuilt methods associated with each type include a set of methods which perform type conversion. For example:

```
string number;
integer value;
number := "10";
value := number.toInteger();
```

This illustrates how to map a `string` to an `integer`. The string must start with some numeric characters, and only these are considered. So if the string's value was “`10h`”, the integer value obtained from it would have been `10`. Had the conversion not been possible because the string did not start with a valid numeric value, then `value` would have been set to `0`.

These method calls can also be made inside event expressions as long as the type of the value returned is of the same type as the parameter where it is used. Therefore one can write:

```
on all StockTick("ACME", number.toFloat());
```

Method calls can be chained. For example one can write:

```
print ((2 + 3).toString().toFloat() + 4.0).toString();
```

Note that as shown in this example, method calls can also be made on literals.

The following table indicates the source and target type-pairs for which type conversion methods are provided.

Source Type	Target Type							
	boolean	decimal	dictionary	event	integer	float	sequence	string
boolean	assign							toString()
decimal		assign			round() ceil() floor()	toFloat()		toString()
dictionary			assign and clone					toString()
event				assign and clone				toString()
integer		toDecimal()			assign and toFloat()			toString()
float		toDecimal()			round() ceil() floor()	assign		toString()
sequence							assign and clone	toString()
string	toBoolean() parse()	toDecimal() parse()	parse()	parse()	toInteger() parse()	toFloat() parse()	parse()	assign and parse()

In the table above, "assign" means values of the type can be directly assigned to another variable of the same type, without calling a type conversion method and "clone" means a value of the type can be copied by calling the `clone()` method.

Comparable types

The following types are comparable, and the operators <, >, <=, >=, =, or `!=` can be used to compare two values of one of these types if both are the same type:

- `boolean`
- `decimal`
- `float`
- `integer`
- `string`
- `context`
- `dictionary` if it contains items that are a comparable type
- `event` if it contains only comparable types

- `location`
- `sequence` if it contains items that are a comparable type
- `com.apama.exceptions.Exception`
- `com.apama.exceptions.StackTraceElement`

The correlator cannot compare the following types of items:

- `action`
- `chunk`
- `dictionary` if it contains items that are an incomparable type
- `event` if it contains at least one incomparable type
- `listener`
- `sequence` if it contains items that are an incomparable type
- `stream`
- Potentially cyclic types

For details about how the correlator compares items of a particular type, see the topic about that type.

In EPL code, you must use a comparable type in the following places:

- As the key for a `dictionary`. The type of the items in the `dictionary` does not need to be comparable.
- In a `sequence` if you want to call the `indexOf()` or `sort()` method on that `sequence`.
- As a key in the following stream query clauses:
  - Equi-join
  - `group by`
  - `partition by`
  - `with unique`

Cloneable types

Since variables of reference types are bound to the runtime location of the value rather than the value itself, direct assignment of a variable of reference type copies the reference (that is, the value's location) and not the value. To make a copy of the value, you must use the `clone` instance method instead of assignment. The types that have this property are called cloneable types.

The cloneable types are `string`, `dictionary`, `event`, `location`, and `sequence`.

For dictionary, event, and sequence types, the behavior of the clone() method varies according to whether or not the instance is potentially cyclic.

- When the instance is potentially cyclic, the correlator preserves multiple references, if they exist, to the same object. That is, the correlator does not create a copy of the object to correspond to each reference. See also "Potentially cyclic types" on page 819.
- When the instance is not potentially cyclic, and there are multiple references to the same object, the correlator makes a copy of that object to correspond to each reference.

While you can call the clone() method on a stream value, or a value that indirectly contains a stream or listener value, cloning returns another reference to the original stream or listener and does not clone it.

Potentially cyclic types

A cyclic object is an object that refers directly or indirectly to itself. For example:

```
event E {
   sequence<E> seq;
}
E e := new E;
e.seq.append(e);
```

When an object is cyclic or contains a reference to a cyclic object, it can be referred to as containing cycles. If it is possible to create an object that contains cycles, the type of that object is referred to as potentially cyclic.

When a type has the potential to contain cycles, and you call parse() on that type, or toString() or clone() on an object of that type, the result is different from when those methods are called on a type, or object of a type that is not potentially cyclic. Consequently, it is sometimes important to understand which types are potentially cyclic and what the string form of these objects looks like.

Which types are potentially cyclic?

A type is potentially cyclic if it contains one or more of the following:

- A dictionary or sequence type that has a parameter that is of the enclosing type. For example:

  ```
  event E {
     dictionary<integer,E> dict;
  }
  event E {
     sequence<E> seq;
  }
  ```

- An action variable member. For example:

  ```
  event E {
     action<E> a;
  }
  ```

- A potentially cyclic type. For example:

  ```
  event E {
     sequence <E> seq;
  }

  event F {
     E e;
  }
  ```

  `F` does not have any members that refer back to `F`, nor does it contain any `action` variables. However, it does contain `E`, which is a potentially-cyclic type. Therefore, an instance of `F` might contain cycles.

  Likewise, a `dictionary` or `sequence` is potentially cyclic if it has a parameter that is a potentially cyclic type. Consider the following event type:

  ```
  event E {
     sequence <E> seq;
  }
  ```

  Given this event type, `dictionary<string, E>` is potentially cyclic because its parameter is potentially-cyclic. Similarly, `sequence<E>` is potentially cyclic.

A cyclic object can indirectly contain itself. Consider the following, using the same definition of `E` as above.

```
E e1 := new E;
E e2 := new E;
e1.seq.append(e2);
e2.seq.append(e1);
```

In this example, both `e1` and `e2` are cyclic:

- `e1` is `e1.seq[0].seq[0]`
- `e2` is `e2.seq[0].seq[0]`

Following is another example of an object that indirectly contains a cycle:

```
E e3 := new E;
E e4 := new E;
e3.seq.append(e4);
e4.seq.append(e4);
```

In this example, `e3` is cyclic, even though it does not refer back to itself. Instead, `e3` refers to `e4` and `e4` refers back to itself.

You can pass objects that contain cycles between EPL and Java. Remember that JMon programs do not support `action` type variables, and so any cyclic types you pass cannot contain them.

String form of potentially cyclic types

A potentially cyclic object might have more that one reference to the same object. When you need the string form of a potentially cyclic object, the correlator uses a special syntax to ensure that you can distinguish multiple references to the same object from references to separate objects that merely have the same content.

When the correlator converts a potentially cyclic object to a string, the correlator labels that object `@0`. If the correlator encounters a second object during execution of the same method, it labels that object as `@1`, and so on. Whenever the correlator encounters an object that it has already converted, it outputs that object's `@`*`index`* label rather than converting it again. For example:

```
event E { sequence<E> seq; }
E e := new E;
e.seq.append(e);
print e.toString(); // "E([@0])"
```

Following is a more complicated example:

```
event Test {
   string str;
   sequence<Test> seq;
   string str2;
}

monitor m {
   action onload() {
      Test t:=new Test;
      t.str:="hello";
      t.str2:=t.str;
      t.seq.append(t);
      Test t2:=new Test;
      t.seq.append(t2);
      t.seq.append(t2);
      t2.seq.append(t);
      print t.toString();
   }
}
```

This prints the following:

```
Test("hello",[@0,Test("",[@0],""),@2],"hello")
```

The objects `@0`, `@1`, `@2`, and `@3` correspond to the following:

`@0`	`Test("hello",[@0,Test("",[@0],""),@2],"hello")`	`t` in the above example
`@1`	`[@0,Test("",[@0],""),@2]`	`t.seq` in the above example
`@2`	`Test("",[@0],"")`	`t2` in the above example
`@3`	`[@0]`	`t2.seq` in the above example

The following example uses the `clone()` method and contains `action` references. The result uses the new string syntax for aliases to the same object.

```
event E {
   action<> act;
   sequence<string> x;
   sequence<string> y;
```

```
}

monitor m {
   action onload() {
      E a:=new E;
      a.x.append("alpha");
      a.y:=a.x;
      E b:=a.clone();
      b.x[0]:="beta";
      print b.y.toString();
      print a.toString();
   }
}
```

The output is as follows:

```
["beta"]
E(new action<>,["alpha"],@1)
```

Note that dictionary keys can never contain aliases so they do not receive `@n` labels for referenced objects in `toString()` and `parse()` methods.

Whether you need to do anything to handle this string syntax depends on why you want a string representation of your object:

- If you are using the string for diagnostic messages, you just need to understand the syntax.
- If you plan to feed the string into the `parse()` method, the `parse()` method will handle it correctly.
- If you plan to feed the string into some other program, you should either avoid repeated references in an object or make sure the other program can handle the `@index` syntax.

Support for IEEE 754 special values

EPL supports the following IEEE 754 special `float` and `decimal` values:

- `NaN` — in EPL, these are quiet `NaNs`. The string representation is "`NaN`".
- `+Infinity` — The string representation is "`Infinity`".
- `-Infinity` — The string representation is "`-Infinity`".

The correlator returns one of these values as the result of an invalid computation. For example, dividing zero by zero or calculating the square root of a negative number. The correlator returns infinities as the result of computations that overflow, for example taking a very large number and dividing it by a very small number.

The correlator can receive external events that contain these special values. You can send, route, emit, and enqueue events that contain these values. If the correlator receives an event that contains a floating point value that is too large to be represented as a 64-bit floating point number the behavior is as if the value had overflowed and the correlator represents the value as infinity.

The following operations return `NaN`:

- 0.0/0.0
- x.sqrt() (where x < 0)
- x.ln() (where x < 0)
- x.log10() (where x < 0)
- Infinity - Infinity
- 0.0 * Infinity

In addition, most operations that accept NaN as a parameter return NaN. For example:

- NaN.exp() = NaN
- NaN + 3.0 = NaN

The NaN value behaves differently when compared to other floating point numbers. NaN does not compare equal to any other number, including itself. It is unordered with respect to all other floating point numbers, so NaN < x and NaN > x are both false.

The following operations return positive infinity (note that IEEE 754 has signed zeroes):

- x/0.0 (where x > 0)
- x/-0.0 (where x < 0)
- Infinity.sqrt()

The following operations return negative infinity:

- x/0.0 (where x < 0)
- x/-0.0 (where x > 0)
- (0.0).ln()

The following table lists the available constants. These are provided to ensure consistent values, and a few have been provided for convenience.

Constant	Value
decimal.E float.E	Euler's number, e.
decimal.PI float.PI	The ratio of a circle's circumference to its diameter (3.14159265).
decimal.MIN float.MIN	The smallest, positive, normalized floating point number (~2e-308).

Constant	Value
decimal.MAX float.MAX	The largest, finite, positive floating point number (~2e +308).
decimal.EPSILON float.EPSILON	The smallest *x* where (1+*x*) > 1. Note that decimal.EPSILON and float.EPSILON are not the same value. The value is dependent on whether the type is decimal or float.
decimal.NAN float.NAN	IEEE 754 Not-a-Number.
decimal.INFINITY float.INFINITY	IEEE 754 positive infinity.
integer.MAX	Largest positive value an integer can take (2^{63} - 1).
integer.MIN	Largest negative value an integer can take (-2^{63}).

Special cases of pow()

In the normal case, x.pow(y) yields exactly what you might expect, so 3.0.pow(3.0) = 27.0 and 2.0.pow(0.5) = 1.41421. But there are a very large number of special cases. The documentation for fdlibm, which is the mathematics library used by the EPL interpreter for float types lists the special cases shown below. Although EPL uses a different math library for decimal types, the behavior is the same for float and decimal types.

- $(anything)^{0} = 1$
- $(x)^{1} = x$, for any x
- $(anything)^{NaN} = NaN$
- $NaN^{(\text{anything except 0})} = NaN$
- $x^{+\infty} = +\infty$, if $|x| > 1$
- $x^{-\infty} = +0$, if $|x| > 1$
- $x^{+\infty} = +0$, if $|x| < 1$
- $x^{-\infty} = +\infty$, if $|x| < 1$
- $\pm 1^{\pm\infty} = NaN$
- $+0^{(\text{+anything except 0 and NaN})} = +0$

- $-0^{(\text{+anything except 0, NaN and odd integer})} = +0$
- $+0^{(\text{-anything except 0 and NaN})} = +\infty$
- $-0^{(\text{-anything except 0, NaN and odd integer})} = +\infty$
- $-0^{(\text{odd integer})} = -(+0^{(\text{odd integer})})$
- $+\infty^{(\text{+anything except 0 and NaN})} = +\infty$
- $+\infty^{(\text{-anything except 0 and NaN})} = +0$
- $-\infty^{(\text{anything})} = -0^{(\text{-anything})}$
- $(-\mathit{anything})^{(\text{integer})} = (-1)^{(\text{integer})} * (+\mathit{anything}^{(\text{integer})})$
- $(-\mathit{anything}\ \text{except 0 and}\ \infty)^{(\text{non-integer})} = \text{NaN}$

33 Events and Event Listeners

In EPL, an event is a data object that is a notification of something happening, such as arrival of a customer order, shipment delivery, sensor state change, stock trade, or myriad other things. Each kind of event has an event type name, zero or more data elements or fields, and zero or more event actions associated with it.

Event objects can also be used simply as complex data structures to hold multiple related data values. They can also be used as a container for actions that can be shared by multiple monitors.

Event objects are hierarchical structures that can contain simple values, other events, and arrays.

When the correlator executes an `on` statement, it creates an event listener. An event listener watches for an event, or a sequence of events, that matches the event or event sequence specified in the `on` statement. Conceptually, event listeners sift the events that come in to the correlator and watch for matching events.

Event definitions

An event definition specifies the event type, and any event fields and/or event action fields.

Example:

```
event MyEvent {
 string s;
 MyOtherEvent e;
 location l;
 wildcard integer i;
}
```

For detailed information, see "Defining event types " on page 40.

Event fields

An event field definition specifies the type and name of the field.

Event fields and variables are similar, but unlike variables, event fields cannot be initialized with a value.

Event fields that do not have the wildcard attribute are indexed by the correlator when you listen for them. There can be at most 32 indexes on an event type. Event fields of the type `location` use two indexes for each field.

An event that contains an `action`, `chunk`, `listener`, and/or `stream` field is valid only within the monitor that creates it. You cannot send, enqueue or route an event that contains, directly or indirectly, a field of such types.

Event actions

An event action is a subprogram or function that is associated with the event definition. It can be invoked or called from any monitor or from another action in the same event. Like monitor actions, the caller must supply actual parameters of the same type and number as the event action's formal parameters and if the action returns a value, then the return value must be consumed by the caller.

Like monitor actions, event actions can optionally be prefixed with annotations. See "Annotations" on page 930.

Unlike monitor actions (see "Monitor actions" on page 849), events do not have the special actions `onload()`, `onunload()`, and `ondie()`.

Event action example:

```
action myEventAction(string s, location l) returns float {
 ...
 return 10.0;
}
```

Event action formal parameters

The formal parameters are a comma-separated list of parameter definitions, enclosed in parentheses. A parameter definition consists of a type name and an identifier. The identifier is the name of a parameter variable which will be bound to a copy of the value of an expression specified by the caller (that is, the value passed by the caller) when the action is invoked. The number and type of actual parameter values passed by a caller must match those listed in the action's formal parameters.

The scope of a parameter variable is the statement or block that forms the action body. Parameter variables are very similar to an action's local variables.

Event action return value

An event action return value specifies the return value type.

If the event action definition includes a `returns` clause, then the action returns a value of the specified type. All control paths within the action body must lead to a `return` statement before the end of the action body.

Event action body

The block construct forms the event action body. All variable references within an event action body must be one of the following:

- A field of the event
- A formal parameter of the action
- A local variable defined in the action body

Event field and action scope

The scope of an event's fields and actions is the same as the scope of the event itself except that the event fields are always referenceable within the event's actions.

Event templates

An event template is a construct that allows you to specify qualifying or matching criteria based on values of one or more of an event's fields. In event templates, you can qualify only on those event fields whose type is a primitive type. Event templates are used with `on` statements. See "The on statement" on page 887.

An event template begins with the name of an event type that is to be matched.

Event templates can be either positional (see "By-position qualifiers" on page 830) or named (see "By-name qualifiers" on page 831) or a combination of both. Further, the criteria can be omitted entirely, in which case any event of the same event type will match. When both positional and named qualifiers are present in an event template qualifier expression list, the positional matches must come first.

Optionally, a colon and an identifier can follow the event expressions. This is called an event coassignment and specifies a variable whose value will become (that is, will be assigned) a reference to the matched event structure when the correlator detects a matching event and listener, and invokes the actions defined in the listener.

See also "Stream source templates" on page 908.

By-position qualifiers

The correlator evaluates a positional event template against the event field that is at the same position in the event definition as the qualifier's position in the qualifier list.

For example, suppose an event has the fields shown below:

```
event sample1
{
   string  itemName;
   float   price;
   integer quantity;
}
```

An example of a by-position qualifier list for this event is as follows:

```
sample1 ("eggs", 0.50, 3)
```

This template matches `sample1` events that have an `itemName` value of `"eggs"`, a `price` value of `0.50`, and a `quantity` value of `3`.

In a by-position qualifier, an asterisk (`*`) matches any value of an event field in the corresponding position.

A range expression matches the event field values in the corresponding position to a low and high boundary value of the range. A match occurs when the field value is within the range. See "Range expressions" on page 831.

The comparison operators < (less than), <= (less than or equal to), > (greater than), >= (greater than or equal to), and = (equal to) specify a comparison of the event field value with the expression value that follows. A match occurs when the relation result is true. The expression to the right of the comparison operator cannot contain any references to the event's fields and must have a result type that is the same as the event field's type and must be one of `decimal`, `float`, `integer` or `string`.

By-name qualifiers

A by-name qualifier names an event field whose value is to be matched, instead of matching by position.

The identifier must be the name of one of the event's fields. The field's type must be `integer`, `decimal`, `float`, or `string`. Each event field is allowed to appear only once on the left side of a by-name qualifier, and the same field is not allowed in both a by-position qualifier and a by-name qualifier in the same event template.

An example of a by-name qualifier list is as follows (see the example in "By-position qualifiers" on page 830 for the event fields that are also used for this example):

```
sample1 (itemName="eggs", price=0.50, quantity=3)
```

If the qualifier uses `= *`, then the qualifier matches all possible values of the specified event field.

If the qualifier uses one of the relational operators `<` (less than), `<=` (less than or equal to), `>` (greater than), `>=` (greater than or equal to), and `=` (equal to), then the event field value is compared with the event template's value, and a match occurs when the result of the comparison is true.

If the qualifier uses `in` followed by a range expression, then the field is compared against the boundary values of the range.

The expression or range expression on the right side is not allowed to refer to any of the event's fields.

The expression or range expression is evaluated once, when the `on` statement containing the template is executed and its event expressions evaluated, not each time an event of the same type is processed by the correlator.

Range expressions

A range expression is a part of a qualifier expression that describes a range of consecutive `decimal`, `float`, `integer`, or `string` values between a low boundary and a high boundary. The correlator tests an event's field value against this range to determine whether or not it falls within the specified range.

The values for the low boundary and the high boundary are the expression values. Both expression values must be of the same type and one of `decimal`, `float`, `integer`, or `string`. Both expression types must be of the same type as the event field being tested. Neither expression can contain any references to the event's fields.

If the low boundary value is greater than the high boundary value, the EPL runtime automatically reverses them.

Example

In the following EPL, the three `on` statements specify event listeners that are all listening for the same range of events:

```
event test
{
   string s;
   float f;
}
monitor RangeExample
{
   test t;
   action onload()
   {
      on test (f > 9.0 ) and test (f <= 10.0)
      {
      }
      on test ("", (9.0 : 10.0])
      {
      }
      on test (f in (9.0 : 10.0])
      {
      }
   }
}
```

Depending on which of the starting operators, `[` or `(`, and ending operators, `]` or `)`, you use, the boundary values will either be included in the range or excluded from it.

- If the starting operator is `[`, then the low boundary value is included and candidate values greater than or equal to the low boundary value are in the range.
- If the starting operator is `(`, then the low boundary value is excluded and candidate values larger than the low boundary value are in the range.
- If the ending operator is `]`, then the high boundary value is included and candidate values less than or equal to the high boundary value are in the range.
- If the ending operator is `)`, then the high boundary value is excluded and candidate values lower than the high boundary value are in the range.

Note that you can have one kind of starting operator at the beginning and the other kind at the end; they do not need to match.

Field operators

Field operators can appear within event templates to define a field value.

The `on` keyword creates an event listener that watches the series of events processed by the correlator for individual events or patterns of particular events. You define the sequence of interest in an event expression made up of one or more event templates. The first part of an event template defines the event type of the event the event listener is to match against, while the section in brackets describes further filtering criteria that must be satisfied by the contents of events of that type for there to be a match. Event template field operators define what values, or range of values, are acceptable for a successful event match.

The value that a field operator applies to can be the result of an expression. Therefore, it is possible to have >, <, >=, <= , and/or = present in both their roles, as expression operators and as field operators, within an event template. This is not a problem, since the latter are unary while the former are binary and the semantics are quite different.

The following table describes the field operators:

Operator	Description
`[`*`value1`*`:`*`value2`*`]`	Specifies a range of values that can match. The values themselves are included in the range to match against. For example: `on stockPrice(*, [0 : 10]) doSomething();` This example will invoke the `doSomething()` action if a `stockPrice` event is received where the price is between 0 and 10 inclusive. You can apply this range operator to `decimal`, `float`, `integer` and `string` types.
`[`*`value1`*`:`*`value2`*`)`	Specifies a range of values that can match. The first value itself is included in the range to match against while the second value is excluded from the range to match against. For example: `on stockPrice(*, [0 : 10)) doSomething();` This example will invoke the `doSomething()` action if a `stockPrice` event is received where the price is between 0 and 9 inclusive (assuming the field was of `integer` type). You can apply this range operator to `decimal`, `float`, `integer` and `string` types.
`(`*`value1`*`:`*`value2`*`]`	Specifies a range of values that can match. The first value is excluded from the range to match against while the second value is included. For example: `on stockPrice(*, (0 : 10]) doSomething();` This example invokes the `doSomething()` action if a `stockPrice` event is received where the price is between 1 and 10 inclusive (assuming the field was an `integer`). This operator can apply to `decimal`, `float`, `integer` and `string` types.
`(`*`value1`*`:`*`value2`*`)`	Specifies a range of values that can match. The values themselves are excluded from the range to match against. For example: `on stockPrice(*, (0 : 10)) doSomething();`

Operator	Description
	This example will invoke the `doSomething()` action if a `stockPrice` event is received where the price is between 1 and 9 inclusive (assuming the field was of `integer` type).You can apply this range operator to `decimal`, `float`, `integer` and `string` types.
`>` *`value`*	All values greater than the value supplied will satisfy the condition for a match. You can apply this operator to `decimal`, `float`, `integer`, and `string` types. When used with a `string`, the operator assumes lexical ordering.
`<` *`value`*	All values less than the value supplied will satisfy the condition for a match. You can apply this operator to `decimal`, `float`, `integer`, and `string` types. When used with a `string`, the operator assumes lexical ordering.
`>=` *`value`*	All values greater than or equal to the value supplied will satisfy the condition for a match. You can apply this operator to `decimal`, `float`, `integer`, and `string` types. When used with a `string`, the operator assumes lexical ordering.
`<=` *`value`*	All values less than or equal to the value supplied will satisfy the condition for a match. You can apply this operator to `decimal`, `float`, `integer`, and `string` types. When used with a `string`, the operator assumes lexical ordering.
`=` *`value`*	All values equal to the value supplied will satisfy the condition for a match. You can apply this operator to `decimal`, `float`, `integer`, and `string` types. When used with a `string`, the operator assumes lexical ordering.
`value`	With one exception, only a value equivalent to the value supplied will satisfy the condition for a match. The exception is a `location` type field. A `location` value consists of a structure with four `float`s representing the coordinates of the corners of the rectangular space being represented. A listener that is watching for a particular value for a `location` field matches when it finds a `location` field that *intersects* with the `location` value specified in the listener's event expression. In the following example, the listener matches each `A` event whose `loc` field

Operator	Description

	specifies a location that intersects with the square defined by `(0.0, 0.0, 1.0, 1.0)`.
	`location l := location(0.0, 0.0, 1.0, 1.0);`
	`on all A(loc = l) ...`

`*`	Any value for this field satisfies the condition for a match.

Event listener definitions

You define an event listener in an `on` statement. See "The on statement" on page 887.

Event lifecycle

An event enters the correlator in one of the following ways:

- An event is received from another component, such as the `engine_send` utility, an adapter, another correlator, or a process that is using the Apama client API. The correlator places the event on the input queue of each context that is subscribed to the channel on which the event is sent. If an event is not sent on a named channel then the correlator places the event on the input queue of each public context and each context that is processing a query.

  Events sent on the `com.apama.queries` channel are put on the input queue of each context that is processing a query. These contexts automatically receive events sent on the `com.apama.queries` channel.

- A correlator pulls an event from a JMS message queue that is set up to distribute events to a cluster of correlators that is processing queries. The correlator adds the event to the input queue of each context that is processing queries.
- An EPL program creates an event instance and executes a `send..to` statement. If the target is a channel then the correlator places the event on the input queue of each context that is subscribed to that channel. If the target is a context (or a sequence of contexts) then the correlator places the event on the input queue of that context (or on the input queue of each context in the sequence).
- An EPL program creates an event instance and executes an `enqueue...to` statement. The correlator places the event on the input queue of the specified context or on the input queue of each context in the specified sequence of contexts.
- An EPL program creates an event instance and executes an `enqueue` statement. The correlator places the event on the input queue of each public context. If the input queue for a public context is full then the correlator keeps the event on a special queue for enqueued events until there is room on the input queue that was full.
- An EPL program creates an event instance and executes a `route` statement. The correlator places the event on the input queue of only the context that contains the monitor instance that routed the event.

Monitors

When the event gets to the front of the context's input queue, the correlator evaluates the event to determine if it is a match for any active event listeners in that context. That is, the correlator checks whether there are any event listeners in that context that are watching for that particular event. If there is a match, the match triggers the event listener. This means that the correlator executes the actions defined in the matching event listener.

It is possible for the actions defined in the event listener to route one or more events back to the context's input queue. A routed event goes right to the front of the context input queue. When the correlator is finished processing the event that triggered the event listener action, the correlator evaluates any routed events before it moves on to the event that was on the input queue after the matching event.

Queries

When the event gets to the front of the context's input queue, the correlator extracts the key of the event according to the definitions of running queries that use that event. The window of events for that key value is retrieved from the distributed cache. The correlator adds the event to the retrieved window, which it writes back to the cache. The event pattern of interest is evaluated against the stored window to determine whether the addition of the event causes a match set.

The event remains in its window until the correlator ejects it to make room for a new event or until the query instance or parameterization terminates.

Event listener lifecycle

When you inject a monitor into the correlator, the correlator instantiates the monitor in the main context and executes the monitor's `onload()` action. The `onload()` action typically specifies at least one `on` statement. An `on` statement includes an event expression that identifies the event or sequence of events that you are interested in. This is what you want to listen for. An `onload()` statement is not required to specify an `on` statement. If there is no `on` statement, the correlator immediately unloads the monitor.

When the correlator executes an `on` statement, it sets up an event listener for the specified event or sequence of events. After the correlator sets up the event listener, the event listener watches for an event that matches its event expression. When the event listener detects a matching event, the event listener triggers and the correlator executes the action specified in the `on` statement.

For an event listener that is looking for a single instance of an event, this is straightforward. However, the event expression that defines what you are looking for can specify all instances of an event, all instances of a sequence of events, and it can have temporal and logical constraints. This makes the lifecycle of an event listener less straightforward.

For example, consider the following event listener:

```
on all A() success;
```

When the correlator sets up this event listener, it sets up an event template to look for an `A` event. When an `A` event arrives, the correlator does the following:

- Executes the `success()` event listener action.
- Sets up a new event template to look for the next `A` event.

Now consider this event listener:

```
on all A() -> all B() success;
```

Again, suppose that the correlator sets up this event listener and an `A` event arrives. This time the correlator does the following:

1. Sets up an event template to listen for the next `B` event.
2. Sets up an event template to listen for the next `A` event.

This event listener will be active until it is explicitly killed because there will always be an event listener that is looking for the next `A` event.

Additional information about event listener lifecycles is in "How the correlator executes event listeners" on page 182.

Event processing order for monitors

As mentioned earlier, contexts allow EPL applications to organize work into threads that the correlator can execute concurrently. When you start a correlator it has a main context. You can create additional contexts to enable the correlator to concurrently process events. Each context, including the main context, has its own input queue. The correlator can process, concurrently, events in each context.

Concurrently, in each context, the correlator

- Processes events in the order in which they arrive on the context's input queue
- Completely processes one event before it moves on to process the next event

When the correlator processes an event within a given context, it is possible for that processing to:

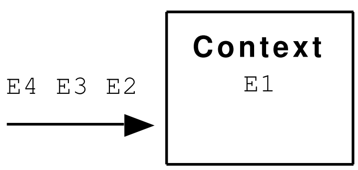
- **Send or enqueue an event to a particular channel.** The correlator places the event on the input queue of each context that is subscribed to the specified channel.
- **Send or enqueue an event to a particular context or to a sequence of contexts.** The correlator places the event on the input queue of the specified context or on the input queue of each context in the specified sequence.
- **Enqueue an event.** The correlator places the enqueued event on the special queue just for events generated by the `enqueue` keyword. A separate thread moves these events to the input queue of each public context. This arrangement ensures that if the input queue of a public context is full, the event generated by `enqueue` still arrives on its special queue, and is moved to each appropriate input queue as soon as that queue has room. Active event listeners will eventually receive events that are enqueued,

once those events make their way to the head of the input queue alongside normal events.

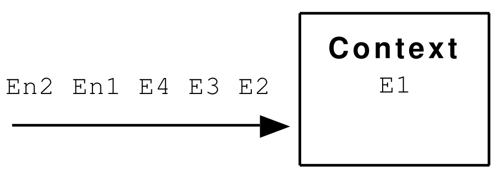
- **Route an event.** The correlator places the routed event at the front of that context's input queue. The correlator processes the routed event before it processes the other events in that input queue.

  If the processing of a routed event routes one or more additional events, those additional routed events go to the front of that context's input queue. The correlator processes them before it processes any events that are already on that context's input queue.

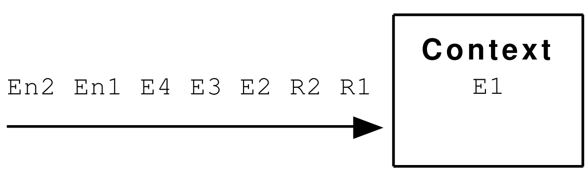
For example, suppose the correlator is processing the `E1` event and events `E2`, `E3`, and `E4` are on the input queue in that order.



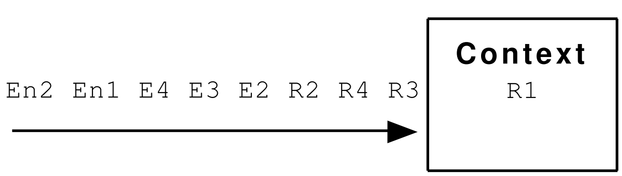
While processing `E1`, suppose that events `En1` and `En2` are created in that order and enqueued. These events go to the special queue for enqueued events. Assuming that there is room on the input queue of each public context, the enqueued events go to the end of the input queue of each public context:



While still processing `E1`, suppose that events `R1` and `R2` are created in that order and routed. These events go to the front of the queue:

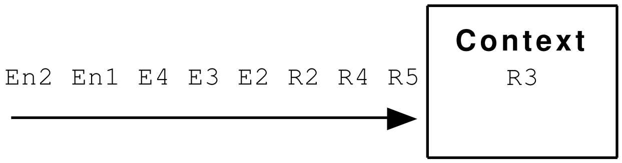


When the correlator finishes processing `E1`, it processes `R1`. While processing `R1`, suppose that two event listeners trigger and each event listener action routes an event. This puts event `R3` and event `R4` at the front of that context's input queue. The input queue now looks like this:



It is important to note that `R3` and `R4` are on the input queue in front of `R2`. The correlator processes all routed events, and any events routed from those events, and so on, before it processes the next routed or non-routed event already on the queue.

Now suppose that the correlator is done processing `R1` and it begins processing `R3`. This processing causes `R5` to be routed to the front of that context's input queue. The context's queue now looks like the following:



See also "Understanding time in the correlator" on page 194.

Event processing order for queries

Unlike EPL monitors, the order in which queries process events is not necessarily the order in which they were sent into the correlator. In particular, if two events that will be processed by the same query with the same key value are sent very close together in time (both events received less than about .1 seconds of each other) then they may be processed as if they had been sent in a different order. For example, consider a query that is looking for an `A` event followed by an `A` event. If two `A` events with the same key arrive 1 millisecond apart then the events might not be processed in the order in which they were sent.

Queries use multiple threads to process events and to scale across multiple correlators on multiple machines. To do this efficiently, there is no enforcement that the events are processed in order. However, when events that have the same key arrive roughly about .5 seconds apart or more then out-of-order processing is typically avoided provided the system can keep up with the load. Therefore, you want to specify a query so that it operates on partitions in which the arrival of consecutive events is spaced far enough apart. For example, consider a query that operates on credit card transaction events, which could mean thousands of events per second. You want to partition this query on the credit card number so that there is one event or less per partition per second. By following this recommendation, it becomes possible to process events that are generated at rates of up to 10,000 events per second.

When creating an `evt` file for testing purposes, the recommendation is to begin the file with a `&FLUSHING(1)` line to cause more predictable and reliable event-processing behavior. See "Event timing" in the "Correlator Utilities Reference" section of *Deploying and Managing Apama Applications*.

Event expressions

An event expression is a special type of expression that is used with the `on` statement to define the rules for detecting events of interest and invoking an action when a matching event is detected. In an event expression, you can specify filtering rules based on an event's field values, sequencing rules for events followed by other events, times and time ranges during which an event is of interest, and other rules. See also "The on statement" on page 887.

Event expressions should not be confused with ordinary EPL expressions of type `event`. Ordinary EPL expressions of all types are described in "Expressions" on page 891.

Event primaries

The event primary is the simplest form of an event expression clause and can be combined with other event primaries and event operators to form more complex event expressions.

An event primary can be an event template (see "Event templates" on page 830) optionally prefixed with `completed` or `unmatched`, or it can be a timer (see "Timers" on page 841).

Event templates are constructs that allow you to specify filtering or matching criteria based on values of one or more of an event's fields.

The completed operator

A `completed` event template matches only after all other work is completed. When an event that matches a `completed` template comes into the correlator, the correlator:

1. Runs all of the event's normal or `unmatched` event listeners. Normal event templates do not specify the `completed` or `unmatched` keyword.
2. Processes all routed events that result from those event listeners.
3. Triggers the `completed` event listeners.

For example:

```
on all completed A(f < 10.0) {}
```

The unmatched operator

An `unmatched` event template matches against events for which both of the following are true:

- Except for `completed` and `unmatched` event templates, the event is not a match with any other event template currently loaded in the context.
- The event matches the `unmatched` event template.

The correlator processes events as follows:

1. The correlator tests the event against all normal event templates in the context. Normal event templates do not specify the `completed` or `unmatched` keyword. If there are any matches, those event listeners trigger and the correlator executes those event listener actions. If execution of the event listener actions routes any events, the correlator then processes those events.
2. If the correlator does not find a match, the correlator tests the event against all event templates in the context that specify the `unmatched` keyword. If the correlator finds one or more matches, it triggers an event listener for each match found. In other words, if multiple `unmatched` event templates match a given event, they all trigger. The correlator executes the event listener actions defined by the event listeners that

trigger. If any events are routed during execution of those actions, the correlator processes the routed events.

3. The correlators tests the event against all event templates in the context that specify the `completed` keyword. If the correlator finds one or more matches, it triggers an event listener for each match found.

Example

For example, suppose you have the following code:

```
on all A("foo",  < 10) : a {
   print "Match: " + a.toString();
   a.count := a.count+1; // count is second field of A
   route a;
}
on all unmatched A(*,*): a {
   print "Unmatched: " + a.toString();
}
on all completed A("foo", *) : a {
   print "Completed: " + a.toString();
}
```

The incoming events are as follows:

```
A("foo", 8);
A("bar", 7);
```

The output is as follows.

```
Match: A("foo", 8)
Match: A("foo", 9)
Unmatched: A("foo", 10)
Completed: A("foo", 10)
Completed: A("foo", 9)
Completed: A("foo", 8)
Unmatched: A("bar", 7)
```

Specify the `unmatched` keyword with care. Be sure to communicate with any others who write event templates. If you are relying on an `unmatched` event template, and someone else injects a monitor that happens to match some events that you expected to match your `unmatched` event template, you will not get the results you expect.

Parenthesized event expressions

Just as with primary and bitwise expressions, event expressions can be enclosed in parentheses to control expression evaluation order or to improve readability.

Timers

Specify a timer with the `wait`, `at`, or `within` keyword. For more detailed information, see "Defining event listeners with temporal constraints" on page 189.

The wait event operator

The `wait` operator can be used to limit the amount of time that an event listener can match an event. The `wait` operator's expression specifies the time in seconds. The result of evaluating the `wait` expression must be of type `float`.

See also "Waiting within an event listener" on page 191.

The at event operator

The at operator allows triggering of an event listener at a specific time or repeatedly at multiple times, depending on how the series of expressions that follow the at operator are constructed.

The time specification of the at operator consists of either five or six expressions, corresponding to the number of minutes of the hour (0 to 59), hour of the day (0 to 23), day of the month (1 to 31), month of the year (1 to 12), day of the week (0 to 6, 0=Sunday), and seconds respectively.

If the optional number of seconds is omitted, 0 is used.

The * operator means that all times (minute, hour, etc.) for the corresponding part of the time specification will match.

You can specify one or more time values separated by commas.

See also "Triggering event listeners at specific times" on page 192.

The within operator

The within operator takes one operand, which is an expression of type float, whose value is the number of elapsed seconds from an event primary's activation time that the event primary can be matched. The within operator's result type is boolean. If the event is matched before the specified time has elapsed, the within operator's result is true. When the time has elapsed and the event has not been matched, the within operator's result is false.

See also "Listening for event patterns within a set time" on page 190.

The not operator

The not operator specifies logical negation.

Example:

```
on A() and not B() executeAction();
```

The all operator

When the all operator appears before an event template, when that event template finds a match, it continues to watch for subsequent events that also match the template.

Consider the following event expression:

```
all A -> B
```

This event listener would match on every A and the first B that follows it. The way this works is that upon encountering an A, the correlator creates a second event listener to seek the next A. Both event listeners would be active concurrently; one looking for a B to successfully match the sequence specified, the other initially looking for an A. If more

As are encountered the procedure is repeated; this behavior continues until either the monitor or the event listener are explicitly killed.

Consider the following sequence of incoming events:

```
C1 A1 F1 A2 C2 B1 D1 E1 B2 A3 G1 B3
```

With these input events, `on all A() -> B()` would return the following:

{A1, B1}, {A2, B1} and {A3, B3}.

Note that `all` is a unary operator and has higher precedence than `->`, `or` and `and`.

The and, xor, and or logical event operators

The logical operators `and`, `xor`, and `or` are binary operators, operating on event expressions that are either side of them. They are similar to the corresponding operators in primary and bitwise expressions, but do not have quite the same precedence. See also "Event expression operator precedence" on page 843.

Operator	Description
`and`	Logical intersection
`xor`	Logical exclusive or
`or`	Logical or

The followed-by event operator

The followed-by operator `->` takes left and right operands, both event expressions. The followed-by operator waits for the left operand to become true and then waits for the right operand to become true. When both are true, then the result value is true. If either becomes false, then the result value is false.

Event expression operator precedence

The following table lists the event expression operators in order by their precedence, from lowest to highest. See "Expression operator precedence" on page 901 for a corresponding table of primary and bitwise expression operator precedence.

Operation	Operator
Logical negation	`not`
All	`all`
Logical intersection	`and`

Operation	Operator
Logical exclusive or	`xor`
Logical union	`or`
Followed-by	`->`

For example, the following expression:

```
on all A()or B() and not C() -> D()
```

is equivalent to this expression:

```
on (
   (all A() )
   or
   (B() and (not C() ))
   ) -> D()
```

Event channels

Adapter and client configurations can specify the channel to deliver events to. A channel is a string name that contexts and receivers can subscribe to in order to receive particular events. In EPL, you can send an event to a specified channel. Sending an event to a channel delivers it to any contexts that are subscribed to that channel, and to any clients or adapters that are listening on that channel.

You can use the `com.apama.Channel` type to send an event to a channel or context. The `Channel` type holds a string or a context. When it holds a string an event is sent to the channel that has that name. When it holds a context an event is sent to that context.

The default channel is the empty string. Events sent to the default channel and events sent without a channel specification are added to the input queue of each public context as well as each context that is processing queries.

You can use the `com.apama.queries` channel to send events to all contexts that process queries.

34 Monitors

A `.mon` file is a file that contains the source text for an optional package specification and one or more event declarations and/or monitor definitions. A file can consist entirely of event declarations without any monitors.

Note: Monitors and queries are the two main EPL programming units. A monitor cannot contain a query. A query cannot contain a monitor. Each unit offers a different approach to event processing. See "Architectural comparison of queries and monitors" on page 79.

A monitor is a group of related variable declarations and actions. An action is a group of related variable declarations and statements. An action can either be part of a monitor or part of an event declaration.

The executable statements (except for global variable initializers) are always inside an action. An action can be either a subprogram or a function. The difference is that a function has a return value and a subprogram does not.

Each file is injected whole or not at all; if some parts compile validly but others do not, nothing is injected and an error is returned. Injecting can also return warnings about the code injected. For example, use of keywords that may be reserved in the future.

Monitor lifecycle

Monitors are compiled and run (executed) by the Apama correlator. The correlator starts executing in the monitor's `onload()` action. To execute a monitor, you load (inject) it into the correlator. The correlator then does the following:

1. Compiles the monitor's source text
2. If no errors are detected, creates the main monitor instance along with its global variables
3. Invokes the monitor instance's `onload()` action

When the `onload()` action has executed to completion (that is, the control path reaches the closing curly brace of the `onload()` action), if the monitor instance has event listeners or streaming networks, then it remains active but in a suspended state.

The correlator calls the monitor instance's event listeners whenever it detects events that match the event listeners' event expressions.

A monitor instance terminates when one of the following events occurs:

- The monitor instance executes a `die` statement in one of its actions.
- A runtime error condition is raised.
- The monitor is terminated externally (for example, with the `engine_delete` utility.
- The monitor instance has executed all its code and there are no remaining listeners or streaming networks. This will occur rapidly if the `onload()` action does not create any.

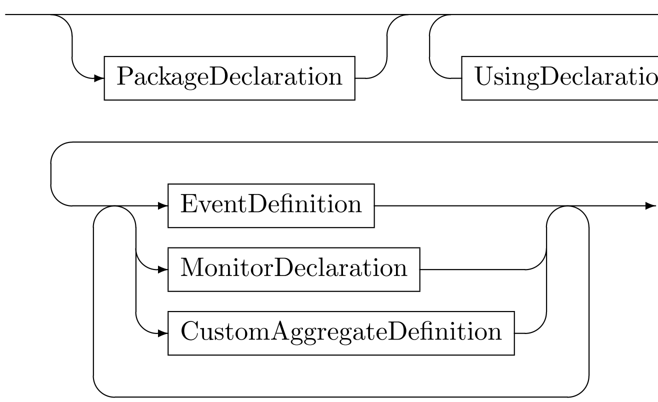
When a monitor instance terminates, the correlator does the following:

1. Invokes the monitor instance's `ondie()` action, if it is defined.
2. If the monitor instance that is terminating is the last active instance of that monitor, the correlator also does the following:
   - Invokes the monitor's `onunload()` action if it is defined.
   - Removes the monitor's code from the correlator.
   - Frees all the monitor's resources.

To summarize, consider that when a monitor spawns monitor instances, there is a set of monitors that includes the original monitor instance and any spawned monitor instances. As the monitor instances in this set terminate, the correlator calls the `ondie()` action, if it is defined, for each monitor instance that terminates. When the last monitor instance in the set terminates, the correlator also calls the `onunload()` action. Thus, the correlator calls `ondie()` once for each monitor instance in the set, and calls `onunload()` only once for the entire set.

Monitor files

An EPL monitor file contains an optional `package` declaration, optional `using` declaration, `event` declarations and/or `monitor` declarations and/or custom aggregate definitions.



Packages

A package declaration provides a scope for events and/or monitors, and/or queries.

Example:

```
package com.myCorporation.myproject;
```

See "Names" on page 929 for further information.

The using declaration

The `using` declaration lets you use a type in a package other than the package the type was defined in without having to specify the fully qualified name of the type.

Insert a `using` declaration (after the optional `package` declaration and before any other declarations) that specifies the fully qualified name of the type. For example:

```
using com.myCorporation.custom.myCustomAggregate;
```

You can specify multiple `using` declarations in a file.

In a file, you cannot specify two `using` declarations that bring in types that have the same base name. See also "Name Precedence" on page 929.

You cannot specify a `using` declaration for named objects such as monitors, JMon monitors, and namespaces.

A `using` declaration can be in a monitor or in a query.

Monitor declarations

Specify `persistent` when you want a persistence-enabled correlator to save the state of the monitor in a recovery datastore on disk. In a monitor, `import` declarations, `event` declarations, variable declarations, and `action` definitions can be freely mixed in any order. For detailed information, see "Defining Monitors" on page 49.

A monitor can be optionally prefixed (before the `persistent` keyword) with annotations. See also "Annotations" on page 930.

The import declaration

The `import` declaration loads a plug-in library and makes it available to an EPL program. Plug-in libraries are shared libraries on Linux and UNIX systems and Dynamic Link Libraries on Windows systems.

On Linux and UNIX systems, the library is loaded from a `libPlugInName.so` file located in one of the directories listed in the environment variable `LD_LIBRARY_PATH`. On Windows, the library is loaded from a `PlugInName.dll` file located in the `bin` folder.

You can name a plug-in. The plug-in name is a library filename, not a full filepath, and is not allowed to contain any of the characters used as directory or device separators (forward slash, colon, or backslash).

You can also give the plug-in an identifier (an alias name) for use in the EPL program when you call the library's actions.

For example, to call a plug-in action `foo()` in the plug-in library `wffftl.so` or `wffftl.dll`, you would write the following:

```
monitor m {
   import "wffftl" as fft;
   action onload()
```

```
    {
       sequence <float> data := [];
       fft.foo (data);
    }
}
```

For detailed information, see "Using Correlator Plug-ins in EPL" on page 355.

Monitor actions

Monitors can have two forms of actions: simple actions and actions with parameters and/or return values. These types of actions are discussed in the topics below.

Monitor actions can optionally be prefixed with annotations. See "Annotations" on page 930.

Simple actions

A simple action has a name and a body consisting of a block. The body contains the executable code of the action. There are no parameters.

The action names given in the table below have special meaning in a monitor. These actions are invoked automatically when certain events in a monitor's life cycle occur. Apama recommends that you do not use these names in queries.

A block must follow the action name. Note that there are no formal parameters in this form of action definition and the action cannot return a value.

Action	Description
`onload()`	This action is invoked immediately after a monitor has been loaded. This action must be present in every monitor.
`ondie()`	If present, this action is invoked by the correlator when a monitor instance terminates.
`onunload()`	If present, this action is invoked by the correlator after all instances of a monitor have terminated, just before the last monitor instance is unloaded.
`onBeginRecovery()`	If present, this action is invoked by the correlator during recovery of a persistence-enabled correlator. The correlator executes `onBeginRecovery()` on monitors and any live events after it reinjects source code and restores state in persistent monitors.

Action	Description
`onConcludeRecovery()`	If present, this action is invoked by the correlator during recovery of a persistence-enabled correlator. The correlator executes `onConcludeRecovery()` on monitors and any live events before it begins to send clock ticks.

Actions with parameters

An action can take an optional list of parameters.

Formal parameters

The formal parameters are a comma-separated list of type name and identifier pairs.

The identifier is the name of a parameter variable that will be bound to a copy of the value of an expression specified by the caller (that is, the value passed by the caller) when the action is invoked. The number and type of actual parameters passed by a caller must match those listed in the action's formal parameters.

The scope of a parameter variable is the statement or block that forms the action body. Parameter variables are very similar to an action's local variables.

Action return value

If you specify a `returns` clause, then the action must return a value whose type matches that specified in the `returns` clause. You specify the return value by using a `return` statement and result expression within the action. Every control path (see "Transfer of control statements" on page 888) within the action body must lead to a `return` statement with a result expression of the correct type.

Action body

After the `returns` clause (or after the formal parameters if there is no `returns` clause), a statement forms the action body. The action body can be a single statement or a block.

Within the action body, you use the parameter variable names to obtain the values that are passed to the action by its caller.

Contexts

Contexts allow EPL applications to organize work into threads that the correlator can concurrently execute. For detailed information, see "Implementing Parallel Processing" on page 303. This also provides information on the properties of a context (see "About context properties" on page 305).

Note: In monitors, you must implement the use of contexts. In queries, the use of contexts is automatically done for you.

You can create any number of contexts. Creating a context just allocates an ID and creates a small object. See also "Creating contexts" on page 306.

For information on how to obtain a reference to a context, see "Obtaining context references" on page 308.

Plug-ins

EPL can be extended through the use of plug-ins, which are modules written either in C ++, C, or Java and loaded dynamically into the EPL runtime with the `import` statement. Plug-in modules are invoked in exactly the same way as actions in an EPL event.

See "Using Correlator Plug-ins in EPL" on page 355.

Garbage collection

EPL, like languages such as Java or C#, relies on garbage collection. Intermittently, the correlator analyses the events that have been allocated, including dictionaries, sequences, closures and streaming networks, and allows memory used by events that can no longer be referenced to be re-used. Thus, the actual memory usage of the correlator might be temporarily above the size of all live objects. While running EPL, the correlator might wait until a listener or `onload()` action completes before performing garbage collection. Therefore, any garbage generated within a single action or listener invocation might not be disposed of before the action/ listener has completed. It is thus advisable to limit individual actions/listeners to performing small pieces of work. This also aids in reducing system latency.

The cost of garbage collection increases as the number of events a monitor instance creates and references increases. If latency is a concern, it is recommended to keep this number low, dividing the working set by spawning new monitor instances if possible and appropriate. Reducing the number of event creations, including string operations that result in a new string being created, also helps to reduce the cost of garbage collection. The exact cost of garbage collection could change in future releases as product improvements are made.

35 Queries

An Apama query is a self-contained processing element that communicates with other queries, and with its environment, by sending and receiving events. Queries are designed to be multithreaded and to scale across machines.

Note: Queries and monitors are the two main EPL programming units. A query cannot contain a monitor. A monitor cannot contain a query. Each unit offers a different approach to event processing. See "Architectural comparison of queries and monitors" on page 79.

You use Apama queries to find patterns within, or perform aggregations over, defined sets of events. For each pattern that is found, an associated block of procedural code is executed. Typically this results in one or more events being transmitted to other parts of the system.

A query is defined in a `.qry` file. A query finds specified event patterns or aggregates event values.

Apama queries are useful when you want to monitor incoming events that provide information updates about a very large set of real-world entities such as credit cards, bank accounts, or cell phones. Typically, you want to independently examine the set of events associated with each entity, that is, all events related to a particular credit card account, bank account, or cell phone. A query application operates on a huge number of independent sets with a relatively small number of events in each set.

The following topics provide reference information for the parts of a query definition. For user guide type information, see "Defining Queries" on page 75.

Query lifetime

You inject queries into a running correlator with the Apama macros for Ant, (`install_dir\etc\apama-macros.xml`) or with Software AG Designer. You can delete queries from a running correlator by performing a delete operation and specifying a query name. You can use the same tools that you use to delete monitors: `engine_delete` utility, Software AG Designer, Apama macros for Ant (`apama-macros.xml`), or `deleteName()` method on the engine client API.

If you are using a cluster of correlators, it is your responsibility to inject each query into each correlator in the cluster, and to delete a query from each correlator in a cluster. This keeps deployed queries in sync across the cluster. In other words, injecting or deleting a query on one host in a cluster does not automatically inject or delete the query on the other cluster members.

Unlike monitors, the lifetime of query instances is either automatic (for non-parameterized queries) or controlled by the Scenario Service (for parameterized queries). There are no `spawn` or `die` equivalents in queries, and you cannot use these EPL statements in queries.

When a non-parameterized query is injected, a single instance of the query is automatically created at injection time and it begins processing events. You cannot use the Scenario Service API to edit or delete this single instance or to create new instances. For parameterized queries, after injection, only the query definition is created automatically. The query does not start processing events specified in its `inputs` section until at least one parameterization is created by means of the Scenario Service. You can control this by using a dashboard or scenario browser. The Scenario Service has methods to create new query instances, edit instances and delete instances.

When using a cluster of correlators, the parameterizations are kept in sync across all members of the cluster. Creating a query instance while connected to one cluster member will create it on all members. The instance can be edited or deleted by any client connected to any member. There may be short delays in replicating parameterization data on each cluster member because this happens asynchronously. However, the recommendation is to edit or delete a particular parameterization from Scenario Service clients that are all connected to the same correlator. This ensures that edit and delete operations are performed in the same order on every cluster member. If you try to edit or delete the same parameterization from different cluster members the results are unpredictable.

If a query executes code in a `where` clause, aggregate or other expression that results in an exception due to the current values in the window, the query ignores the exception and continues running. For example, an attempt to divide an integer by zero causes an `ArithmeticException`. If a query experiences an exception that means it cannot continue (such as repeated exceptions while trying to retrieve or store window data), then the query instance will enter the failed state, which will be reported by the Scenario Service. In this case, the query does not process additional events. The correlator log file should contain information that explains why the query failed. The problem that caused the failed state needs to be corrected. After correcting the problem, if the query is a parameterized query, you should delete the failed parameterization and then re-create it. For a non-parameterized query, you must delete and then re-inject the query.

When a query is deleted with the `engine_delete` utility or equivalent, all instances of the query are terminated and the Scenario Service will reflect that the query definition has been unloaded. The query can be re-injected, if needed. Remember that deletions and injections must be performed on every member in a cluster.

Lifetime of find statements

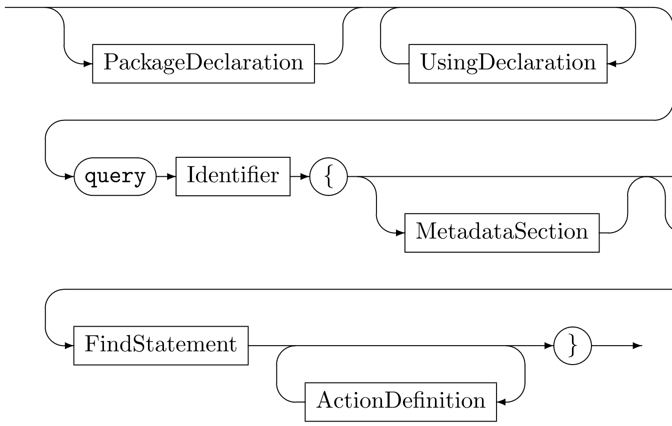
As long as a query is active, the `find` statement in a query is active for each value of the key that is specified in the query's `inputs` section. Thus, `find A:a` in a query is similar to `on all A():a` in a monitor. The `find` statement generates a match set each time the latest event causes a match. If the `find` statement specifies any aggregates and the `every` modifier, which can only be used with aggregates, then each new match set causes the `find` statement to add to the aggregate.

In monitors, listeners can match either the first set of matching events, or specify the `all` operator to fire for every set of matching events. For example, `on A():a -> B():b` fires on the first `A` and `B` events, while `on all A():a -> all B():b` fires for every combination of an `A` event with a later `B` event. In a query, `find A:a -> B:b` fires on every `B` event after an `A` event if an `A` event is still in the window defined in the `inputs` section. The match set contains the most recent `A` event and the most recent `B` event. The following table provides examples. The assumption is that all input events remain in the query's window.

Input events	Query match sets for: find A:a -> B:b	Query match sets for: find every A:a -> B:b select... - inputs to aggregates	Monitor match sets for: on A():a -> B():b	Monitor match sets for: on all A():a -> all B():b
A(1)				
B(1)	A(1), B(1)	A(1), B(1)	A(1), B(1)	A(1), B(1)
A(2)				
B(2)	A(2), B(2)	A(1), B(1) A(1), B(2) A(2), B(2)		A(1), B(2) A(2), B(2)
B(3)	A(2), B(3)	A(1), B(1) A(1), B(2) A(2), B(2) A(1), B(3) A(2), B(3)		A(1), B(3) A(2), B(3)

Query definition

A query searches for an event pattern that you specify. You define a query in a file with the extension `.qry`. Each `.qry` file contains the definition of only one query.



If specified, any `package` or `using` statements must be before the `query` declaration. See "Packages" on page 847 and "The using declaration" on page 848.

You must specify an identifier for the query name. See "Identifiers" on page 919. The convention for specifying the name of a query is to use UpperCamelCase, as shown in the example below.

Specification of metadata is optional. See "Metadata section" on page 858. The convention for specifying the key in the key-value pair of the metadata is to use lowerCamelCase as shown in the example below.

Specification of query parameters is optional. See "Parameters section" on page 858.

An `inputs` section is required. It specifies at least one event type. These are the event types that the query operates on. See "Inputs section" on page 858.

The `find` statement is required. It specifies the event pattern of interest and a block that contains procedural code. See "Find statement" on page 860.

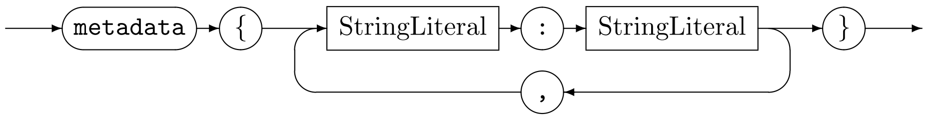
Action definitions, in the same form as actions in events, are optional. See "Event actions" on page 828.

Example:

```
query ImprobableWithdrawalLocations {
    metadata {
        "author":"Apama",
        "version":"1"
    }
    parameters {
        float period;
    }
    inputs {
        Withdrawal() key cardNumber within (period);
    }
    find
        Withdrawal:w1 -> Withdrawal:w2
        where w2.country != w1.country {
        log "Suspicious withdrawal: " + w2.toString() at INFO;
    }
}
```

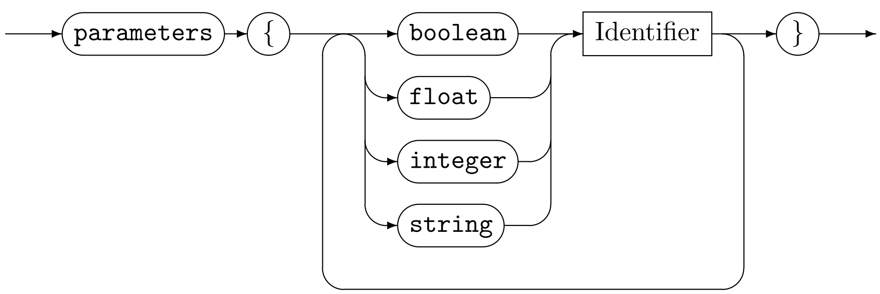
Metadata section

In a query, the optional `metadata` section specifies a list of key-value pairs. If there is a `metadata` section, it must be the first section in the query. See "Defining metadata in a query" on page 88 for further information.



Parameters section

In a query, the optional `parameters` section specifies any parameters used by the query. If there is a `parameters` section, it must follow the `metadata` section, if defined, and it must precede the `inputs` section. Parameter values are available throughout a query. See "Implementing parameterized queries" on page 146 for further information.



Inputs section

In a query, the required `inputs` section specifies the events that the query operates on.

At least one input definition is required. Typically, no more than four input definitions are specified.

If there is a `parameters` section, then the `inputs` section follows it. The `inputs` section must be before the `find` statement.

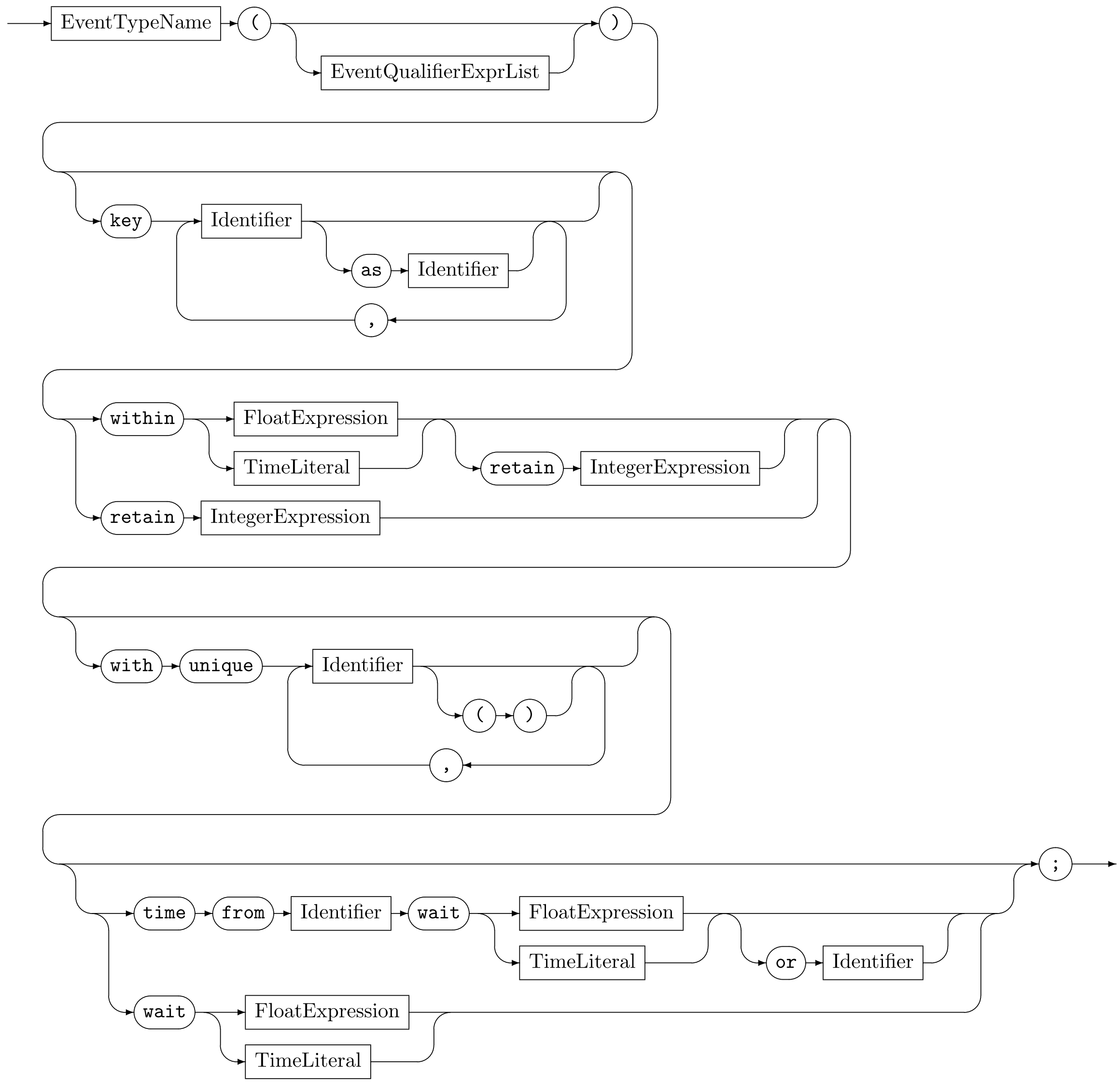
Example:

```
inputs {
   A() key k retain 20;
   B() key k retain 10;
}
```

For more information, see "Defining query input" on page 94.

Query input definition

In a query, the required `inputs` section must contain at least one input definition.



An event type you specify must be parseable. See "Type properties summary" on page 811. Event type names can come from the root namespace, a `using` declaration, or a local package as specified in a `package` declaration.

Event filters are optional. Specifying a filter here determines which events are added to a query window. The rules for what you can specify for the event filter are the same as for what you can specify in an event template in EPL. See "Event templates" on page 830.

Specification of a key is optional, but rarely omitted. If there is no key specification, all events are in one partition. The correlator uses the key to partition events. Each partition is identified by a unique key value. Specify one or more fields that are in the input event type. One or two fields in a key is typical. Three fields in a key is unusual and rarely needed. More than three fields is discouraged. If you define more than one input in a query

- The number, type, and order of the key fields in each input definition must be the same.
- If the names of the key fields are not the same in each input definition, you must insert the `as` keyword to specify aliases so that the names match. For details, see "About keys that have more than one field" on page 93.

A `retain` clause or a `within` clause is required. Alternatively, you can specify both.

A `retain` clause indicates how many events to hold in the window. Follow the `retain` keyword with a positive `integer`. If you specify a negative integer or zero, it is a runtime error that terminates the query.

A `within` clause indicates the length of time that an event stays in the window. Follow the `within` keyword with a positive `float` expression or a time literal. If you specify a negative `float` value or zero it is a runtime error that terminates the query.

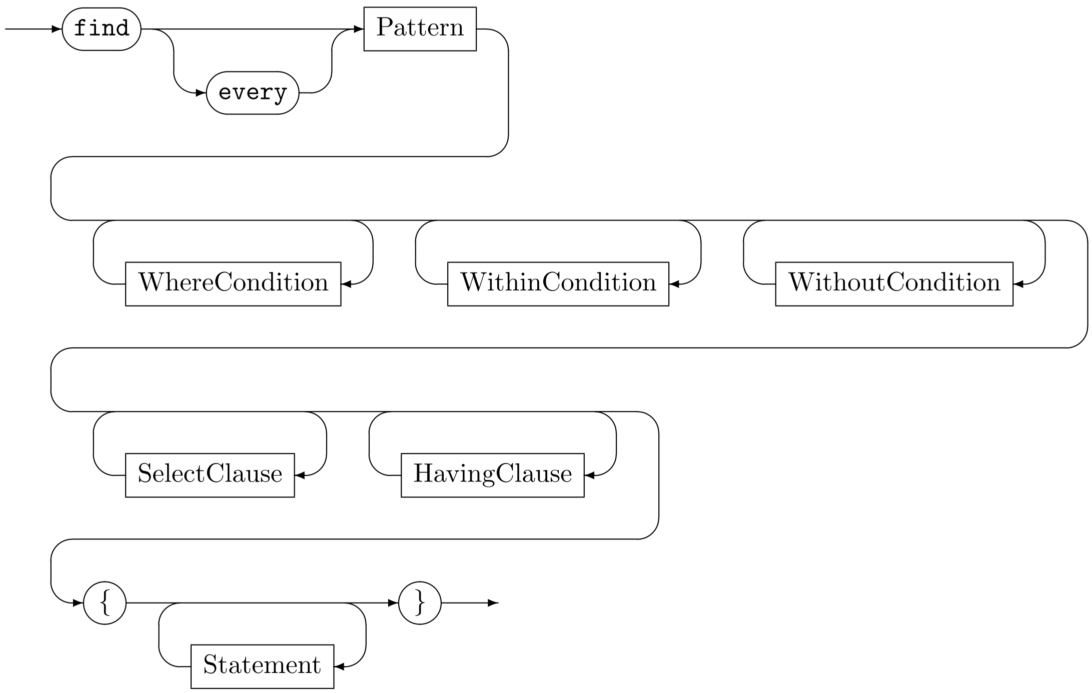
For information on other clauses, see "Format of input definitions" on page 97.

Examples:

```
inputs {
   Withdrawal(amount > 500) key userId within 1 hour;
 }
inputs {
   APNR() key road within(150.0);
   Accident() key roadName as road within(10.0);
}
```

Find statement

A query `find` statement tries to find a match for the event pattern that the `find` statement specifies. When the query finds a match it executes the EPL in the `find` statement block.



When a `find` statement specifies a `select` or `having` clause, the `every` modifier is required. Conversely, you cannot specify the `every` modifier if you do not specify a `select` or `having` clause.

When a `find` statement specifies the `every` identifier, the identifiers in the `select` clause are available in the `having` clause and in the `find` block, but the coassignments in the pattern are not available.

Pattern coassignments are available in a `where` clause that applies to the pattern.

When you do not specify the `every` modifier, all pattern coassignments, except a `without` clause coassignment, are available in the `find` block.

In a `where` clause that is part of a `without` clause, pattern coassignments as well as the coassignment in the `without` clause are available.

Example:

```
find Withdrawal:w1 -> Withdrawal:w2
   where w1.country = "UK" and w2.country = "Narnia" {
      // Recent card fraud in Narnia against UK customers
      emit SuspiciousWithdrawal(w2);
}
```

Pattern

In a query definition, the `find` statement specifies the event pattern of interest followed by a procedural block that specifies what you want to happen when a pattern match is found.

A coassignment variable specified in an event pattern is within the scope of the `find` block and it is a private copy in that block. Changes to the content that the variable points to do not affect any values outside the query. Unlike EPL event expressions, you need not declare this identifier before you coassign a value to it.

In an event pattern in a `find` statement, each coassignment variable identifier must be unique. You must ensure that an identifier in an event pattern does not conflict with an identifier in the `parameters` section or `inputs` section.

If a pattern specifies a `wait` operator, then it must be at the beginning of a pattern, at the end of a pattern, or both. It cannot be in the middle of a pattern. The followed-by operator must be after or before each instance of the `wait` operator. For example:

```
wait(1):w -> (A:a and B:b)                // Allowed
{(A:a and B:b) -> wait(1):w }             // Allowed
wait(1):w1 -> (A:a and B:b) -> wait(1):w2 // Allowed
wait(1):w and A:a                         // Not allowed
A:a -> wait(1):w -> B:b                   // Not allowed
```

A `wait` operator must specify a positive `float` value or a time literal. A `float` value always indicates a number of seconds.

Optionally specify `and` or `->` and then specify an *`event_type`* and coassignment variable. Parentheses are allowed in the pattern specification and you can specify multiple operators, each followed by an *`event_type`* and coassignment variable. For example, the following is a valid `find` statement:

```
find (A:a1 -> ((A:a2)) -> (A:a3) ->
    (A:a4 -> A:a5 -> A:a6) ->
    (((A:a7) -> A:a8) -> A:a9) -> A:a10 {
    print "query with 10: "+a1.toString()+ " - "+a10.toString();
}
```

Where condition

A `find` statement can specify a `where` clause that filters which events match the specified event pattern.

Note: You can specify a find `where` clause that applies to the event pattern, and you can also specify a without `where` clause that is part of a `without` clause. Any `where` clauses that you want to apply to the event pattern must precede any `within` or `without` clauses.

Specify the `where` keyword followed by a Boolean expression that refers to the events you are interested in. The Boolean expression must evaluate to true for the events to match.

The `where` clause is optional. You can specify zero, one or more `where` clauses.

Coassignment variables specified in the `find` or `select` statements are in scope in a find `where` clause. Also available in a find `where` clause are any parameter values and key values.

Example:

```
find Withdrawal:w1 -> Withdrawal:w2
   where w2.country != w1.country {
   log "Suspicious withdrawal: " + w2.toString() at INFO;
}
```

Within condition

In a find statement, a within clause sets the time period during which all events in the match set or some events in the match set must have been added to their windows.

A pattern can specify zero, one, or more within clauses. These must appear after any find where clauses and before any without clauses.

Specify the within keyword followed by a float expression or a time literal, which indicates the time period during which the events in the match set must be received.

Optionally, specify a between clause to indicate that the time constraint applies to only some of the events in the match set. See "Between clause" on page 864.

Example:

```
find LoggedIn:lc -> OneTimePass:otp
   where lc.user = otp.user
   within 30.0 {
      emit AccessGranted(lc.user);
}
```

Without condition

In a find statement, a without clause specifies an event type whose presence prevents a match.

Specify the without keyword followed by an event type coassigned to an identifier.

An event type that you specify in a without clause must be specified in the inputs block of the query. A pattern can specify zero, one, or more without clauses.

Optionally, after each without clause, you can specify one where clause, which is referred to as a without where clause to distinguish it from a find where clause. When a where clause is part of a without clause:

- The Boolean expression must evaluate to true for the presence of the specified event to prevent a match. In other words, when the Boolean expression evaluates to false then there can be a match even when the specified event is in the window.
- The where clause applies to the event specified in its without clause.
- The Boolean expression can refer to parameters, coassignment identifiers in the event pattern, and the coassignment identifier in the without clause.

A without clause cannot use the -> or and pattern operators. However, you can specify multiple without clauses. If there are multiple without clauses each one can refer to only its own coassignment and not coassignments in other without clauses. However, all without clauses can make use of the pattern's standard coassignments.

If there are multiple without clauses, a matching event for any one of them prevents a pattern match. Multiple without clauses can use the same type and the same coassignment, which is useful only when their where conditions are different.

Typically, a without `where` clause references the event in its `without` clause, but this is not a requirement.

Optionally, after each `without` clause, you can specify a `between` clause, which lists two or more coassigned events or `wait` operators. For an event to cause a match, the type specified in the `without` clause cannot be added to the window between the points specified in the `between` clause. See "Between clause" on page 864.

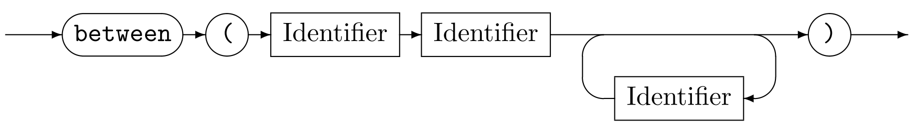
Any `without` clauses must be after any find `where` clauses and `within` clauses. If you specify both optional clauses, the without `where` clause must be before the `between` clause.

Example:

```
find OuterDoorOpened:od -> InnerDoorOpened:id
   where od.user = id.user
   without SecurityCodeEntered:sce where od.user = sce.user {
      emit Alert("Intruder "+id.user);
}
```

Between clause

In a `within` clause and in a `without` clause, an optional `between` clause restricts which part of the pattern the `within` or `without` clause applies to.



Specify the `between` keyword followed by two or more identifiers that are specified in the event pattern. Enclose the identifiers in parentheses.

The identifiers set a period of time that starts when one of the specified events is received and ends when one of the other specified events is received. The range is exclusive. That is, the range applies only after the first event is received and before the last event is received.

A `between` clause is the only place in which you can specify a coassignment identifier that was assigned in a `wait` clause. You cannot specify identifiers used in a `without` clause. Also, the same event cannot match both the coassignment identifier in the `without` clause and an identifier in a `between` clause.

The condition that the `between` clause is part of must occur in the range of identifiers specified in the `between` clause.

It is illegal to have two `within` clauses with identical `between` ranges. This would be redundant, as only the shortest `within` duration would have any effect. It is, however, legal to have more than one `without` clause with the same `between` range. Typically, these would refer to different event types or `where` conditions.

Example:

```
find A:a -> B:b -> (C:c and D:d)
   within 10.0 between (a b)
   within 10.0 between (c d)
```

See "Query condition ranges" on page 136 for an explanation of this example.

Select clause

A find statement that specifies the every keyword can specify a select clause to calculate an aggregate value in order to find data based on many sets of events.

Specify the select keyword followed by a projection expression coassigned to an identifier. The projection expression contains aggregate function(s) that operate on one or more input events. See "Built-in aggregate functions" on page 870 as well as "Custom aggregates" on page 876.

The projection expression can use coassignments from the pattern if the coassignments are within a single aggregate function call. For example, the following pattern computes the average value of the x member of event type A in the query's input and coassigns that average value to aax.

```
find every A:a select avg(a.x):aax
```

A select clause can use parameter and key values.

In an aggregating find statement, only the projection expression can use the coassignments from the pattern. The procedural block of code can use projection coassignments and any parameters or key values, but it cannot use coassignments from the pattern.

In find statements without the every modifier, only the most recent set of events that match the pattern are used to invoke the procedural code block. With the every modifier, every set of events that matches the pattern is available for use by the aggregate function, provided that the latest event is present in one of the sets of events. Any events or combinations of events that do not match the pattern or do not match the where clause, or are invalidated due to a within or without clause, are ignored; their values are not used in the aggregate calculation.

Examples:

```
find every ATMWithdrawal:w
   select last(w.transactionId):tid
   having last(w.amount) > THRESHOLD * avg(w.amount) {
   route SuspiciousTransaction(tid);
}
find every A:a -> B:b
   where b.x >= 2
   select avg(a.x + b.x):aabx {
   print aabx.toString();
}
```

See "Aggregating event field values" on page 139 for explanations of these examples, as well as additional examples.

Having clause

A find statement that specifies the every keyword can specify a having clause to restrict when procedural code is invoked.

Specify the `having` keyword followed by a Boolean projection expression. The Boolean projection expression refers to an aggregate calculation. Procedural code is executed only when the Boolean projection expression evaluates to true.

You can specify zero, one, or more `having` clauses. When you specify more than one `having` clause, it is equivalent to specifying the `and` operator. That is, each Boolean projection expression must evaluate to true for the procedural code to be executed.

A `having` clause can refer to an aggregate value by using the `select` coassignment name.

When you want to test for an aggregate condition but you do not want to use the aggregate value, you can specify a `having` clause without specifying a `select` clause.

Examples:

```
find every A:a
   select avg(a.x):aax
   having aax > 10.0 {
   print aax.toString();
}
find every A:a
   having avg(a.x) > 10.0 {
   print "Average value is greater than ten!";
}
```

Reserved words in queries

In a query, the following are reserved words, also referred to as keywords. To use one of these words as an identifier in a query, you must escape it. For details see "Escaping keywords to use them as identifiers" on page 923.

- `as`
- `between`
- `every`
- `find`
- `having`
- `inputs`
- `key`
- `parameters`
- `query`
- `retain`
- `select`
- `where`
- `within`

- `without`

36 Aggregate Functions

In Apama queries and in EPL stream queries, you can specify aggregate functions in the `select` clause. An aggregate function calculates a single value across all items currently in the window. EPL provides a number of commonly used aggregate functions. If a supplied aggregate function does not meet your needs, you can define a custom aggregate function.

See "Select clause" on page 865 for information about the `select` clause in Apama queries.

See also "Stream queries" on page 903.

Built-in aggregate functions

EPL provides the built-in aggregate functions listed in the table below. All of these functions are available for either bounded or unbounded use.

How to make use of the built-in aggregate functions

The built-in aggregate functions reside in the `com.apama.aggregates` package. To use a built-in aggregate function in a query, you must do one of the following:

- Specify the full name of the aggregate function. For example:

  ```
  select com.apama.aggregates.sum(x)
  ```

- For each aggregate function you want to use in your code, add a `using` statement. This lets you specify aggregate function names without specifying the package name. For example:

  ```
  using com.apama.aggregates.mean;
  using com.apama.aggregates.stddev;
  ...
  ...select MeanSD( mean(s), stddev(s) );
  ```

  Insert the `using` statement after the optional package declaration and before any other declarations in the `.mon` file.

Overview of the built-in aggregate functions

The argument names (for example, *`value`* and *`weight`*) in the following table are placeholders for expressions. Additional information about some of these functions is provided after the table.

Aggregate Function	Argument Type	Return Type	Result Description

`avg(`*`value`*`)`
or
`mean(`*`value`*`)`
	`decimal` or `float`	Same as *`value`*	The arithmetic mean of the values in the window. The `avg()` and `mean()` functions do exactly the same

Aggregate Function	Argument Type	Return Type	Result Description
			thing. They are aliases for each other.
`count()`	*no argument*	`integer`	The number of items in the window, including any not-a-number (NaN) items.
`count(`*`predicate`*`)`	`boolean`	`integer`	The number of items for which the argument is true. You can specify, for example, `count(value != "")`. The predicate expression is re-evaluated each time.
`countUnique(`*`value`*`)`	`string`	`integer`	The number of unique strings within the window.
`first(`*`value`*`)`	`decimal`, `float`, `integer`, `string`, `boolean` or `location`	Same as *`value`*	The earliest value in the window being aggregated over.
`last(`*`value`*`)`	`decimal`, `float`, `integer`, `string`, `boolean` or `location`	Same as *`value`*	The latest value in the window being aggregated over.
`max(`*`value`*`)`	`decimal`, `float` or `integer`	Same as *`value`*	The maximum value.
`min(`*`value`*`)`	`decimal`, `float` or `integer`	Same as *`value`*	The minimum value.

Aggregate Function	Argument Type	Return Type	Result Description
`nth(`*`value`*`,`*`index`*`)`	`decimal`, `float`, `integer`, `string`, `boolean` or `location` for the *`value`* `integer` for the *`index`*	Same as *`value`*	The value of the specified item in the *`index`* position, starting with the earliest item in the window (item 0) and moving toward the latest item. `nth(`*`value`*`,0)` returns the same item as `first(`*`value`*`)`. A negative *`index`* gets the items from the end of the window (`-1` means the last item, `-2` means the second last item, and so on).
`percentile(`*`value`*`,`*`rank`*`)`	`float` or `decimal` for *`value`* `float` for *`rank`*	Same as *`value`*	The value that `r` percent (`0<= r <= 100`) of the data in the window is equal-to or less-than.
`stddev(`*`value`*`)`	`decimal` or `float`	Same as *`value`*	The standard deviation of the values.
`stddev2(`*`value`*`)`	`decimal` or `float`	Same as *`value`*	The sample standard deviation of the values.
`sum(`*`value`*`)`	`decimal`, `float` or `integer`	Same as *`value`*	The sum of the values.
`wavg(`*`value`*`,`*`weight`*`)`	`decimal,decimal` or `float,float`	Same as *`value`*	The weighted average of the values where each value is weighted by

Aggregate Function	Argument Type	Return Type	Result Description
			the corresponding weight.

Calculations by the built-in aggregate functions might be affected by underflow and overflow. For example, adding a very large number to the collection that the `sum()` function operates on, then adding a very small number, and then removing the very large number will probably result in `0.0`, and not the very small number. Just adding the very small number would result in behavior that you would expect. As with the rest of EPL, the overflow and underflow characteristics are as defined for IEEE 64-bit floating point numbers.

Deprecated built-in aggregate functions

The following functions are deprecated. It is recommended that you use the alternative functions mentioned in the table below.

Aggregate Function	Argument Type	Return Type	Result Description
`count(`*`value`*`)`	`decimal` or `float`	`integer`	The number of items where the `decimal` or `float` value is not NaN. Use the alternative predicate aggregate function `count(not value.isNaN())` instead.
`prior(`*`value`*`,`*`index`*`)`	`decimal`, `integer` or `float`, `integer`	Same as *`value`*	The value of the specified `decimal` or `float` item in the *`index`* position, starting with the most recent item in the window (item 0) and moving toward the earliest item. `prior(`*`value`*`,0)` returns the same item as `last(`*`value`*`)`. Use the alternative function `nth(`*`value`*`,`*`index`*`)` instead.

Positional functions

For the `first()`, `last()`, `nth()`, and `prior()` (deprecated) functions, all values (`NaN`, `+-`, ∞, and so on) are treated the same, and position in the window is the only thing that matters.

Operating on empty windows

Except for the `sum()` and `count()` functions, if the window being aggregated over is empty or insufficiently large, then the result is not-a-number (NaN). The `sum()` and `count()` functions return zero if the window is empty.

IEEE special values in aggregate functions

Several of the built-in aggregate functions take `decimal` or `float` arguments. It is possible for a `decimal` or `float` value to be one of the following:

- Positive infinity
- Negative infinity
- Not-a-number (NaN)
- A finite number

The positional aggregates `first()`, `last()`, `nth()` and `prior()` (deprecated) are agnostic to the values in them and return the selected item regardless of its value. If the selected item does not exist (for example, selecting the fifth item from a window of three items), then the aggregate returns `NaN`. The index for `nth()` and `prior()` (deprecated) must not be negative. If it is, the correlator terminates the monitor instance.

All the remaining (arithmetic) aggregate functions that take `float` or `decimal` arguments ignore any NaN items that are in the window being aggregated. The result is the aggregate of the window without the NaN items. If you want to count all items including NaN items, then use the `count()` aggregate function that takes no arguments.

The behavior of arithmetic aggregate functions over windows that contain positive and negative infinities varies depending on the particular function. The result is either an infinity, NaN or a finite value. The table below shows for a window containing one or more positive infinities and no negative infinities, one or more negative infinities and no positive infinities, or at least one positive and at least one negative infinity, which aggregate function gives which result. In the case of the `wavg()` function, the result depends on whether the infinity is the value or the weight.

Input	Outputs Positive Infinity	Outputs Negative Infinity	Outputs NaN	Outputs Finite Value

Positive Infinity	`max()`
	`mean()`
	`sum()`
			`stddev()`
			`wavg(`*`weight`*`)`
				`min()`

Input	Outputs Positive Infinity	Outputs Negative Infinity	Outputs NaN	Outputs Finite Value
	`wavg(value)`			

Negative Infinity		`mean()`
		`min()`
		`sum()`
		`wavg(value)`
			`stddev()`
			`wavg(weight)`
				`max()`

Both	`max()`	`min()`	`mean()`
			`stddev()`
			`sum()`
			`wavg(value)`	

The following table shows the results for the `percentile()` function. The output depends on the input for the *`rank`*. As with the aggregate functions that are listed in the previous table, NaN inputs for the `percentile()` function are ignored and are not counted.

Input	Outputs Positive Infinity	Outputs Negative Infinity	Outputs NaN	Outputs Finite Value
Positive Infinity	If ordinal rank corresponds to a positive infinity value			If ordinal rank does not correspond to a positive infinity value
Negative Infinity		If ordinal rank corresponds to a negative infinity value		If ordinal rank does not correspond to a negative infinity value
Both	If ordinal rank corresponds to a	If ordinal rank corresponds to a	If ordinal rank lies between a negative	If ordinal rank does not correspond

Input	Outputs Positive Infinity	Outputs Negative Infinity	Outputs NaN	Outputs Finite Value
	positive infinity value	negative infinity value	infinity value and a positive infinity value	to a positive or negative infinity value

See also:

"Select clause" on page 865 for information about the `select` clause in Apama queries.

"Working with Streams and Stream Queries" on page 205

"Aggregating items in projections" on page 238

Custom aggregates

In an Apama query and in a stream query, you can specify an aggregate function in the `select` clause. If one of the supplied aggregate functions does not meet your needs, you can define a custom aggregate function for use in a `select` clause.

You define custom aggregate functions in a `.mon` file and outside of an event or a monitor. The aggregate function's scope is the package in which you declare it. To use custom aggregate functions in monitors and in Apama queries in other packages, specify the aggregate function's fully-qualified name, for example:

```
from a in all A() select com.myCorporation.custom.myCustomAggregate(a)
```

Alternatively, you can specify a `using` statement. See "The using declaration" on page 848.

Specify `bounded` when you are defining a custom aggregate function that will work with only a bounded window. That is, a stream query cannot specify `retain all`. Specify `unbounded` when you are defining a custom aggregate function that will work with only an unbounded window. That is, a stream query must specify `retain all`. Do not specify either `bounded` or `unbounded` when you are defining a custom aggregate function that will work with either a bounded or an unbounded window.

A custom aggregate function that you want to use in an Apama query must either be a `bounded` function or it must support both bounded and unbounded operation.

The name of a custom aggregate function must be unique within a package; you cannot overload it or define an event, monitor, or query with the same name as an aggregate function.

The list of formal parameters consists of zero or more comma-separated type/name pairs. Each pair indicates the type and the name of an argument that you are passing to the aggregate function. For example, `(float price, integer quantity)`.

The data type name must be an EPL type. This is the type of the value that your aggregate function returns.

The body of a custom aggregate function can contain fields that are specific to one instance of the custom aggregate function and actions to operate on the state.

Actions

In a custom aggregate function, the `init()`, `add()`, `remove()` and `value()` actions are special. They define how Apama queries and stream queries interact with custom aggregate functions.

- `init()` — If a custom aggregate function defines an `init()` action, it must take no arguments and must not return a value. The correlator executes the `init()` action once for each new aggregate function instance it creates in a query (stream query or Apama query).
- `add()` — A custom aggregate function must define an `add()` action. The `add()` action must take the same ordered set of arguments that are specified in the custom aggregate function signature. That is, the names, types, and order of the arguments must all be the same. The correlator executes the `add()` action once for each item added to the set of items that the aggregate function is operating on.
- `remove()` — A bounded aggregate function must define a `remove()` action. An unbounded aggregate function must not define a `remove()` action. If you do not specify either `bounded` or `unbounded`, the `remove()` action is optional. The `remove()` action must take the same ordered set of arguments as the `add()` action, followed by an argument of the type returned by `add()`, if any, and must not return a value. The correlator executes the `remove()` action once for each item that leaves the set of items that the aggregate function is operating on. The value that `remove()` is called with is the same value that `add()` was called with.
- `value()` — All custom aggregate functions must define a `value()` action. The `value()` action must take no arguments and its return type must match the return type in the aggregate function signature. The correlator executes the `value()` action as follows:
  - In an Apama query, once for each match set and returns the current aggregate value to the query.
  - In a stream query, once per batch per group and returns the current aggregate value to the query.

Custom aggregate functions can declare other actions, including actions that are executed by the above named actions. A custom aggregate function cannot contain a field whose name is `onBeginRecovery`, `onConcludeRecovery`, `init`, `add`, `value`, or `remove`, even if, for example, the custom aggregate function does not define a `remove()` action.

Fields

In the body of a custom aggregate function, you can define fields that are specific to the custom aggregate instance they are in.

37 Statements

Sequences of EPL statements define the steps that are performed by a program. They are executed in the order they are written: sequentially from top to bottom and left to right within a statement block. (For expressions, the evaluation order is affected by parentheses, associativity, and operator precedence.)

The order in which statements are executed is called the flow of control or the control path. Some statements can contain other statements enclosed within their structure and can be used to execute statements conditionally, thus altering the normal control path. You can use the `break`, `continue`, and `return` statements to change the normal control path.

A block is zero or more statements enclosed in curly braces. A block can be used wherever a single statement can be used. Variables declared in a block are able to be referenced only in the block in which they are declared, and only in statements that come after the variable's declaration.

Simple statements

Simple statements are statements that do not enclose other statements or statement blocks and that do not cause a transfer of control. They are executed in the order they are written.

The assignment statement

The assignment statement binds a value to a variable. The value is determined by evaluating the expression on the right side of the assignment operator `:=`. The result type of the expression must match the type of the variable. For variables of the reference types, the same value can be bound to more than one variable. See "Reference types" on page 785.

The emit statement

The `emit` statement publishes an event to a named channel of the correlator's output queue. If a channel name is not specified, then the event goes to the default channel whose name is the empty string (`""`). External receivers get events on the default channel only if they are subscribed to all channels.

Note: The `emit` statement will be deprecated in a future release. Use the `send` statement instead. See "The send . . . to statement" on page 884.

The first expression is an expression whose result type is either an event type or string. If the type is string, then the value of the string is assumed to be in the same format as that produced by the event's `toString()` method.

The expression following the keyword `to` must be of type `string` and is the name of the channel to which the event will be sent.

The `emit` method dispatches events to external registered event receivers. That is, the emit statement causes events to go out of the correlator. Active event listeners will not receive events that are emitted.

Events are emitted onto named channels. For an application to receive events from the correlator it must register itself as an event receiver and subscribe to one or more channels. Then if events are emitted to those channels they will be forwarded to it.

Channels effectively allow both *point-to-point* message delivery as well as through *publish-subscribe*. Channels can be set up to represent topics. External applications can then subscribe to event messages of the relevant topics. Otherwise a channel can be set up purely to indicate a destination and have only one application connected to it.

You cannot emit an event whose type is defined inside a monitor.

You cannot emit an event that has a field of type `action`, `chunk`, `listener`, or `stream`.

When you emit an event type that has a dictionary field, the items in the dictionary are sorted in ascending order of their key values.

The enqueue statement

The `enqueue` statement sends an event to the back of the input queue of each public context. The expression is evaluated and the resulting event is sent to all input queues of public contexts. If an input queue is full, then the enqueued event is saved on a temporary holding queue until the input queue has room for it. There is one temporary holding queue for all contexts. When an input queue is full, processing in the context that enqueued the event blocks until the enqueued event arrives on all public input queues.

Note that enqueued events are processed in the order they are enqueued.

The expression's result type must be an `event` type or `string`. When it is a string, the correlator parses it as an event.

Enqueued events are put on the back of the input queue, behind any externally sourced events already queued.

You cannot enqueue an event whose type is defined inside a monitor.

You cannot enqueue an event that has a field of type `action`, `chunk`, `listener`, or `stream`.

The enqueue . . . to statement

The `enqueue...to` statement sends an event to a context you identify.

Note: The `enqueue...to` statement is superseded by the `send...to` statement. The `enqueue...to` statement will be deprecated in a future release. Use the `send...to` statement instead. See "The send . . . to statement" on page 884.

You must enqueue an expression of type `event`, and the destination must be one of the following:

- `context` — The `enqueue...to` statement sends an event to the back of the input queue of the specified context. The expression is evaluated and the resulting event is sent to the input queue of only the specified context.
- `sequence<context>` — The `enqueue...to` statement sends a copy of the event to the back of the input queue of each context in the specified sequence. The expression is evaluated and the resulting event is sent to the input queue of all the contexts in the sequence.

  For example:

  ```
  sequence <context> ctxs := [ c1, c2, c3 ];
  Ping ping = Ping();
  enqueue ping to ctxs;
  ```

You cannot enqueue an event to a `com.apama.Channel` object that contains a context. You cannot enqueue an event to a dictionary of contexts. However, it is a common pattern to enqueue to a sequence generated by `dictionary.values()`. For example:

```
enqueue x to d.values;
```

If the target context's input queue is full the sending context blocks and waits for space on the queue unless doing so would cause a deadlock. See "Deadlock avoidance when parallel processing" on page 324.

Note that enqueued events are processed in the order they are enqueued. Enqueued events are put on the back of the input queue, behind any externally sourced events already queued.

You must create the context before you enqueue an event to the context. You cannot enqueue an event to a context that you have declared but not created. For example, the following code causes the correlator to terminate the monitor instance:

```
monitor m {
   context c;
   action onload()
   {
      enqueue A() to c;
   }
}
```

If you enqueue an event to a sequence of contexts and one of the contexts has not been created first then the correlator terminates the monitor instance. For details, see "Sending an event to a particular context" on page 312.

Enqueueing an event to a sequence of contexts is non-deterministic. For details, see "Sending an event to a sequence of contexts" on page 314.

In an `enqueue...to` statement, you cannot enqueue an event that has a field of type `action`, `chunk`, `listener`, or `stream`.

The expression statement

An expression that does not return a value can be used as a statement.

One would use an expression statement if the expression has desired side effects. For example, an action or method call can be used in this way.

To be used as a statement, an expression must return nothing.

The log statement

The `log` statement writes messages and accompanying date and time information to the correlator's log file, if one was specified when the correlator was started.

If there is no log file, then the message is written to the correlator's standard output stream `stdout`.

The expression that you log must be of type `string`. The value is written only if the current logging level in effect is a priority equal to or higher than the log level specified in the `log` statement, with the exception of `OFF`. If you do not specify a level, `CRIT`, the highest priority level, is used. At a log level equal to `OFF`, only logs explicitly set to this level will be written. For details, see "Logging and printing" on page 295.

For example:

```
log "Your message here" at INFO;
```

This EPL statement produces a log message that looks like this:

```
2010-07-11 09:08:49.200 INFO [3716] - MyMonitor[1] Your message here
```

The print statement

The `print` statement writes textual messages followed by a newline to the correlator's standard output stream — `stdout`. The expression you print must be of type `string`.

For example:

```
print "Your message here.";
```

This EPL statement produces output that looks like this:

```
Your message here.
```

The `print` statement is less useful for reporting diagnostic information than the `log` statement, as it does not contain any information about the time or origin of the message, and cannot be turned off by changing the log level.

For more detailed information, see "Logging and printing" on page 295.

The route statement

The `route` statement evaluates the expression and then sends the resulting event to the front of the current context's input queue.

The expression you route must be an event. The event is processed only within the same context that executes the `route` statement.

Routed events are put on the input queue, ahead of any externally sourced events, and ahead of any previously routed events that have not yet been processed. For more details, see "Event processing order for monitors" on page 837.

The `isExternal()` property on events is not changed by routing an event.

You cannot route an event that has a field of type `action`, `chunk`, `listener`, or `stream`.

In Apama queries, `route` statements are not allowed.

The send . . . to statement

The `send...to` statement sends an event to the channel, context, sequence of contexts, or `com.apama.Channel` object that you specify.

You must send an expression of type `event`, and the destination must be one of the following:

- `string` — The `send...to` statement sends the event to the specified channel. All contexts and external receivers subscribed to that channel receive the event. If there are no subscribers to the specified channel or if no receivers are listening on the specified channel then the event is discarded.
- `context` — The `send...to` statement sends the event to the back of the input queue of the specified context. The event expression is evaluated and the resulting event is sent to the input queue of only the specified context.
- `sequence<context>` — The `send...to` statement sends a copy of the event to the back of the input queue of each context in the specified sequence. The event expression is evaluated and the resulting event is sent to the input queue of each context in the sequence.

  For example:

  ```
  sequence <context> ctxs := [ c1, c2, c3 ];
  Ping ping = Ping();
  send ping to ctxs;
  ```
- `com.apama.Channel` — The `send...to` statement sends the event to the specified `Channel` object. If the `Channel` object contains a string, the event is sent to the channel with that name. If the `Channel` object contains a context, the event is sent to that context. You cannot send an event to an empty context object.

You cannot send an event to a dictionary of contexts. However, it is a common pattern to send to a sequence generated by `dictionary.values()`. For example:

```
send x to d.values;
```

If the target context's input queue is full the sending context blocks and waits for space on the queue unless doing so would cause a deadlock. See "Deadlock avoidance when parallel processing" on page 324.

Sent events are processed in the order they are sent. Sent events are put on the back of the input queue, behind any events already queued.

You must create the context before you send an event to the context. You cannot send an event to a context that you have declared but not created. For example, the following code causes the correlator to terminate the monitor instance:

```
monitor m {
   context c;
   action onload()
   {
```

```
        send A() to c;
    }
}
```

If you send an event to a sequence of contexts and one of the contexts has not been created first then the correlator terminates the monitor instance. For details, see "Sending an event to a particular context" on page 312.

Sending an event to a sequence of contexts is non-deterministic. For details, see "Sending an event to a sequence of contexts" on page 314.

In a `send...to` statement, you cannot send an event that has a field of type `action`, `chunk`, `listener`, or `stream`.

The spawn statement

The `spawn` statement creates a copy of the currently executing monitor instance in the current context.

See also "Spawning monitor instances" on page 55.

The spawn *action* to *context* statement

The `spawn` *`action`*`()` `to` *`context`* statement creates a copy of the currently executing monitor instance in the specified context. A monitor instance must have a reference for the specified context in order to spawn to that context.

The expression that you spawn must be of type `context`. The `spawn` *`action`*`()to` `context` statement spawns a new monitor instance in the specified context.

For more detailed information, see "Spawning to contexts" on page 309.

Variable declaration statements

A variable declaration statement can appear anywhere in a block. Variables declared in a block are in scope in that block and can be used in statements that follow the declaration.

See "Variable declarations" on page 910.

Compound statements

Compound statements enclose other statements or blocks and affect how the enclosed statements are executed.

The for statement

The `for` statement is used to iterate over the members of a `sequence` and execute the enclosing statement or block once for each member.

The iteration variable is assigned a value successively obtained from each element of the sequence, starting with the first, and if the last sequence entry has not been reached, the statement that forms the loop body is executed.

The iteration variable's type must match the type of the `sequence` elements.

The loop body is either a single statement or a block.

Within the loop body, the `break` statement can be used to cause early termination of the loop by transferring control to the next statement after the loop body. The `continue` statement can be used to transfer control to the end of the body, after which the sequence size is tested to determine if the last entry has been reached. If it has not, then the loop body is executed. The `return` statement can be used to terminate both the loop and the action that contains it.

For more information, see "Defining loops" on page 291.

The from statement

The `from` statement is used to create a stream listener. A stream listener watches for items from a stream and passes output items to procedural code.

A `from` statement is similar to an `on` statement, which listens for events processed by the correlator and then executes an event listener action for each matching event or pattern. See "The on statement" on page 887.

You can assign the result of a `from` statement to a `listener` variable. This lets you call `quit()` on the stream listener.

A stream listener passes output items from a stream to procedural code. The stream, specified in the expression, can be a reference to an existing stream or a stream source template. Alternatively, it can be the stream created by an in-line stream query.

A colon and an identifier follow the expression or in-line stream query. This signifies a coassignment: when new items are available from the stream, the stream listener coassigns each output item to the specified variable.

The statement following the identifier can be a single EPL statement or a block of EPL statements. The `from` statement passes the output item to this statement or block and executes the statement or block once for each output item. If the output of the query is a lot that contains more than one item, and you want to execute the statement or block just once for the lot, coassign the output to a `sequence`. See "Working with Streams and Stream Queries" on page 205, and "Working with lots that contain multiple items" on page 245.

The if statement

The `if` statement is used to conditionally execute a statement or block.

The condition, whose result type must be `boolean`, is evaluated and if its result is `true` the block following the `then` keyword is executed. After the body of the `then` clause has been executed, control is transferred to the next statement following the `if` statement.

If the condition result is `false`, and an `else` clause is present, the statement or block following the `else` is executed. After the body of the `else` clause has been executed, control is transferred to the next statement following the `if` statement.

If the condition result is `false`, and the `else` clause is not present, control is transferred to the next statement following the `if` statement.

For more information, see "Defining conditional logic" on page 290.

The on statement

The `on` statement is used to create an event listener that looks for input events that match the pattern specified by an event condition. When a matching event is detected, the event listener fires (also referred to as triggers) and the specified event listener action is executed.

A listener assignment clause is used to obtain a reference to the event listener that is created by the `on` statement. One can either define a new variable of type `listener` or specify a reference to an existing `listener` variable.

An Apama query cannot specify an `on` statement.

Example:

```
listener l := on ...
sequence <listener> aSequence;
aSequence[0] := on ...
```

The event condition specifies what events are of interest. See "Event expressions" on page 839.

A listener action defines the processing that will be performed when a matching event is detected and the event listener fires. The listener action can be one of the following:

- A statement
- A block

The listener action is invoked automatically by the correlator when the event condition is satisfied. This may be:

- When a matching event is detected.
- If `unmatched` is specified in the condition, the event matches the condition, and there are no matching event listeners that do not specify the `unmatched` keyword.
- If `completed` is specified in the condition, and any matching events have been completely processed by other event listeners.

For more information, see "Specifying the on statement" on page 163.

The while statement

The `while` statement is used to repeatedly evaluate a `boolean` condition and execute a block as many times as the condition result is found to be `true`.

The condition, whose result type must be `boolean`, is evaluated and if the result is `true`, the block is executed. Control then transfers to the top of the loop and the condition is evaluated again. When the condition result is `false`, control is transferred to the next statement following the `while` statement.

The body of the loop must be a block; it must be inside curly braces.

Within the loop body, the `break` statement can be used to cause early termination of the loop by transferring control to the next statement after the loop body. The `continue` statement can be used to transfer control to the end of the body, after which the condition will be evaluated again and the loop body executed if the condition result is `true`. The `return` statement can be used to terminate both the loop and the action that contains it.

For more information, see "Defining loops" on page 291.

The try-catch statement

The `try-catch` statement is used to handle runtime exceptions.

The `catch` clause must specify a variable whose type is `com.apama.exceptions.Exception`.

You can nest `try-catch` statements in an action, and you can specify multiple actions in a `try` block and specify a `try-catch` statement in any number of actions.

See also "Catching exceptions" on page 293.

Example:

```
using com.apama.exceptions.Exception;
...
action getExchangeRate(
   dictionary<string, string> prices, string fxPair) returns float {
   try {
      return float.parse(prices[fxPair]);
   } catch(Exception e) {
      return 1.0;
   }
}
```

Transfer of control statements

Transfer of control statements alter the normal control path by stopping the sequential execution of statements within a block. All of them end execution of the block that contains them. After a `continue` statement is executed, the containing block might be executed again in a new loop iteration. The `die` and `return` statements also end the action in which they are executed.

The break statement

The `break` statement transfers control to the next statement following the loop (`for` or `while` statement) that encloses the `break` statement. A `break` statement can only be used within a `for` or `while` statement. Any statements between the `break` statement and the end of the block are not executed. For more information, see "Defining loops" on page 291.

The continue statement

The `continue` statement can be used in a block enclosed by a `for` or `while` statement to end execution of the current iteration and transfer control to the beginning of the loop. When a `continue` statement is executed, control is immediately transferred to the beginning of the inner most enclosing `for` or `while` statement. Any statements between the `continue` statement and the end of the block are not executed. For more information, see "Defining loops" on page 291.

The die statement

The `die` statement terminates the execution of a monitor. When the correlator executes a `die` statement, it terminates only the monitor instance that contains the `die` statement being executed. If the monitor instance that spawned the monitor instance being terminated is still active, that monitor instance is not affected. If that original monitor instance spawned any other monitor instances, those monitor instances are not affected. If the monitor instance being terminated defines an `ondie()` action, the correlator executes the `ondie()` action for just the monitor instance being terminated, and then terminates the monitor instance.

An Apama query cannot specify a `die` statement.

For more information, see "Terminating monitor instances" on page 58.

The return statement

The `return` statement ends the execution of an action and control is transferred to the action's caller, at the point following the action call (which might be in the middle of an expression). Any statements between the `return` statement and the end of action are not executed.

If the action does not have a `returns` clause, then an expression is not permitted in the `return` statement.

If the action has a `returns` clause, then an expression whose value is the action's return value is required in the `return` statement. The expression type must match the type specified in the `returns` clause.

For more information, see "Format for defining actions" on page 271.

38 Expressions

In many programs, much work is performed by evaluating expressions, which are combinations of operators, operands, and punctuation. They are used to detect events of interest to the program, perform calculations, comparisons, invoke actions, invoke inbuilt methods, compute parameter values passed to action and method calls, and so on.

Introduction to expressions

EPL has several kinds of expressions:

- Primary expressions, bitwise expressions, logical expressions etc. are used for computations.
- In a monitor, a stream query definition creates a derived stream from an existing stream.
- In a monitor, a stream source template creates a new stream from an event template.

Event expressions are used in `on` statements for event pattern matching and sequence detection. Event expressions are not ordinary EPL expressions. See "Event expressions" on page 839.

When an expression is evaluated (that is, it is executed), it will produce a result value if the expression is a variable, a literal, or a combination of values and operators. If the expression is an action or inbuilt method call, then evaluating the expression produces a result value when the action or inbuilt method returns a value, but if the action or inbuilt method does not return a value, then the expression does not produce a result. Note that when an expression includes action or method calls, then evaluating the expression might produce side effects. A side effect is a change in the state of the execution environment. For example, a called action might change the value of a global variable or generate a derived event. If evaluating an expression produces a result, then in addition to a value, the expression result has a type. This is the expression type. An expression's type is always known at compile time.

The elements of an expression are evaluated roughly from left to right, taking into account parentheses and operator precedence. Binary operators have a left operand and a right operand. If an operator is left-associative, its left operand is evaluated first, followed by the right, and then the operation is performed. If an operator is right-associative, its right operand is evaluated first, followed by the left, then the operation is performed. In action calls, the actual parameter list expressions are evaluated from left to right. Many of the operators used in expressions are polymorphic and can operate on operands of several types. For example, the addition operator performs floating point addition when its operands are of type `decimal` or `float` and performs integer addition when its operands are of type `integer`. Here are some examples of expressions:

```
i := (a.size() + b[3]) / (n -1);
i := "foo" + s + " " + b.toString() + f.formatFixed(8);
```

Primary expressions

The primary expression is the simplest form of expression. It can take the following forms:

- **Identifier.** In an expression, an identifier is a variable name, an instance method name, a type method name, or an action name.
- **Literal.** A literal in an expression is a compile-time constant value as described in "Literals" on page 925.
- **Postfix expression.** See "Postfix expressions" on page 902.
- **Action/method.** See "Action and method calls" on page 903.

Bitwise logical operators

The bitwise logical operators examine one bit at a time in their operands and compute the corresponding bit value in the result.

The bitwise operators `and`, `or`, and `xor` are binary operators that have a left and right operand. The bitwise operator `not` is a unary operator that has only a right operand.

The result type of all four bitwise operators is `integer`. Note that EPL integers are 64 bits wide.

Bitwise intersection (and)

The bitwise intersection operator `and` produces a result by comparing all 64 bits of its left and right operands, which must be expressions of type `integer`, one bit at a time. For each bit in the two operands, the corresponding bit in the result value is set to `1` if both operand bit values are `1` and set to `0` if either operand bit value is `0`.

Example

The following illustrates this using 64-bit binary values.

- `a := 42;`

  `0000000000000000000000000000000000000000000000000000000000101010`

- `b := 642;`

  `0000000000000000000000000000000000000000000000000000001010000010`

- `a and b`

  `0000000000000000000000000000000000000000000000000000000000000010`

Bitwise union (or)

The bitwise union `or` produces a result by comparing all 64 bits of its left and right operands, which must be expressions of type `integer`, one bit at a time. For each bit in the two operands, the corresponding bit in the result value is set to `1` if either or both operands bit values is `1` and set to `0` if both operand bit values are `0`.

Example

The following illustrates this using 64-bit binary values.

- `a := 42;`

  `0000000000000000000000000000000000000000000000000000000000101010`

- `b := 642;`

  `0000000000000000000000000000000000000000000000000000001010000010`

- `a or b`

  `0000000000000000000000000000000000000000000000000000001010101010`

Bitwise exclusive (xor)

The bitwise exclusive `or` operator `xor` produces a result by comparing all 64 bits of its left and right operands, which must be expressions of type `integer`, one bit at a time. For each bit in the two operands, the corresponding bit in the result value is set to `1` if either operand's bit value is `1` and the other is `0` and set to `0` if both operand bit values are `0` or both are `1`. In other words, the result bit is `1` if both bit values are different and `0` if they are the same.

Example

The following illustrates this using 64-bit binary values.

- `a := 42;`

  `0000000000000000000000000000000000000000000000000000000000101010`

- `b := 642;`

  `0000000000000000000000000000000000000000000000000000001010000010`

- `a xor b`

  `0000000000000000000000000000000000000000000000000000001010101000`

Note that the expression `a xor b` yields the same result as `not (a and b).`

Unary bitwise inverse

The unary bitwise `not` operator produces a result by computing the bitwise complement or inverse of its right operand, which must be an expression of type `integer`. For each bit in the operand's value, the corresponding bit in the result value is set to `1` if the operand's bit value is `0` and `0` if the operand's bit value is `1`.

Example

The following illustrates this using 64-bit binary values.

- `b := 42;`

  `0000000000000000000000000000000000000000000000000000000000101010`

- `not b`

  `1111111111111111111111111111111111111111111111111111111111010101`

Logical operators

The logical operators `and`, `or`, `xor` and `not` perform Boolean arithmetic on their operands.

The logical operators' left and right operands are expressions whose result type must be `boolean`. The result type of all four operators is `boolean`.

Logical intersection (and)

The `and` operator produces a result of `true` if both of its operand values are `true` and `false` otherwise.

When the correlator evaluates a logical `and` expression it evaluates the left operand first. If the left operand evaluates to false then the correlator does not evaluate the right operand since the expression cannot be true. For example:

```
a and b
```

If `a` is false then whether or not `b` is true the expression will be false so the correlator does not evaluate `b`. This lets you write code such as the following:

```
if (dict.hasKey(k) and dict[k] = "someValue")
```

If `k` is not in the dictionary then the left operand evaluates to false and so the entire logical expression is false. The correlator never evaluates `dict[k] = "someValue"`, which would cause an error if `k` is not in the dictionary.

Logical union (or)

The `or` operator produces a result of `true` if either of its operand values is `true` and `false` otherwise.

When the correlator evaluates a logical `or` expression it evaluates the left operand first. If the left operand evaluates to true then the correlator does not evaluate the right operand since the expression will always be true. For example:

```
a or b
```

If `a` is true then regardless of what `b` evaluates to the expression will be true so the correlator does not evaluate `b`.

Logical exclusive or (xor)

The `xor` operator produces a result of `true` if either of its operand values is `true` and the other is `false` and `false` if both are `true` or both are `false`.

Unary logical inverse (not)

The unary `not` operator produces the result `true` if its right operand value is `false`, and `false` if the operand value is `true`.

Shift operators

The shift operators << and >> perform a shift of an integral value, moving bits in the result a specified number of positions to the right or left. The result type of both shift operators is `integer`.

The left operand is an expression of type `integer` whose value is to be shifted. The right operand is the shift count, an expression of type `integer` whose value is the number of bits the left operand value is to be shifted.

The shift count must be a nonnegative value less than 64. If the shift value is zero, then the result value is equal to the left operand value. Values less than zero or greater than 63 will produce unpredictable results and should not be used.

Left shift operator

The left shift operator << produces a result by moving the left operand value's bits to the left and filling the vacated bits on the right with 0 bits. Bits that are moved beyond the leftmost bit (the sign bit) position are discarded.

Example

The following illustrates this using 64-bit binary values.

- `i := 42;`

  `0000000000000000000000000000000000000000000000000000000000101010`

- `i << 24`

  `0000000000000000000000000000000000101010000000000000000000000000`

Right shift operator

The right shift operator >> produces its result by moving the left operand value's bit to the right. The vacated bits on the left are filled with 0 bits if the left operand value is zero or positive and filled with 1 bits if the left operand value is negative. Bits that are moved to beyond the rightmost bit (the least significant bit) position are discarded.

Example

The following illustrate this using 64-bit binary values.

- `i := 42;`

  `0000000000000000000000000000000000000000000000000000000000101010`

- `i >> 24`

  `0000000000000000000000000000000000000000000000000000000000000000`

- `i := -42;`

  `1111111111111111111111111111111111111111111111111111111111010110`

- `i >> 24`

  `1111111111111111111111111111111111111111111111111111111111111111`

Comparison operators

The comparison operators are used to determine the equality, inequality, or relative values of their left and right operands.

The left and right operands must be expressions of the same type and the type must be allowed for that operator. You can use each comparison operator on `decimal`, `float`, `integer`, and `string` types (see "Primitive and string types" on page 768). On `boolean` types, you can use the = and `!=` comparison operators.

The result type of all comparison operators is `boolean`.

The comparison operators are:

Operator	Operation	Description
<	Less than	Produces the result `true` if the left operand's value is smaller than the right operand's value and `false` otherwise.
<=	Less than or equal	Produces the result `true` if the left operand's value is smaller than or equal to the right operand's value and `false` otherwise.
=	Equality	Produces the result `true` if the left operand's value is equal to the right operand's value and `false` if they are not equal.
!=	Inequality	Produces the result `true` if the left operand's value is not equal to the right operand's value and `false` if they are equal.
=>	Greater than or equal to	Produces the result `true` if the left operand's value is larger than or equal to the right operand's value and `false` otherwise.

Operator	Operation	Description
>	Greater than	Produces the result `true` if the left operand's value is larger than the right operand's value and `false` otherwise.

Additive operators

The additive operators are used to perform arithmetic on two operands of matching type: both of type `decimal`, both of type `integer`, or both of type `float`. The result type of the additive operators is the same as the type of the operands.

The additive operators are:

Operator	Operation	Description
+	Addition	Produces a result by computing the numeric sum of its left and right operands. If the two operands are both expressions of type `integer`, then integral addition is performed and the result is of type `integer`. If the two operands are both of type `decimal` or both of type `float`, then floating-point addition is performed and the result type is the same as the operand type.
–	Subtraction	Produces a result by computing the numeric difference between the left and right operands by subtracting the value of the right operand from the left. If the two operands are both expressions of type `integer`, then integral subtraction is performed and the result is of type `integer`. If the two operands are both of type `decimal` or both of type `float`, then floating-point subtraction is performed and the result type is the same as the operand type.
+	String concatenation	Produces a result by "adding" two strings together. The result is a new string whose value is the value of the right operand, an expression of type `string`, appended to the value of the left operand, an expression of type `string`. The result type of the `string` concatenation operator is `string`.

Multiplicative operators

The multiplicative operators are used to perform arithmetic on two operands of matching type: both `decimal`, or both `float`, or both `integer`.

The left and right operands must both be expressions of type `decimal`, or both be of type `float`, or both be of type `integer`.

The result type of the multiplicative operators is the same as the type of the operands.

The multiplicative operators are:

Operator	Operation	Description
`*`	Multiplication	Produces a result by computing the numeric product of its two operands. If the two operands are both expressions of type `integer`, then integral multiplication is performed and the result is of type `integer`. If the two operands are both of type `decimal` or both of type `float`, then floating-point multiplication is performed and the result type is the same as the operand type.
`/`	Division	Produces a result by computing the numeric quotient of its two operands. The left operand value, the dividend, is divided by the right operand value, the divisor. If both operands are of type `integer`, any fractional part of the result value is discarded. In other words, the result is truncated toward zero. For example, the expression `13/5` yields a result of `2`. If both operands are of type `integer`, then integral division is performed and the result is of type `integer`. If both operands are of type `decimal` or both are of type `float`, then floating-point division is performed and the result type is the same as the operand type. If the right operand's value is zero, a runtime error is raised.
`%`	Remainder	Produces a result by computing the numeric remainder from dividing the left operand value by the right operand value. For example, the expression `13%5` yields a result of `3`. If both operands are of type `integer`, then the integral remainder is computed and the result is of type `integer`. If both operands are of type `decimal`

Operator	Operation	Description
		or both of type `float`, then the floating-point remainder is computed and the result type is the same as the operand type. If the right operand's value is zero, a runtime error is raised.

Unary additive operators

The unary additive operators are used to perform arithmetic on one right operand of type `decimal`, `float` or `integer`. The result type of the unary arithmetic operators is the same as the type of the operand.

Both of the unary arithmetic operators have one operand, which must be an expression of type `decimal` , `float` or `integer`. The result type is the same as the type of the operand.

Unary inverse

The unary additive inverse operator produces a result that is its right operand value with the sign reversed. If the operand value is negative, the result value is positive. If the operand value is positive, the result value is negative. If the operand value is zero, the result value is zero.

Unary identity

The unary additive identity operator + produces a result that is its right operand value.

Expression operators

You can use the following operators wherever you can specify an expression. Note that they are all binary operators.

Operator	Operation	Description
+	Addition	Returns a `decimal`, `float` or an `integer` according to the operands, or concatenation in the case of `string` operands
-	Subtraction	Returns a `decimal`, `float` or an `integer` according to the operands
`%`	Modulus	Returns an integer and is a valid operator only for integers

Operator	Operation	Description
/	Division	Returns a `decimal`, `float` or an `integer` according to the operands
*	Multiplication	Returns a `decimal`, `float` or an `integer` according to the operands
>	Greater than	Returns a `boolean` value indicating whether the condition expressed is true or false
<	Less than	Returns a `boolean` value indicating whether the condition expressed is true or false
>=	Greater than or equal to	Returns a `boolean` value indicating whether the condition expressed is true or false
<=	Less than or equal to	Returns a `boolean` value indicating whether the condition expressed is true or false
=	Equivalence	Returns a `boolean` value indicating whether the condition expressed is true or false
!=	Not equals	Returns a `boolean` value indicating whether the condition expressed is true or false
`or`	Logical `or`, bitwise `or`	On `boolean` types, on `integer`s
`and`	Logical `and`, bitwise `and`	On `boolean` types, on `integer`s
`xor`	Logical `xor`, bitwise `xor`	On `boolean` types, on `integer`s
`not`	Logical `not`	On `boolean` types

Expression operator precedence

The following table lists the primary and bitwise expression operators in order by their precedence, from lowest to highest. See also "Event expression operator precedence" on page 843.

Operation	Operator	Precedence
Logical or bitwise union	`or`	1
Logical or bitwise exclusive or	`xor`	2
Logical or bitwise intersection	`and`	3
Unary logical or bitwise inverse	`not`	4
Relational	`<, <=, >, >=, !=, =`	5
Additive	`+, -`	6
String concatenation	`+`	6
Multiplicative	`*, /, %`	7
Unary additive	`+, -`	8
Name qualifier (Dot)	`.`	9
Object constructor	`new`	9
Subscript	`[ ]`	9
Action call	`ActionName()`	10
Parenthesized expression	`( )`	10
Stream query	`from`	10
Stream source template	`all`	10

Postfix expressions

A primary followed by a `"."` symbol, and an identifier must represent a variable reference, an action call, or a method call. Action and method calls are described in "Action and method calls" on page 903.

An expression enclosed by the [and] symbols denotes a subscript operation for a sequence or dictionary. This can be used on the right or left side of an assignment statement.

The new operator is used to create an instance of a reference type or event type.

Action and method calls

An action call within an expression transfers control to the statements within the action body during expression evaluation and temporarily suspends the expression evaluation. If the action has parameters, then their values are copied to the action's formal parameter variables. When the control flow reaches the action's end or the action executes a return statement, control is transferred back to the expression and evaluation continues.

The actual parameters are a comma-separated list of expressions. The entire list is enclosed in parentheses. It forms the set of parameter values that are passed when the action is called. Each expression value is copied to the corresponding parameter variable specified in the action definition's formal parameters, and the expression result type must match the parameter variable's type. The number and order of actual parameters passed by a caller must also match those listed in the action definition's formal parameters.

The action or method being invoked in the expression must return a value. The action's return type becomes the expression result type.

The subscript operator [ ]

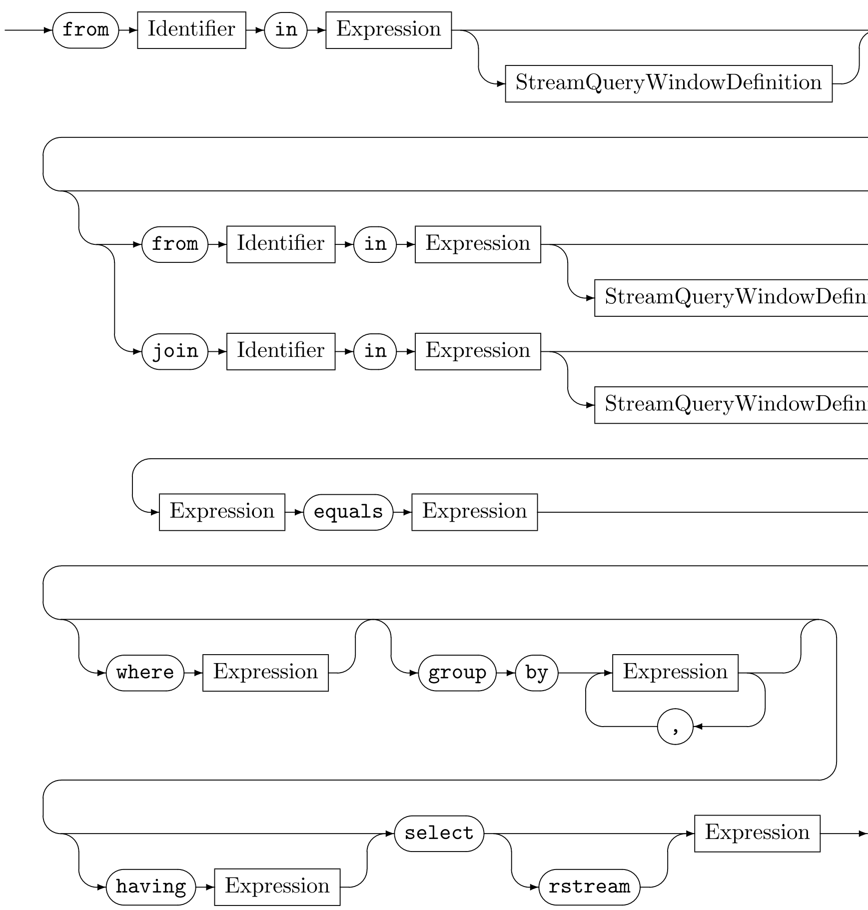
The subscript operator takes one operand. The operand can be an integer index into a sequence or a key type index of a dictionary. The subscript operator produces a result of the same type as the sequence's entry type or dictionary's item type.

The new object creation operator

The operator new produces a result whose type is the type of the object parameter. It has one operand, the name of the type of object to be created.

Stream queries

A stream query defines an operation that the correlator applies continuously to one or two streams of items. The output of a stream query is a continuous stream of derived items, stream<*X*>, where *X* is the type returned by the expression in the select clause. See also "Defining stream queries" on page 211.



A `from` clause specifies a stream that the query is operating on.

An item in a stream can be an event, a simple type (`boolean`, `decimal`, `float`, `integer` or `string`) or a `location` type. The first *`Identifier`* is the identifier that represents the current item in the stream you are querying. You use this identifier in subsequent clauses in the stream query.

The first *`Expression`* identifies the stream that you want to query.

A stream query window definition is optional. If you do not specify any window then the stream query operates on only the items that arrive on the stream for a given activation of that query. See "Stream query window definitions " on page 905.

A subsequent `from` clause indicates a cross-join operation.

Alternatively, a subsequent `join` clause indicates an equi-join operation. An equi-join has a key expression for each of the two streams that are being joined. Two items are joined into an output item only if the values of their key expressions are equal.

A `where` clause qualifies the items produced from a window or a join operation.

A `group by` clause organizes the qualified items, or the items produced from a window or join operation.

A `having` clause filters the output items produced from the projection.

The required `select` clause specifies how to generate the output items.

Semantic constraints

from *Identifier* in *Expression* join *Identifier* in *Expression*

The identifier can be any legal identifier and, within the stream query's scope, is associated with items from the source stream and therefore has their type. In a joined stream query, the two identifiers must be distinct.

The expression's result must be a value of some stream type. The correlator evaluates the expression outside the stream query's scope. For example:

```
stream<A> a := all A();
from a in a ...
```

This is legal, because the identifier `a` is not in scope for evaluation of the expression `a`.

on *Expression1* equals *Expression2*

The correlator evaluates both expressions within the stream query's scope.

`Expression1` must contain the first item identifier and cannot contain the second. *`Expression2`* must contain the second item identifier and cannot contain the first.

The two expressions must return the same type, and that type must be a comparable type.

where *Expression* group by *Expression*, *Expression*, ...

The item identifier or identifiers are in scope and should be used in these expressions. The `where` expression must return a `boolean` value. The `group by` expressions can return any comparable types.

having *Expression*

The item identifier or identifiers are in scope and can be used in this expression. The presence of this clause implies that the projection must be an aggregate projection. The expression must return a `boolean` value.

You can use one or more aggregate functions in the `having` expression. In fact, you can use aggregate functions only in `having` expressions and `select` expressions.

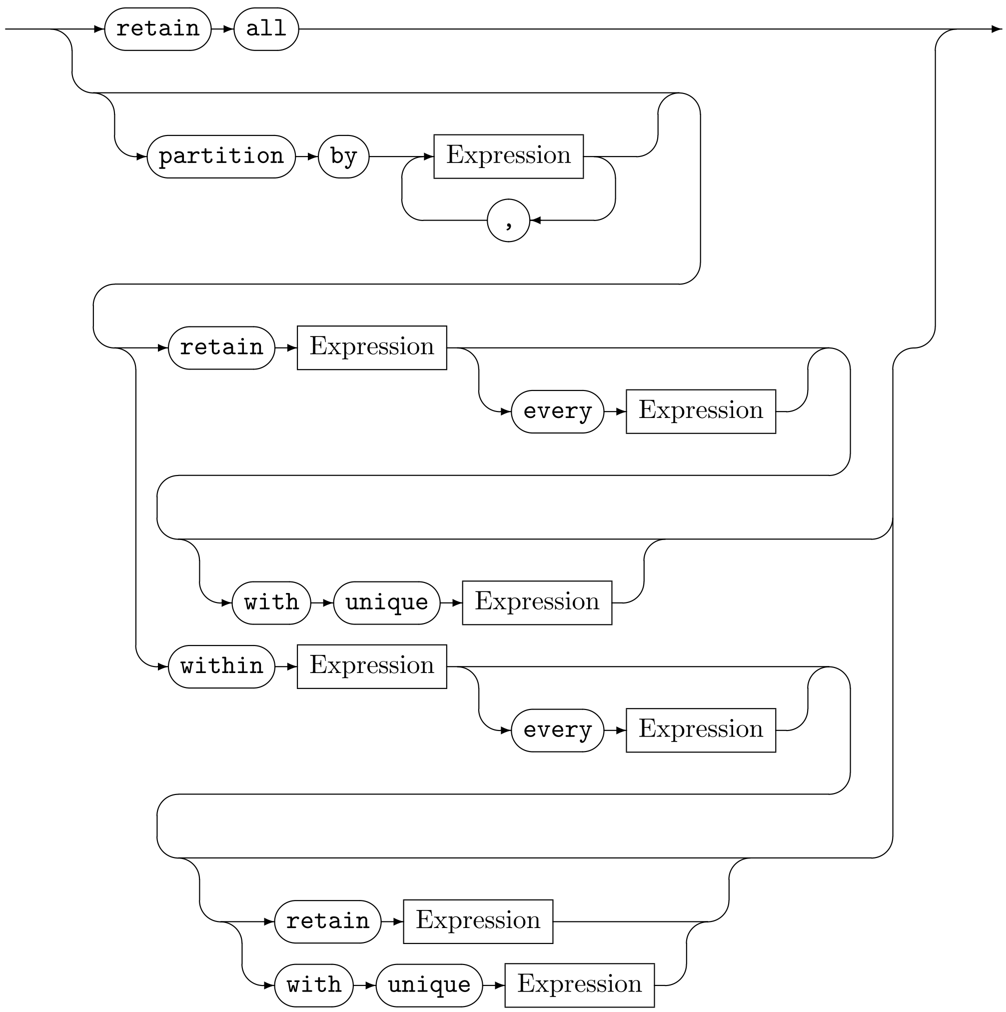
select [rstream] *Expression*

The item identifier or identifiers are in scope and can be used in this expression. The expression must return a value.

You can use one or more aggregate functions in a `select` expression. In fact, you can use aggregate functions only in `having` expressions and `select` expressions. If you specify an aggregate function you cannot specify the `rstream` keyword.

Stream query window definitions

In a stream query, the optional window definition specifies which items in a stream to operate on. See also "Adding window definitions to from and join clauses" on page 218.



Typically, stream queries process a window over a stream. A stream is an ordered sequence of items over time. A window specifies which items to operate on. Windows can contain a portion of the stream based on number of items, time of item arrival, content of item, or other criteria.

When the stream query window definition is `retain all`, the window contains all items that have ever been in the stream. Conceptually, once an item enters a `retain all` window, it remains in the window indefinitely, or until the stream query is terminated. The `retain all` clause specifies an unbounded window. Unbounded windows have restrictions on their use:

- You cannot have a partitioned or batched unbounded window.
- You cannot perform a join operation on an unbounded window.
- You cannot specify an unbounded window when you use `rstream` in the `select` clause of a stream query.

When you use a custom aggregate function in a stream query that contains an unbounded window, you cannot use a bounded aggregate function. You should also be aware that, if you use a badly implemented custom aggregate function in a stream query that contains an unbounded window, then this can result in uncontrolled memory usage.

A `partition by` clause divides the input data into several partitions and then applies the stream query window definition separately to each partition. The `partition by` expressions must be comparable types.

The `retain` clause specifies the maximum number of items to be retained by the window. The `retain` expression must be an `integer` expression. In a size-based window, as each new item arrives in the stream, it is added to the window. After the number of items in the window reaches the window size limit specified in the `retain` clause, the arrival of a new item causes removal of the oldest item from the window.

The `within` clause specifies the number of seconds to keep each new item in the window. The `within` expression must be a `float` expression. In a time-based window, as each new item arrives in the stream, it is added to the window. As soon as an item has been in the window for the number of seconds specified by the `within` expression, the correlator removes the item from the window.

By default, the contents of a window change upon the arrival of each item. The `every` keyword can be used to control when the contents of the window change, which causes the items to be added to the window in batches of several items at once. Time-based windows can be controlled to update only every *p* seconds and size-based windows can be controlled to update only every *m* events.

The contents of the window can also depend on the content of individual items in the stream. Specify `with unique`*`Expression`* to limit the window to containing only the most recent item for each key value identified by the expression.

Semantic constraints

In a stream query window definition for one of a joined stream query's input streams, it is always an error to refer to the other input stream's item identifier.

`partition by` ***`Expression`*****`,`** ***`Expression`*****`, ...`**
You should use the item identifier in each expression. Expressions can return any comparable types.

`retain` ***`Expression`*** **`[every`** ***`Expression`*****`]`**
You cannot use the item identifier in these expressions. These expressions must return `integer` values.

`within` ***`Expression`*** **`[every`** ***`Expression`*****`]`**
You cannot use the item identifier in these expressions. These expressions must return `float` values.

`with unique` ***`Expression`***
You should use the item identifier in this expression. The expression can return any comparable type.

Stream source templates

A stream can be created from an event template using the `all` keyword. This is referred to as a stream source template.

A stream source template is the `all` keyword followed by a single event template. The output of a stream source template is a continuous stream of items, `stream<X>`, where *X* is the type specified by the event template.

See also "Creating streams from event templates" on page 208.

39 Variables

Variables are names that are bound to data values (in the case of primitive types) or the location of data values (in the case of reference types). Variables are declared by specifying a type, a name, and optionally, an initial value. With the exception of the `string` type, once declared, new values can be computed and assigned to variables as needed. Strings are immutable and variable assignment causes a new string value to be created and bound to the `string` variable.

Variable declarations

Before a variable can be referenced in a program, it must be declared. The declaration gives the variable a unique name, a type and, optionally, an initial value.

Variable declarations in actions and blocks are statements that are executed when the program's control flow reaches them.

Variable and expression types must match in a declaration.

Example:

```
location rect := location(1.0, 1.0, 5.0, 5.0);
integer i;
boolean c := true, d := false;
sequence <integer> s := [1, 3, 5, 7, 11, 13, 17];
string s1 := "abcdefghijklmnopqrstuvwxyz";
```

Variable scope

The parts of a program in which a particular variable can be referenced (that is, its value used or a new value assigned) is called the scope of the variable. In EPL, variables can have scopes that include:

- All monitors. These are global variables that are part of EPL, also called predefined variables.
- The monitor within which they are declared.
- The action within which they are declared.
- The block within which they are declared.
- The event within which they are declared.
- The custom aggregate function in which they are declared.
- The stream query within which they are identified.

Regardless of the scope of a variable, it cannot be referenced in statements or expressions until after it has been declared or specified as an item identifier in a stream query. Further, variables scoped to actions or blocks cannot be referenced until a value has been assigned.

Within a scope at a particular level, variables declared at that level must have unique names. They can, however, have names that are the same as variables defined at an outer scope and in that case the variables declared at the inner level hide or mask the ones defined at the outer level(s) until the end of their scope.

Predefined variable scope

Predefined variables are defined by the correlator and are accessible in all monitors. See "Provided variables" on page 912.

Monitor scope

A variable that is defined in a monitor is visible and can be referenced in all parts of the monitor. Such variables are also called global variables.

Action scope

A variable that is declared in an action (also called a local variable) can only be referenced within the action. A variable that is a formal parameter of an action can only be referenced within the action. If a local variable declared in an action has the same name as a global variable declared at the monitor level, the local variable hides the global variable until the end of the action.

Block scope

A variable that is declared within a block can only be referenced within the block. A block is one or more statements enclosed within curly braces (the characters `{` and `}`). If a local variable declared in a block has the same name as a global variable declared at the monitor level, or a local variable declared at the action level, the block's local variable hides the global variable or the action's variable, or both if all three have the same name, until the end of the block (the closing `}`).

Event action scope

The fields of an event are part of the event declaration. An event field's scope depends on where it is declared. When an event also includes action definitions, the statements in the action can reference the event's fields as simple identifiers. From the point of view of an event's action, the fields can be said to be scoped to the event.

Custom aggregate function scope

A variable that is declared in a custom aggregate function (also called a local variable) can only be referenced within the custom aggregate function. If a local variable declared in a custom aggregate function has the same name as a global variable declared at the monitor level, the local variable hides the global variable until the end of the custom aggregate function.

Provided variables

The EPL execution environment provides several variables. You can use these variables in the same way as variables you declare yourself, except that you cannot assign values to them. Instead, the correlator automatically assigns values to these variables.

currentTime

The `currentTime` variable is a read-only `float` global variable that contains a timestamp value with the current time and date as read from the correlator's clock. Timestamps are encoded as the number of seconds and fractional seconds elapsed since midnight, January 1, 1970 UTC and do not have a time zone associated with them.

The current time is the time indicated by the most recent clock tick. Use the `currentTime` variable to obtain the current time. The value of the `currentTime` variable is always changing to reflect the correlator's current time.

If you have multiple contexts, it is possible for the current time to be different in different contexts. A particular context might be doing so much processing that it cannot keep up with the time ticks on its queue. In other words, if contexts are mostly idle, then they would all have the same current time.

In a context, the current time is never the same as the current system time. In most circumstances it is a few milliseconds behind the system time. This difference increases when the context's input queue grows.

When a listener executes an action, it executes the entire action before the correlator starts to process another event. Consequently, while the listener is executing an action, time and the value of the `currentTime` variable do not change. Consider the following code snippet,

```
float a;
action checkTime() {
   a := currentTime;
}
// ... Lots of additional code
// A listener calls the following action some time later
action logTime() {
   log a.toString(); // The time when checkTime was called
   log currentTime.toString(); // The time now
}
```

In this code, an event listener sets `float` variable `a` to the value of `currentTime`, which is the time indicated by the most recent clock tick. Some time later, a different event listener logs the value of `a` and the value of `currentTime`. The values logged might not be the same. This is because the first use of `currentTime` might return a value that is different from the second use of `currentTime`. If the two event listeners have processed the same event, the logged values are the same. If the two event listeners have processed different events, the logged values are different.

The correlator maintains a clock that advances at a fixed interval (default) of 0.1 seconds. The clock does not advance while an event is being processed.

Event timestamps

The correlator defines an arrival timestamp for every event it receives. The arrival time value is set from the main context's clock when an event is received by the correlator, just before it is placed on the input queue of each public context.

You can access the arrival timestamp by calling the event's inbuilt `getTime()` method (see "event" on page 796). After the correlator creates an event or after you coassign an event, the `getTime()` method returns the time in the context when the event was created or coassigned. An event's arrival timestamp has the same scope as the event itself.

self

The predefined variable `self` is an event reference that can be used to refer to an event instance within the event's definition.

Within an event action body, you can use the `self` variable to refer an event instance of that event type. In other words, the scope of `self` is each action body in the event definition. For example:

```
event Circle
{
   float radius;
   location position;
   action area () returns float
   {
      return (float.PI * radius * radius);
   }
   action circumference () returns float
   {
      return (2.0 * float.PI * self.radius);
   }
}
```

Note: You cannot use the `self` variable in an Apama query.

Specifying named constant values

A constant is a named literal and its value cannot be changed during runtime. It resembles a variable declaration with `constant` before it.

You can declare an identifier for a constant value in an event type definition or in a monitor. A constant appears in memory once. Spawning a monitor that contains a constant does not make copies of the constant.

The type of a constant must be `boolean`, `decimal`, `float`, `integer`, or `string`.

The name you assign to a constant must be unique within the event type or monitor that contains the constant definition.

The literal that you assign to the constant must be the specified type.

When you define a constant event field, you can refer to that constant from outside the event. Qualify the name of the constant with the event name, for example, `MyEvent.myConstant`.

You cannot declare a constant in an action, directly in a package, or in a custom aggregate function.

See also "Specifying named constant values" on page 270.

40 Lexical Elements

The lexical rules of the EPL grammar describe how sequences of characters are used to form the basic elements of the language, that is, identifiers, constants (string, numeric, and so on), operators, separators, white space, comments, and language keywords. These elements, after discarding any white space and comments, form the symbols used in the syntactical grammar of the language.

Program text

A program's source text is composed of an optional UTF-8 byte-order marker followed by characters that form a sequence of symbols, white space, comments, and line terminators, up to the end of file (denoted by the EOF symbol).

The UTF-8 byte order marker is a sequence of three consecutive bytes with the values `0xEF`, `0xBB`, and `0xBF` respectively, appearing at the beginning of a file containing EPL source text. The UTF-8 character encoding format does not need a byte-order marker to indicate the byte order because UTF-8 is by definition a bytewise encoding. A UTF-8 byte-order marker at the start of a file just indicates that the program text is encoded in the UTF-8 format. It is inserted automatically by some text editors, such as Notepad on Windows systems.

A program's source text can be encoded as Unicode UTF-8, as 7-bit ASCII (which is a proper subset of UTF-8), or various other encodings. The comiler will convert the source text from the locale's encoding to UTF-8 if necessary. In practice, this really only affects comments, white space, and string literals because all other EPL constructs are limited to the ASCII subset. "Identifiers" on page 919, for example, are limited to only a few of the many possible Unicode characters.

Comments

Comments are explanatory notes or text intended for human readers to help them understand what a program or section of a program does.

There are two kinds of comments: block comments and end-of-line-comments.

Block comments begin with the character sequence slash-asterisk `/*`, which is followed by any number of other characters and line breaks, followed by a closing asterisk-slash `*/` sequence. The entire contents of all block comments are ignored.

End-of-line comments begin with two consecutive slash characters `//` followed by any number of characters up to and including the end of the current line. The entire contents of all end-of-line comments are ignored.

White space

White space characters are characters such as spaces and tabs that are used between symbols to separate them. White space characters are sometimes required between symbols when they would otherwise be misinterpreted or unrecognizable. For example, the symbol `/` is used as the division operator and the symbol `*` is used as the multiplication operator, but the character pair `/*` with no white space between them marks the beginning of a block comment.

Though they act as separators between symbols, white space characters are otherwise ignored and discarded during program compilation.

Judicious use of white space improves a program's readability.

The ASCII white space characters and their encodings are listed below:

Code Point	UTF-8 Encoding	ASCII Encoding	Name
`0x0020`	`0x20`	`0x20`	Space
`0x0009`	`0x09`	`0x09`	Horizontal Tab
`0x000c`	`0x0c`	`0x0c`	Form Feed
`0x001c`	`0x1c`	`0x1c`	File Separator
`0x001d`	`0x1d`	`0x1d`	Group Separator
`0x001e`	`0x1e`	`0x1e`	Record Separator
`0x001f`	`0x1f`	`0x1f`	Unit Separator

The Unicode white space characters, as defined by the Unicode character dictionary, and their encodings are listed below:

Code Point	UTF-8 Encoding	Name
`0x0085`	`0xc2 0x85`	unnamed control character
`0x00a0`	`0xc2 0xa0`	NO-BREAK SPACE
`0x1680`	`0xe1 0x9a 0x80`	OGHAM SPACE MARK
`0x180e`	`0xe1 0xa0 0x8e`	MONGOLIAN VOWEL SEPARATOR
`0x2000`	`0xe2 0x80 0x80`	EN QUAD
`0x2001`	`0xe2 0x80 0x81`	EM QUAD
`0x2002`	`0xe2 0x80 0x82`	EN SPACE

Code Point	UTF-8 Encoding	Name
`0x2003`	`0xe2 0x80 0x83`	EM SPACE
`0x2004`	`0xe2 0x80 0x84`	THREE-PER-EM SPACE
`0x2005`	`0xe2 0x80 0x85`	FOUR-PER-EM SPACE
`0x2006`	`0xe2 0x80 0x86`	SIX-PER-EM SPACE
`0x2007`	`0xe2 0x80 0x87`	FIGURE SPACE
`0x2008`	`0xe2 0x80 0x88`	PUNCTUATION SPACE
`0x2009`	`0xe2 0x80 0x89`	THIN SPACE
`0x200a`	`0xe2 0x80 0x8a`	HAIR SPACE
`0x2028`	`0xe2 0x80 0xa8`	LINE SEPARATOR
`0x2029`	`0xe2 0x80 0xa9`	PARAGRAPH SEPARATOR
`0x202f`	`0xe2 0x80 0xaf`	NARROW NO-BREAK SPACE
`0x205f`	`0xe2 0x81 0x9f`	MEDIUM MATHEMATICAL SPACE
`0x3000`	`0xe3 0x80 0x80`	IDEOGRAPHIC SPACE

All white space characters appearing between two symbols are ignored. However, note that white space appearing within string literals is not ignored. See "Literals" on page 925.

Line terminators

Line terminators are used to mark the end of a line of source text. Different operating systems use different characters or character sequences to mark the end of a line.

The following terminators are used on various operating systems:

Operating System	Line Terminator
Mac OS X	ASCII Carriage Return (`0x0D`)
UNIX	ASCII Newline (`0x0A`)

Operating System	Line Terminator
Linux	ASCII Newline (`0x0A`)
Windows	ASCII Carriage Return (`0x0D`) followed by ASCII Newline (`0x0A`)

In general, any number of line terminators can be used between any two symbols in a program and they are treated the same as other white space. A line terminator appearing at the end of an end-of-line comment terminates the comment.

Symbols

Symbols (also called tokens, atoms, or lexemes) are the elements and words of the language, consisting of identifiers, keywords, operators, separators, and literals. Symbols are composed of one or more characters, excluding white space, comments, and line terminators.

Sometimes you must use at least one white space character between two symbols in order to make them distinguishable from each other and from another symbol. For example, the symbol >> is the right-shift operator and the symbol > is used to indicate the end of the element type in a sequence declaration. Since you can have a sequence of sequences, such a declaration could have two adjacent symbols. Since >> in a sequence declaration looks just like the right-shift operator, you have to write them with a white space character between them: > >. On the other hand, the expression `a-b` (subtract the value of the variable named `b` from the value of the variable named `a`) is unambiguous and no extra white space characters are needed. If you wrote it as `a - b` it would mean the same thing.

Identifiers

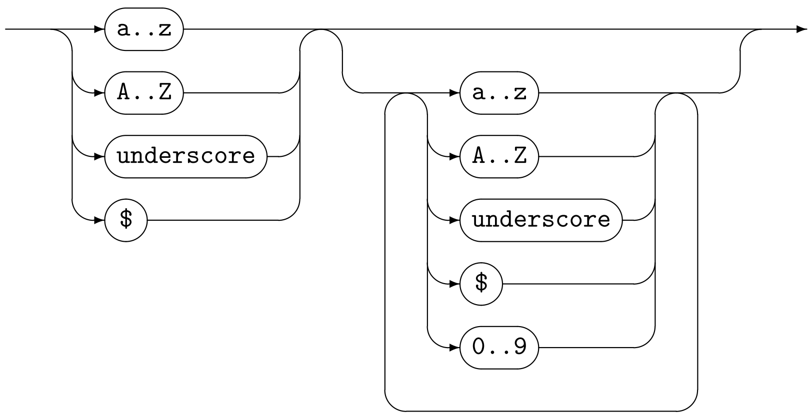
An identifier is a character sequence composed of a combination of the following characters:

- The 26 letters of the Roman alphabet in upper and lower case
- Digits `0` through `9`
- Underscore (_) character
- Dollar sign (`$`) character

The first character may not be a digit. Identifiers are case sensitive. An identifier cannot have the same spelling as a keyword. For example, the word `action` is a keyword and cannot be used as an identifier. See "Lexical Elements" on page 915 for a list of the EPL keywords.

The length of an identifier is limited by available memory. In practice, this means you can make them as long as you want, but very long identifiers are hard to type and harder to read.

An identifier can also contain a hash symbol (`#`) as the first character. See "Escaping keywords to use them as identifiers" on page 923.



Keywords

In EPL, reserved words are referred to as keywords. You must escape them to use them as identifiers in your code.

List of EPL keywords

The table below lists the reserved words called keywords. EPL keywords are case sensitive. You cannot use keywords as identifiers in EPL programs unless you prefix them with a hash symbol (`#`). See "Escaping keywords to use them as identifiers" on page 923.

The superscript numbers on the keywords indicate:

[1] You can safely use these keywords outside the scope of an Apama query without prefixing a hash symbol.

[2] You can safely use these keywords outside the scope of a stream query without prefixing a hash symbol.

For example, suppose you define the `E` event type and it has a field named `parameters`. If you intend to use `E` as an input event for a query and want to access the `parameters` field, then you must specify `#parameters` as the field name. Apama recommends that you avoid defining events that are primarily for queries and that contain query keywords.

`action`	`aggregate`	`all`	`and`

as	at	between [1]	boolean
bounded	break	by [2]	call
catch	chunk	completed	constant
context	continue	currentTime	day [1]
days [1]	decimal	dictionary	die
else	emit	enqueue	event
every [1 and 2]	false	find [1]	float
for	from	group [2]	having [1 and 2]
hour [1]	hours [1]	if	import
in	inputs [11]	integer	join [2]
key [1]	largest [2]	location	log
millisecond [1]	milliseconds [1]	min [1]	minute [1]
minutes [1]	monitor	msec [1]	new
not	on	optional	or
package	parameters [1]	partition [2]	persistent
print	query [1]	retain [1 and 2]	return
returns	route	rstream [2]	sec [1]
second [1]	seconds [1]	select [1 and 2]	send
sequence	smallest [2]	spawn	static

stream	streamsource	string	then
throw	to	true	try
unbounded	unique [2]	unmatched	using
wait	where [1 and 2]	while	wildcard
with [2]	within	without [1]	xor

Some reserved keywords are actually operators. Nevertheless, the restriction still applies. Some Apama tools, such as the Event Modeler, generate code based on EPL and in such code there might be symbols that resemble identifiers but contain hash (`#`) characters, which are not allowed in identifiers. These "identifiers" are placeholders that are later replaced with valid identifiers that do not contain the hash character.

The `string join()` method is still supported. That is, you can still use the following and you do not receive a warning: `string.join()`. Also, note that the `join` keyword has a stream query scope and `join` is also a reserved word for use outside stream queries in a future release.

Note that `ondie`, `onload`, `onunloadonBeginRecovery`, and `onConcludeRecovery` are not reserved keywords. They are the names of special actions. While you can use them as identifiers, doing so is not recommended.

List of identifiers reserved for future use

EPL might use the identifiers listed in the table below as keywords in a future release. In this release, if you use one of these reserved words, the correlator logs a warning.

In this table, some identifiers are flagged with an asterisk (*). These identifiers are reserved as keywords only within stream queries. That is, the correlator logs a warning only if you use this identifier inside a stream query. To use one of these identifiers inside a stream query without logging a warning, prefix it with a hash symbol (`#`). See "Escaping keywords to use them as identifiers" on page 923.

abstract	ALL *	AND *
assert	bignum	BY *
byte	case	char
class	default	enum
EQUALS *	eval	EVERY *

except	extends	FALSE *
finally	FROM	GROUP *
HAVING	immutable	implements
IN *	instanceof	interface
JOIN	LARGEST *	native
NOT *	null	OR *
otherwise	PARTITION *	private
protected	public	RETAIN *
RSTREAM *	runtime	SELECT *
SMALLEST *	sortedsequence	switch
sync	SYNC *	synchronized
table	throws	transient
TRUE *	UNIQUE *	void
volatile	WHERE *	window
WITH *	WITHIN *	

Escaping keywords to use them as identifiers

You can use a keyword as an identifier if you escape it with a hash symbol (#). For example:

```
package com.company.#monitor.client;
using com.company.#monitor.server.Event;
```

In a stream query, you can use a query-scope keyword as an identifier if you prefix it with a hash symbol (#). For example:

```
event Tick
{...
   string partition;
   ...
}
from t in all Tick() partition by t.#partition retain 5 ...
```

You can define a JMon event type that has a field name that is the same as an EPL keyword. To refer to that field in EPL, prefix it with a hash symbol (#). For example:

```
class MyEvent extends Event {
   int integer;
   ...
}
on all MyEvent(#integer = 5): m { ... }
```

To avoid warning messages if you use a reserved word as an identifier, escape the reserved word with a hash symbol (#).

Operators

Operators are symbols used in expressions and statements to perform a computation on or test a relation between data values or, in event expressions, to detect sequences and patterns of events. As you will see, the same symbol is sometimes used for different operations, depending on the context in which the operator is used. For example, the `and` operator is used both in logical expressions, and event sequencing and the `*` operator is used both for integer and floating point multiplication and to match any value in event templates.

Ordinary operators

The ordinary operators are used in primary and bitwise expressions. See "Expressions" on page 891 to perform calculations and comparisons on variables, data values, and other constructs. "Types" on page 767 provides information about the operators that you can use with values of each type.

The ordinary operators are grouped into the following subcategories:

- **Arithmetic operators.** See the corresponding topics in "Expressions" on page 891.
- **Comparison operators.** See "Comparison operators" on page 897.
- **Logical operators.** See the corresponding topics in "Expressions" on page 891.

Event operators

Event operators are special operators that are used in the `on` statement's event expression. An `on` statement defines an event listener. See "Event expressions" on page 839 and "Event expression operator precedence" on page 843.

An `on` statement is not allowed in an Apama query.

Field operators

Field operators are used within event expressions to define conditions on individual fields in an event template. See "Field operators" on page 832.

Separators

Separators are symbols that are used in certain statements and expressions. These are:

`{`

`}`

`[`

`]`

`(`

`)`

`.`

`;`

`,`

`:`

white space

Separators are used to:

- Keep the various parts from bumping into each other, for example commas between parameter values in an action call.
- Group related elements together, for example the left and right braces at the beginning and end of a block of statements.

Literals

A literal is a source text representation of a constant value of a primitive type, or a `location`, `dictionary`, or `sequence` type.

You might want to declare a constant for a frequently used literal so that you can refer to it by name. See "Specifying named constant values" on page 913.

Boolean literals

There are two Boolean literal values: `true` and `false`.

Example:

```
a := true;
b := false;
```

Integer literals

Integer literal values can be written either base 10 (decimal) or base 16 (hexadecimal).

Base 10 literals

Base 10 integral literal values are a sequence of one or more of the digits `0` through `9`.

Examples:

```
i := 0;
i := 11;
i := 1023;
i:= 9223372036854775807;
```

The value can optionally be preceded by a sign. If the sign is omitted, `+` is assumed.

The number `9223372036854775807` or ($2^{63} - 1$) is the largest base 10 integer literal value that can be represented.

Base 16 literals

Base 16 integral literal values begin with the characters `0x`, and consist of a combination of the decimal digits `0` through `9` and the hexadecimal digits `a` through `f` and `A` through `F`.

Examples:

```
j := 0x0;
j := 0x0d;
j := 0x0aFF;
j := 0x7fffffffffffffff;
```

The number `0x7fffffffffffffff` or ($2^{63} - 1$) is the largest base 16 integer literal value that can be represented.

You cannot specify a negative hexadecimal literal. The correlator treats hexadecimal literals as unsigned integers. For example, the following is illegal:

```
-0x43af
```

Floating point and decimal literals

Floating-point literal values can take one of the following forms:

- Optional sign, integer digits followed by an exponent.
- Optional sign, integer digits, a decimal point, and an optional exponent,
- Optional sign, integer digits, a decimal point, fraction digits, and an optional exponent.
- Optional sign, a decimal point, fraction digits, and an optional exponent.

If the sign is omitted, '+' is assumed. If the exponent is omitted, e0 is assumed.

The exponent is the letter 'e' followed by an optional sign, and one or more decimal digits.

Examples:

```
f := 0.0;
f := 1.;
```

```
f := 200128.00005
f := 3.14159265358979;
f := 1e4;
f := 1e-4;
f := 10000e0;
f := .1234;
f := .1234e4;
f := 1.E-32;
f := 1.E-032;
f := 6.0221415E23;
f := 1.7976931348623157e308;
```

The largest positive floating point literal value that can be represented in EPL is `1.7976931348623157 * 10`^{308}. The smallest positive nonzero value that can be represented is `2.2250738585072014 * 10`$^{-308}$. If you write a floating-point literal whose value would be outside the range of values that can be represented, the compiler raises an error.

String literals

A string literal is a sequence of characters enclosed in double quotes.

The backslash character is used as an escape character to allow inclusion of special characters such as newlines and horizontal tabs.

To include a double quote in a string literal, precede it with a `\` character which serves as an escape character, which means "do not treat this quote as the end of the string literal".

To include a newline, use `\n`.

To include a tab character, use `\t`.

To include a single `\` character, use two: `\\`. The compiler will remove the extra backslashes.

Examples:

```
s := "Hello, World!";
s := "\ta\tstring\twith\ttabs\tbetween\twords";
s := "a string on\n two lines";
s := "a string with \\ a backslash and a \" quote";
```

The length of a string literal is limited only by available memory at compile time andruntime. In practice, this means you can make them as long as you need.

Location literals

The four float literals form the location's corner point coordinates, `x1`, `y1` and `x2`, `y2`.

Example:

```
location(0.0, 0.0, 10.0, 10.0)
```

Dictionary literals

A `dictionary` literal can contain one or more pairs of key/item values.

The first expression in a `dictionary` literal entry is the key value and the second expression is the item value. In a `dictionary` literal, all key values must be the same type and all item values must the same type. Both must be of a type that matches the types specified in the `dictionary` variable's definition.

A `dictionary` literal must contain at least one key/item pair except when the `dictionary` literal is in an initializer. For example, the following statement is valid:

```
myDictionary := {};
```

The following statement is not valid:

```
takesADictionaryArgument({});
```

Example:

```
{1:"One", 2:"Two", 3:"Three"}
```

Sequence literals

A `sequence` literal can contain one or more sequence item values.

Each expression in the comma separated list is one entry in the `sequence` literal. The types must all be the same and must match the `sequence` type.

A `sequence` literal must contain at least one item except when the `sequence` literal is in an initializer. For example, the following statement is valid:

```
mySequence := [];
```

The following statement is not valid:

```
takesASequenceArgument([]);
```

Example:

```
[1,2,3,4]
```

Time literals

In Apama query definitions, time literals can be in `within` clauses. They are either `float` or `integer` literals followed by a unit. Not all units are required, but they have to be in order.

You can specify the following time literals, in the following order:

- `day`/`days`
- `hour`/`hours`
- `min`/`minute`/`minutes`
- `sec`/`second`/`seconds`
- `msec`/`millisecond`/`milliseconds`

For example:

- `10 hours`

- `1.5 days`
- `1 day 2.5 hours 10 min 4 sec`
- `2 day 3.5 minutes`

A space is required between a `float` or `integer` literal and its associated time unit. A space is required between a time unit and a `float` or `integer` literal that follows it. Additional whitespace is also allowed.

You cannot specify a negative number.

Outside a query, you can use these keywords as identifiers. Inside a query, you cannot use these keywords as identifiers unless you prefix them with a hash symbol (`#`). See "Escaping keywords to use them as identifiers" on page 923.

Names

Names are used in EPL programs to refer to the various different kinds of entities in the program. Actions, variables and reference variable members, parameters, monitors, queries, methods, aggregate functions, events, packages, and plug-ins all have names.

Description

Names are either simple or qualified. Simple names consist of a single identifier. Qualified names consist of a sequence of identifiers separated by `.` symbols, with an optional `.` prefix.

Every name has a scope, which is the part of a program's text where the name can be used as a simple identifier. The scope is determined by where in the program the name is declared. See "Variable scope" on page 910.

Do not create EPL structures in the `com.apama` namespace. This namespace is reserved for future Apama features. If you inadvertently create an EPL structure in the `com.apama` namespace, the correlator might not flag it as an error in this release, but it might flag it as an error in a future release.

Name Precedence

When there are duplicate unqualified names for types, the correlator searches for the associated definition in the following order, and uses the first one it finds:

1. The monitor-internal type definitions, for example, event type definitions and custom aggregate function definitions
2. Definitions that have been brought in with a `using` declaration in the current file
3. Definitions in the current package (this could be the root namespace if a package was omitted)
4. The root namespace

The fully qualified name of a type can always be named by using a dot (.) followed by the fully qualified name. For example, `select .com.apama.aggregates.avg(x)` uses the built-in `avg` type, even if `com` is a name in the current package.

If you try to create a package-level type that has the same name as a definition brought in with a `using` declaration, it causes a compiler error and the code does not inject. For example:

```
package foo;
using bar.Bar;
event Bar { // Causes an error when injecting as Bar has already been
            // defined by a "using" declaration.}
```

You cannot define a type that has the same fully-qualified name as another type.

If two types have the same name but are in different packages, either one can take precedence over the other depending on their ordering in the precedence list. The correlator uses the first match it finds even if that results in an error when a lower-priority match would have worked. For example:

```
X x;
```

This causes an error if, for example, there is an aggregate function called `X` in the current package even if there is an event type called `X` in the root namespace. You can use a `.` prefix on the name to force it to be looked up from the root namespace, in which case the fully qualified name must be used.

Annotations

A program can contain predefined annotations before specific language elements. For detailed information, see "Adding predefined annotations" on page 68.

41 Limits

EPL enforces the limits described in the following table.

EPL Limit	Value
Lowest integer	$–2^{63}$ (–9223372036854775808)
Highest integer	$2^{63} – 1$ (9223372036854775807)
Integer precision	64 bits (about 18 decimal digits)
Maximum integer left shift	63 bits
Maximum integer right shift	63 bits
Lowest negative floating point value	$–1.7976931348623157 \text{ x}10^{308}$
Highest negative nonzero floating point value	$–2.2250738585072014 \text{ x } 10^{–308}$
Lowest positive nonzero floating point value	$2.2250738585072014 \text{ x } 10^{–308}$
Highest positive floating point value	$1.7976931348623157 \text{ x } 10^{308}$
Floating point precision	About 15 decimal digits
Lowest negative decimal floating point value	$–9.999999999999999 * 10^{384}$
Highest negative nonzero decimal floating point value	$–10^{-398}$
Lowest positive nonzero decimal floating point value	10^{-398}

EPL Limit	Value
Highest positive decimal floating point value	$9.999999999999999 * 10^{384}$
Decimal precision	Exactly 16 decimal digits
Maximum identifier length	Limited by available memory
Maximum number of entries in a sequence	Limited by available memory
Maximum number of entries in a dictionary	Limited by available memory
Maximum number of characters in a string	Limited by available memory
Maximum number of active listeners	Limited by available memory, typically many tens of thousands
Maximum number of active monitors	Limited by available memory
Maximum number of fields in an event	2^{16} (65536)
Maximum number of actions in an event	2^{16} (65536)
Maximum indexed fields in an event	32
Memory address space available to EPL runtime	The correlator stops if it runs out of memory
Maximum number of active stream queries	Limited by available memory
Maximum stream window size	Limited by available memory

42 Obsolete Language Elements

As EPL has evolved, some older language constructs have been supplanted by more useful and flexible ones. The new constructs can accomplish the same effects and more and their use is preferred. Nevertheless, existing programs may still use the obsolete constructs, which are described in this section.

Old style listener calls

Do not specify the following:

```
on A() foo;
```

Instead, specify the following:

```
on A() foo();
```

Old style spawn statements

Do not specify the following:

```
spawn actionName;
```

Instead, specify the following:

```
spawn actionName();
```

A EPL Naming Conventions

It is recommended that you use the following naming conventions in EPL. These conventions closely follow Java naming conventions. Using these conventions makes it easier to collaborate and makes it faster for Software AG Global Support personnel to follow your code.

Item	Convention	Notes and Examples
Acronyms	Do not always use all capitals	Names often contain standard abbreviations, such as IAF for Integration Adapter Framework. Names such as `iafInterface` for an attribute or `IafInterface` for a monitor are easier to read than `iAFInterface` and `IAFInterface`.

Actions	lowerCamelCase	Actions should be verbs, in mixed case with the first letter lowercase, and the first letter of each internal word capitalized. For example:
		`handleQuery();`
		`startDaemonProcess();`
		`quit();`

Channels	package. UpperCamelCase	Channel names should start with an EPL package name (lowercase), optionally followed by an UpperCamelCase noun. Qualifying channel names with a package is important because channel names form a global namespace that is shared by all applications running in a correlator. For example: `com.mycompany.AllTransactions`

Constants	ALL_CAPITALS	Identifiers for constants should be all uppercase with words separated by underscores. For example:
		`constant integer MAX_SIZE;`
		`constant string DEFAULT_HOST;`

Contexts	UpperCamelCase	Context names should be nouns, initial capital, in mixed case with the first letter of each internal word capitalized. Context names should be simple and should describe the work being done in the context. Use whole words. Avoid acronyms and abbreviations unless the abbreviation is much more widely used than the long form, such as URL or IAF. For example: `context("Calculation");`

Item	Convention	Notes and Examples
		`context("Inventory", true);`

Custom aggregate functions	lowerCamelCase	Custom aggregate functions should be in mixed case with the first letter lowercase, and the first letter of each internal word capitalized.
		`aggregate bounded myCustomAggregate()`
		`   returns integer { aggregateBody }`

Events	UpperCamelCase	Event names should have an initial capital, and mixed case with the first letter of each internal word capitalized. Event names should be simple and descriptive. Use whole words. Avoid acronyms and abbreviations unless the abbreviation is much more widely used than the long form, such as URL or IAF. For example:
		`event Tick`
		`event SubscriptionConfiguration`
		`event IafEvent`

Monitors	UpperCamelCase	Monitor names should be nouns, initial capital, in mixed case with the first letter of each internal word capitalized. Monitor names should be simple and descriptive. Use whole words. Avoid acronyms and abbreviations unless the abbreviation is much more widely used than the long form, such as URL or IAF. For example:
		`monitor SubscriptionManager`
		`monitor IafMonitorService`

Packages	lowercase	The prefix of a unique package name is always written in all-lowercase ASCII letters and should preferably be one of the top-level domain names (`com`, `edu`, `gov`, `mil`, `net`, `org`) or one of the two-letter codes identifying countries as specified in ISO 3166-1 alpha-2. Subsequent components of the package name vary according to an organization's own internal naming conventions. Such conventions might specify that certain directory name components be division, department, project, machine, or login names. For example: `com.apamax.accounting`
Queries	UpperCamelCase	Query names should be nouns, initial capital, in mixed case with the first letter of each internal word capitalized. Query names should be descriptive. Use whole words. Avoid acronyms and

Item	Convention	Notes and Examples

		abbreviations unless the abbreviation is much more widely used than the long form, such as URL or IAF. For example:
		`query FaultyWithdrawalLocations`
		`query CloseInTimeButDistantTransactions`

Variables	lowerCamelCase	Variables and parameters should have initial lowercase. This is left to your discretion, but lowercase is preferable. Internal words start with capital letters.
		
		Variable names should be short yet meaningful. The choice of a variable name should be mnemonic: that is, designed to indicate to the casual observer the intent of its use. One-character variable names should be avoided except for temporary, throwaway, variables. Common names for temporary variables are `i`, `j`, `k`, `m`, and `n` for integers.
		`integer i;`
		`float myPrice;`
		`MyEvent myEvent;`

B EPL Keyword Quick Reference

EPL is case-sensitive.

There are a number of identifiers that EPL has reserved for future use. In this release, if you use a reserved identifier, the correlator logs a warning. For a list of reserved identifiers, see "List of identifiers reserved for future use" on page 922.

The following table describes EPL keywords and special identifiers. Some keywords are reserved only in the scope of a stream query in a monitor or in an Apama query. Where applicable, this is noted in the description. You can use an EPL keyword as an identifier if you prefix it with a hash symbol (#). See "Escaping keywords to use them as identifiers" on page 923.

<table>
<tr><th>Keyword</th><th>Description / Syntax and Example</th></tr>
<tr><td>

`action`

</td><td>

References or declares an action. Required in each action declaration.

Also an EPL type.

```
action action_name ([arglist])returns retType{
do_something>;
}

action notifyUser(){
   log "Event sequence detected.";
}
```

</td></tr>
<tr><td>

`aggregate`

</td><td>

Keyword required in the definition of a custom aggregate function that can be used in a stream query.

```
aggregate [bounded|unbounded] aggregateName (
   [arglist]) returns retType {
aggregateBody }

aggregate bounded wstddev( decimal x, decimal w )
   returns decimal {
      do something}
```

</td></tr>
<tr><td>

`all`

</td><td>

Appears just before an event template to indicate that you want to continue listening for all instances of the specified event, and not just the first matching event.

```
all event_template

on all StockTick(*,*):newTick processTick();
```

</td></tr>
<tr><td></td><td>

Appears just before an event template that uses no other operators and creates a stream rather than an event listener. This is a stream source template, which continuously listens for all instances of the specified

</td></tr>
</table>

Keyword	Description / Syntax and Example

	event and inserts all matching events into a newly created stream.
	`all event_template_with_no_other_operators`
	`stream<Tick> ticks := all Tick(symbol="APMA");`

	See also: " retain all" on page 953.

`and`	Logical operator in an event expression.
	`on event_template and event_template action;`
	`on A() and B() executeAction();`

	Logical operator in an `if` statement or other Boolean expression.
	`if ordinary_exp and ordinary_exp then block;`
	`if x and y then {myBlock;}`

`as`	Specified to import a correlator plug-in, either a Java class or a C/C++ library.
	`import "plug-in-library" as identifier;`
	`import "MyPlugin" as foo;`

	Specified to make event fields with different names but the same content appear to have the same name so they can be used as the key in an Apama query. Replace *duration* with a `retain` clause, a `within` clause, or both.
	`event1() key field1 duration;`
	`event2() key field2 as field1 duration;`
	`CarNum() key road within 1 hour;`
	`Accident() key roadName as road within 1 hour;`

`at`	Temporal operator in event expressions. Triggers a timer at a specific time or at repeated intervals.
	`at(minutes, hours, days_of_month, months, days_of_week [,seconds])`
	`on all at(5, 9, *, *, *) success;`

	Identifies the log level in a `log` statement.
	`log string [at log_level];`
	`log "Your message here" at INFO;`

`between`	In an Apama query, restricts which part of the pattern a `within` clause or a `without` clause applies to. Two

Keyword	Description / Syntax and Example

	or more identifiers can be specified in a `between` clause.
	`between (identifier1 identifier2 ...)`
	`between (a b)`

`boolean`	Boolean type. Value is `true` or `false`.
	`boolean identifier;`
	`boolean marketOpen;`

`bounded`	Optional keyword in a custom aggregate function definition. Indicates a function that can be used only with a bounded stream query window. See the syntax and example for "aggregate" on page 939.
`break`	In a `for` or `while` statement, transfers control to the next statement following the block that encloses the `break` statement. `break;`
`by`	Part of a `partition by` or `group by` clause in a stream query. Valid as an identifier outside a stream query. See the syntax and example for "group by" on page 945 and "partition by" on page 952.
`catch`	Part of a `try...catch` statement for handling exceptions. See the syntax and example for "try" on page 956.

`chunk`	Data type. References a dynamically allocated opaque object whose contents cannot be seen or directly manipulated in EPL. Typically used to manage plug-in data.
	`chunk identifier;`
	`chunk complexProductInfo;`

`completed`	Event expression that matches only after all other processing on the matching event is completed.
	`on all completed event_expression action;`
	`on all completed A(f < 10.0) {}`

Keyword	Description / Syntax and Example

`constant`	Specifies an unchanging literal value.
	`constant type name := literal;`
	
	`constant float GOLDEN := 1.61803398874;`

`context`	Type. Enables parallel processing.
	`context(string name)`
	`context(string name, boolean receivesInput)`
	
	`context c:=context("test");`

`continue`	In a `for` or `while` statement, ends execution of the current iteration and transfers control to the beginning of the loop. `continue;`

`currentTime`	Special EPL variable that returns the current time in the correlator.
	`log currentTime.toString();`
	`send TestEvent(currentTime) to "output";`

`decimal`	Type. Signed floating point decimal number with `d` at the end to distinguish it from a `float` type.
	`decimal identifier;`
	
	`decimal exactValue;`
	`exactValue := 1.2345d;`

`day`
`days`
	Part of a time literal you can specify in an Apama query `within` clause.
	`within integer day | days`
	
	`within 3 days`

`dictionary`	Type. Stores and retrieves data based on a key.
	`dictionary <key_type, data_type> identifier;`
	
	`dictionary <integer, string> myOrders;`

`die`	Terminates execution of the monitor instance.
	`die;`
	
	`on NewStock (chosenStock.name,`
	`   chosenStock.owner) die;`

`else`	Part of an `if` statement. See the syntax and example for "if" on page 946.

Keyword	Description / Syntax and Example

`emit`	Publishes an event on the correlator's output queue.
	`emit event ;`
	
	`emit newEvent;`

`emit...to`	To publish an event to a named channel of the correlator's output queue, specify `to channel`. This statement will be deprecated in a future release. Use `send...to` instead.
	`emit event to channel ;`
	
	`emit newEvent to "com.apamax.pricechanges";`

`enqueue`	Sends an event to the correlator's special queue for enqueued events. The event is then moved to the back of the input queue of each public context.
	`enqueue event ;`
	
	`enqueue newEvent;`

`enqueue ...to`	To send an event to the back of the input queue of a particular context specify `to context_expr`. Or, to send an event to the back of the input queues for a sequence of contexts, specify `to sequence< context_expr>`. This statement will be deprecated in a future release. Use `send...to` instead.
	`enqueue event_expr to context_expr ;`
	`enqueue event_expr to sequence<context_expr>;`
	
	`enqueue tick to c;`

`event`	Declares an event type.
	
	Required in each event type definition.
	`event event_type {`
	`   [ [wildcard] field_type field_name ; |`
	`   constant field_type field_name := literal ; |`
	`   action_definition ... ]`
	`}`
	
	`event StockTick {`
	`   string name;`
	`   float price;`
	`}`

`every`	In a stream query, if you specify a `within` window, specification of `every` updates the window every *`batchPeriodExpr`* seconds.

Keyword	Description / Syntax and Example

	In a monitor, the `every` keyword is valid as an identifier outside a stream query.
	`every batchPeriodExpr`
	
	`from v in values`
	`   within 3.0 every 3.0`
	`   select v`

	If you specify a `retain` window without also specifying `within,` specification of `every` updates the window after every *batchSizeExpr* items are received.
	`every batchSizeExpr`
	
	`from v in values`
	`   retain 3 every 3`
	`   select v`

	In an Apama query, specify `every` to aggregate values over multiple match sets.
	`find every event :coassignment`
	`   select_or_having_clause`
	
	`find every A:a`
	`   select avg(a.x):aax { }`

`false`	Possible value of a Boolean variable.

`find`	In an Apama query, specifies the pattern of interest and a procedural block to execute when a match set is found.
	`find`
	`   [every]`
	`   query_event_pattern`
	`   [where_clause ]`
	`   [within_clause ]`
	`   [without_clause ]`
	`   [select_clause ]`
	`   [having_clause ] {`
	`   block`
	`   }`
	
	`find`
	`   Withdrawal:w1 -> Withdrawal:w2`
	`   where w2.country != w1.country {`
	`      log "Suspicious withdrawal: "`
	
	`   }`

`float`	Type. Signed floating point number. `float identifier;`

<table>
<tr><th>Keyword</th><th>Description / Syntax and Example</th></tr>
<tr><td></td><td><pre>float squareRoot;</pre></td></tr>
<tr><td><code>for</code></td><td>Iterates over the members of a <code>sequence</code> and executes the enclosing statement or block once for each member.<pre>
forStatement ::= for counter
   in sequence block ;

for i in s {
   print i.toString();
}</pre></td></tr>
<tr><td><code>from</code></td><td>Introduces a stream query definition. Specifies the stream, and optionally a window (stream subset), that the stream query is operating on.<pre>
from itemIdentifier in streamExpr
   [windowDefinition]

from t in ticks retain 3</pre></td></tr>
<tr><td></td><td>Two consecutive <code>from</code> clauses specify a cross-join, which combines items from two streams to create one stream.<pre>
from itemIdentifier in streamExpr
   [windowDefinition]
from itemIdentifier in streamExpr
   [windowDefinition]

from x in letters retain 2
   from y in numbers retain 2
   select P(x,y)</pre></td></tr>
<tr><td></td><td>Specifies a stream listener that obtains items from a stream and passes them to procedural code.<pre>
[listener :=] from streamExpr :
identifier statement

float p;
from t in all Tick(symbol="APMA")
   select t.price : p {
   print "'APMA' price is: " +
      p.toString();
}</pre></td></tr>
<tr><td><code>group by</code></td><td>Controls how a stream query groups data when generating aggregate output items.

It is valid to use <code>group</code> as an identifier outside a stream query.<pre>
group by groupByExpr [, groupByExpr]...

from t in ticks
   within 60.0 group by t.symbol</pre></td></tr>
</table>

<table>
<tr><th>Keyword</th><th>Description / Syntax and Example</th></tr>
<tr><td></td><td><pre>   select mean(t.price)</pre></td></tr>
<tr><td rowspan="2"><code>having</code></td><td>Filter the items coming out of a stream query's aggregate projection. In a monitor, valid as an identifier outside of a stream query.
<pre>from t in all Temperature()
   within 60.0
   having count() > 10
   select mean(t.value)</pre></td></tr>
<tr><td>In an Apama query <code>find</code> statement, restricts when procedural code block is executed.
<pre>having boolean_projection_expr

find every ATMWithdrawal:w
   having last(w.amount) > THRESHOLD
      * avg(w.amount)
   select last(w.transactionId):tid {
   send SuspiciousTransaction(tid) to
      SuspiciousTxHandler;
   }</pre></td></tr>
<tr><td><code>hour</code>
<code>hours</code></td><td>Part of a time literal you can specify in an Apama query <code>within</code> clause.
<pre>within integer hour | hours

within 5 hour</pre></td></tr>
<tr><td><code>if</code></td><td>Conditionally executes a statement or block.
<pre>ifStatement ::=
   if booleanExpression then block
   | if booleanExpression
      then block else block
   | if booleanExpression
      then block else ifStatement block
   ::= {
statementList
   }

if floatVariable > 5.0 then {
   integerVariable := 1;
} else if floatVariable < -5.0 then {
   integerVariable := -1;
} else {
   integerVariable := 0;
}</pre></td></tr>
<tr><td><code>import</code></td><td>Loads a plug-in into the correlator and makes it available to your monitor, event, or aggregate function.
<pre>import "plug-in_name" as identifier;

import "complex_plugin" as complex;</pre></td></tr>
</table>

<table>
<tr><th>Keyword</th><th>Description / Syntax and Example</th></tr>
<tr><td><code>in</code></td><td>Identifies range membership in an event expression.

```
on event_name(event_field in [range])

on all A(m in [0:10])
```
</td></tr>
<tr><td></td><td>Part of <code>for</code> statement.

See the syntax and example for "for" on page 945.</td></tr>
<tr><td></td><td>Part of <code>from</code> statement.

See the syntax and example for "from" on page 945.</td></tr>
<tr><td><code>inputs</code></td><td>In an Apama query, there must be an input definition for each event type that the query operates on. The input definitions must be in the <code>inputs</code> section. The <code>inputs</code> section follows the <code>parameters</code> section, if there is one, and precedes the required <code>find</code> statement. See also "Format of input definitions" on page 97.

```
inputs {
event_type(event_filter)
   key query_key
   [within_clause]
   [retain_clause]
   [with_unique_clause]
   [time_from_clause wait_clause
       [or_clause]] ;

   [ event_type(event_filter)
   key query_key
   [within_clause]
   [retain_clause]
   [with_unique_clause]
   [time_from_clause wait_clause
       [or_clause]] ; ]...
}
inputs {
   Transaction() key
      source as txSource,
      dest as txDest
      within PERIOD;
   Acknowledgement() key
      dest as txSource,
      source as txDest
      within PERIOD
}
```
</td></tr>
<tr><td><code>integer</code></td><td>Type. Negative, zero, and positive integers.

```
integer identifier;

integer count;
```
</td></tr>
</table>

Keyword	Description / Syntax and Example

`join`	Combines matching items from two streams to create one stream. This is an equi-join.
	
	Valid as an identifier outside a stream query.
	
	`join itemIdentifier in streamExpr`
	`   [windowDefinition]`
	`   on joinKeyExpr1 equals joinKeyExpr2`
	
	`from r in priceRequest`
	`   join p in prices`
	`   partition by p.symbol retain 1`
	`   on r.symbol equals p.symbol`
	`   select p.price`

	Built-in method on strings that concatenates a `sequence` of strings.
	
	`join(sequence<string> s)`
	
	`sequence<string> s :=`
	`   ["Something", "Completely", "Different"];`
	`   print ", ".join(s);`
	
	This prints the following:
	
	`"Something, Completely, Different"`

`key`	In an Apama query input definition, the `key` clause identifies one or more fields in the input event types. The correlator uses these fields as the query key and partitions incoming events so that all events with the same key value are in their own partition.
	
	`key field_name [as field_name2] duration`
	`inputs {`
	`   Withdrawal() key cardNumber within (period);`
	`}`

`largest`	Reserved for future use.
`location`	Type. An EPL type used to describe rectangular areas in a two-dimensional, unitless, Cartesian, coordinate plane. Locations are defined by the `float` coordinates of two points `x1`, `y1` and `x2`, `y2` at diagonally opposite corners of an enclosing boundary rectangle. `location(15.23, 24.234, 19.1232, 28.873)`

`log`	Writes messages and accompanying date and time information to the correlator's log file
	
	`log string [at log_level];`
	
	`log "Your message here" at INFO;`

<table>
<tr><th>Keyword</th><th>Description / Syntax and Example</th></tr>
<tr><td><code>millisecond</code>
<code>milliseconds</code>
<code>msec</code></td><td>Part of a time literal you can specify in an Apama query <code>within</code> clause.<pre>within integer millisecond | milliseconds | msec

within 100 msec</pre></td></tr>
<tr><td><code>minute</code>
<code>minutes</code>
<code>min</code></td><td>Part of a time literal you can specify in an Apama query <code>within</code> clause.<pre>within integer minute | minutes | min

within 3 min</pre></td></tr>
<tr><td rowspan="2"><code>monitor</code></td><td>Declares a monitor. Required in each monitor definition. Braces enclose event type definitions, global variable declarations, and actions.<pre>monitor monitor_name {
...
}

monitor SimpleShareSearch {
...
}</pre></td></tr>
<tr><td>Specifies subscription to a named channel or unsubscription from a previously subscribed channel. Subscription/unsubscription statements are located in action blocks.<pre>monitor.subscribe("channel_name");
monitor.unsubscribe("channel_name");

action start_trade()
   {
      // Subscribe to two channels:
      monitor.subscribe(“SOW_Ticks");
      monitor.subscribe(“IBM_Ticks");
   }</pre></td></tr>
<tr><td><code>new</code></td><td>Allocates a new object.<pre>new typeName;

b := new Foo();</pre></td></tr>
<tr><td rowspan="2"><code>not</code></td><td>Logical operator in an event expression.<pre>not event_template

on A() and not B() executeAction();</pre></td></tr>
<tr><td>Logical operator in an <code>if</code> statement or other Boolean expression.<pre>if not ordinary_exp then block;</pre></td></tr>
</table>

<table>
<tr><th>Keyword</th><th>Description / Syntax and Example</th></tr>
<tr><td></td><td><pre>if not x then myBlock;</pre></td></tr>
<tr><td><code>on</code></td><td>Declares an event listener.
<pre>on [all] event_expression action;

on NewsItem("ACME",*) findStockChange();</pre></td></tr>
<tr><td></td><td>Part of an equi-join clause.
See the syntax and example for join.</td></tr>
<tr><td><code>onBeginRecovery</code></td><td>If defined, action that the correlator executes when the correlator restarts.
Note that <code>onBeginRecovery</code> is not a keyword. It is a special identifier. It is good practice to refrain from using this identifier for any other purpose.
<pre>action onBeginRecovery() { }

action onBeginRecovery() {
   if (timeFormatPlugin.getTime() -
      currentTime > (60.0 * 60.0 * 2)
      then
      { longDowntime:=true;
         ... // do something if
             // downTime was long
      }
}</pre></td></tr>
<tr><td><code>onConcludeRecovery</code></td><td>If defined, action that the correlator executes when the correlator finishes recovery.
Note that <code>onConcludeRecovery</code> is not a keyword. It is a special identifier. It is good practice to refrain from using this identifier for any other purpose.
<pre>action onConcludeRecovery() { }

action onConcludeRecovery() {
  initiateListener(); // go back
                      //to normal
}</pre></td></tr>
<tr><td><code>ondie</code></td><td>If defined, action that the correlator executes when a monitor instance terminates.
Note that <code>ondie</code> is not a keyword. It is a special identifier. It is good practice to refrain from using this identifier for any other purpose.
<pre>action ondie() { }

action ondie() {
   log "sub-monitor terminating for "
      + myId;</pre></td></tr>
</table>

Keyword	Description / Syntax and Example
	`route InternalError("Foo");` `}`

`onload`	Name of the action that the correlator executes when you inject a monitor. Every monitor must declare an `onload` action.
	
	Note that `onload` is not a keyword. It is a special identifier. It is good practice to refrain from using this identifier for any other purpose.
	
	`action onload(){ ... }`
	
	`action onload() {`
	`   on all StockTick(*,*):newTick {`
	`      processTick();`
	`   }`
	`}`

`onunload`	If defined, action that the correlator executes when the last instance of a particular monitor terminates.
	
	Note that `onunload` is not a keyword. It is a special identifier. It is good practice to refrain from using this identifier for any other purpose.
	
	`action onunload() { };`
	
	`action onunload() {`
	`   route LastMonitorTerminating();`
	`}`

`optional`	Reserved for future use.

`or`	Logical operator in an event expression.
	
	`on` *`event_template`* `or` *`event_template action`*`;`
	
	`on A() or B() executeAction();`

	Logical operator in an `if` statement or other Boolean expression.
	
	`if` *`ordinary_exp`* `or` *`ordinary_exp`* `then` *`block`*`;`
	
	`if x or y then myBlock;`

`package`	Mechanism for adding context to monitor and event names. Monitors and global events in the same package must each have a unique name within the package.
	
	`package` *`identifier`*`;`
	
	`package com.apamax.orders;`

Keyword	Description / Syntax and Example

`parameters`	If an Apama query specifies the optional `parameters` section, it must be the first section in the query. Parameters must be `integer`, `float`, `string` or `boolean` types. Specify one or more *`data_type parameter_name`* pairs.
	`parameters {`
	`   data_type parameter_name;`
	`   [ data_type parameter_name; ]...`
	`}`
	
	`parameters {`
	`   integer threshold;`
	`   float period;`
	`}`

`partition by`	Effectively creates a separate window for each encountered distinct value of the `partition by` expression.
	`partition` is valid as an identifier outside a stream query.
	`partition by partitionByExpr`
	`   [, partitionByExpr]...`
	
	`from t in all Tick()`
	`   partition by t.symbol`
	`   retain 10 with unique t.price`
	`   select t.price`

`persistent`	At the beginning of a `monitor` declaration, indicates that you want that monitor to be persistent.
	`persistent monitor string`
	
	`persistent monitor ManageOrders`

`print`	Writes textual messages followed by a newline to the correlator's standard output stream — `stdout`.
	`print string;`
	
	`print "Your message here.";`

`query`	Declares a query. Required in each query definition. Braces enclose the optional `parameters` section, required `inputs` section, required `find` statement, and optional `action` definitions.
	`query name {`
	`   [ parameters { parameters_block } ]`
	`   inputs { inputs_block }`
	`   find  pattern block`
	`   [ action_definition ... ]`
	`}`

Keyword	Description / Syntax and Example

	`query FraudulentWithdrawalDetection2 {`
	`   inputs {`
	`      Withdrawal() key userId retain 3;`
	`   }`
	`   find Withdrawal:w1 -> Withdrawal:w2`
	`      where w1.city != w2.city {`
	`         log "Suspicious withdrawal: "`
	`            + w2.toString() at INFO;`
	`   }`
	`}`

`retain`	In an Apama query input definition or in a stream query, specifies that the window contains only the last *n* events of this type that have been received.
	`retain` *`windowSizeExpr`*
	
	`inputs {`
	`      Withdrawal() key userId retain 3;`
	`   }`
	
	`from v in values`
	`   retain 10`
	`   select mean(v)`

`retain all`	Specifies a stream query window that aggregates values calculated over the lifetime of the query. This is an unbounded window.
	`retain all`
	
	`from v in values`
	`   retain all`
	`   select mean(v)`

`return`	In an `action` body, specifies the value to return from that action. Required if an action returns a value.
	`returns` *`typeToReturn`*
	`return` *`retValue`*
	
	`action complexAction(`
	`   integer i, float f) returns string {`
	`   // do something`
	`   return "Hello";`
	`}`

`returns`	In an `action` declaration, specifies the type of value returned by an action. Required if an action returns a value. Also used in custom aggregate function declarations and when naming `action` types. See previous example.

Keyword	Description / Syntax and Example

`route`	Sends an event to the front of the current context's input queue.
	`route event();`
	
	`route StockTick();`

`rstream`	In a query with a window definition and a simple projection, indicates that you want the query to output its *remove* stream, that is, the items it removes from the window.
	Specification of `rstream` in an aggregate projection is not useful so it is not allowed.
	Valid as an identifier outside a stream query.
	`select [rstream] selectExpr`
	
	`from i in inputs`
	`   retain 2`
	`   select rstream i;`

`second`
`seconds`
`sec`
	Part of a time literal you can specify in an Apama query `within` clause.
	`within integer second | seconds | sec`
	
	`within 3 sec`

`select`	Identifies the item(s) you want the query to output.
	In a monitor, this keyword is valid as an identifier outside a stream query.
	`select [rstream] selectExpr`
	
	`from v in values`
	`   retain 10`
	`   select mean(v);`

	In an Apama query, a `select` clause aggregates event field values in order to find data based on many sets of events. A pattern that aggregates values specifies the `every` modifier in conjunction with `select` and/or `having` clauses.
	`select projection_expr:identifier`
	
	`find every ATMWithdrawal:w`
	`   having last(w.amount) > THRESHOLD * avg(w.amount)`
	`   select last(w.transactionId):tid {`
	`      send SuspiciousTransaction(tid) to`
	`         SuspiciousTxHandler;`
	`}`

Keyword	Description / Syntax and Example

`send...to`	Sends an event to the specified channel, context, or sequence of contexts. Contexts and external receivers subscribed to that channel receive the event.
	`send event_expr to channel;`
	`send event_expr to context;`
	`send event_expr to sequence<channel>;`
	
	`send tick to "ticks-SOW";`

`sequence`	Type. Ordered set or array of entries whose values are all of the same primitive or reference type.
	`sequence<data_type> identifier;`
	
	`sequence<float> myPrices;`

`smallest`	Reserved for future use.

`spawn`	Creates a copy of the currently executing monitor instance.
	`spawn action([parameter_list]);`
	
	`action onload() {`
	`   spawn forward("a", "channelA");`
	`   spawn forward("b", "channelB");`
	`}`

`spawn...to`	To create a copy of the currently executing monitor instance in the specified context specify `spawn` with `to`*`context_expr`*.
	`spawn action([arg_list]) to context_expr;`
	
	`spawn doCalc(cal) to context(“Calculation”);`

`static`	Reserved for future use.

`stream`	Type. Refers to a stream of items. An item can be a `boolean`, `decimal`, `float`, `integer`, `string`, `location`, or `event` type.
	`stream<type> name;`
	
	`stream<decimal> prices;`

`streamsource`	Reserved for future use.

`string`	Type. Text string.
	`string identifier;`
	
	`string message;`

Keyword	Description / Syntax and Example
then	Part of conditional if statement. See the syntax and example for "if" on page 946.
throw	Reserved for future use.
to	Indicates target of an emit, enqueue, send or spawn operation. See examples for "emit...to" on page 943, "enqueue...to" on page 943, send...to, and "spawn...to" on page 955.
true	Possible value of a Boolean variable.

try	Part of a try...catch statement for handling exceptions.
	
	`try block1`
	`   catch(Exception variable) block2`
	`try {`
	`   return float.parse(prices[fxPair]);`
	`   } catch(Exception e) {`
	`      return 1.0;`
	`   }`

unbounded	Optional keyword in a custom aggregate function definition. Indicates a function that can be used with only an unbounded (retain all) stream query window. See the syntax and example for "aggregate" on page 939.
unique	Part of the optional with unique clause in a stream query. See the syntax and example for "with unique" on page 958.

unmatched	Except for completed and unmatched event expressions, the event is not a match with any event expression currently within the context.
	
	`on all unmatched event_expression[:coassignment] action;`
	
	`on all unmatched Tick():tick processTick();`

Keyword	Description / Syntax and Example

`using`	In a monitor, an Apama query, or a stream query, allows use of an event type or a custom aggregate function that is defined in another package.
	`using packageName .{aggregateName | eventName };`
	
	`using com.apamax.custom.myAggregateFunction;`

`wait`	Temporal operator in an event expression. Inserts a pause in an event expression. Once activated, a `wait` expression becomes true automatically once the specified amount of time passes.
	`wait(float)`
	
	`on A() -> wait(10.0) -> C() success;`

	In an Apama query, requires an amount of time to pass before or after the event pattern. The value must be a `float` or time literal. Typically used in conjunction with a `without` clause to detect the absence of an event before or after another event.
	`wait(value ):identifier`
	`find wait(1 minute):previous`
	`   -> DoorOpened:d without Unlock:u`

`where`	Filter the items in the stream query's window or the items that result from a join operation.
	
	In a monitor, valid as an identifier outside a stream query.
	`where booleanExpr`
	
	`from t in ticks`
	`   retain 100 where t.price*t.volume>threshold`
	`   select mean(t.price)`

	In an Apama query, a `where` clause filters which events cause a match set. You can specify a find `where` clause that applies to the event pattern and you can also specify a without `where` clause that is part of a `without` clause. Any `where` clauses that you want to apply to the event pattern must precede any `within` or `without` clauses.
	`where booleanExpr`
	
	`find LoggedIn:lc -> OneTimePass:otp`
	`   where lc.user = otp.user`
	`   within 30.0 {`
	`      emit AccessGranted(lc.user);`
	`   }`

Keyword	Description / Syntax and Example

`while`	Repeatedly evaluates a `boolean` expression and executes an enclosed statement or block as many times as the expression result is found to be `true`.
	`whileStatement ::= while booleanExpression`
	`   block`
	
	`while integerVariable > 10 {`
	`   integerVariable := integerVariable - 1;`
	`   on StockTick(`
	`      "ACME", integerVariable) doAction(); }`

`wildcard`	In an event type definition, indicates a parameter that you will never specify as a match criteria in an event template.
	`wildcard param_type param_name ;`
	
	`event StockTick {`
	`   string name;`
	`   float price;`
	`   wildcard string exchange;`
	`}`

`with unique`	In a query or stream query, if there is more than one item in the window that has the same value for the key identified by *`keyExpr`*, only the most recently received item is part of the result set.
	
	`with` and `unique` are valid as identifiers outside a query or stream query.
	`with unique keyExpr`
	
	`from p in pairs`
	`   retain 3 with unique p.letter`
	`   select sum(p.number)`

`within`	Temporal operator in an event expression. Specifies a time limit for the event listener to be active.
	`within(float)`
	
	`on A() -> B() within(30.0) notifyUser();`

	In a stream query, specifies a window that contains only those items received in the last *`windowDurationExpr`* seconds.
	`within windowDurationExpr`
	
	`from v in values`
	`   within 20.0`
	`   select mean(v);`

<table>
<tr><th>Keyword</th><th>Description / Syntax and Example</th></tr>
<tr><td></td><td>In an Apama query, a `within` clause sets the time period during which events in the match set must have been added to their windows. The value of *`durationExpression`* must be a `float` literal or a time literal. A `float` literal always indicates a number of seconds.
<pre>
within durationExpression
   [between (identifer1 identifier2 ...)]

find Withdrawal:w1 -> Withdrawal:w2
    where w2.country != w1.country
    within 1 hour {
    log "Suspicious withdrawal: "
       + w2.toString() at INFO;
   }
</pre></td></tr>
<tr><td>without</td><td>In an Apama query `find` pattern, a `without` clause specifies that the presence of a particular event type prevents a match. Optionally, you can specify a `where` clause that filters which instances of the specified event type prevent a match and/or a `between` clause to restrict when the exclusion applies.
<pre>
without typeId : coassignmentId
   [where boolean_expression]
   [between (identifier1 identifier2 ...)]

find OuterDoorOpened:od -> InnerDoorOpened:id
   where od.user = id.user
   without SecurityCodeEntered:sce
      where od.user = sce.user {
   emit Alert("Intruder "+id.user);
}
</pre></td></tr>
<tr><td>xor</td><td>Logical exclusive `or` operator that can apply to an event template.
<pre>
xor event_template

on A() xor B() notifyUser();
</pre></td></tr>
<tr><td></td><td>Logical operator in an `if` statement or other Boolean expression.
<pre>
if ordinary_exp xor ordinary_exp then block;

if x xor y then myBlock;
</pre></td></tr>
<tr><td>#</td><td>Escapes names of variables that clash with EPL keywords.
<pre>
#identifier

print f.#integer.toString();
</pre></td></tr>
</table>

C EPL Methods Quick Reference

This reference lists all EPL methods. It is meant as a concise reminder of the method signatures for convenient printing and viewing. For more detailed information on these methods, see "Types" on page 767, which is part of the EPL Reference.

action methods

The only operation that you can perform on an `action` variable is to call it. You do this in the normal way by passing a set of parameters in parentheses after an expression that evaluates to the `action` variable. For an example and additional details, see "Using action type variables" on page 276.

For more information on the `action` type, see "action" on page 786.

boolean methods

Method	Result
`canParse(`*`string`*`)`	Returns `true` if the string argument can be successfully parsed.
`parse(`*`string`*`)`	Returns the `boolean` instance represented by the `string` argument.
`toString()`	Returns a `string` representation of the `boolean`.

For more information on the `boolean` type, see "boolean" on page 768.

Channel methods

Method	Result
`canParse()`	Returns `true` if the string argument can be successfully parsed to create a `Channel` object.
`clone()`	Returns a new `Channel` that is an exact copy of the `Channel` the `clone()` method is called on. The original content of the `Channel` is copied into the new `Channel`.
`empty()`	Returns true if the `Channel` object contains an empty context.

Method	Result
`parse()`	Returns the `Channel` instance represented by the `string` argument.
`toString()`	Returns a string representation of the `Channel` object.

For more information on the `Channel` type, see "Channel" on page 788.

chunk methods

Method	Result
`clone()`	Returns a new `chunk` that is an exact copy of the `chunk` that `clone()` was called on.
`empty()`	Returns `true` if the chunk is empty.
`getOwner()`	Returns a `string` that contains the name of the correlator plug-in that the chunk belongs to.

For more information on the `chunk` type, see "chunk" on page 789.

context methods

Method	Result
`current()`	Returns a `context` object that is a reference to the current context.
`getId()`	Returns an `integer` that is the ID of the context.
`getName()`	Returns a `string` that is the name of the context.
`isPublic()`	Returns a `boolean` true if the context is public.
`toString()`	Returns a `string` that contains the properties of the context.

In addition, the `current()` static method returns a reference to the current `context`.

For more information on the `context` type, see "context" on page 790.

decimal and float methods

Unless noted otherwise, if you call a method on a `decimal` type, the return value is a `decimal`, and if you call the method on a `float` type, the return value is a `float`.

Method	Result
`abs()`	Returns the absolute value.
`acos()`	Returns the inverse cosine.
`acosh()`	Returns the inverse hyperbolic cosine.
`asin()`	Returns the inverse sine in radians.
`asinh()`	Returns the inverse hyperbolic sine.
`atan()`	Returns the inverse tangent.
`atan2(`*y*`)`	Returns the two-parameter inverse tangent.
`atanh()`	Returns the inverse hyperbolic tangent.
`bitEquals(`*decimal*`)` `bitEquals(`*float*`)`	Returns `true` if the value it is called on and the value passed as an argument to the method are the same. The value the method is called on and the argument to the method must both be `decimal` types or must both be `float` types.
`canParse(`*string*`)`	Returns `true` if the argument can be successfully parsed.
`cbrt()`	Returns the cube root.
`ceil()`	Returns the smallest possible `integer` that is greater than or equal to the operand.
`cos()`	Returns the cosine.
`cosh()`	Returns the hyperbolic cosine.
`erf()`	Returns the error function.

Method	Result
`exp()`	Returns `e` to the power *x* or `e`*x*, where *x* is the value of the `decimal` or `float` and where `e` is approximately 2.71828183.
`exponent()`	When called on a `float` value: returns the exponent where *x* `= mantissa*2`exponent assuming `0.5 <= |mantissa| < 1.0`. When called on a `decimal` value: returns the exponent where *x* `= mantissa*10`exponent assuming `0.1 <= |mantissa| < 1.0`.
`floor()`	Returns the largest possible `integer` that is less than or equal to the value the method is called on.
`fmod(y)`	Returns `mod` *y* in exact arithmetic.
`formatFixed(`*integer*`)`	Returns a `string` representation of the value the method is called on where the value is rounded to the number of decimal places specified in the argument.
`formatScientific(`*integer*`)`	Returns a `string` representation of the value the method is called on where the value is truncated to the number of significant figures specified in the argument and formatted in Scientific Notation.
`fractionalPart()`	Returns the fractional component.
`gammal()`	Returns the logarithm of the gamma function.
`ilogb()`	Returns an `integer` that is the binary exponent of non-zero operand.
`integralPart()`	Returns an `integer` that is the integral part of a floating point value. Similar to `floor()` which rounds down, and `ceil()` which rounds up. `integralPart()` rounds towards zero.
`isFinite()`	Returns `true` if and only if the value it is called on is not `+Infinity`, `-Infinity`, or `NaN`.

Method	Result
`isInfinite()`	Returns `true` if and only if the value it is called on is `+Infinity` or `-Infinity`.
`isNaN()`	Returns `true` if and only if the value it is called on is `NaN`.
`ln()`	Returns the natural log.
`log10()`	Returns the log to base 10.
`mantissa()`	When called on a `float` value: returns a mantissa where *x* = mantissa*$2^{exponent}$ assuming that `0.5 <= |mantissa| < 1.0`. When called on a `decimal` value: returns a mantissa where *x* = mantissa*$10^{exponent}$ assuming that `0.1 <= |mantissa| < 1.0`.
`max(`*decimal*`, `*decimal*`)` `max(`*float*`, `*float*`)`	Returns the value of the larger operand. You can call this method on the `decimal` or `float` type, or on an instance of a `decimal` or `float` type.
`min(`*decimal*`, `*decimal*`)` `min(`*float*`, `*float*`)`	Returns the value of the smaller operand. You can call this method on the `decimal` or `float` type, or on an instance of a `decimal` or `float` type.
`nextafter(`*y*`)`	Returns the next distinct floating-point number after the operand that is representable in the underlying type in the direction toward *y*.
`parse(`*string*`)`	Returns the `decimal` or `float` instance represented by the `string` argument.
`pow(`*decimal*`)`	Returns *x* to the power *y* (where *y* is the argument) or *xy*.
`pow(`*float*`)`	
`rand()`	Returns a random value from 0.0 up to (but not including) the value the method was invoked on.
`round()`	Rounds to the nearest integer using banker's rounding.

Method	Result
`scalbn(integer)`	When called on a `float` value: returns *x**2*n*, where *n* is of `integer` type. When called on a `decimal` value: returns *x**10*n*, where *n* is of `integer` type.
`sin()`	Returns the sine.
`sinh()`	Returns the hyperbolic sine.
`sqrt()`	Returns the positive square root.
`tan()`	Returns the tangent.
`tanh()`	Returns the hyperbolic tangent.
`toDecimal()`	Returns a `decimal` representation of the `float`.
`toFloat()`	Returns a `float` representation of the `decimal`.
`toString()`	Returns a `string` representation.

For more information on the `decimal` type, see "decimal" on page 769.

For more information on the `float` type, see "float" on page 770.

dictionary methods

Method	Result
`add(key, item)`	Adds an entry to the dictionary.
`canParse(string)`	When the item type is parseable: returns `true` if the `string` argument can be successfully parsed to create a `dictionary` object.
`clear()`	Sets the size of the `dictionary` to 0, deleting all entries.
`clone()`	Returns a new `dictionary` that is an exact copy.

Method	Result
`getOr(`*`key`*`, `*`alternative`*`)`	Returns the item that corresponds to the specified key. If the specified key is not in the dictionary, the `getOr()` method returns *`alternative`*.
`getOrDefault(`*`key`*`)`	Retrieves an existing item by its key, or returns a default instance of the dictionary's item type if the dictionary does not contain the specified key.
`getOrAdd(`*`key`*`, `*`alternative`*`)`	Retrieves an existing item by its key, or adds the specified key to the dictionary with *`alternative`* as its value if it is not already present and also returns the specified alternative.
`getOrAddDefault(`*`key`*`)`	Retrieves an existing item by its key or, if it is not already present, adds the specified key with a default instance of the dictionary's item type and returns that instance.
`hasKey(`*`key`*`)`	Returns `true` if a key exists within the dictionary.
`keys()`	Returns a `sequence` of the dictionary's keys sorted in ascending order.
`parse(string)`	When the item type is parseable: returns the `dictionary` object represented by the `string` argument.
`remove(`*`key`*`)`	Removes an entry by key.
`size()`	Returns as an `integer` the number of elements in the dictionary.
`toString()`	Converts the entire dictionary in ascending order of key values to a `string`.
`values()`	Returns a `sequence` of the dictionary's items sorted in ascending order of keys.
`[key]`	Retrieves or overwrites an existing item by its key, or creates a new item.

For more information on the `dictionary` type, see "dictionary" on page 791.

event methods

Method	Result
`canParse(string)`	On events that are parseable: returns `true` if the `string` argument can be successfully parsed.
`clone()`	Returns a new `event` that is an exact copy.
`getFieldNames()`	Returns a `sequence` of strings that contain the field names of an event type.
`getFieldTypes()`	Returns a `sequence` of strings that contain the type names of an event type's fields.
`getFieldValues()`	Returns a `sequence` of strings that contain the field values of an event.
`getName()`	Returns a `string` whose value is an event's type name.
`getTime()`	Returns a `float` that indicates a time expressed in seconds since the epoch, January 1st, 1970.
`isExternal()`	Returns `true` if the event was generated by an external source.
`parse(string)`	On events that are parseable: returns the `event` object represented by the `string` argument.
`toString()`	Returns a `string` representation of the event.

For more information on the `event` type, see "event" on page 796.

Exception methods

The `Exception` type is defined in the `com.apama.exceptions` namespace.

Method	Result
`getMessage()`	Returns a `string` that contains the exception message.

Method	Result
`getStackTrace()`	Returns a `sequence` of `StackTraceElement` objects that represent the stack trace for when the exception was first thrown.
`getType()`	Returns a `string` that contains the exception type.
`toString()`	Returns a `string` that contains the exception message and the exception type.
`toStringWithStackTrace()`	Returns a `string` that contains the exception message, the exception type, and the stack trace elements.

For more information on the `Exception` type, see "Exception" on page 800.

integer methods

Method	Result
`abs()`	Returns as an `integer` the absolute value.
`canParse(`*`string`*`)`	Returns `true` if the argument can be successfully parsed.
`getUnique()`	Generates a unique `integer` in the scope of the correlator. This is a type method as well as an instance method.
`max(`*`integer`*`, `*`integer`*`)`	Returns as an `integer` the value of the larger operand. You can call this method on the `integer` type or on an instance of an `integer` type.
`min(`*`integer`*`, `*`integer`*`)`	Returns as an `integer` the value of the smaller operand. You can call this method on the `integer` type or on an instance of an `integer` type.
`parse(`*`string`*`)`	Returns the `integer` instance represented by the argument. You can call this method on the `integer` type or on an instance of an `integer` type.
`pow(`*`integer`*`)`	Returns as an `integer` the value of the operand to the power of the argument.

Method	Result
`rand()`	Returns a random `integer` value from `0` up to (but not including) the value of the operand.
`toDecimal()`	Returns a `decimal` representation.
`toFloat()`	Returns a `float` representation.
`toString()`	Returns a `string` representation.

For more information on the `integer` type, see "integer" on page 777.

listener methods

Method	Result
`quit()`	Immediately terminates the listener.

For more information on the `listener` type, see "listener" on page 803.

location methods

Method	Result
`canParse(`*`string`*`)`	Returns `true` if the argument can be successfully parsed.
`clone()`	Returns a new `location` that is an exact copy.
`expand(`*`float`*`)`	Returns a new `location` expanded by the value of the parameter in each direction.
`inside(`*`location`*`)`	Returns `true` if the location is entirely enclosed by the space defined by the parameter.
`parse(`*`string`*`)`	Returns the `location` instance represented by the argument.
`toString()`	Returns a `string` representation.

For more information on the `location` type, see "location" on page 803.

monitor methods

Method	Result
`onload()`	Invoked immediately after a monitor has been loaded.
`ondie()`	Invoked when a monitor instance terminates.
`onunload()`	Invoked after all instances of a monitor have terminated.
`onBeginRecovery()`	Invoked at the start of recovery of a persistence-enabled correlator.
`onConcludeRecovery()`	Invoked at the end of recovery of a persistence-enabled correlator.

For more information on monitors, see "Monitors" on page 845 and "Simple actions" on page 849.

sequence methods

Method	Result
`append(`*`item`*`)`	Appends the item to the end of the operand.
`appendSequence(`*`sequence`*`)`	Appends the sequence to the end of the operand.
`canParse(`*`string`*`)`	Returns `true` if the string argument can be successfully parsed to create a `sequence` object.
`clear()`	Sets the size of the sequence to `0`, deleting all entries.
`clone()`	Returns a new `sequence` that is an exact copy.
`indexOf(`*`item`*`)`	Returns as an `integer` the location of the first matching item.
`insert(`*`item, integer`*`)`	Inserts the item specified in the location indicated by the second argument.
`parse(`*`string`*`)`	Returns the `sequence` object represented by the string argument.

Method	Result
`remove(`*`integer`*`)`	Removes the n^{th} element in the sequence, moves all the elements above it down, which reduces the size by 1. The first element in a `sequence` is at location `0`.
`reverse()`	Reverses the order of the items in the sequence.
`setCapacity(`*`integer`*`)`	Sets the amount of memory initially allocated for the sequence.
`setSize(`*`integer`*`)`	Sets the number of elements in the sequence.
`size()`	Returns as an `integer` the number of elements in the sequence.
`sort()`	Sorts the sequence in ascending order.
`toString()`	Converts the sequence to a `string`.
`[`*`integer`*`]`	Retrieves or overwrites the sequence entry located at the index specified. EPL sequence elements are indexed from `0`.

For more information on the `sequence` type, see "sequence" on page 805.

StackTraceElement methods

The `StackTraceElement` type is defined in the `com.apama.exceptions` namespace.

Method	Result
`getActionName()`	Returns a `string` that contains the name of the action in which the exception occurred.
`getFilename()`	Returns a `string` that contains the name of the file that contains the code in which the exception occurred.
`getLineNumber()`	Returns an `integer` that indicates the line number of the code in which the exception occurred.
`getTypeName()`	Returns a `string` that indicates the type (event, aggregate, monitor) that contains the action in which the exception occurred.

Method	Result
`toString()`	Returns a string whose format is `"typeName.actionName() filename:linenumber"`.

For more information on the `StackTraceElement` type, see "StackTraceElement" on page 809.

stream methods

Method	Result
`clone()`	Returns the original `stream`. It does not clone it.
`quit()`	Causes a stream listener to terminate.

For more information on the `stream` type, see "stream" on page 809.

string methods

Method	Result
`canParse(string)`	Returns `true` if the string argument can be successfully parsed.
`clone(string)`	Returns a reference to the specified `string`.
`find(substring)`	Returns an `integer` indicating the index position of the argument. EPL string indices start at `0`.
`findFrom(substring, fromIndex)`	Behaves like `find()`, but starts searching at *fromIndex*.
`intern()`	Marks the `string` as interned. Subsequent incoming events that contain a `string` that is identical to an interned `string` use the same `string` object.
`join(sequence<string> s)`	Concatenates the strings in *s* using the operand as a separator.
`length()`	Returns an `integer` indicating the length of the string.

Method	Result
`ltrim()`	Returns a `string` where all whitespace characters at the beginning have been removed.
`parse(`*`string`*`)`	Returns the `string` value represented by the `string` argument without enclosing that value in quotation marks. You can call this method on the `string` type or on an instance of a `string` type.
`replaceAll(`*`string1`*`, `*`string2`*`)`	Makes a copy of the string, replaces instances of *`string1`* with instances of *`string2`* and returns the revised string.
`rtrim()`	Returns a `string` where all whitespace characters at the end have been removed.
`split(string)`	Returns a `sequence` of strings that represent the argument split at occurrences of the operand string.
`substring(`*`integer`*`, `*`integer`*`)`	Returns the substring indicated by the `integer` arguments.
`toBoolean()`	Returns `true` if the string is "`true`".
`toDecimal()`	Returns a `decimal` representation of the string.
`toFloat()`	Returns a `float` representation of the string.
`toInteger()`	Returns an `integer` representation of the string.
`toLower()`	Returns an all-lowercase `string` representation.
`toUpper()`	Returns an all-uppercase `string` representation.
`tokenize(string)`	Categorizes each character in the argument as either part of a delimiter (the character appears in the operand string) or part of a token (any other character), divides the argument into tokens separated by delimiters, and returns the tokens as a `sequence` of strings.

Method	Result
`toString()`	Returns the contents of the string value, exactly the same as using the string directly.

For more information on the `string` type, see "string" on page 780.

D EPL Streams: A Quick Tour

Apama EPL allows code authors to express event-driven programs using natural event-processing constructs.

Note: This quick tour assumes that you are using monitors, and not Apama queries, in your Apama application.

An EPL program consists of a set of interacting monitors that receive, process and emit events. Monitor instances are self-contained, communicating with other monitor instances via events. An Apama application can thus be viewed as a dynamic network of interacting monitor instances communicating via events. Why dynamic? Because the application creates and destroys monitor instances in response to the external events received; similarly, the monitor instances dynamically subscribe and unsubscribe to particular event patterns or complex event expressions as needed. Thus, at any given instant, the application has only the monitor instances it needs and is only listening for the events of interest at that time. This approach makes Apama a highly efficient and responsive tool for complex event processing.

Complex event processing systems come in different flavors, one of which is event stream processing. The event stream processing approach is similar to the Apama approach, but tends to involve networks that are much less dynamic. These networks are constructed from streams and processing nodes, where a processing node is typically a query, defined using declarative, relational language elements.

Event stream processing is useful in cases where one or more flows of raw events are to be converted into a set of "refined" flows of added-value events. For these operations, the use of event stream processing language elements allows these operations to be expressed more clearly and concisely than when using procedural language constructs. For this reason, Apama EPL includes event stream processing elements.

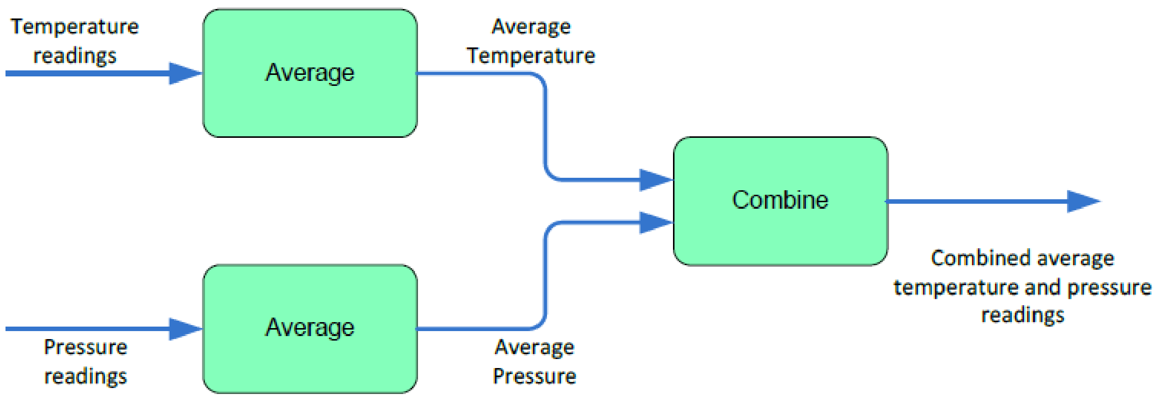
The event stream processing constructs in EPL maintain the Apama ethos of operational responsiveness. Thus you will find that Apama stream queries are not static and that they are closely integrated with the rest of the EPL language. Application developers can write code to add and remove stream queries as required, and the streams language elements allow the values controlling the stream query behavior to be varied dynamically.

For complete information about using Apama stream queries, see "Working with Streams and Stream Queries" on page 205.

About the Apama event stream processing model

The Apama event stream processing model consists of a network of streams and processing nodes; a processing node whose logic is expressed in terms of a relational query expression is a stream query.

The diagram below shows an example of a stream processing network.



The network consists of five streams[1] and three stream queries. Each stream query has one or more input streams, from which it receives events, and one output stream, to which it transmits events.

In Apama, each event stream has a single generator but can have multiple consumers. Each stream or stream query is created within and owned by an Apama monitor instance. The streams and stream queries within a monitor instance are used to convert the events received by the monitor instance into added-value events. These added-value events are then available for use by standard EPL actions.

[1]In Apama, the term "stream" is used to refer both to the channel through which the events flow and also to the events flowing through the channel. Some members of the CEP fraternity use the term event channel to refer to the former and event stream to refer to the latter. In Apama, the term channel is already in use and so stream is used to refer to the "event channels" connecting stream queries.

Example events for stream queries

The following events are used by the stream query examples:

```
event Temperature {
   string sensorId;
   float temperature;
}

event Pressure {
   string sensorId;
   float pressure;
}

event TemperatureAndPressure {
   string sensorId;
   float temperature;
   float pressure;
}
```

Processing events using streams

To receive events directly into a listener action, an `on` statement is used, for example:

```
Temperature t;
on all Temperature(sensorId="S001"):t { print t.toString(); }
```

If, instead, the events are to be received into a stream, a `stream` assignment statement is used:

```
stream<Temperature> temperatures := all Temperature(sensorId="S001");
```

This statement declares the `stream` variable `temperatures`, which is used to refer to a stream of `Temperature` events. On the right side of the assignment, the `all Temperature(sensorId="S001")` expression is a stream source template. A stream source template is an event template preceded by the `all` keyword; it uses no other event operators. It creates a stream that contains events that are received by the monitor instance and that match the event template.

The following code shows how the events in the stream are processed.

```
Temperature temperature;
stream<Temperature> temperatures := all Temperature(sensorId="S001");
from t in temperatures retain 3
select Temperature("S001", mean(t.temperature)) : temperature {
   print temperature.toString();
}
```

A `from` statement is similar to an `on` statement in form. It consists of three parts:

- A stream query

  ```
  from t in temperatures retain 3
  select Temperature("S001", mean(t.temperature))
  ```

- Followed by a co-assignment

  ```
  : temperature
  ```

- Followed by a listener action

  ```
  { print temperature.toString(); }
  ```

In this example, the stream query processes events from the `temperatures` stream and computes the average temperature value of the three *most recent* events. A new output event is created for each new input event, having the literal value `"S001"` for the `sensorId` field and the evaluated average temperature value for the `temperature` field. Each output event, in turn, is co-assigned to the variable `temperature` and this is used in the `print` statement, within the listener action.

The average temperature value is calculated using the built-in[2] `mean()` aggregate function.

The following topics provide examples of using the streams language elements.

[2] Apama provides a number of commonly used aggregates as predefined *built-in* aggregates. It is also possible to create user-defined *custom* aggregates.

Creating a stream network

The code example below implements the simple stream network illustrated in "About the Apama event stream processing model " on page 978. The code illustrates that stream queries can be used in `from` statements and also on the right side of a stream assignment. Executing a stream assignment statement does two things:

- Creates the defined query within the stream network.
- Updates the `stream` variable (on the left side of the assignment) to refer to the stream query's output stream.

Up to now, streams have been referred to as *event streams*. In Apama, the type of a stream need not be an event; it is possible to create streams of simple types such as `decimal`, `float`, `integer`, `boolean`, and `string`.[3]

```
01. TemperatureAndPressure tp;
02. stream<Temperature> temperatures := all Temperature(sensorId="T001");
03. stream<Pressure> pressures := all Pressure(sensorId="P001");
04. stream<float> meanTs := from t in temperatures
05.    retain 3 select mean(t.temperature);
06. stream<float> meanPs := from p in pressures
07.    retain 3 select mean(p.pressure);
08. from t in meanTs retain 1 from p in meanPs retain 1
09. select TemperatureAndPressure("S001",t,p) : tp {
10.    print tp.toString();
11. }
```

Line 8 of the code example shows one method for joining two streams. The stream query contains two `from` clauses, where each `from` clause specifies that the most recent item in the stream is retained. A query with two `from` clauses identifies that a *cross-join* operation should be performed between the two source item sets. In the code example, when a new item is available on the `meanPs` stream, it is joined with the most recent item on the `meanTs` stream, and when a new item is available on the `meanTs` stream, it is joined with the most recent item on the `meanPs` stream.

[3] It is for this reason that, in *Developing Apama Applications in EPL*, and in other documentation, the contents of streams are referred to as items, not as events.

Using inline stream source template expressions

The previous code example can be re-written in a more concise format by writing the stream source template expressions inline, as illustrated below.

```
TemperatureAndPressure tp;
stream<float> meanTs := from t in all Temperature(sensorId="T001")
    retain 3 select mean(t.temperature);
stream<float> meanPs := from p in all Pressure(sensorId="P001")
    retain 3 select mean(p.pressure);
from t in meanTs retain 1 from p in meanPs retain 1
select TemperatureAndPressure("S001",t,p) : tp {
   print tp.toString();
}
```

Using compound stream queries

The complete stream network for the example presented in the previous topics can be expressed as a single compound query:

```
TemperatureAndPressure tp;
from t in
   from t in all Temperature(sensorId="T001")
     retain 3 select mean(t.temperature)
   retain 1
from p in
   from p in all Pressure(sensorId="P001")
     retain 3 select mean(p.pressure)
   retain 1
select TemperatureAndPressure("S001",t,p) : tp {
   print tp.toString();
}
```

Note that the *item identifiers*, `t` and `p`, in the `from` clauses for the inner queries use the same names as those in the outer queries. This does not cause any ambiguity because the scope of the item identifier in the inner query is restricted to the inner query, and within the inner query hides the name used in the outer query. Hence, the item identifier, `t`, in the inner query refers to `Temperature` events from the stream `all Temperature(sensorId="T001")`, whereas the item identifier, `t`, in the outer query refers to the `float` items produced by the inner query. Using the same identifier is a matter of style; different identifiers could be used if preferred (for example, `avgT` and `t`).

Using dynamic values in stream queries

One of the great features of Apama stream queries is that the values used in the stream query expression can be dynamically changed throughout the lifetime of the query. This is useful (for example) for setting dynamic thresholds or for changing the aggregation period of a query. The code examples below illustrate these cases.

```
TemperatureAlert alert;
from t in all Temperature(sensorId="T001") where t.temperature > threshold
select TemperatureAlert(t.sensorId,t.temperature): alert { emit alert; }
```

```
TemperatureRange range;
from t in all Temperature(sensorId="T001") within period every period
select TemperatureRange(t.sensorId,min(t.temperature),max(t.temperature)):
  range {
    print range.toString();
  }
```

In the code examples above, if the variables `threshold` and `period` are local variables[4], then the value used by the queries are the values of the local variables when the `from` statement is executed.[5] Even if the local variable is assigned a new value at some later point in the program execution, the values used by the queries will be constant throughout the lifetime of the query.

However, if global variables[6] or event member variables[7] are used and, at a later time, the values of these variables are changed, then these value changes will affect the behavior of the stream queries. The full code examples for the dynamic use-cases are given below.

```
event Temperature { string sensorId; float temperature; }
event TemperatureAlert { string sensorId; float temperature; }
event ChangeThreshold { float temperature; }
```

```
monitor TemperatureAlertMonitor {
  float threshold := 60.0; // a global variable is used
  action onload() {
    TemperatureAlert alert;
    from t in all Temperature(sensorId="T001")
      where t.temperature > threshold
    select TemperatureAlert(t.sensorId,t.temperature): alert { emit alert; }
    ChangeThreshold ct;
    on all ChangeThreshold():ct { threshold := ct.temperature; }
  }
}
```

```
event Temperature { string sensorId; float temperature; }
event TemperatureRange { string sensorId; float minTemperature;
  float maxTemperature; }
event ChangePeriod { float period; }
```

```
using com.apama.aggregates.max; using com.apama.aggregates.min;
event TemperatureRangeService {
  float period; // an event member variable is used
  action init( string id, float _period ) {
     period := _period;
     TemperatureRange range;
     from t in all Temperature(sensorId=id) within period every period
     select TemperatureRange(id,min(t.temperature),max(t.temperature)):
       range {
         print range.toString();
       }
  }
  action setPeriod(float _period ) { period := _period; }
}
monitor UsesTemperatureRangeService {
  action onload() {
  TemperatureRangeService trs := new TemperatureRangeService;
  trs.init("S001",60.0);
  ChangePeriod cp;
  on all ChangePeriod ():cp { trs.setPeriod(cp.period); }
  }
}
```

[4] A local variable is defined within the body of an action.

[5] This is exactly the same mechanism as is used when creating event listeners (that is, when using `on` statements).

[6] When the stream query is defined within a monitor action.

[7] When the stream query is defined within an event action.

Using stream variables

Because streams are values in EPL, you can pass stream references between the code elements within a monitor. This is useful when writing services. A common service (that is, a service used by two or more monitors) is normally implemented using a *service event*. This event contains the logic to implement the service or to access an external service. A stream can be used as part of the interface to the service: the stream and stream query specification is encapsulated within the service event code and a reference to the stream created by this code is returned, from the service action to the client monitor code, as the return value of an action call. This is illustrated in the following code example.

```
event Temperature { string sensorId; float temperature; }
event TemperatureRange { string sensorId; float minTemperature;
  float maxTemperature; }
```

```
01. using com.apama.aggregates.max; using com.apama.aggregates.min;
02. event TemperatureRangeService {
03.   float period;
04.   action init( string id, float _period ) returns stream<TemperatureRange> {
05.      period := _period;
06.      return
07.         from t in all Temperature(sensorId=id) within period every period
08.         select TemperatureRange(id,min(t.temperature),max(t.temperature));
09.   }
10. }
11. monitor UsesTemperatureRangeService {
12.   action onload() {
13.      TemperatureRangeService service := new TemperatureRangeService;
14.      stream<TemperatureRange> ranges := service.init("S001",60.0);
15.      TemperatureRange range;
16.      from r in ranges select r : range { print range.toString(); }
17. }
```

Using the short-form from statement

In the previous example, on line 16 of the code, the query used is very simple:

```
from r in ranges select r : range { print range.toString(); }
```

It merely selects the current item in the stream and co-assigns it to the variable `range`. This is a common use-case and the EPL provides an alternate, short-form version that can be used instead, as illustrated below.

```
from ranges: range { print range.toString(); }
```

To further simplify the code in the previous example, note that instead of declaring a `ranges` stream variable, you can place the expression for the stream (that is, `service.init("S001",60.0)`) directly inline, in the `from` statement:

```
from service.init("S001",60.0): range { print range.toString(); }
```

Hence, the monitor code in the example in the previous topic can be rewritten as follows:

```
monitor UsesTemperatureRangeService {
   action onload() {
      TemperatureRangeService service := new TemperatureRangeService;
      TemperatureRange range;
      from service.init("S001",60.0): range { print range.toString(); }
   }
}
```

Stream lifetime

When considering the lifecycle of a stream, first reflect on how the stream is created. A `from` statement is similar to an `on` statement, in that both create stream listeners. When creating the stream listener, a `listener` variable can be assigned to refer to the stream listener. The `listener` variable can then be used (at a later time) to quit the stream listener.[8]

When creating a stream query and assigning it to a `stream` variable, the `stream` variable can be used (at a later time) to quit the stream query.

Once created, a stream (and the stream query supplying it) remains in existence until any of the following occur:

- It is quit.
- All of its downstream connections are removed.
- Removal of an upstream stream means that the stream (stream query) can generate no more output.

The above statements sound rather complicated but are quite straightforward. Consider the following code example:

```
event Temperature { string sensorId; float temperature; }
event Quit { string what; }
```

```
using com.apama.aggregates.mean;
monitor StreamLifetimes {
   action onload() {
      float temperature;
      stream<Temperature> temperatures := all Temperature(sensorId="S001");
      stream<float> meanTs := from t in temperatures within 60.0
         select mean(t.temperature);
      listener freezing := from t in meanTs where t < 0.0
         select t: temperature {
         print "It's freezing! The temperature is " + temperature.toString();
   }
   listener boiling := from t in meanTs where t > 100.0
      select t: temperature {
      print "It's boiling! The temperature is " + temperature.toString();
   }
   on Quit("temperatures") { temperatures.quit(); }
   on Quit("meanTs") { meanTs.quit(); }
   on Quit("freezing") { freezing.quit(); }
   on Quit("boiling") { boiling.quit(); }
```

```
20.    }
21. }
```

In this example, the stream network consists of two streams (declared on lines 5 and 6-7) and two stream listeners (declared on lines 8-11 and 12-15). The stream variables `temperatures` and `meanTs` refer to the two streams, and the `listener` variables `freezing` and `boiling` refer to the two stream listeners. Let's take a look at what happens when `quit()` is called on each of the listener and stream variables:

- If `freezing.quit()` is called, then only the stream listener referred to by `freezing` becomes inactive. Similarly, if `boiling.quit()` is called, then only the stream listener referred to by `boiling` becomes inactive.
- If `meanTs.quit()` is called, then all of the streams, stream queries and stream listeners will become inactive. This is because the `meanTs` query is the only downstream connection for the `temperatures` stream, and once `meanTs` is quit, the two stream listeners for `freezing` and `boiling` can no longer produce any output.
- Finally, if `temperatures.quit()` is called, then there would be no further input to the stream query for `meanTs`. However, items in the window of the stream query may remain within the window for up to 60.0 seconds after the `temperatures` stream is quit. Hence the `meanTs` stream query, and any queries/ listeners downstream of it, will remain active until all items in the `meanTs` stream query window have expired (been ejected from the window).

[8] This is identical to an EPL `on` statement, where a `listener` variable can be used to quit a standard event listener.

Using windows in stream queries

Various examples in earlier sections have used window operators. Within a stream query, when a window operator is applied to a stream, it causes some of the past items in the stream to be retained. These are the items upon which the relational query operations are performed. For example, consider the following query:

```
from t in all Temperature(sensorId="T001") retain 10 select mean(t.temperature)
```

For sensor `"T001"`, this query calculates the mean temperature value from the set of the most recent 10 temperature readings from that sensor. Now consider the following query:

```
from t in all Temperature(sensorId="T001") within 60.0 select mean(t.temperature)
```

For sensor `"T001"`, this query calculates the mean temperature value from the set of all temperature readings for that sensor within the last 60.0 seconds.

The table below gives a guide to the window operators and their combinations:

Syntax	Description
`retain all`	Retains all of the items input to the stream since its creation. [9]

Syntax	Description
`retain` *number*	Retains (up to) the *number* of most recent items input to the stream.
`within` *duration*	Retains all items input to the stream within the last *duration* seconds.
`within` *duration* `retain` *number*	Retains (up to) the *number* of most recent items input to the stream within the last *duration* seconds.
`retain` *number* `with unique key`	Retains (up to) the *number* of most recent items input to the stream. A new item with a given `key` value will displace an existing item with the same `key` value.
`within` *duration* `with unique key`	Retains items input to the stream within the last *duration* seconds. A new item with a given `key` value will displace an existing item with the same `key` value.

If no window operator is applied to a stream then the set of items on which the relational query operations are performed is the set of items that is current for the stream. Using a stream without applying any window operations to it can be useful when used within a `join` query.

[9] The implementation achieves this behavior without actually retaining all of the items.

Using joins in stream queries

There are two types of joins that can be used within a stream query: cross-joins and equi-joins.

A cross-join of two sets combines every item from one set with each item from the other set. A cross-join is performed by using two, top-level `from` clauses in a query. We have already seen an example of this:

```
TemperatureAndPressure tp;
stream<Temperature> temperatures := all Temperature(sensorId="T001");
stream<Pressure> pressures := all Pressure(sensorId="P001");
stream<float> meanTs := from t in temperature
  retain 3 select mean(t.temperature);
stream<float> meanPs := from p in pressure
  retain 3 select mean(p.pressure);
from t in meanTs retain 1
from p in meanPs retain 1
select TemperatureAndPressure("S001",t,p) : tp {
```

```
   print tp.toString();
}
```

An equi-join is performed by following the initial `from` clause with a `join` clause. An equi-join of two sets combines items in the two sets where a specified key value of the item in the first set matches a specified key value of the item in the second set. Separate key value expressions for each source item identify the key values to be compared. For example:

```
TemperatureAndPressure tp;
from t in all Temperature() partition by t.sensorId retain 1
join p in all Pressure() partition by p.sensorId retain 1
on sensorNumber(t.sensorId) equals sensorNumber(p.sensorId)
select TemperatureAndPressure(combinedId(t.sensorId), t.temperature,
   p.pressure) : tp {
     print tp.toString();
  }
```

When considering performance, cross-joins will in general be less efficient than equi-joins. It is advised that cross-joins only be used where the number of items in the stream windows is small, as in the example at the beginning of this topic.

Note that joins can be performed between a stream[10] and a window. For example:

```
TemperatureAndPressure tp;
stream<Temperature> temperatures := all Temperature(sensorId="T001"); 1
stream<Pressure> pressures := all Pressure(sensorId="P001");
from t in temperatures from p in pressures retain 1
   select TemperatureAndPressure ("S001",t.temperature,p.pressure) : tp {
   print tp.toString();
}
```

This join will produce an output item whenever there is a new `Temperature` event for the sensor but not when there is a new `Pressure` event. The temperature and pressure events arrive at different times; when the temperature event arrives, because of the `retain 1` in the right side `from` clause, there is a pressure event available for joining with; but, because there is no window operation in the left side `from` clause, when a pressure event arrives, there is no temperature event to join with.

[10] That is, where no window operators are applied to the stream, in the query.

Using partitions and groups in stream queries

The second code example in "Using joins in stream queries" on page 987 uses the `partition by` clause. The `partition by` clause splits a stream into partitions, based on a key value. When a window operator is applied to a partitioned stream, the behavior is as if a separate window operator had been applied to each partition. We often refer to the result of using `partition by` followed by a window operator as a partitioned window; queries with partitioned windows are used to retain a set of items for each partition, as illustrated in the second code example in topic about using joins. Following is another example of using the `partition by` clause:

```
Temperature temperature;
from t in all Temperature() partition by t.sensorId retain 3
group by t.sensorId select Temperature(t.sensorId, mean(t.temperature)):
   temperature {
   print temperature.toString();
```

```
}
```

The combined `partition by` and `retain` clauses cause the last three values for each sensor to be retained. In contrast, the `group by` clause's effect is to alter the behavior of the projection (the item generated by the `select` clause) such that aggregate values are generated for each group in the collection and not for the collection as a whole. For example, when a new `Temperature` event occurs for sensor `"S001"`, the event will be directed to the partition for that sensor. It will cause the window contents for that partition to change, which, in turn, will affect the collection of events over which the aggregate projection is being performed. Because a `group by` clause is present, a new projected value will be produced only for the group(s) affected by the update. In this case, the group for `sensorId"S001"`. The result is that an incoming temperature event, for sensor `"S001"`, causes a new outgoing mean temperature event for sensor `"S001"` to be produced. The `group by` clause can also be used without `partition by`, as in the following code sample.[11]

```
Temperature temperature;
from t in all Temperature() within 60.0
group by t.sensorId select Temperature(t.sensorId, mean(t.temperature)):
   temperature {
      print temperature.toString();
   }
```

[11] As implied by the example, there is usually little point in partitioning a time-based (a `within`) window. One exception to this is when it is combined with the `with unique` clause.

Using rstream

Normally, in stream queries, you select items that are currently in the stream or window. Adding the keyword `rstream` to a `select` clause causes it to select the items that are currently leaving the stream or window. The main use of this is to delay events, either by a time period or by a number of events. The delayed event is typically compared to the set of events that arrived after it, up until the current time, as illustrated by the code example below.

```
stream<float> tNow := from t in all Temperature(sensorId="T001")
   select t.temperature;
stream<float> tDelayed := from t in tNow retain 10 select rstream t;
float t; 05. from t1 in tDelayed from t2 in tNow retain 10 where t2 > t1 * 1.
select t2 : t
   print "Rapid temperature rise: " + t.toString();
}
```

Common stream query patterns

The following topics describe a few common patterns. You have seen many of them in the earlier code examples.

Aggregation in stream queries

Examples in earlier topics show the calculation of running averages of the temperature and pressure readings. A common use-case, illustrated below, is the calculation of the volume-weighted average price of a stock. This example uses the weighted-average aggregate function, `wavg()`.

```
using com.apama.aggregates.wavg;
event Tick { string symbol; decimal price; decimal volume; }
monitor CalculateVwap {
   action onload() {
      decimal vwap;
      from t in all Tick(symbol="SOW") within 300.0
         select wavg(t.price,t.volume): vwap {
            print vwap.toString();
         }
   }
}
```

Aggregation can also be used in combination with `group by` to generate the aggregate results for different groups of items, as illustrated in the code examples in "Using partitions and groups in stream queries" on page 988. Note that code authors are not restricted to the set of built-in aggregates as it is possible to define custom aggregates.

Throttling in stream queries

Sometimes it is the case that results are only required at a given rate. We can extend the example in "Aggregation in stream queries" on page 990 by adding an `every` clause, so that the query generates values only every 10 seconds.

```
using com.apama.aggregates.wavg;
event Tick { string symbol; float price; float volume; }
monitor CalculateVwap {
   action onload() {
      float vwap;
      from t in all Tick(symbol="SOW") within 300.0 every 10.0
      select wavg(t.price,t.volume): vwap {
         print vwap.toString();
      }
   }
}
```

Dynamic filters in stream queries

Event listeners, created using `on` statements, are very efficient at matching events. But they have the drawback that the values of any variables or expressions used within an event template are evaluated only when the `on` statement is executed. That is, they are evaluated only when the event listener is created and they remain fixed thereafter.

For example, suppose you are using event listeners only and you need to change one of the match values each time a match is found. You would need to quit the current listener and recreate it with the new match value. An alternative approach is to use streams. For example, if you want to receive `Temperature` events for a given sensor, but to select only those where the temperature value is greater than a given, static threshold, you could do the following:

```
event Temperature { string sensorId; float temperature; }
monitor StaticFilter {
   action onload() {
      Temperature temperature;
      on all Temperature (sensorId="T001", temperature>38.0): temperature {
         print temperature.toString();
      }
   }
}
```

If, instead, you need to change the temperature threshold dynamically, then the following code could be used:

```
event Temperature { string sensorId; float temperature; }
event Threshold { string sensorId; float temperature; }
monitor StaticFilter {
   Threshold threshold := Threshold("T001",38.0);
   action onload() {
      Temperature temperature;
      from t in all Temperature(sensorId="T001")
      where t.temperature > threshold.temperature select t : temperature {
         print temperature.toString();
      }
      on all Threshold(sensorId="T001"): threshold {}
   }
}
```

In the static case (that is, where the threshold value does not change), the code in the first example above is more efficient than that of the second example. This is because the events that are not of interest are rejected as early as possible, that is, before being passed to the monitor instance. In the dynamic case, that is, where a changing threshold value is required, the second example above is more elegant and typically more efficient than using a non-streams approach.

In the dynamic threshold use case, choosing which solution to prefer – using only event listeners or using streams - would depend on how frequently the threshold value is expected to change. The cost of quitting the current listener and recreating it with the new threshold value may be acceptable if the threshold value changes only infrequently.

Joining the most recent event on each of two streams

Another common pattern that has already been seen is that of comparing the most recent values from two event streams. The following code example illustrates this pattern with a use case example of calculating the price spread between two stocks.

```
event Price { string symbol; float price; }
monitor ComputeSpreads {
   action onload() {
      float spread;
      from a in all Price(symbol="IBM") retain 1
      from b in all Price(symbol="MSFT") retain 1
      select a.price - b.price : spread {
         print spread.toString();
      }
   }
}
```

Retaining the most recent item in each partition of a partitioned stream

There are some situations where you want to join the most recent events from two sources, based on a common key. Typically you are processing all events from those sources and not a subset of those events. This pattern is similar to the previous example, but with a `partition by` clause added to each *leg* of the join.

```
event Temperature { string sensorId; float temperature; }
event Pressure { string sensorId; float pressure; }
event TemperatureAndPressure { string sensorId; float temperature;
   float pressure; }
monitor CombineTheLatestTemperatureAndPressureReadings {
   action onload() {
      TemperatureAndPressure tp;
      from t in all Temperature() partition by t.sensorId retain 1
      join p in all Pressure() partition by p.sensorId retain 1
      on t.sensorId equals p.sensorId
      select TemperatureAndPressure(t.sensorId, t.temperature,
         p.pressure) : tp {
           print tp.toString();
         }
   }
}
```

Joining an event with a previous event

Another use case that is reasonably common is where an item output from a stream query needs to be compared to the previous output item. For example, suppose you need to detect for a given sensor when the average temperature value was below a threshold value but now is above the threshold value.

```
using com.apama.aggregates.mean;
event Temperature { string sensorId; float temperature; }
monitor DetectBreach {
   action onload() {
      stream<float> temperatures := all Temperature(sensorId="S001");
      stream<boolean> current := from t in temperatures within 60.0
      select mean(t.temperatures) > 97.0;
      stream<boolean> previous := from c in current
           retain 1 select rstream c;
      string text;
      from c in current from p in previous where c and not p
      select "Temperature breach" : text {
         print text;
      }
   }
}
```