

Technical Document

# Niagara Developer Guide

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niagara<sup>4</sup>

# Niagara Developer Guide

## **Tridium, Inc.**

3951 Westerre Parkway, Suite 350  
Richmond, Virginia 23233  
U.S.A

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### User Interface

In Niagara AX there are three different types of User Interface Technology a developer can choose from...

- **bajau:** Niagara's own Java based User Interface toolkit. The Workbench Applet is required to run this User Interface in the browser.
- **Hx:** A light weight Servlet based approach to creating HTML based User Interfaces.
- **Mobile:** An HTML5 based User Interface technology specifically designed for smart tablets and phones.

In Niagara 4 we're trying to transition away from these technologies because....

- Modern web browsers are moving away from supporting the Java plug-in.
- Three different skills sets are required to cover all bases (bajau, Hx and Mobile).
- Three times the amount of effort is needed to cover all bases.

Niagara 4 has a new User Interface stack based upon HTML5...

*Please note, bajaux support for Mobile will not be available in Niagara 4.0!*

**Workbench has an HTML5 Web Browser:** you can now surf the web in Workbench. We recognize a lot of Niagara AX developers have created their existing User Interfaces in Java. By adding a browser to Workbench, you can transition away from Java for User Interfaces and use HTML5 instead.

- **JavaScript:** use JavaScript, HTML and CSS to create your Web Applications. We've provided a suite of JavaScript libraries to make this as easy as possible. This includes BajaScript, bajaux and much more.
- **Web Server:** we've switched our web server to use [Letty](#). We've improved our Java Servlet support along the way.
- **bajau and Hx:** due to the massive investment our customers have in Niagara AX User Interface technology, we still support both bajau and Hx in Niagara 4.

## Niagara 4 Open Web Technologies

Our new User Interface technology uses HTML5. This consists of HTML, JavaScript and CSS. For information on developing your own applications using this technology, please see the section on [Building JavaScript Applications](#).

- [RequireJS](#): RequireJS is used to write Modular JavaScript code. In Java, packages are used to organize your code. In JavaScript, [AMD \(Asynchronous Module Definition\)](#) is the mechanism for defining modules of reusable JavaScript code. All new JavaScript code in Niagara 4 is modular and uses AMD.
- [BajaScript](#): BajaScript is a JavaScript library that's used to access Niagara data. *It's important to note that BajaScript isn't a User Interface library.* It's just for the data.
- [bajaux](#): bajaux is used to write User Interface Widgets in JavaScript. Code once and use everywhere. A bajaux Widget will run in both Hx and Workbench. These tutorials cover a lot of ground and utilize BajaScript, lexicons, dashboards and dialogs to create HTML5 web applications.
- [webEditors](#): a library of widgets, editors and frameworks built using bajaux.
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## Web Server

Niagara's web server can be extended in 3 different ways. In Niagara AX, you could extend via Servlet Views and Web Servlet Components. In Niagara 4, you can also extend via standard Java Servlets.

- [Niagara Web Modules](#): create Java Servlets in Niagara Modules.
- [Servlet Views](#): create a view that is also a Servlet.

[Web Servlet Components](#): create a component that's also a Servlet.

In Niagara AX 3.7, we added support for [Apache Velocity](#) to Niagara. Velocity is a powerful Server Side Templating tool.

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# Niagara Overview

## Mile High View

**Niagara:** a Java software framework and infrastructure with a focus on three major problems:

- Integrating heterogeneous systems, protocols, and fieldbuses;
- Empowering non-programmers to build applications using graphical programming tools;
- Targeted for highly distributed, embedded systems;

## Problem Space

### Java

The framework uses the Java VM as a common runtime environment across various operating systems and hardware platforms. The core framework scales from small embedded controllers to high end servers. The framework runtime is targeted for Java 8 SE compact3 profile compliant VMs. The user interface toolkit and graphical programming tools are targeted for Java 8 SE VMs.

### Integrating Heterogenous Systems

Niagara is designed from the ground up to assume that there will never be any one "standard" network protocol, distributed architecture, or fieldbus. Niagara's design center is to integrate cleanly with all networks and protocols. The Niagara Framework standardizes what's inside the box, not what the box talks to.

### Programming for Non-programmers

Most features in the Niagara Framework are designed for dual use. These features are designed around a set of Java APIs to be accessed by developers writing Java code. At the same, most features are also designed to be used through high level graphical programming and configuration tools. This vastly increases the scope of users capable of building applications on the Niagara platform.

### Embedded Systems

Niagara is targeted for embedded systems capable of running a Java VM. This excludes low devices without 32-bit processors or several megs of RAM. But even embedded systems with the horsepower of low end workstations have special needs. They are always headless and require remote administration. Embedded systems also tend to use solid state storage with limited write cycles and much smaller volume capacities than hard drives.

### Distributed Systems

The framework is designed to provide scalability to highly distributed systems composed of 10,000s of nodes running the Niagara Framework software. Systems of this size span a wide range of network topologies and usually communicate over unreliable Internet connections. Niagara is designed to provide an infrastructure for managing systems of this scale.

## Component Software

Niagara tackles these challenges by using an architecture centered around the concept of "Component Oriented Development". Components are pieces of self-describing software that can be assembled like building blocks to create new applications. A component centric architecture solves many problems in Niagara:

- Components provide a model used to normalize the data and features of heterogeneous protocols and networks so that they can be integrated seamlessly.
- Applications can be assembled with components using graphical tools. This allows new applications to be built without requiring a Java developer.
- Components provide unsurpassed visibility into applications. Since components are self-describing, it is very easy

for tools to introspect how an application is assembled, configured, and what is occurring at any point in time. This provides immense value in debugging and maintaining Niagara applications.

- Components enable software reuse.



# Architecture

## Overview

This chapter introduces key concepts and terminology used in the Niagara architecture.

## Programs

There are typically four different programs (or processes) associated with a Niagara system. These programs and their network communication are illustrated via the [Communications Diagram](#):

- **Station:** is the Niagara runtime - a Java VM which runs a Niagara component application.
- **Workbench:** is the Niagara tool - a Java VM which hosts Niagara plugin components.
- **Daemon:** is a native daemon process. The daemon is used to boot stations and to manage platform configuration such as IP settings.
- **Web Browser:** is standard web browser such as IE or FireFox that hosts one of Niagara's web user interfaces.

## Protocols

There are typically three network protocols that are used to integrate the four programs described above:

- **Fox:** is the proprietary TCP/IP protocol used for station-to-station and workbench-to-station communication.
- **HTTP:** is the standard protocol used by web browsers to access web pages from a station.
- **Niagarad:** is the proprietary protocol used for workbench-to-daemon communication.

## Platforms

Niagara is hosted on a wide range of platforms from small embedded controllers to high end servers:

- **Jace:** the term Jace (Java Application Control Engine) is used to describe a variety of headless, embedded platforms. Typically a Jace runs on a Flash file system and provides battery backup. Jaces usually host a station and a daemon process, but not workbench. Jaces typically run QNX or embedded Windows XP as their operating system.
- **Supervisor:** the term Supervisor is applied to a station running on a workstation or server class machine. Supervisors are typically stations that provide support services to other stations within a system such as history or alarm concentration. Supervisors by definition run a station, and may potentially run the daemon or workbench.
- **Client:** most often clients running a desktop OS such as Windows or Linux access Niagara using the workbench or a web browser.

## Stations

The Niagara architecture is designed around the concept of component oriented programming. [Components](#) are self contained units of code written in Java and packaged up for deployment as [modules](#). Components are then wired together to define an application and executed using the [station](#) runtime.

A Niagara application designed to be run as a station is stored in an XML file called [config.bog](#). The bog file contains a tree of components, their property configuration, and how they are wired together using [links](#). Station databases can be created using a variety of mechanisms:

- Created on the fly and in the field using workbench graphical programming tools.
- Created offline using workbench graphical programming tools.
- Predefined and installed at manufacturing time.
- Programmatically generated in the field, potentially from a learn operation.

Stations which restrict their programmability to accomplish a dedicated task are often called *appliances*.

Often the term Supervisor or Jace will be used interchangeably with station. Technically the term station describes the component runtime environment common all to all platforms, and Supervisor and Jace describe the hosting platform.

## Daemon

The Niagara daemon is the one piece of Niagara written in native code, not Java. The daemon provides functionality used to commission and bootstrap a Niagara platform:

- Manages installing and backing up station databases;
- Manages launching and monitoring stations;
- Manages configuration of TCP/IP settings;
- Manages installation and upgrades of the operating system (QNX only);
- Manages installation and upgrades of the Java virtual machine;
- Manages installation and upgrades of the Niagara software;
- Manages installation of lexicons for localization;
- Manages installation of licenses;

On Windows platforms, the daemon is run in the background as a Window's service. On QNX it is run as a daemon process on startup.

The most common way to access daemon functionality is through the workbench. A connection to the daemon is established via the "Open Platform" command which opens a PlatformSession to the remote machine. A suite of views on the PlatformSession provides tools for accomplishing the tasks listed above.

Another mechanism used to access daemon functionality is via the plat.exe command line utility. This utility provides much of the functionality of the workbench tools, but via a command line program suitable for scripting. Run plat.exe in a console for more information.

## Workbench

Niagara includes a powerful tool framework called the [workbench](#). The workbench is built using the [bajau](#) widget framework which is itself built using the standard Niagara component model.

The workbench architecture is designed to provide a common shell used to host plugins written by multiple vendors. The most common type of plugin is a *view* which is a viewer or editor for working with a specific type of object such as a component or file. Other plugins include sidebars and tools.

Workbench itself may be morphed into new applications using the [BWbProfile](#) API. Profiles allow developers to reuse the workbench infrastructure to create custom applications by adding or removing menu items, toolbar buttons, sidebars, and views.

## Web UI

An important feature of Niagara is the ability to provide a user interface via a standard web browser such as IE or FireFox. Niagara provides both server side and client side technologies to build [web](#) UIs.

On the server side, the [WebService](#) component provides HTTP and HTTPS support in a station runtime. The WebService provides a standard servlet engine. Servlets are deployed as components subclassed from [BWebServlet](#). Additional classes and APIs are built upon this foundation to provide higher level abstractions such as [BServletView](#).

There are two client side technologies provided by Niagara. The first is *web workbench* which allows the standard workbench software to be run inside a web browser using the Java Plugin. The web workbench uses a small applet called *wbapplet* to download modules as needed to the client machine and to host the workbench shell. These modules are cached locally on the browser's hard drive.

In addition to the web workbench, a suite of technology called [hx](#) is available. The hx framework is a set of server side servlets and a client side JavaScript library. Hx allows a real-time user interface to be built without use of the Java Plugin. It requires only web standards: HTML, CSS, and JavaScript.

## Fox

The Niagara Framework includes a proprietary protocol called *Fox* which is used for all network communication between

stations as well as between Workbench and stations. Fox is a multiplexed peer to peer protocol which sits on top of a TCP connection. The default port for Fox connections is 1911. Fox features include:

- Layered over a single TCP socket connection
- Digest authentication (username/passwords are encrypted)
- Peer to peer
- Request / response
- Asynchronous eventing
- Streaming
- Ability to support multiple applications over a single socket via channel multiplexing
- Text based framing and messaging for easy debugging
- Unified message payload syntax
- High performance
- Java implementation of the protocol stack

## API Stack

Niagara provides a broad suite of Java APIs used to customize and extend the station and workbench. The [software stack](#) diagram illustrates the various software layers of the architecture:

- **Baja:** The foundation of the architecture is defined via the [baja](#) module APIs. These APIs define the basics such as modules, component model, naming, navigation, and security.
- **Horizontal:** Niagara includes an extensive library of prebuilt components applicable to various M2M domains. The modules provide standard components and APIs, including: [control](#), [alarming](#), [historical](#) data collection, [scheduling](#), and [BQL](#).
- **Drivers:** Niagara is designed from the ground up to support multiple heterogeneous protocols. Modules designed to model and synchronize data with external devices or systems are called *drivers* and are typically built with the [driver framework](#). Drivers integrate both fieldbus protocols like BACnet and Lonworks as well as enterprise systems like relational databases and web services.
- **Human Interfaces:** An extensive software stack is provided for user interfaces. The [gx](#) framework provides a standard model and APIs for low level graphics. Built upon gx is the [bajau](#) module which provides a professional toolkit of standard widgets. Built upon bajau is the [workbench](#) framework which provides the standard APIs for writing plugin tools. The [px](#) framework and tools are used to enable non-programmers and developers alike to create new user interfaces via XML.

## Niagara 4 Directory Structure Change

### Overview

In order to improve the security of a Niagara installation and adopt standard application installation patterns, the directory structure for Niagara 4 was redesigned. The new design makes it easier for system administrators to manage security of the core application as well as the security of “user” data.

### Who is Impacted

Anyone who manages a Niagara installation and is familiar with the Niagara AX directory structure.

### What Changed

With a Niagara AX installation, configuration data and runtime data were intermixed. This required that users would need full access permissions to a Niagara AX installation and provided little to no flexibility for administrators to regulate access. In Niagara 4, an installation is composed of two pieces: the runtime piece and the user piece.

The runtime piece is where the core Niagara components are installed. In a typical Windows environment, this may be `C:\Program Files\Niagara 4\` or in a typical Linux environment this may be `/opt/niagara4`. The runtime piece (except for upgrades, etc) can be read only since no configuration files are present.

The “user” piece is where the all the configurable data resides. This includes stations, system.properties, templates, etc. There are actually two types of users. The first type of user is a person (operator, administrator, etc) who logs into the system with credentials. In Windows 7, this type of user would have a directory `C:\Users\<username>\Niagara4.0\<brandId>\`. A Linux user would have a directory `/home/<username>/Niagara4.0/<brandId>`. The second type of user is the system user. This is the user that runs the Niagara Daemon. Depending on the installation, this may also be a conventional user directory or a special directory for the system account.

From within Java, these directories can be accessed by querying `Sys.getNiagaraUserHome()` and `Sys.getNiagaraHome()`.

The impact of this will mostly be felt when manipulating stations. When a new station is created in Workbench, it gets created in the Niagara User Home directory. In order to start it from Niagara Daemon, it must be installed just like you would install to a remote Niagara Daemon. Not only does this provide the security benefits that allow restricting direct access to running stations, it also allows for you to test run them yourself (with the console). Of course you have to watch out for conflicting ports.

Niagara Path	File Ord	Shortcut API
Niagara Home	!	<code>Sys.getNiagaraHome()</code>
Niagara User Home	~	<code>Sys.getNiagaraUserHome()</code>
Niagara Shared User Home	N/A	<code>Sys.getNiagaraSharedUserHome()</code>
Station Home	^	<code>Sys.getStationHome()</code>
Protected Station Home	^^	<code>Sys.getProtectedStationHome()</code>

### New Locations of Files

#### Niagara Home

```
\bin
\cleanDist
\conversion
\defaults
|- bacnetObjectTypes.xml
|- colorCoding.properties
|- lonStandardConversion.xml
|- niagaraAxBacnetObjectTypes.xml
|- nre.properties
```

```

|- system.properties
|- unitConversion.xml
|- unitDifferentialConversion.xml
|- units.xml
|- workbench
|   |- facetKeys.properties
|   |- newComponents.bog
|   |- newWidgets.bog
|   |- newfiles
\docs
\etc
|- gradle
|   |- <gradle build scripts and plugins>
|- brand.properties
|- extensions.properties
\jre
|- <Java8 VM>
\lib
|- licenseAgreement.txt
|- readmeLicenses.txt
\modules
|- <Niagara Modules>
\security
|- certificates
|- licenses
|- policy
\sw

```

### Niagara User Home

```

\etc
\logging
|- logging.properties
\registry
\security
|- .kr
|- cacerts.jceks
|- exemptions.tes
|- keystore.jceks
\shared - shared user home
\stations

```

Note: Due to application differences, there are some minor differences between the complete list of files in the logged in user's Niagara User Home and the Niagara Daemon's Niagara User Home. For instance, daemon.properties only exists in the Niagara Daemon's Niagara User Home. And navTree.xml only exists in the logged in user's Niagara User Home.

### Niagara Shared User Home

With the introduction of the Security Manager, we now have tighter controls on which applications can access which parts of the file system. In particular, access to the Niagara User Home has been restricted to a few core modules.

In order to allow non-Tridium applications to be able to read and write files, we have created a new directory named "shared" under the Niagara User Home directory. All applications (including non-Tridium modules as well as program objects) have read, write and delete access to this directory.

Note that this directory is different from the "shared" directory under station home - it provides a space outside station home, so that applications may create and manage files not directly related to a particular station.

### Protected Station Home

We now have tighter controls on which applications have access to which parts of the file system. The stations/<stationName>/shared directory is a publicly available folder under that station to which any module

can read to and write from (this is the new stationHome directory). All other directories under the station directory are protected by the security manager.

## Notes

When creating a new station via the New Station Wizard, the new station get created under the logged in user's niagaraUserHome (C:\Users\<username>\Niagara4.0\<brandId>). To start this station via the Platform Daemon (niagarad), use the Station Copier to copy this station from your niagaraUserHome to the daemon's niagaraUserHome.

By default, the platform daemon (niagarad)'s niagara\_user\_home is C:\ProgramData\NiagaraN.N\<brandId> where N.N is the Niagara minor version number and brandId is the brand.id property in brand.properties. Example: C:\ProgramData\Niagara4.0\tridium. Each user has an etc directory for providing overrides to user configurable files. For Niagara 4.0, these contents of these files replace the contents of those in <niagara\_home>/etc. In the future this will allow the files in the <niagara\_user\_home>/etc to be merged with those in <niagara\_home>/etc when doing upgrades so that the files can be updated while maintaining user overrides.

# API Information

## Overview

There are a huge number of APIs available which are documented to varying degrees. In working with a specific API there are a couple key points to understand:

- **Stability:** a designation for the maturity of the API and its likelihood for incompatible changes;
- **Baja vs Tridium:** public APIs are published under `java.baja` packages, and implementation specific code is published under `com.tridium`;

## Stability

Public APIs are classified into three categories:

- **Stable:** this designation is for mature APIs which have been thoroughly evaluated and locked down. Every attempt is made to keep stable APIs source compatible between releases (a recompile may be necessary). Only critical bug fixes or design flaws are just cause to break compatibility, and even then only between major revisions (such 3.0 to 3.1). This does not mean that stable APIs are frozen, they will continue to be enhanced with new classes and new methods. But no existing classes or methods will be removed.
- **Evaluation:** this designation is for a functionally complete API published for public use. Evaluation APIs are mature enough to use for production development. However, they have not received enough utilization and feedback to justify locking them down. Evaluation APIs will likely undergo minor modification between major revisions (such 3.0 to 3.1). These changes will likely break both binary and source compatibility. However, any changes should be easily incorporated into production code with reasonable refactoring of the source code (such as a method being renamed).
- **Development:** this designation is for code actively under development. It is published for customers who need the latest development build of the framework. Non-compatible changes should be expected, with the potential for large scale redesign.

## What is Baja?

Baja is a term coined from **B**uilding **A**utomation **J**ava **A**rchitecture. The core framework built by Tridium is designed to be published as an open standard. This standard is being developed through Sun's Java Community Process as JSR 60. This JSR is still an ongoing effort, but it is important to understand the distinction between Baja and Niagara.

## Specification versus Implementation

Fundamentally Baja is an open specification and the Niagara Framework is an implementation of that specification. As a specification, Baja is not a set of software, but rather purely a set of documentation. The Baja specification will include:

- Standards for how Baja software modules are packaged;
- The component model and its APIs;
- Historical database components and APIs;
- Alarming components and APIs;
- Control logic components and APIs;
- Scheduling components and APIs;
- BACnet driver components and APIs;
- Lonworks driver components and APIs;

Over time many more specifications for features will be added to Baja. But what is important to remember is that Baja is only a specification. Niagara is an implementation of that specification. Furthermore you will find a vast number of features in Niagara, that are not included under the Baja umbrella. In this respect Niagara provides a superset of the Baja features.

## **javax.baja versus com.tridium**

Many features found in Niagara are exposed through a set of Java APIs. In the Java world APIs are grouped together into *packages*, which are scoped using DNS domain names. Software developed through the Java Community Process is usually scoped by packages starting with `java` or `javax`. The APIs developed for Baja are all grouped under `javax.baja`. These are APIs that will be part of the open Baja specification and maybe implemented by vendors other than Tridium. Using these APIs guarantees a measure of vendor neutrality and backward compatibility.

Software developed by Tridium which is proprietary and outside of the Baja specification is grouped under the `com.tridium` packages. The `com.tridium` packages contain code specific to how Niagara implements the Baja APIs. The `com.tridium` code may or may not be documented. Most often these packages have their components and slots documented (doc=bajaonly), but not their low level fields and methods. In general `com.tridium` APIs should never be used by developers, and no compatibility is guaranteed.

Note: Tridium has developed some APIs under `javax.baja` even though they are not currently part of the Baja specification. These are APIs that Tridium feels may eventually be published through Baja, but are currently in a development stage.



# Modules

## Overview

The first step in understanding the Niagara architecture is to grasp the concept of modules. Modules are the unit of deployment and versioning in the Niagara architecture. A module is a set of related **module files** having the same module name/

A module file:

- Is a JAR file compliant with PKZIP compression;
- Contains a XML manifest in meta-inf/module.xml;
- Is independently versioned and deployable;
- States its dependencies on other module files and their versions;
- Has contents for a single **runtime profile**;

Additionally, a module file has a **module part name** that is used by other module files to declare dependencies against it. The module part name is usually a concatenation of the module name and runtime profile (*e.g.* control-rt), but in a few cases is set explicitly in the module file's **manifest**.

## Runtime Profile

A runtime profile is used in the following ways:

- Describes the contents of a module file;
- Describes the capabilities of a Niagara Runtime Environment in a way that the bootstrap can filter out module files that can't be or aren't configured to be used (*e.g.* headless station, full Java UI with doc, station with applet support, *etc.*);
- Allows installer tools to correctly decide which module files should be installed to a particular Niagara system;

Runtime profiles describe what a module file's contents are used for, and if the contents include Java classes, which Java Runtime profiles can load them. The table below uses the module files that comprise the control module as an example:

Runtime Profile	Example Module Name	Built with JRE Version	Notes
rt	control-rt	Java 8 Compact3	CompactData model and communication: Fox, Box and Web Servlets
ux	control-ux	Java 8 Compact3	BajaUX,HTML5,CSS,JavaScript code providing web-based user interaction
wb	control-wb	Java 8 SE	Java code supporting old Workbench-based user interaction - views, field editors, etc. These JARs inject AWT dependencies at runtime if AWT is supported on the platform. They are a special case where a single jar file contains code that is compiled against Java SE but executes in a compact3 environment. Special care must be taken by

se	control-se	Java 8 SE	developers to avoid using classes that may not be present. Anything that has a direct dependence upon Java SE code - database technologies, AWT, Swing, etc.
doc	control-doc	N/A	Documentation. Includes no class files or other runnable content.

## Versions

Versions are specified as a series of whole numbers separated by periods, for example "1.0.3042". Two versions can be compared resulting in equality, less than, or greater than. This comparison is made by comparing the version numbers from left to right. If two versions are equal, except one contains more numbers then it is considered greater than the shorter version. For example:

```
2.0 > 1.0
2.0 > 1.8
2.0.45 > 2.0.43
1.0.24.2 > 1.0.24
```

Every module declares a "vendor" name and "vendorVersion". The vendor name is a case insensitive identifier for the company who developed the module and the vendorVersion identifies the vendor's specific version of that module.

Tridium's vendorVersions are formatted as "major.minor.build[.patch]":

- Major and minor declare a feature release such as 3.0.
- The third number specifies a build number. A build number starts at zero for each feature release and increments each time all the softwares modules are built.
- Additional numbers may be specified for code changes made off a branch of a specific build. These are usually patch builds for minor changes and bug fixes.

So the vendorVersion "3.0.22" represents a module of build 22 in Niagara release 3.0. The vendorVersion "3.0.45.2" is the second patch of build 45 in release 3.0.

## Manifest

All module JAR files must include a manifest file in "meta-inf/module.xml". The best way to examine the contents of this file is to take an example:

```
<?xml version="1.0" encoding="UTF-8"?>
<module
  name = "control"
  runtimeProfile = "rt"
  vendor = "Tridium"
  vendorVersion = "3.0.20"
  description = "Niagara Control Module"
  preferredSymbol = "c"
>

<moduleParts>
  <modulePart name="control-wb" runtimeProfile="wb"/>
  <modulePart name="control-doc" runtimeProfile="doc"/>
</moduleParts>

<dependencies>
  <dependency name="baja" vendor="Tridium" vendorVersion="3.0"/>
  <dependency name="bql-rt" vendor="Tridium" vendorVersion="3.0"/>
  <dependency name="gx" vendor="Tridium" vendorVersion="3.0"/>
</dependencies>

<dirs>
```

```

<dir name="javax/baja/control"/>
<dir name="javax/baja/control/enum"/>
<dir name="javax/baja/control/ext"/>
<dir name="javax/baja/control/trigger"/>
<dir name="javax/baja/control/util"/>
</dirs>

<defs>
  <def name="control.foo" value="something"/>
</defs>

<types>
  <type name="FooBar" class="javax.baja.control.BFooBar"/>
</types>

<lexicons brand="*">
  <lexicon module="bajai" resource="fr/bajai_fr.lexicon" language="fr"/>
</lexicons>

</module>

```

Looking at the root `module` element the following attributes are required:

- **name:** The globally unique name of the module that the file comprises. Developers should use a unique prefix for their modules to avoid name collisions. Module names must be one to 25 ASCII characters in length.
- **vendor:** The company name of the module's owner.
- **vendorVersion:** Vendor specific version as discussed above.
- **description:** A short summary of the module's purpose.
- **preferredSymbol:** This is used during XML serialization.
- **runtimeProfile:** Describes the contents of the module file as described in the runtime profile section above. There may be only one module file having a particular combination of module name, runtime profile and version.

Additionally, the root `module` element may have an optional **modulePartName** attribute which provides the module part name for the file. If omitted, the module part name will be a concatenation of the module name and the runtime profile, for example "control-rt".

If the module is composed of more than one module file, then the manifest for the file with the lowest runtimeProfile (rt being lowest, doc being highest) must identify the other module files by including a `moduleParts` element. That element contains one or more **modulePart** sub-elements, each of which has a mandatory **runtimeProfile** attribute and a mandatory **name** attribute which specifies the module part name (not the module name or file name!) for a sibling module file.

All modules must include a `dirs` element, which contains a `dir` subelement for each of the module's content directories. Each `dir` has a **name** attribute which contains a system-home relative file path for a directory in the module.

All module files include zero or one `dependencies` element. This element contains zero or more dependency elements which enumerate the module's dependencies. Dependencies must be resolved by the framework before the module can be successfully used. Each dependency has one required attribute. The **name** attribute specifies the module part name (not the file name or module name!) for the dependent module file. The **vendorVersion** attribute specifies the lowest vendorVersion of the dependent module file required. It is assumed that higher versions of a module are backward compatible, thus any version greater than the one specified in a dependency is considered usable. The **vendor** attribute may be specified without the **vendorVersion** attribute, but not *vice versa*. Module files having the `doc` runtimeProfile may have no dependencies, nor can other module files specify dependencies on them. Additionally, dependencies toward other module files are limited as described in the table below:

#### Target Module File's Runtime Profile

	rt	ux	se	wb	doc
rt	Yes	No	No	No	No
ux	Yes	Yes	No	No	No

Declaring Module File's Runtime Profile					
<b>wb</b>	Yes	Yes	Yes	No	No
<b>se</b>	Yes	Yes	Yes	Yes	No
<b>doc</b>	No	No	No	No	No

Modules can declare zero or more `def` elements which store String name/value pairs. The defs from all modules are collapsed into a global def database by the [registry](#).

Modules which contain concrete Niagara BObjects also include a `types` element. This element includes zero or more `type` elements. Each `type` element defines a mapping between a Baja type name and a Java class name. This definition is specified in the two required attributes **type** and **class**.

Modules can declare zero or one `lexicons` element, which contains zero or more `lexicon` elements. The lexicon has an optional `brand` attribute which filters lexicon file usage based on brand. The value of this attribute may contain "\*" (string) or "?" (single character) wildcards. Each lexicon will associate a resource file containing lexicon properties with a specific module. Typically modules containing lexicons will not contain other elements, but it is possible to include lexicon files in any module. Lexicon information is loaded into a global lexicon database by the [registry](#). This data is used by the lexicon system to apply locale-specific elements (text, icons, etc.) as needed.

# Object Model

## Niagara Types

The heart of Niagara is its type system layered above Java type system. Niagara Types are monikers to a Java class in a specific module. The interface [javax.baja.sys.Type](#) is used to represent Types in the Niagara Framework. Every Type is globally identified by its *module name* and its *type name*. As previously discussed, a *module name* globally identifies a Niagara software module. The *type name* is a simple String name which is mapped to a Java class name by the "module.xml" manifest file. Type's are commonly identified using a format of:

```
{module name}:{type name}
```

Examples:

```
baja:AbsTime
bajau:TextField
```

Note: to avoid confusion with the various uses of the word *type*, we will use capitalization when talking about a Niagara Type.

## BObject

All Java classes which implement a Niagara Type are subclassed from [BObject](#) . It is useful to compare [Type](#) and [BObject](#) to their low level Java counter parts:

	Java	Niagara
	<code>java.lang.Object</code>	<code>javax.baja.sys.BObject</code>
	<code>java.lang.Class</code>	<code>javax.baja.sys.Type</code>
	<code>java.lang.reflect.Member</code>	<code>javax.baja.sys.Slot</code> (discussed <a href="#">later</a> )

Type and Slot capture the concepts of meta-data, while BObject provides the base class of Niagara object instances themselves.

## BInterface

Java interfaces may be mapped into the Niagara type system by extending [BInterface](#). You can query whether a Type maps to a class or an interface using the method `isInterface()`.

Classes which implement **BInterface** must also extent **BObject**. All **BInterfaces** class names should be prefixed with "BI".

## BObject Semantics

Subclassing from BObject provides some common semantics that all instances of Niagara Types share:

- They all support a `getType()` method.
- Types installed on a system can be extensively queried using the [registry](#).
- All BObjects have an icon accessed via `getIcon()`.
- All BObjects have a set of agents accessed via `getAgents()`. Most agents are user agents which provide some visualization or configuration mechanism for the BObject.

## Building BObject

By subclassing BObject you make an ordinary Java class into a Niagara Type. You must obey the following rules when

creating a Type:

- Types must declare a mapping between their type name and their qualified Java class name in "module.xml". The Java class name must always be prefixed with 'B', but the type name doesn't include this leading 'B'. For example:

```
<type name="FooBar" class="javax.baja.control.BFooBar"/>
```

- All Types must override the `getType()` method to return a statically cached Type instance created by the `Sys.loadType()` method:

```
public Type getType() { return TYPE; }  
public static final Type TYPE = Sys.loadType(BFooBar.class);
```

# Component Model

## Introduction

Built upon Niagara's [object model](#) is the component model. Components are a special class of `BObjects` used to assemble applications using graphical programming tools.

## Slots

Niagara components are defined as a collection of [Slots](#). There are three types of slots:

- [javax.baja.sys.Property](#): Properties represent a storage location of another Niagara object.
- [javax.baja.sys.Action](#): An action is a slot that specifies behavior which may be invoked either through a user command or by an event.
- [javax.baja.sys.Topic](#): Topics represent the subject of an event. Topics contain neither a storage location, nor a behavior. Rather a topic serves as a place holder for an event source.

The Java interfaces used to model slots in the Niagara framework are:

```

javax.baja.sys.Slot
|
+- javax.baja.sys.Property
|
+- javax.baja.sys.Action
|
+- javax.baja.sys.Topic

```

Every slot is identified by a String name which is unique within its Type. Slot names must contain ASCII letters or numbers. Other characters may be escaped using "\$xx" or "\$uxxxx". Refer to [SlotPath](#) for the formal grammar of slot names and utilities for escaping and unescaping.

Slots also contain a 32-bit mask of flags which provide additional meta-data about the slot. These flag constants are defined in the [javax.baja.sys.Flags](#) class. Additional meta-data which is not predefined by a flag constant may be specified using [BFacets](#) which support arbitrary name/value pairs

Slots are either *frozen* or *dynamic*. A frozen slot is defined at compile time within a Type's Java class. Frozen slots are consistent across all instances of a specified Type. Dynamic slots may be added, removed, renamed, and reordered during runtime. The power of the Niagara Framework is in providing a consistent model for both compile time slots and runtime slots. Frozen and dynamic slots are discussed in detail in [Building Complexes](#).

## BValue

All values of Property slots are instances of [javax.baja.sys.BValue](#). The BValue class hierarchy is:

```

javax.baja.sys.BObject
|
+- javax.baja.sys.BValue
|
+- javax.baja.sys.BSimple
|
+- javax.baja.sys.BComplex
|
+- javax.baja.sys.BStruct
|
+- javax.baja.sys.BComponent

```

`BSimples` are atomic Types in the Niagara Framework, they never contain any slots themselves. The `BComplex` class is used to built Types which are composed of slots. Every `BComplex` can be recursively broken down into its primitive `BSimples`.

## Building BValues

To define new BValues types refer to the following for rules and design patterns:

- [Building Simple](#) Details for building BSimple Types;
- [Building Enums](#) Details for building BEnum Types;
- [Building Complexes](#) Details for building BComplex and BComponent Types;



# Building Simples

## Overview

[BSimple](#) is the base class for all atomic data types in Niagara. As an atomic data type, BSimples store a simple piece of data which cannot be decomposed. All simples are immutable, that is once an instance is created it may never change its state. Concrete subclasses of BSimples must meet the following requirements:

- Meet the common rules applicable to all [BObjects](#);
- Must declare a public static final field named DEFAULT which contains a reference to the default instance for the BSimple;
- All BSimples must be immutable! Under no circumstances should there be any way for an instance of BSimple to have its state changed after construction;
- Every concrete subclass of BSimple must be declared final;
- Every BSimple must implement the equals( ) method to compare the equality of its atomic data;
- Every BSimple must implement binary serialization:

```
public abstract void encode(DataOutput out);
public abstract BObject decode(DataInput in);
```

- Every BSimple must implement text serialization:

```
public abstract String encodeToString();
public abstract BObject decodeFromString(String s);
```

- Convention is to make constructors private and provide one or more factory methods called make.

## Example

The following source provides an example:

```
/*
 * Copyright 2000 Tridium, Inc. All Rights Reserved.
 */
package javax.baja.sys;

import java.io.*;

/**
 * The BInteger is the wrapper class for Java primitive
 * int objects.
 */
public final class BInteger
    extends BNumber
{
    public static BInteger make(int value)
    {
        if (value == 0) return DEFAULT;
        return new BInteger(value);
    }

    private BInteger(int value)
```

```

    {
        this.value = value;
    }

    public int getInt()
    {
        return value;
    }

    public float getFloat()
    {
        return (float)value;
    }

    public int hashCode()
    {
        return value;
    }

    public boolean equals(Object obj)
    {
        if (obj instanceof BInteger)
            return ((BInteger)obj).value == value;
        return false;
    }

    public String toString(Context context)
    {
        return String.valueOf(value);
    }

    public void encode(DataOutput out)
        throws IOException
    {
        out.writeInt(value);
    }

    public BObject decode(DataInput in)
        throws IOException
    {
        return new BInteger( in.readInt() );
    }

    public String encodeToString()
        throws IOException
    {
        return String.valueOf(value);
    }

    public BObject decodeFromString(String s)
        throws IOException
    {
        try
        {
            return new BInteger( Integer.parseInt(s) );
        }
        catch(Exception e)
        {
            throw new IOException("Invalid integer: " + s);
        }
    }

    public static final BInteger DEFAULT = new BInteger(0);

    public Type getType() { return TYPE; }

```

```
    public static final Type TYPE = Sys.loadType(BInteger.class);  
    private int value;  
}
```

# Building Enums

## Overview

The [BEnum](#) base class is used to define enumerated types. An enum is composed of a fixed set of int/String pairs called its *range*. The int identifiers are called *ordinals* and the String identifiers are called *tags*. Enum ranges are managed by the [BEnumRange](#) class.

There are three subclasses of BEnum. BBoolean is a special case which models a boolean primitive. The BDynamicEnum class is used to manage weakly typed enums which may store any ordinal and range. Strongly typed enums may be defined at compile time by subclassing BFrozenEnum. The Niagara Framework builds a BFrozenEnum's range using the following set of introspection rules:

- Meet the common rules applicable to all [BObjects](#);
- Meet the common rules applicable to all [BSimples](#) (although BFrozenEnum is not required to declare a DEFAULT field);
- Define a set of public static final fields which reference instances of the BFrozenEnum's range. Each of these BFrozenEnum must declare a unique ordinal value. By convention ordinals should start at zero and increment by one. Each of these BFrozenEnum must have a type exactly equal to the declaring class.
- There can be no way to create other instances of the BFrozenEnum outside of the fields declaring its range. This means no other instances declared in static fields, returned by a static method, or instantable through non-private constructors.
- There must be at least one BFrozenEnum declared in the range.
- The default value of a BFrozenEnum is the first instance, by convention with an ordinal value of zero.
- By convention a public static final int field is defined for each BFrozenEnum in the range to provide access to the ordinal value.

## Example

The following source provides a complete example of the implementation for BOrientation:

```
/*
 * Copyright 2000 Tridium, Inc. All Rights Reserved.
 */
package javax.baja.ui.enum;

import javax.baja.sys.*;

/**
 * BOrientation defines a widget's orientation as
 * either horizontal or vertical.
 */
public final class BOrientation
    extends BFrozenEnum
{
    public static final int HORIZONTAL = 0;
    public static final int VERTICAL = 1;

    public static final BOrientation horizontal = new BOrientation(HORIZONTAL);
    public static final BOrientation vertical = new BOrientation(VERTICAL);

    public Type getType() { return TYPE; }
    public static final Type TYPE = Sys.loadType(BOrientation.class);

    public static BOrientation make(int ordinal)
```

```
{
    return (BOrientation)horizontal.getRange().get(ordinal);
}

public static BOrientation make(String tag)
{
    return (BOrientation)horizontal.getRange().get(tag);
}

private BOrientation(int ordinal) { super(ordinal); }
}
```

# Building Complexes

## BStructs vs BComponents

[BComplex](#) is the base class for both [BStruct](#) and [BComponent](#). Classes never subclass [BComplex](#) directly (it doesn't support any public or protected constructors). Rather developers subclass from [BStruct](#) or [BComponent](#) depending on their needs. In general structs are used as complex data types. BStructs can be built only using frozen properties. BComponents support much more flexibility and are built using frozen and dynamic slots of all types:

		BStruct	BComponent
	<b>Frozen Property</b>	X	X
	<b>Frozen Action</b>		X
	<b>Frozen Topic</b>		X
	<b>Dynamic Property</b>		X
	<b>Dynamic Action</b>		X
	<b>Dynamic Topic</b>		X

As you will learn, BComponents are also the basis for many other features such as BORDs, links, and the event model. You may wonder why you would use a BStruct? There are two main reasons. The first is that because of its limited feature set, it is more memory efficient. The other reason is that properties containing BComponents cannot be linked, but BStructs can be (see [Links](#)).

## Building BComplexes

All concrete subclasses of [BComplex](#) must meet the following requirements:

- Meet the common rules applicable to all [BObjects](#);
- Must declare a public constructor which takes no arguments;
- Declare frozen slots using the introspection patterns defined below.

## Introspection Patterns

We have discussed how frozen slots are defined at compile time. Let's take a look at the frameworks knows when frozen slots have been declared. Every slot is composed of two or three Java members. A member is the technical term for a Java field, method, or constructor. At runtime the framework uses Java reflection to examine the members of each class, looking for patterns to self-discover slots. These patterns are based on the patterns used by JavaBeans, with significant extensions. Remember introspection is used only to define frozen slots, dynamic slots are not specified in the classfile itself. There is a different pattern for each slot type.

These introspection patterns require a fair amount of boiler plate code. Although it is not too painful to write this code by hand, you may use [Slot-o-matic](#) to generate the boiler plate code for you.

## Frozen Properties

### Rules

Every frozen property must follow these rules:

- Declare a `public static final Property` field where the field name is the property name.
- The property field must be allocated a `Property` instance using the `BComplex.newProperty()` method. This method takes a set of flags for the property, and a default value.

- Declare a public getter method with JavaBean conventions: `type getCapitalizedName()`.
- Declare a public setter method with JavaBean conventions: `void setCapitalizedName(type v)`.
- The getter must call `BObject.get(Property)`. The method must not perform any addition behavior.
- The setter must call `BObject.set(Property, BObject)`. The method must not perform any additional behavior.
- The only types which may be used in a property are: subclasses of `BValue`, `boolean`, `int`, `long`, `float`, `double`, and `String`. The six non-`BValue` types have special accessors which should be used in the getter and setter implementations.

## Semantics

The introspection rules map Property meta-data as follows:

- **Name:** The Property name is the same as the field name.
- **Type:** The Property type is the one declared in the getter and setter methods.
- **Flags:** The Property flags are the ones passed to `newProperty()`.
- **Default Value:** The Property's default value is the instance passed to `newProperty()`.

## Example

The following illustrates an example for different property types:

```
// boolean property: fooBar
public static final Property fooBar = newProperty(0, true);
public boolean getFooBar() { return getBoolean(fooBar); }
public void setFooBar(boolean v) { setBoolean(fooBar, v); }

// int property: cool
public static final Property cool = newProperty(0, 100);
public int getCool() { return getInt(cool); }
public void setCool(int v) { setInt(cool, v); }

// double property: analog
public static final Property analog = newProperty(0, 75.0);
public double getAnalog() { return getDouble(analog); }
public void setAnalog(double v) { setDouble(analog, v); }

// float property: description
public static final Property description = newProperty(0, "describe me");
public String getDescription() { return getString(description); }
public void setDescription(String x) { setString(description, v); }

// BObject property: timestamp
public static final Property timestamp = newProperty(0, BAbsTime.DEFAULT);
public BAbsTime getTimestamp() { return (BAbsTime)get(timestamp); }
public void setTimestamp(BAbsTime v) { set(timestamp, v); }
```

## Frozen Actions

### Rules

Every frozen action must follow these rules:

- Declare a `public static final Action` field where the field name is the action name.
- The action must be allocated an Action instance using the `BComponent.newAction()` method. This method takes a set of flags for the action and an optional default argument.
- Declare a public *invocation* method with the action name. This method must return `void` or a `BObject` type. This method must take zero or one parameters. If it takes a parameter, it should be a `BObject` type.

- Declare a public *implementation* method, which is named *doCapitalizedName*. This method must have the same return type as the invocation method. This method must have the same parameter list as the invocation method.
- The implementation of the invocation method must call `BComponent.invoke()`. No other behavior is permitted in the method.

## Semantics

The introspection rules map Action meta-data as follows:

- **Name:** The Action name is the same as the field name.
- **Return Type:** The Action return type is the one declared in the invocation method.
- **Parameter Type:** The Action parameter type is the one declared in the invocation method.
- **Flags:** The Action flags are the ones passed to `newAction()`.

## Example

The following illustrates two examples. The first action contains neither a return value nor an argument value. The second declares both a return and argument value:

```
// action: makeMyDay
public static final Action makeMyDay = newAction(0);
public void makeMyDay() { invoke(makeMyDay, null, null); }
public void doMakeMyDay() { System.out.println("Make my day!"); }

// action: increment
public static final Action increment = newAction(0, new BInteger(1));
public BInteger increment(BInteger v)
{ return (BInteger)invoke(increment, v, null); }
public BInteger doIncrement(BInteger i)
{ return new BInteger(i.getInt()+1); }
```

## Frozen Topics

### Rules

Every frozen topic must follow these rules:

- Declare a `public static final Topic` field where the field name is the topic name.
- Declare a fire method of the signature: `void fireCapitalizedName(EventType)`.
- The implementation of the fire method is to call `BComponent.fire()`. No other behavior is permitted in the method.

## Semantics

The introspection rules map Topic meta-data as follows:

- **Name:** The Topic name is the same as the field name.
- **Event Type:** The Topic event type is the one declared in the fire method.
- **Flags:** The Topic flags are the ones passed to `newTopic()`.

## Example

The following code example illustrates declaring a frozen topic:

```
// topic: exploded
public static final Topic exploded = newTopic(0);
public void fireExploded(BString event) { fire(exploded, event, null); }
```



## Dynamic Slots

Dynamic slots are not declared as members in the classfile, but rather are managed at runtime using a set of methods on `BComponent`. These methods allow you to add, remove, rename, and reorder dynamic slots. A small sample of these methods follows:

```
Property add(String name, BValue value, int flags);  
void remove(Property property);  
void rename(Property property, String newName);  
void reorder(Property[] properties);
```

Note: You will notice that methods dealing with dynamic slots take a `Property`, not a `Slot`. This is because all dynamic slots including dynamic Actions and Topics are also Properties. Dynamic Actions and Topics are implemented by subclassing `BAction` and `BTopic` respectively.

# Registry

## Overview

The registry is a term for a small database built by the Niagara runtime whenever it detects that a module has been added, changed, or removed. During the registry build process all the types in all the modules are scanned. Their classfiles are parsed to build an index for the class hierarchy of all the Niagara types available in the installation.

Some of the functions the registry provides:

- query modules installed without opening each jar file
- query class hierarchy without loading actual Java classes
- query agents registered on a given Type
- map file extensions to their BIFile Types
- map ord schemes to their BOrdScheme Types
- defs provide a global map of name/value pairs
- query lexicons registered on a given module

## API

The [Registry](#) database may be accessed via `Sys.getRegistry()`. Since the primary use of the registry is to interrogate the system about modules and types without loading them into memory, the registry API uses light weight wrappers:

Registry Wrapper	Real McCoy
<a href="#">ModuleInfo</a>	<a href="#">BModule</a>
<a href="#">TypeInfo</a>	<a href="#">Type</a>

## Agents

An agent is a special BObject type that provides services for other BObject types. Agents are registered on their target types via the module manifest and queried via the Registry interface. Agents are used extensively in the framework for late binding - such as defining views, popup menus, or exporters for specified target types. Typically agent queries are combined with a type filter. For example, to find all the BExporters registered on a given file:

```
AgentFilter filter = AgentFilter.is(BExporter.TYPE);
AgentList exporters = file.getAgents(null).filter(filter);
```

A couple of examples of how an agent type is registered on a target type in the module manifest (module-include.xml):

```
<type name="ValueBinding" class="javax.baja.ui.BValueBinding">
  <agent><on type="bajai:Widget"/></agent>
  <agent><on type="baja:Value"/></agent>
</type>

<type name="PropertySheet"
class="com.tridium.workbench.propsheet.BPropertySheet">
  <agent requiredPermissions="r"><on type="baja:Component"/></agent>
</type>
```

Agents can be registered on a target only for a specific application using the app attribute within the agent tag. The application name can be queried at runtime via the `AgentInfo.getAppName()` method. Agent application names are

used in conjunction with the `getAppName()` method of [BwbProfile](#) and [BHxProfile](#). An example application specific agent:

```
<type name="ApplianceUserManager"
class="appliance.ui.BApplianceUserManager">
  <agent app="demoAppliance">
    <on type="baja:UserService"/>
  </agent>
</type>
```

## Defs

Module's can declare zero or more defs in their module manifest. Defs are simple String name/value pairs that are collapsed into a single global map by the registry. A good use of defs is to map a device id to a typespec, bog file, or some other metadata file. Then the registry may be used to map devices to Niagara information at learn time.

Since the defs of all modules are collapsed into a single map, it is important to avoid name collisions. Convention is to prefix your defs using module name plus a dot, for example "lonworks."

When using Niagara's standard build tools, defs are defined in your "module-include.xml":

```
<defs>
  <def name="test.a" value="alpha"/>
  <def name="test.b" value="beta"/>
</defs>
```

Use the registry API to query for defs:

```
String val = Sys.getRegistry().getDef("test.a");
```

## Spy

A good way to learn about the registry is to navigate its [spy pages](#).

## Collections

### Overview of Changes from Niagara AX

There are several inadequacies in the Baja Collections API - [javax.baja.collection](#) and [javax.baja.sys.Cursor](#). The current API suffers from a number of problems that hinder performance and encourage inefficient implementations for cases where data sets are large. The API changes aim to help developers be more productive with the collection API, and to pave the way for better implementation when underlying data sets are large.

### Impacts

Any module that makes use of the `javax.baja.collection` classes or `javax.baja.sys.Cursor` is impacted by these changes. Depending on what methods and classes of the API the code uses you may need to refactor your code. Any implementations of `BICollection`, `BILList`, and `BITable` will be impacted by these changes. In the unlikely event that you implemented the `javax.baja.bql.BIRelational` interface in your code, you will also be impacted.

### Changes

#### Removed BICollection

One of the biggest issues with Niagara AX's Collections API is the `BICollection` interface. `BICollection` requires every implementation to model itself as a collection, a list, and a table. This puts a heavy burden on developers implementing a collection, and in many cases it does not make sense to model a list as a table, and vice-versa. So this interface has been removed entirely.

#### Code Impacts

The interface only had methods for converting the underlying collection to a list or table. Every implementation of `BICollection` in the framework now implements `BITable`. If you were casting objects to `BICollection` you should be able to safely cast them to `BITable` now. Almost invariably this is due to ord resolution of a bql query:

*Niagara AX*

```
BICollection result = (BICollection)BOrd.make("bql:select
displayName").get(base);
BITable table = result.toTable();
```

*Niagara 4*

```
BITable table = (BITable)BOrd.make("bql:select displayName").get(base);
```

Any public methods that took a `BICollection` will need to be refactored to expect a `BITable`.

#### Removed BILList

This change is probably the most significant in terms of fundamental philosophy change. As part of the design philosophy for collections in Niagara 4, we wanted to discourage random-access methods. In fact, they have essentially been removed from the collection API in favour of cursor-based access. Don't worry, you can still work with a table in a random-access way (details below). The 'BILList' interface essentially required random-access support for every collection. Further, an analysis of the entire framework showed that there were zero concrete implementations of `BILList`/`BICollection` in the public API that did not also implement `BITable`. This indicates that the `BITable` API is more useful to the framework as a whole.

#### Code Impacts

Similar to `BICollection` above, you should be able to cast any reference to a `BILList` to a `BITable` now. If by chance you had a public method that expected a `BILList`, you will need to refactor that API to take a `BITable`.

#### Refactored BITable

The [BITable](#) interface has been greatly simplified and all random-access methods have been removed.

You can iterate the rows in the table by obtaining a [TableCursor](#). The `TableCursor` gives you access to the table that contains the row, the [Row](#) object itself (see below), and a convenience method to obtain a cell value for the current row.

Each row in a table is modelled as a `Row` object. The row object gives you direct access to the underlying [BIObject](#) backing the row, as well as column cell values, flags, and facets.

### Code Impacts

The biggest impact will occur if your code was iterating a `BITable` using the random-access methods of the old API. You have a few options.

First, change your code to iterate the table using a cursor. This is the best option.

```
// Iterate a BITable using a TableCursor
//
BITable table = (BITable)bqlOrd.resolve().get();
Column[] columns = table.getColumns().list();
try(TableCursor<BIObject> cursor = table.cursor())
{
    // Just for printing purposes, not for random access.
    int row = 0;
    while (cursor.next())
    {
        System.out.print(row + ": ");
        for (Column col : columns)
        {
            System.out.print(cursor.cell(col) + ", ");
        }
        System.out.println();
        ++row;
    }
}
```

If you must access the table using random-access indexing, you can convert it to a [BIRandomAccessTable](#) using the `javax.baja.collection.Tables` utility class.

```
BITable table = (BITable)ordThatResolvesToTable.resolve().get();
BIRandomAccessTable rat = Tables.slurp(table);

System.out.println(String.format("This table has %d rows", rat.size()));
for (int i=0; i<rat.size(); ++i)
{
    Row row = rat.get(i);
    // Do something with each row...
}
```

### Refactored Cursor Interface

There are a few major changes to the `javax.baja.sys.Cursor` interface.

1. [javax.baja.sys.Cursor](#) now implements `java.lang.AutoCloseable`. This means you should be a good citizen of every cursor you work with. Failing to close a cursor may result in a resource leak and degraded system performance. The try-with-resources statement introduced in Java 7 can help manage opening and closing cursors.
2. `Cursor` is now generic: `public interface Cursor<E> extends AutoCloseable`
3. This means it can iterate over any type; not just Niagara types.
4. Since it can iterate any type, we removed the `nextComponent()` method from the interface and moved it into `SlotCursor`. This seems to be its primary use case anyway.
5. A new [javax.baja.sys.IterableCursor](#) interface has been added that extends `Cursor` and implements Java's `Iterable` interface. This enables a `Cursor` to be used in a for each statement as well as accessing the `Cursor` as an `Iterator`, `Splititerator` or `Stream`.
6. [javax.baja.sys.SlotCursor](#) also implements the `Iterable` interface so it can be used to iterate over a collection of [Slots](#) (not [BValue](#)).

If you need to implement your own Cursor, use the utility class [javax.baja.collection.AbstractCursor](#), which stubs out all methods in the interface and handles close semantics for you. You only need to provide an implementation of `advanceCursor()` and `doGet()`.

Here are some example of the new SlotCursor design that use Java 8's Stream API...

```
// Remove all dynamic Properties from a point...
point.getProperties()
    .stream()
    .filter(Slot::isDynamic)
    .forEach(point::remove);

// Print out the path string of all folders under a point...
point.getProperties()
    .stream()
    .map(point::get)
    .filter(v -> v.getType().is(BFolder.TYPE))
    .forEach(v -> System.out.println(v.asComponent().toPathString()));
```

### BIRelational Interface Breaking Changes

In the unlikely event that you implemented the [javax.baja.bql.BIRelational](#) interface in your code, you will need to add a [Context](#) argument to its single method. The updated interface class is shown below:

```
public interface BIRelational<T extends BIObject>
{
    /**
     * Get the relation with the specified identifier.
     *
     * @param id A string identifier for the relation. The format
     *    of the string is implementation specific.
     *
     * @param cx The Context associated with this request.
     *    This parameter was added starting in Niagara 4.0.
     *
     * @return Returns the relation identified by id or null if the relation
     *    cannot be found.
     */
    BITable<T> getRelation(String id, Context cx);

    Type TYPE = Sys.loadType(BIRelational.class);
}
```

# Naming

## Overview

Niagara provides a uniform naming system to identify any resource which may be represented using an instance of `BObject`. These names are called *ords* for **O**bject **R**esolution **D**escriptor. You can think of a ords as URIs on steroids.

An ord is a list of one or more queries separated by the "|" pipe symbol. Each query is an ASCII string formatted as "<scheme>:<body>". The scheme name is a globally unique identifier which instructs Niagara how to find a piece of code to lookup an object from the body string. The body string is opaque and is formatted differently depending on the scheme. The only rule is that it can't contain a pipe symbol.

Queries can be piped together to let each scheme focus on how to lookup a specific type of object. In general absolute ords are of the format: `host | session | space`. Some examples:

```
ip:somehost|fox:|file:/dir/somefile.txt
ip:somehost|fox:1912|station:|slot:/Graphics/Home
local:|module://icons/x16/cut.png
```

In the examples above note that the "ip" scheme is used to identify a host machine using an IP address. The "fox" scheme specifies a session to that machine usually on a specific IP port number. In the first example we identify an instance of a file within somehost's file system. In the second example we identify a specific component in the station database.

The third example illustrates a special case. The scheme "local" which always resolves to `BLocalHost.INSTANCE` is both a host scheme and a session scheme. It represents objects found within the local VM.

## APIs

The core naming APIs are defined in the [javax.baja.naming](#) package. Ords are represented using the [BOrd](#) class.

Ords may be resolved using the `BOrd.resolve()` or `BOrd.get()` methods. The `resolve` method returns an intermediate `OrdTarget` that provides contextual information about how the ord was resolved. The `get` method is a convenience for `resolve().get()`.

Ords may be absolute or relative. When resolving a relative ord you must pass in a base object. If no base object is specified then `BLocalHost.INSTANCE` is assumed. Some simple examples of resolving an ord:

```
BIFile f1 = (BIFile)BOrd.make("module://icons/x16/cut.png").get();
BIFile f2 = (BIFile)BOrd.make("file:somefile.txt").get(baseDir);
```

## Parsing

Ords may be parsed into their constituent queries using the method `BOrd.parse()` which returns `OrdQuery[]`. In many cases you might cast a `OrdQuery` into a concrete class. For example:

```
// dump the names in the file path
BOrd ord = BOrd.make("file:/a/b/c.txt");
OrdQuery[] queries = ord.parse();
FilePath path = (FilePath)queries[0];
for(int i=0; i<path.depth(); ++i)
    System.out.println("path[" + i + "] = " + path.nameAt(i));
```

## Common Schemes

The following is an informal introduction some common ord schemes used in Niagara.

### ip:

The "ip" scheme is used to identify a `BIPHost` instance. Ords starting with "ip" are always absolute and ignore any base which may be specified. The body of a "ip" query is a DNS hostname or an IP address of the format "dd.dd.dd.dd".

### fox:

The "fox" scheme is used to establish a Fox session. Fox is the primary protocol used by Niagara for IP communication. A "fox" query is formatted as "fox:" or "fox:<port>". If port is unspecified then the default 1911 port is assumed.

### file:

The "file" scheme is used to identify files on the file system. All file ords resolve to instances of [javax.baja.file.BIFile](#). File queries always parse into a `FilePath` File ords come in the following flavors:

- Authority Absolute: "//hostname/dir1/dir2"
- Local Absolute: "/dir1/dir2"
- Sys Absolute: "!lib/system.properties"
- User Absolute: "^config.bog"
- Relative: "myfile.txt"
- Relative with Backup: "../myfile.txt"

Sys absolute paths indicate files rooted under the Niagara installation directory identified via `Sys.getBajaHome()`.

User absolute paths are rooted under the user home directory identified via `Sys.getUserHome()`. In the case of station VMs, user home is the directory of the station database.

### module:

The "module" scheme is used to access `BIFiles` inside the module jar files. The module scheme uses the "file:" scheme's formatting where the authority name is the module name. Module queries can be relative also. If the query is local absolute then it is assumed to be relative to the current module. Module queries always parse into a `FilePath`

```
module://icons/x16/file.png
module://baja/javax/baja/sys/BObject.bajadoc
module:/doc/index.html
```

### station:

The "station" scheme is used to resolve the `BComponentSpace` of a [station](#) database.

### slot:

The "slot" scheme is used to resolve a `BValue` within a `BComplex` by walking down a path of slot names. Slot queries always parse into a `SlotPath`.

### h:

The "h" scheme is used to resolve a `BComponent` by its handle. Handles are unique String identifiers for `BComponents` within a `BComponentSpace`. Handles provide a way to persistently identify a component independent of any renames which modify a component's slot path.

### service:

The "service" scheme is used to resolve a `BComponent` by its service type. The body of the query should be a type spec.

### spy:



The "spy" scheme is used to navigate spy pages. The [javax.baja.spy](#) APIs provide a framework for making diagnostics information easily available.

**bql:**

The "bql" scheme is used to encapsulate a [BQL](#) query.

# Links

## Overview

Links are the basic mechanism of execution flow in the Niagara Framework. Links allow components to be wired together graphically by propagating an event on a one slot to another slot. An event occurs:

- When property slot of a [BComponent](#) is modified.
- When an action slot is invoked.
- When a topic slot is fired.

## Links

A link is used to establish an event relationship between two slots. There are two sides to the relationship:

- **Source:** The source of the link is the `BComponent` generating the event either because one its properties is modified or one its topics is fired. The source of a link is always passive in that it has no effect on the component itself.
- **Target:** The target is the active side of the link. The target `BComponent` responds to an event from the source.

A link is established using a property slot on the *target* `BComponent` which is an instance of [BLink](#). The `BLink` struct stores:

- **Source Ord:** identifier for the source `BComponent`;
- **Source Slot:** name of the source component's slot;
- **Target Slot:** name of the target component's slot to act upon;

**Note:** The target ord is not stored explicitly in a `BLink` because it is implicitly derived by being a direct child of the target component.

The following table diagrams how slots may be linked together:

	Source	Target	Semantics
	Property	Property	When source property changes, set the target property
	Property	Action	When source property changes, invoke the action
	Action	Action	When source action is invoked, invoke target action (action chaining)
	Action	Topic	When source action fires, fire target topic
	Topic	Action	When source topic fires, invoke the action
	Topic	Topic	When source topic fires, fire target topic (topic chaining)

## Link Check

Every component has a set of predefined rules which allow links to be established. These rules are embodied in the [LinkCheck](#) class. Subclasses may override the `BComponent.doLinkCheck()` method to provide additional link checking.

## Direct and Indirect Links

Links are constructed as either *direct* or *indirect*. A direct link is constructed with a direct Java reference to its source `BComponent`, source slot, and target slot. A direct link may be created at anytime. Neither the source nor target components are required to be mounted or running. These links must be explicitly removed by the developer. Direct

links are never persisted. Examples of creating direct links:

```
target.linkTo("linkA", source, source.slot, target.slot);
```

...or...

```
BLink link = new BLink(source, source.slot, target.slot);
target.add("linkA", link);
link.activate();
```

An indirect link is created through indirect names. A BOrd specifies the source component and Strings are used for the source and target slot names. Since an indirect link requires resolution of a BOrd to get its source component, the source is required to be mounted when the link is activated. Indirect links are automatically removed if their source component is unmounted while the link is activated. Examples of creating an indirect link:

```
BLink link = new BLink(BOrd.make("h:77"), "sourceSlot", "targetSlot");
target.add("linkA", link);
```

**Note:** Links are rarely created programmatically, but rather are configured using the graphical programming tools. The major exception to this rule is building GUIs in code. In this case it is best to establish direct links in your constructor.

## Activation

Links exist in either an *activated* or *deactivated* state. When a link is activated it is actively propagating events from the source slot to the target slot. Activated links also maintain a [Knob](#) on the source component. Knobs are basically a mirror image of a link stored on the source component to indicate the source is actively propagating events over one or more links. When a link is deactivated event propagation ceases and the Knob is removed from the source component.

Activation:

1. Links are activated when the `BLink.activate()` method is called. If the link is indirect, then the source ord must be resolvable otherwise an `UnresolvedException` is thrown.
2. If creating a direct link using the `BComponent.linkTo()` method the link is automatically activated.
3. Enabled links are activated during `BComponent` start. This is how most indirect links are activated (at station boot time).
4. Anytime a `BLink` value is added as a dynamic property on a running `BComponent` it is activated.

Deactivation:

1. Links are deactivated when the `BLink.deactivate()` method is called.
2. Anytime a property with a `BLink` value is removed from `BComponent` it is deactivated and the target property is set back to its default value.
3. Anytime the source component of a active *indirect* link is unmounted, the link is deactivated and removed from the target component.

# Execution

## Overview

It is important to understand how `BComponent`s are executed so that your components play nicely in the Niagara Framework. The Niagara execution model is based upon:

- **Running State:** Every component may be started or stopped.
- **Links:** Links allow events to propagate between components.
- **Timers:** Timers are established using the `Clock` class.
- **Async Actions:** Async actions are an important feature which prevent tight feedback loops.

## Running State

Every `BComponent` maintains a *running* state which may be checked via the `BComponent.isRunning()` method. A component may be put into the running state via the `BComponent.start()` method and taken out of the running state via the `BComponent.stop()` method.

By default whenever a `BComponent` is started, all of its descendent components are also started recursively. This behavior may be suppressed using the `Flags.NO_RUN` flag on a property. During startup, any properties encountered with the *noRun* flag set will not be recursed.

Every `BComponent` may add its component specific startup and shutdown behavior by overriding the `started()` and `stopped()` methods. These methods should be kept short; any lengthy tasks should be spawned off on another thread.

**Note:** Developers will rarely call `start()` and `stop()` themselves. Rather these methods are automatically called during station bootstrap and shutdown. See [Station Bootstrap](#).

## Links

The primary mechanism for execution flow is via the link mechanism. Links provide a powerful tool for configuring execution flow at deployment time using Niagara's graphical programming tools. Developers should design their components so that hooks are exposed via property, action, and topic slots.

One of the requirements for link propagation is normalized types. Therefore Niagara establishes some standard types which should be used to provide normalized data. Any *control point* data should use one of the standard types found in the [javax.baja.status](#) package.

## Timers

Niagara provides a standard timer framework which should be used by components to setup periodic and one-shot timers. Timers are created using the `schedule()` and `schedulePeriodically()` methods on [Clock](#). Timer callbacks are an action slot. The `BComponent` must be mounted and running in order to create a timer.

There are four types of timers created with four different methods on `Clock`. Two are one-shot timers and two are periodic timers. The difference between the two one-shots and periodic timers is based on how the timers drift. Refer to the `Clock` bajadoc for more information.

## Async Actions

The Niagara execution model is *event based*. What this means is that events are chained through link propagation. This model allows the possibility of *feedback loops* when an event will loop forever in a cyclical link chain. To prevent feedback loops, component which might be configured with cyclical links should use *async actions*. An async action is an action slot with the `Flags.ASYNC` flag set.

Normal actions are invoked immediately either through a direct invocation or a link propagation. This invocation occurs

on the callers thread synchronously. On the other hand, async actions are designed to run asynchronously on another thread and immediately return control to the callers thread. Typically async actions will coalesce multiple pending invocations.

By default async actions are scheduled by the built in engine manager. The engine manager automatically coalesces action invocations, and schedules them to be run in the near future (100s of ms). Thus between actual execution times if the action is invoked one or one hundred times, it is only executed once every execution cycle. This makes it a very efficient way to handle *event blasts* such as dozens of property changes at one time. However all timer callbacks and async actions in the VM share the same engine manager thread, so developers should be cautious not to consume this thread except for short periods.

Niagara also provides a hook so that async actions may be scheduled by subclasses by overriding the `post ( )` method. Using this method subclasses may schedule the action using their own queues and threads. A standard library for managing invocations, queues, and threads is provided by the following utility classes:

- [Invocation](#)
- [Queue](#)
- [CoalesceQueue](#)
- [Worker](#)
- [ThreadPoolWorker](#)
- [BWorker](#)
- [BThreadPoolWorker](#)

## System Clock Changes

Some control algorithms are based on absolute time, for example a routine that runs every minute at the top of the minute. These algorithms should ensure that they operate correctly even after system clock changes using the callback `BComponent.clockChanged(BRelTime shift)`.

# Station

## Overview

A station is the main unit of server processing in the Niagara architecture:

- A station database is defined by a single `.bog` file `"file:!stations/{name}/config.bog"`;
- Stations are booted from their `config.bog` file into a single VM/process on the host machine;
- There is usually a one to one correspondance between stations and host machines (Supervisors or Jaces). However it is possible to run two stations on the same machine if they are configured to use different IP ports;

## Bootstrap

The following defines the station boot process:

1. **Load:** The first phase of bootstrap is to deserialize the `config.bog` database into memory as a [BStation](#) and mount it into the ord namespace as `"local:|station:"`.
2. **Service Registration:** Once the bog file has been loaded into memory and mounted, the framework registers all services. Services are defined by implementing the [BIService](#). After this step is complete each service from the bog file may be resolved using the `Sys.getService()` and `Sys.getServices()` methods.
3. **Service Initialization:** Once all services are registered by the framework, each service is initialized via the `Service.serviceStarted()` callback. This gives services a chance to initialize themselves after other services have been registered, but before general components get started.
4. **Component Start:** After service initialization the entire component tree under `"local:|station:"` is started using `BComponent.start()`. This call in turn results in the `started()` and `descendentsStarted()` callbacks. Once this phase is complete the entire station database is in the running state and all active links continue propagation until the station is shutdown.
5. **Station Started:** After all the components under the BStation have been started, each component receives the `stationStarted()` callback. As a general rule, external communications should wait until this stage so that all components get a chance to initialize themselves.
6. **Steady State:** Some control algorithms take a few seconds before the station should start sending control commands to external devices. To handle this case there is a built-in timer during station bootstrap that waits a few seconds, then invokes the `BComponent.atSteadyState()` callback. The steady state timer may be configured using the `"nre.steadystate"` system property. Use `Sys.atSteadyState()` to check if a station VM has completed its steady state wait period.

# Remote Programming

## Overview



Remote programming is one of the most powerful features of Niagara. It is also the number one cause of confusion and performance problems. The term *remote programming* broadly applies to using the component model across a network connection. Some topics like subscription are critical concepts for many subsystems. But most often remote programming applies to programming with components in the workbench across a fox connection to a station ([illustration](#)).

The component model provides a number features for network programming:

- Lazy loading of a component tree across the network;
- Automatic synchronization of database tree structure over network;
- Ability to subscribe to real-time property changes and topic events;
- Ability to invoke an action over the network like an RPC;
- Support for timed subscriptions called leasing;
- Automatic support for propagating components changes over network;
- Ability to batch most network calls;

## Fundamentals

The component model has the ability to make remote programming virtually transparent. In this [diagram](#), the component "/a/b" is accessed in the workbench VM, but actually lives and is executing in the station VM. The instance of the component in the workbench is called the *proxy* and the instance in the station is called the *master*.

The first thing to note in Niagara is that both the proxy and master are instances of the same class. This is unlike technologies such as RMI where the proxy is accessed using a special interface. Also unlike RMI and its brethren, nothing special is required to make a component remote accessible. All Niagara components are automatically remotable by virtue of subclassing BComponent.

From an API perspective there is no difference between programming against a proxy or a master component. Both are instances of the same class with the same methods. However, sometimes it is important to make a distinction. The most common way to achieve this is via the BComponent.isRunning() method. A master component will return true and a proxy false. Although isRunning() is usually suitable for most circumstances, technically it covers other semantics such as working offline. The specific call for checking proxy status is via

```
BComponent.getComponentSpace().isProxyComponentSpace().
```

Note that proxy components receive all the standard change callbacks like `changed()` or `added()`. Typically developers should short circuit these callbacks if the component is not running since executing callback code within a proxy can produce unintended side effects.

## Proxy Features

The framework provides a host of features which lets you program against a proxy component transparently:

- The proxy can maintain the state of the master by synchronizing all properties in real-time;
- Actions on the proxy act like RPCs;
- Any changes to the proxy are automatically propagated to the master;

The framework provides the ability to keep a proxy's properties completely synchronized in real-time to the master using *subscription*. While subscribed all property changes are immediately reflected in the proxy. This enables easy development of user interfaces that reflect the current state of a component. Note that only properties support this feature - other fields of your class will not be synchronized, and likely will be invalid if they are populated via station execution. Subscription is covered in more detail later.

Another feature of Niagara is that all actions automatically act like RPCs (Remote Procedure Calls). When you invoke an action on a proxy, it automatically marshals the argument across the network, invokes the action on the master, and then marshals the result back to the proxy VM. Note that all other methods are invoked locally.

Perhaps the most powerful feature of proxies is the ability to transparently and automatically propagate proxy side changes to the master. For example when you set a property on a proxy, it actually marshals the change over the network and makes the set on the master (which in turn synchronizes to the proxy once complete). This functionality works for all component changes: sets, adds, removes, renames, reorders, flag sets, and facet sets. Note that if making many changes it is more economical to batch the changes using a Transaction; this is discussed later.

## Proxy States

A proxy component exists in three distinct states:

- **Unloaded:** in this state the proxy has not even been loaded across the network.
- **Loaded:** in this state the proxy is loaded across the network and is known to the proxy VM; it may or may not be out-of-date with the master.
- **Subscribed:** in this state the proxy is actively synchronized with the master.

When a session is first opened to a station, none of the components in the station are known in the workbench. Rather components are lazily loaded into the workbench only when needed. Components which haven't been loaded yet are called *unloaded*.

Components become *loaded* via the `BComplex.loadSlots()` method. Components must always be loaded according to their tree structure, thus once loaded it is guaranteed that all a component's ancestors are also loaded. Rarely does a developer use the `loadSlots()` method. Rather components are loaded as the user expands the navigation tree or a component is resolved by ord.

A loaded component means that a proxy instance representing the master component has been created in the workbench. The proxy instance is of the same class as the master, and occupies a slot in the tree structure identical to the master (remember all ancestors must also be loaded). The proxy has the same *identity* as the master. That means calling methods such as `getName()`, `getHandle()`, and `getSlotPath()` return the same result. However, note that the absolute ords of a proxy and master will be different since the proxy's ord includes how it was accessed over the network ([see diagram](#)).

Once a proxy component has been loaded, it remains cached in the loaded state until the session is closed. Loaded proxies maintain their structure and identity automatically through the use of NavEvents. NavEvents are always routed across the network to maintain the proxy tree structure independent of the more fine grained component eventing. For example if a loaded component is renamed, it always reflects the new name independent of subscription state. Or if removed it is automatically removed from the cache.

Loaded components provide a cache of structure and identity, but they do not guarantee access to the current state of the



master via its properties. The *subscribed* state is used to synchronize a proxy with its master. Subscription is achieved using a variety of mechanisms discussed next. Once subscribed a component is guaranteed to have all its property values synchronized and kept up-to-date with the master. Subscription is an expensive state compared to just being loaded, therefore it is important to unsubscribe when finished working with a proxy.

## Subscription

Subscription is a concept used throughout the framework. Components commonly model entities external to the VM. For example, proxy components model a master component in the station VM. Likewise, components in a station often model an external system or device. Keeping components synchronized with their external representations is usually computationally expensive. Therefore all components are built with a mechanism to be notified when they really need to be synchronized. This mechanism is called *subscription*.

Subscription is a boolean state. A component can check its current state via the `BComponent.isSubscribed()` method. The `subscribed()` callback is invoked when entering the subscribed state, and `unsubscribed()` when exiting the subscribed state. The subscribed state means that something is currently interested in the component. Subscribed usually means the component should attempt to keep itself synchronized through polling or eventing. The unsubscribed state may be used to disable synchronization to save CPU, memory, or bandwidth resources.

Subscriptions often chain across multiple tiers. For example when you subscribe to a component in the workbench, that subscribes to the master in a station. Suppose the station component is a proxy point for a piece of data running in a Jace. That causes a subscription over the station-to-station connection resulting in the Jace's component to be subscribed. If the Jace component models an external device, that might initiate a polling operation. Keep in mind that n-tier subscribes might introduce delays. The stale status bit is often used with subscription to indicate that a value hasn't yet been updated from an external device.

A component is moved into the subscribed state if any of the following are true:

- If the component is running and any slot in the component is used as the source of an active link: `isRunning() && getKnobs().length > 0`.
- There are one or more active [Subscribers](#).
- The component is permanently subscribed via the `setPermanentlySubscribed()` method. A typical example is a control point with an extension that returns true for `requiresPointSubscription()`.

Collectively these three cases are used by the framework to indicate interest in a component. The framework does not make a distinction between how a component is subscribed, rather all three cases boil down to a simple boolean condition: subscribed or unsubscribed.

The [Subscriber](#) API is the standard mechanism to register for component events. You can think of Subscriber as the `BComponent` listener API. Subscriber maintains a list of all the components it is subscribed to, which makes cleanup easy via the `unsubscribeAll()` method. Subscribers receive the `event()` callback for any component [event](#) in their subscription list. Note that workbench developers typically use [BWBComponentView](#) which wraps the Subscriber API and provides automatic cleanup.

## Leasing

A common need is to ensure that a component is synchronized, but only as a snapshot for immediate use. The framework provides a feature called *leasing* to handle this problem. A lease is a temporary subscription, typically for one minute. After one minute, the component automatically falls back to the unsubscribed state. However, if the component is leased again before the minute expires, then the lease time is reset.

Leasing is accomplished via the `BComponent.lease()` method.

## Batch Calls

Although the framework provides a nice abstraction for remote programming, you must be cognizant that network calls are occurring under the covers and that network calls are extremely expensive operations. The number one cause of performance problems is too many round robin network calls. The golden rule for remote programming is that one large batch network call is almost always better performing than multiple small network calls. Niagara provides APIs to batch many common operations.

## Batch Resolve

The first opportunity to batch network calls is when resolving more than one ord to a component. Resolving a component deep down in the tree for the first time requires loading the component and all its ancestors across the network. And if the ord is a handle ord, a network call is needed to translate the handle into a slot path. The most efficient way to batch resolve is the via the [BatchResolve](#) API.

## Batch Subscribe

Subscription is another key area to perform batch network calls. There are three mechanisms for batch subscribe:

1. The first mechanism is to subscribe using a depth. The common case for subscription is when working with a subsection of the component tree. Depth based subscribe allows a component and a number of descendent levels to be subscribed via one operation. For example if working with the children and grandchildren of a component, then subscribe with a depth of 2.
2. On rare occasions you may need to subscribe to a set of components scattered across the database. For this case there is a subscribe method that accepts an array of BComponents. Both the Subscriber and BWbComponentView classes provide methods that accept a depth or an array.
3. The third mechanism for batch subscribe is do a batch lease. Batch leasing is accomplished via the static `BComponent.lease()` method.

## Transactions

By default, when making changes to a proxy component, each change is immediately marshaled over the network to the master. However, if making many changes, then it is more efficient to batch these changes using [Transaction](#). Note most Transactions are used to batch a network call, but do not provide atomic commit capability like a RDBMS transaction.

Transactions are passed as the Context to the various change methods like `set()` or `add()`. Instead of committing the change, the change is buffered up in the Transaction. Note that Transaction implements [Context](#) and is a [SyncBuffer](#). Refer to [Transaction's](#) class header documentation for code examples.

## Debugging

The following provides some tips for debugging remote components:

The spy pages provide a wealth of information about both proxy and master components including their subscribe state. A component spy's page also contains information about why a component is subscribed including the knobs and registered Subscribers. Note that right clicking a proxy component in the workbench causes a local lease, so it does introduce a Heisenberg effect; one work around is to bookmark the spy page to avoid right clicks.

The outstanding leases of a VM can be accessed via the [LeaseManager](#) spy page.

The most common performance problem is not batching up network calls. The mechanism for diagnosis is to turn on fox tracing. Specially the "fox.broker" log will illustrate network calls for loads, subscribes (sub), unsubscribes (unsub), and proxy side changes (syncToMaster). The simplest way to turn on this tracing is [Log Setup](#) spy page.

# Files

## Overview

The Niagara Framework is built upon the fundamental principle that everything of interest is modeled as a BObject. Files are one of the most basic entities which are mapped into the object model.

The Niagara file model is a comprehensive architecture for mapping all files into a consistent set of APIs:

- Files on the local file system (`java.io.File`);
- Files stored within modules and zip files;
- Files over the network using Fox;
- Files over the network using HTTP;
- Files over the network using FTP;
- Files in memory;
- Files which are autogenerated;

## API

The [javax.baja.file](#) package provides the core APIs used for file access. There are three core concepts in the file model:

1. [BIFile](#): represents a file. In general file extensions are mapped to specific Types of BIFile using the registry. Effectively the Niagara Type wraps the MIME type. For example common file types include `file:TextFile`, `file:XmlFile`, `file:ImageFile`, `file:WordFile`. The "file" module contains mappings for common file extensions.
2. [BIFileStore](#): models a BIFile backing store. For example a `file:TextFile` might exist on the file system, in a zip file, or over a network. Each of these file storage mechanism reads and writes the file differently. There a BIFileStore for every BIFile which may be accessed via the `BIFile.getStore()` method. Common store types include `baja:LocalFileStore`, `baja:MemoryFileStore`, and `baja:ZipFileEntry`.
3. [BFileSpace](#): represents a set of files with a common storage model. BFileSpaces are responsible for resolving FilePaths into BIFiles. The prototypical file space is the singleton for local file system [BFileSystem](#). The ord "local:|file:" always maps to `BFileSystem.INSTANCE`.

## Mapping File Extensions

You can create custom file types for specific file extensions by following these rules:

- Create an implementation of BIFile. Utilize one of the existing base classes such as `baja:DataFile`. If you wish to utilize agents such as file text editors then you must extent `file:TextFile` or at least implement `file:ITextFile`.
- Make sure you override `getMimeType()` to return the MIME type for the file's contents:

```
public String getMimeType() { return "text/html"; }
```

- Provide a custom icon if you wish by overriding the `getIcon()` method:

```
public BIcon getIcon() { return icon; }
private static final BIcon icon = BIcon.std("files/html.png");
```

- Map one of more file extensions to your type using in "module-include.xml":

```
<type name="HtmlFile" class="javax.baja.file.types.text.BHtmlFile">
  <file>
    <ext name="html"/>
    <ext name="htm"/>
  </file>
</type>
```

# Localization

## Overview

All aspects of the Niagara framework are designed for localization. The basic philosophy for localization is that one language may be supported in-place or multiple languages may be supported via indirection. The foundation of localization is based on the Context and Lexicon APIs.

## Context

Any framework API which is designed to return a string for human display, takes a [Context](#) parameter. Context provides information to an API about the context of the call including the desired locale. Many APIs implement Context directly including [OrdTarget](#), [ExportOp](#), and [WebOp](#). For example if you are processing a web HTTP request, you can pass the WebOp instance as your Context and the framework will automatically localize display strings based on the user who is logged in for that HTTP session.

Note that Workbench code always uses the default locale of the VM, so it is typical to just use `null` for Context. However code designed to run in a station VM should always pass through Context.

## Lexicon

Lexicons are Java properties files which store localized key/value pairs. They are either deployed within modules or located in a directory called "file:lexicon/". A module may contain multiple lexicon files, each of which is associated with a language. The "file:lexicon/" directory may contain zero or more *lang* subdirectories, which are used to store the lexicon files for specific languages, where lang is the locale code. Within the directory there is a file per module named "*moduleName.lexicon*". Every module with a lexicon should also provide a fallback lexicon bundled in the root directory of module's jar file: "*module://moduleName/moduleName.lexicon*" (note in the source tree it is just "module.lexicon").

Access to lexicons is provided via the [Lexicon](#) API.

## BFormat

Many Niagara APIs make use of the [BFormat](#) class to store a formatted display string. BFormat provides the ability to insert special function calls into the display string using the percent sign. One of these calls maps a string defined in a lexicon via the syntax "%lexicon(module:key)%". Whenever a display string is stored as a BFormat, you may store one locale in-place or you may use the %lexicon()% call to indirectly reference a lexicon string.

## Slots

One of the first steps in localization, is to provide locale specific slot names. Every slot has a programmatic name and a context sensitive display name. The process for deriving the display name for a slot:

1. **BComplex.getDisplayName(Slot, Context):** The first step is to call this API. You may override this method to provide your own implementation for localization.
2. **NameMap:** The framework looks for a slot called "displayNames" that stores a [BNameMap](#). If a NameMap is found and it contains an entry for the slot, that is used for the display name. Note the NameMap value is evaluated as a BFormat, so it may contain a lexicon call. NameMaps are useful ways to localize specific slots, localize instances, or to localize dynamic slots.
3. **Lexicon:** Next the framework attempts to find the display name for a slot using the lexicon. The lexicon module is based on the slot's declaring type and the key is the slot name itself.
4. **Slot Default:** If we still haven't found a display name, then we use a fallback mechanism. If the slot is frozen, the display name is the result of `TextUtil.toFriendly(name)`. If the slot is dynamic the display name is the result of `SlotPath.unescape(name)`.

## Facets

Sometimes facets are used to store display string. In these cases, the string is interpreted as a BFormat so that a %lexicon()% call may be configured. This design pattern is used for:

- Boolean trueText
- Boolean falseText

## FrozenEnums

Compile time enums subclass from [BFrozenEnum](#). Similar to slot names and display names, enums have a programmatic tag and a display tag. Localization of display tags uses the following process:

1. **Lexicon:** The framework first attempts to map the display tag to a lexicon. The module is the declaring type of the FrozenEnum and the key is the programmatic tag.
2. **Default:** If a display tag isn't found in the lexicon, then the fallback is the result of `TextUtil.toFriendly(tag)`.

## DynamicEnums

Localization of [BDynamicEnums](#) is done via the [BEnumRange](#) API. An EnumRange may be associated with a DynamicEnum directly via DynamicEnum.make() or indirectly via Context facets. An EnumRange may be composed of a FrozenEnum's range and/or dynamic ordinal/tag pairs. Any portion of the frozen range uses the same localization process as FrozenEnum. The dynamic portion of the range uses the following process:

1. **Lexicon:** If BEnumRange.getOptions() contains a "lexicon" value, then we attempt to map the display tag to a lexicon where the module is the value of the "lexicon" option and the key is the programmatic tag.
2. **Default:** If a display tag is not found using the lexicon, and the ordinal does map to a programmatic tag, then the result of `SlotPath.unescape(tag)` is returned.
3. **Ordinal:** The display tag for an ordinal that isn't included in the range is the ordinal itself as a decimal integer.

## User Interface

When building a user interface via the bajoui APIs, all display text should be localizable via lexicons. In the case of simple BLabels, just using the Lexicon API is the best strategy.

The [Command](#) and [ToggleCommand](#) APIs also provide built-in support for fetching their label, icon, accelerator, and description from a lexicon. Take the following code example:

```
class DoIt extends Command
{
    DoIt(BWidget owner) { super(owner, lex, "do.it"); }

    static final Lexicon lex = Lexicon.make(MyCommand.class);
}
```

In the example above DoIt would automatically have its display configured from the declaring module's lexicon:

```
do.it.label=Do It
do.it.icon=module://icons/x16/build.png
do.it.accelerator=Ctrl+D
do.it.description=Do it, whatever it is.
```

## Locale Selection

Every time a Niagara VM is started it attempts to select a default locale using the host operating system. The OS default may be overridden via the command line flag "-locale:lang", where lang is the locale code. The locale code can be any string that maps to a lexicon directory, but typically it is a ISO 639 locale code such as "fr". The default locale of the VM may be accessed via the `Sys.getLanguage()` API.

When the workbench is launched as a desktop application it follows the rules above to select its locale. Once selected the

entire workbench uses that locale independent of user accounts used to log into stations.

The locale for web browser access to a station follows the rules:

1. **User.language:** If the language property of user is a non-empty string, then it defines the locale to use.
2. **Accept Language:** Next the framework tries to select a locale based on the "Accept-Language" passed in the browser's HTTP request. Typically this is configured in the browser's options.
3. **Default:** If all else fails, then the default locale of the station's VM is used

## Time Formatting

The default time format is defined by the lexicon key `baja:timeFormat`. But it may be selectively overridden by users. To change the time format in the Workbench use General Options under Tools | Options. Use the `User.facets` property to change it for browser users.

Niagara' time format uses a simple pattern language:

Pattern	Description
YY	Two digit year
YYYY	Four digit year
M	One digit month
MM	Two digit month
MMM	Abbreviated month name
D	One digit day of month
DD	Two digit day of month
h	One digit 12 hour
hh	Two digit 12 hour
H	One digit 24 hour
HH	Two digit 24 hour
mm	Two digit minutes
ss	Seconds (and milliseconds if applicable)
a	AM/PM marker
z	Timezone
anything else	Character literal

In addition to the time format configured by the user, developers may customize the resolution via the following facets:

```

BFacets.SHOW_TIME
BFacets.SHOW_DATE
BFacets.SHOW_SECONDS
BFacets.SHOW_MILLISECONDS
BFacets.SHOW_TIME_ZONE

```

To programmatically format a time using this infrastructure use the [BAbsTime](#) or [BTime](#) APIs.

## Unit Conversion

By default the framework displays all numeric values using their configured units (via Context facets). Users may override this behavior to have all values converted to the US/English system or SI/Metric systems. To enable this feature in Workbench use General Options under Tools | Options. Use the User.facets property to enable it for browser users.

The list of units known to the system and how to convert is configured via the file:lib/units.xml XML file. The mapping of those units between English and Metric is done in the file:lib/unitConversion.xml XML file.

To programmatically format and auto-convert numerics use the [BFloat](#) or [BDouble](#) APIs.

Note this unit conversion is independent of the conversion which may be performed by [ProxyExts](#) when mapping a point into a driver.



# Spy

## Overview

The Niagara Framework is built upon a principle of high visibility. By modeling everything as a `BObject`s most data and functionality is automatically made visible using the tools built into the workbench. However it is infeasible to model all data using the component model. The spy framework provides a diagnostics window into the system internals for debugging which goes beyond the component model.

Spy pages are accessed via the [spy:/](#) ord.

See [javax.baja.spy](#) package for more details.

# Licensing

## Overview

The Niagara licensing model is based upon the following elements:

- **HostId** A short String id which uniquely identifies a physical box which runs Niagara. This could be a Windows workstation, Jace-NP, or any Jace-XXX embedded platform. You can always check your hostId using the command "nre -version".
- **Certificate:** A file ending in "certificate" which matches a vendor id to a public key. Certificates are granted by Tridium, and digitally signed to prevent tampering. Certificates are stored in the "{home}\certificates" directory.
- **License File:** A file ending in "license" which enables a set of vendor specific features. A license file is only valid for a machine which matches its hostId. Licenses are digitally signed by a specific vendor to prevent tampering. License files are stored in the "{home}\licenses" directory.
- **Feature:** A feature is a unique item in the license database keyed by a vendor id and feature name. For example "Tridium:jade" is required to run the Jade tool.
- **API:** The [javax.baja.license](#) package provides a simple API to perform checks against the license database.

## License File

A license file is an XML file with a ".license" extension. License files are placed in "{home}\licenses". The filename itself can be whatever you like, but convention is to name the file based on the file's vendor id. The following is an example license file:

```
<license
  version="1.0"
  vendor="Acme"
  generated="2002-06-01"
  expiration="never"
  hostId="Win-0000-1111-2222-3333">
  <feature name="alpha"/>
  <feature name="beta" expiration="2003-01-15"/>
  <feature name="gamma" count="10"/>
  <signature>MC0CFACwUvUwA+mNXMfogNb6PVURneerAhUAgZnTYb6kBCsvsmC2by1tUe/5k/4=
</signature>
</license>
```

## Validation

During bootstrap, the Niagara Framework loads its license database based on the files found in the "{home}\licenses" directory. Each license file is validated using the following steps:

1. The hostId attribute matches the license file to a specific machine. If this license file is placed onto a machine with a different hostId, then the license is automatically invalidated.
2. The expiration attribute in the root element specifies the master expiration. Expiration must be a format of "YYYY-MM-DD". If the current time is past the expiration, the license file is invalidated. The string "never" may be used to indicate no expiration.
3. The generated attribute in the root element specifies the license file generation date as "YYYY-MM-DD". If the current time is before the generated date, the license file is invalidated.
4. The vendor attribute is used to inform the framework who has digitally signed this license file. In order to use a license file, there must be a corresponding certificate file for that vendor in the "{home}\certificates" directory.
5. The signature element contains the digital signature of the license file. The digital signature is created by the vendor using the vendor's private key. The signature is verified against the vendor's public key as found in the vendor's certificate. If the digital signature indicates tampering, the license file is invalid.

## Features

A license database is a list of features merged from the machine's license files that are validated using the procedure discussed above. Each feature is defined using a single XML element called `feature`. Features are identified by the vendor id which is signed into the license file and a feature name defined by the `name` attribute.

The `expiration` attribute may be specified in the feature element to declare a feature level expiration. Expiration is a string in the format of "never" or "YYYY-MM-DD". If expiration is not specified then never is assumed.

Each feature may declare zero or more name/value properties as additional XML attributes. In the example license above the "gamma" feature has one property called "count" with a value of "10".

## Predefined Features

The following is a list of predefined features used by the Niagara Framework. All of these features require a vendor id of "Tridium":

- **workbench:** Required to run the workbench tool.
- **station:** Required to run a station database.

## API Usage

The following are some snippets of Java code used to access the license database:

```
// verify that the "Acme:CoolFeature" is licensed on this machine
try
{
    Sys.getLicenseManager().checkFeature("Acme", "CoolFeature");
    System.out.println("licensed!");
}
catch(LicenseException e)
{
    System.out.println("not licensed!");
}

// get some feature properties
Feature f = Sys.getLicenseManager().getFeature("Acme", "gamma");
f.check();
String count = f.get("count");
```

## Checking Licenses

You may use the following mechanisms to check your license database:

1. Use the console command "nre -licenses".
2. Use the [spy page](#).

# XML

## Overview

The [javax.baja.xml](#) package defines the core XML API used in the Niagara architecture. The two cornerstones of this APIs are:

1. **XElem:** Provides a standard representation of an XML element tree to be used in memory. It is similar to the W3's DOM, but much lighter weight.
2. **XParser:** XParser is a light weight XML parser. It may be used in two modes: to read an entire XML document into memory or as a pull-parser.

The Baja XML APIs are designed to be small, fast, and easy to use. To achieve this simplicity many advanced features of XML are not supported by the `javax.baja.xml` APIs:

- Only UTF-8 and UTF-16 encodings are supported. Unicode characters in attributes and text sections are escaped using the standard entity syntax '&#dd;' or '&#xhh;'.
- All element, attribute, and character data productions are supported.
- CDATA sections are supported.
- Namespaces are supported at both the element and attribute level.
- Doctype declarations, DTDs, entity declarations are all ignored by the XML parser. XML used in Niagara is always validated at the application level for completeness and efficiency.
- Processing instructions are ignored by the XML parser.
- No access to comments is provided by the XML parser.
- Character data consisting only of whitespace is always ignored.

## Example XML

For the code examples provided we will use this file "test.xml":

```
<root xmlns="ns-stuff" xmlns:u="ns-user">
  <u:user name="biff" age="29">
    <u:description>Biff rocks</u:description>
    <u:skills sing="true" dance="false"/>
  </u:user>
  <user name="elvis" alive="maybe" xmlns="">
    <skills sing="true" dance="true"/>
  </user>
  <attr1="1" u:attr2="2"/>
</root>
```

## Working with XElem

The [XElem](#) class is used to model an XML element tree. An element is defined by:

- **Namespace:** Elements which are in a namespace will return a non-null value for `ns()`. You may also use the `prefix()` and `uri()` methods to access the namespace prefix and URI. The "xmlns" attribute defines the default namespace which will apply to all child elements without an explicit prefix. The "xmlns:{prefix}" attribute defines an namespace used by child elements with the specified prefix.
- **Name:** The `name()` method returns the local name of the element without the prefix. You may also use `qname()` to get the qualified name with the prefix.
- **Attributes:** Every element has zero or more attributes declared within the element start tag. There are an abundance of convenience methods used to access these attributes. Attributes without an explicit prefix are assumed to be in no namespace, not the default namespace.

**Content:** Every element has zero or more content children. Each content child is either an `XText` or `XElem` instance. Character data (including CDATA) is represented using `XText`.

The following code illustrates many of the commonly used methods on `XElem`:

```
// parse the test file
XElem root = XParser.make(new File("test.xml")).parse();

// dump xml tree to standard out
root.dump();

// dump root identity
System.out.println("root.name    = " + root.name());
System.out.println("root.ns      = " + root.ns());

// get elements
System.out.println("elems()      = " + root.elems().length);
System.out.println("elems(user) = " + root.elems("user").length);

// biff
XElem biff = root.elem(0);
System.out.println("biff.name    = " + biff.name());
System.out.println("biff.ns      = " + biff.ns());
System.out.println("biff.age     = " + biff.get("age"));

// elvin
XElem elvis = root.elem(1);
XElem skills = elvis.elem("skills");
System.out.println("elvis.name   = " + elvis.name());
System.out.println("elvis.ns     = " + elvis.ns());
System.out.println("skills.sing  = " + skills.getb("sing"));
```

Output from code above:

```
root.name    = root
root.ns      = ns-stuff
elems()      = 3
elems(user)  = 2
biff.name    = user
biff.ns      = ns-user
biff.age     = 29
elvis.name   = user
elvis.ns     = null
skills.sing  = true
```

## Working with XParser

The [XParser](#) class is used to parse XML input streams into `XElems`. The easiest way to do this is to parse the entire document into memory using the `parse()` method:

```
// parse and close input stream
XElem root = XParser.make(in).parse();
```

The above code follows the W3 DOM model of parsing a document entirely into memory. In most cases this is usually acceptable. However it can create efficiency problems when parsing large documents, especially when mapping the `XElems` into other data structures. To support more efficient parsing of XML streams, `XParser` may also be used to read elements off the input stream one at a time. This is similar to the SAX API, except you pull events instead of having them pushed to you. A pull model is much easier to work with.

To work with the pull `XParser` APIs you will use the `next()` method to iterate through the content instances. This

effectively tokenizes the stream into XElem and XText chunks. Each call to `next()` advances to the next token and returns an int constant: `ELEM_START`, `ELEM_END`, `TEXT`, or `EOF`. You may also check the type of the current token using `type()`. You may access the current token using `elem()` or `text()`.

XParser maintains a stack of XElems for you from the root element down to the current element. You may check the depth of the stack using the `depth()` method. You can also get the current element at any position in the stack using `elem(int depth)`.

It is very important to understand the XElem at given depth is only valid until the parser returns `ELEM_END` for that depth. After that the element will be reused. The XText instance is only valid until the next call to `next()`. You can make a safe copy of the current token using `copy()`.

The following code illustrates using XParser in pull mode:

```
XParser p = XParser.make(new File("test.xml"));

p.next(); // /root start
System.out.println("root.start: " + p.elem().name() + " " + p.depth());
p.next(); // root/user(biff) start
System.out.println("biff.start: " + p.elem().name() + " " + p.depth());
p.next(); // root/user/description start
System.out.println("desc.start: " + p.elem().name() + " " + p.depth());
p.next(); // root/user/description text
System.out.println("desc.text: " + p.text() + " " + p.depth());
p.next(); // root/user/description end
System.out.println("desc.end: " + p.elem().name() + " " + p.depth());
p.skip(); // skip root/user/skills
p.next(); // root/user(biff) end
System.out.println("biff.end: " + p.elem().name() + " " + p.depth());
p.next(); // root/user(elvis) start
System.out.println("elvis.start: " + p.elem().name() + " " + p.depth());
```

Output from code above:

```
root.start:  root      1
biff.start:  user      2
desc.start:  description 3
desc.text:   Biff rocks 3
desc.end:    description 3
biff.end:    user      2
elvis.start: user      2
```

# Bog Files

## Overview

Niagara provides a standard XML format to store a tree of BValues. This XML format is called "bog" for Baja Object Graph. The bog format is designed for the following criteria:

- Easy to serialize a graph to an output stream using one pass;
- Easy to deserialize a graph from an input stream using one pass;
- Compact XML, using single letter element and attribute names;
- Ability to compress using zip;

Bog files are typically given a ".bog" extension. Although the ".palette" extension can be used to distinguish a bog designed for use as palette; other than extension bog and palette files are identical.

Bog files can be flat XML files or stored inside zip files. If zipped, then the zip file contains a single entry called "file.xml" with the XML document. You use workbench to copy any BComponent to a directory on your file system to easily generate a bog.

## API

In general the best way to read and write bog files is via the standard APIs. The [BogEncoder](#) class is used to write BValues to an output stream using bog format. Note that [BogEncoder](#) subclasses [XWriter](#) for generating an XML document. You can use the `XWriter.setZipped()` method to compress the bog file to a zip file with one entry called "file.xml". In general you should use the `encodeDocument()` method to generate a complete bog document. However you can also use [BogEncoder](#) to stream multiple BValues to an XML document using `encode()`.

The [BogDecoder](#) class is used to decode a bog document back into BValue instances. Note that [BogDecoder](#) subclasses [XParser](#) for parsing XML. When decoding a bog file, [XParser](#) will automatically detect if the file is zipped or not. General usage is to use `decodeDocument()` in conjunction with `BogEncoder.encodeDocument()` for decoding the entire XML document as a BValue. However [BogDecoder](#) can also be used to decode BValues mixed with other XML data using `BogDecoder.decode()` and the standard [XParser](#) APIs.

`BogEncoder.marshal()` and `BogDecoder.unmarshal()` are convenience methods to encode and decode a BValue to and from a String.

## Syntax

The bog format conforms to a very simple syntax. The root of a bog document must always be "bajaObjectGraph". Under the root there are only three element types, which map to the three slot types:

Element	Description
<b>p</b>	Contains information about a property slot
<b>a</b>	Contains information about a frozen action slot
<b>t</b>	Contains information about a frozen topic slot

All other information is encoded into XML attributes:

Attribute	Description
<b>n</b>	This required attribute stores the slot name.
<b>m</b>	Defines a module symbol using the format "symbol=name". Once defined, the

	symbol is used in subsequent t attributes.
<b>t</b>	Specifies the type of a property using the format "symbol:typename", where symbol must map to a module declaration earlier in the document. If unspecified, then the type of the property's default value is used.
<b>f</b>	Specifies slot flags using the format defined by <code>Flags.encodeToString()</code>
<b>h</b>	This attribute specifies the handle of BComponents
<b>x</b>	Specifies the slot facets using format defined by <code>BFacets.encodeToString()</code>
<b>v</b>	Stores the string encoding of BSimples.

In practice the XML will be a series of nested p elements which map to the structure of the BComplex tree. The leaves of tree will be the BSimples stored in the v attribute.

## Example

A short example of a kitControl:SineWave linked to a kitControl:Add component. The Add component has a dynamic slot called description where value is "hello", operator flag is set, and facets are defined with multiLine=true.

```
<?xml version="1.0" encoding="UTF-8"?>
<bajaObjectGraph version="1.0">
<p m="b=baja" t="b:UnrestrictedFolder">
  <p n="SineWave" h="1" m="kitControl=kitControl" t="kitControl:SineWave">
    </p>
    <p n="amplitude" v="35"/>
  </p>
  <p n="Add" h="3" t="kitControl:Add">
    </p>
    <p n="Link" t="b:Link">
      <p n="sourceOrd" v="h:1"/>
      <p n="sourceSlotName" v="out"/>
      <p n="targetSlotName" v="inA"/>
    </p>
    <p n="description" f="o" x="multiLine=b:true" t="b:String" v="hello"/>
  </p>
</p>
</bajaObjectGraph>
```



## Distributions

### Overview

A distribution is a platform-specific archive of deployable software. The distribution file:

- Is a JAR file compliant with PKZIP compression;
- Contains an XML manifest in meta-inf/dist.xml;
- Contains files to be deployed;
- May contains files to assist with deployment;
- States its dependencies on any *parts* such as hardware, operating system, Niagara or third-party software

### JAR Entry Paths

The JAR entry paths mirror their intended filesystem paths directly. Paths are mapped either to the target host's root directory or the {baja home} directory, according to the manifest. Unless specified otherwise by the manifest or end-user request, and except for the dist.xml manifest itself, each file will be copied to the target host (*i.e.*, there is no facility provided for the user or an installation program to choose which specific pieces to install).

### Manifest

The distribution manifest is found in the meta-inf/dist.xml JAR entry. It

- provides some high-level descriptive information about the distribution,
- specifies the distribution's external dependencies and exclusions,
- provides a summary description of its contents to assist installer software in dependency analysis,
- identifies contents that should never be copied to the host,
- identifies resources that can assist with installation,
- identifies modifications that need to be made to the host's platform.bog file, and
- specifies under which conditions existing files are to be replaced.

An example distribution file manifest is provided as a reference for most of the remaining specification:

```
<dist name="qnx-jace-york"
      version="2.1.6"
      description=""
      buildDate="Thu Jan 18 10:58:39 Eastern Standard Time 2007"
      buildHost="BRUTUS"
      reboot="true"
      noRunningApp="true"
      absoluteElementPaths="true"
      osInstall="true"
>

<dependencies>
  <part name="york" desc="York System Board" />
</dependencies>

<exclusions>
  <os name="qnx-jace-york" version="2.2" />
</exclusionss>

<provides>
  <os name="qnx-jace-york" version="2.1.6" />
</provides>
<fileHandling>
```

```

    <file name="dev/shmem/york.image" replace="oscr" />
  </fileHandling>
</dist>

```

The root **dist** element has the following attributes:

- **name** [required]: Name of the distribution.
- **version** [required]: Version of the distribution, dot delimited. If version is nonzero, then it and the name must uniquely identify the file's contents - they *must not be reused* with different contents.
- **vendor** [optional]: Vendor name for the provider of the distribution.
- **description** [optional]: Brief description of the what the distribution provides.
- **buildDate** [optional]: Timestamp for when the distribution was created. May be generated by a build tool, useful in tracking development builds.
- **buildHost** [optional]: Host on which the distribution was created. May be generated by a build tool, useful in tracking development builds.
- **reboot** [optional]: true or false, defaults to true. If true, the host to which this distribution is installed must be rebooted after installation is complete.
- **noRunningApp** [optional]: true or false, defaults to true. If true, then the distribution may not be installed while any Niagara stations or Sedona applications are running.
- **absoluteElementPaths** [optional]: true or false, defaults to false. If true, then the JAR entry path maps directly to the host's root directory, otherwise the entry path maps to {baja\_home}.
- **osInstall** [optional]: true or false, defaults to false. Meaningless for Win32 platforms. If true, then the distribution contains an operating system image that must be installed after the files are downloaded and before the host is rebooted.
- **hostId** [optional]: If present, represents the hostid of the system for which the distribution (probably a backup) was created.

## platform Element [optional]

Sub-elements are XML in bog file format and will be merged *by name* into the host's existing platform.bog file, or will be used to initialize a new platform.bog file. This allows a distribution to provide new platform services without clobbering or re-initializing any existing platform services.

## dependencies Element [optional]

describes the *parts* which must be present on a target host before the distribution can be installed. Each *part* is identified by a sub-element:

### arch element [optional]

Describes a chipset dependency. Required **name** attribute specifies the chipset architecture name.

### model element [optional]

Describes a model dependency. Required **name** attribute specifies the model name.

### os element [optional]

Describes an operating system dependency. Attributes:

- **name** [required]: operating system name
- **vendor** [optional]: operating system vendor
- **version** [required]: operating system version, dot delimited.
- **rel** [optional]: describes how the version is evaluated. Possible values are "minimum" (default), "maximum", and "exact".

### nre element [optional]

Describes a dependency on a Niagara runtime version. Attributes:

- **name** [required]: NRE name
- **vendor** [optional]: NRE vendor
- **version** [required]: NRE version, dot delimited.
- **rel** [optional]: describes how the version is evaluated. Possible values are "minimum" (default), "maximum", and "exact".

#### **brand element [optional]**

Describes a dependency on a brand. Required attribute **name** uniquely identifies the brand that must be specified in a target host's license for the dependency to be met.

#### **module element [optional]**

Describes a module dependency. Attributes are the same as those for the **dependency** element in the module.xml manifest (see modules.html), and the optional **rel** option is supported.

#### **part element [optional]**

Describes a dependency on any other kind of *part*, such as a piece of hardware. Required attribute **name** is a unique name for the part, and required attribute **description** provides a brief description. Optional **version** attribute, if present, specifies a version requirement for the part, and the optional **rel** attributed specifies how the version is evaluated.

#### **exclusions Element [optional]**

Describes the *parts* which must *not* be present on a target host if the distribution is to be installed. The sub-elements allowed are the same as those used in the **dependencies** section.

#### **provides Element [optional]**

If present, describes exactly one **part** that is to be installed by this distribution, whose part name matches the distribution name (*i.e.* if the part is named qnx-jace-james, the dist file must be named qnx-jace-james.dist).

If the distribution file doesn't contain a single discrete named, versioned part (for example a system backup) then it must omit the provides element. Also, if for any other reason the distribution should not be installed automatically by a client to satisfy dependencies expressed in other files, it must omit the provides element.

The part is described by a sub-element:

#### **os element [optional]**

Describes an operating system element. Attributes:

- **name** [required]: operating system name
- **vendor** [optional]: operating system vendor
- **version** [required]: operating system version, dot delimited.

#### **vm element [optional]**

Describes an installable java virtual machine. Attributes:

- **name** [required]: virtual machine name
- **vendor** [optional]: VM vendor
- **version** [required]: VM version, dot delimited.

#### **nre element [optional]**

Describes an installable Niagara runtime engine (NRE). Attributes:

- **name** [required]: NRE product name
- **vendor** [optional]: NRE vendor

- **version** [required]: NRE version, dot delimited.

### resources Element [optional]:

If present, specifies elements whose files are used to support the distribution's installation, and are not to be copied to the host. Each sub-element has a **content** attribute that identifies the entry path. At this time, it may contain the following sub-element:

#### installable element [optional]

Describes an installable file that the installing client should import into its software registry (Workbench's software registry is maintained using its {baja\_home}/sw directory). Using installable resources makes the distribution much bigger, but is useful for creating single files that have all of the necessary contents to meet their own software dependencies. Attributes:

- **source** [required]: element path containing the installable file
- **type** [required]: can be "module" or "dist"
- **name** [required]: name specified by the installable's manifest
- **vendor** [required]: vendor name specified by the installable's manifest
- **vendorVersion** [required]: version specified by the installable's manifest

### fileHandling Element [optional]

Specifies the rules by which files are replaced, and identifies directories and files which must be removed before installation begins. The optional **replace** attribute specifies the rules for replacing existing files - its values can be "always" if the file is always to be replaced, "never" if it is never to be replaced, and "crc" if the file is to be replaced only if the CRC checksums for the distribution and current versions of the file are not the same. By default, no files or directories are to be removed by the installer prior to installation, and the "crc" replacement rule is used. The **fileHandling** element may contain the following sub-elements:

#### remove element

Specifies a file or directory to be removed prior to installation. Its required **name** attribute specifies the path (according to absoluteElementPaths element) to the file/directory. If **name** specifies a directory, exceptions may be specified using the **keep** sub-element.

#### keep element [optional]

Specifies a file or directory that should not be removed as the result of a **remove** element. Its required **name** attribute specifies the path.

#### file element [optional]

Specifies a file replacement rule that differs from the default in the **fileHandling** element or any **dir** element that might apply to the file's path. Its required **name** attribute specifies the file path, and the required **replace** attribute specifies the rules for replacing the existing file - its values can be "always" if the file is always to be replaced, "never" if it is never to be replaced, "crc" if the file is to be replaced only if the CRC checksums for the distribution and current versions of the file are not the same, "osrc" if the file's CRC checksum is to be checked against a CRC value returned by the niagarad for the OS image, "nocopy" if the file is never to be copied to the host, or "hostid" if the file is to be copied only if the host's hostid matches the value of the **dist** element's **hostid** attribute.

#### dir element [optional]

Specifies a file replacement rule for a given directory path that differs from the default in the **fileHandling** element or in **dir** elements for parent paths. Its required **name** attribute specifies the directory's path. Its optional **replace** attribute can be "always", "never", "crc", "nocopy" or "hostid". Its optional **clean** attribute, if present and equal to "true", indicates that any file or subdirectory that isn't part of the distribution should be deleted by the installer.

# Niagara AX Automated Testing with TestNg

## Overview

Prior to Niagara AX 3.8, the Niagara Framework contained its own testing framework, and test methods contained in a BTest subclass were required to follow a specific naming convention. These testing capabilities were closely modeled after JUnit, which is a well-known tool for unit testing of Java code. However, it has several shortcomings that make it unattractive for Niagara testing. TestNG is a similar but more capable testing tool also widely used in the Java community, and it was selected as the tool we will use to generate and execute automated tests. The syntax for creating basic unit tests is very similar to JUnit 4. Additional functionality includes:

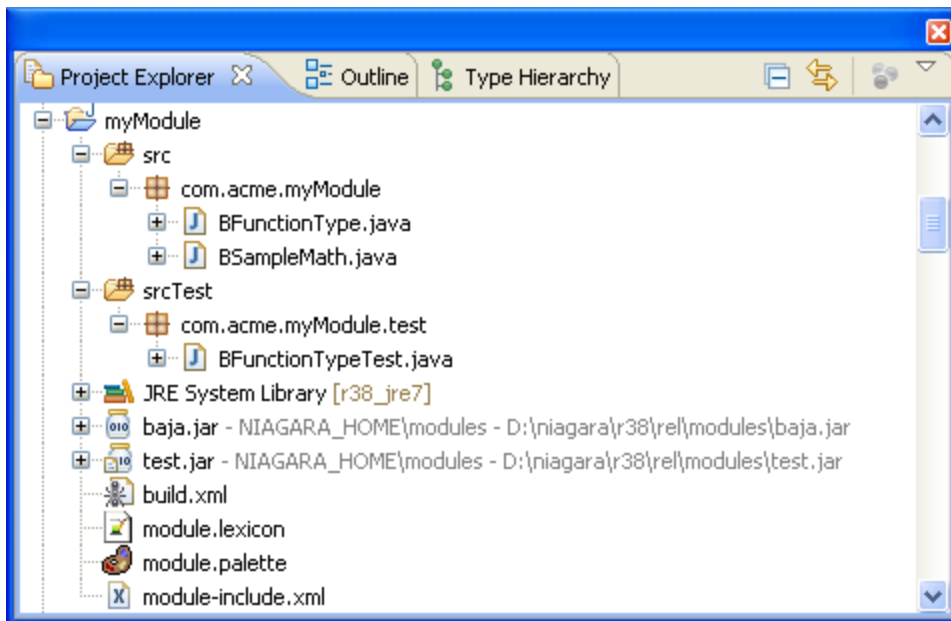
- Flexible annotation-based test configuration (setup/teardown)
- Automatic reporting of test results
- Dependencies and sequencing
- Data-driven testing and parameterized test methods
- Parallel testing

Starting with 3.8, the Niagara build.exe tool supports co-located test code (that is, source code and test code are contained in the same module development folder) and the Niagara test module will support writing TestNG test methods. The syntax requires the use of annotations, so test classes must be compiled with at least Java 5. Review the [TestNG Documentation](#) for additional information not covered here.

## Basic Test Case

### Test Package, Class, and Methods

Establish a srcTest folder in the module, and create the test packages and test source code there. Here is an example of a module with a test class:



Each test class should extend **com.tridium.testng.BTestNg**, and will include standard Baja code to declare the Type. TestNg will treat each test method as a single test case. A test method is defined with the @Test attribute:

```
package com.acme.myModule.test;

import javax.baja.sys.Sys;
import javax.baja.sys.Type;
import org.testng.Assert;
```

```

import org.testng.annotations.Test;
import com.acme.myModule.BFunctionType;
import com.tridium.testng.BTestNg;

public class BFunctionTypeTest extends BTestNg
{
    public Type getType() { return TYPE; }
    public static final Type TYPE = Sys.loadType(BFunctionTypeTest.class);
    @Test
    public void addTest()
    { Assert.assertEquals(BFunctionType.add,
        BFunctionType.make(BFunctionType.ADD)); }
}

```

There are several `assert*()` methods available in to test equality, null, true/false, etc. See the TestNg [TestNg Javadocs](#) for the complete list. The `pass()` and `fail()` methods for `BTestNg` have been integrated with TestNg, so the existing `BTest verify*()` methods can be used as well. Note that any test method that begins with **test** will be considered a standard Niagara test case and will run when tests are executed with the **-btest** option:

```

@Test
public void testAdd() { verify(BFunctionType.add ==
    BFunctionType.make(BFunctionType.ADD)); }

```

### build.xml

Include a dependency on the test module and set the dependency, package, and resource attributes appropriately, so the resulting build will create a separate `<moduleName>Test.jar` module:

```

<dependency name="test" vendor="Tridium" vendorVersion="3.8" test="true"/>
<package name="com.acme.myModule.test" edition="j2se-5.0" test="true" />

```

Remember to include the **edition= "j2se-5.0"** attribute for any test packages.

### module-include.xml

Types for test classes must be declared, but there is nothing unique about these entries:

```

<type name="FunctionTypeTest"
class="com.acme.myModule.test.BFunctionTypeTest" />

```

### Compile and execute

Execute the build process with the **-t** option to generate the test module jar file:

```

build <modulePath> -t

```

Execute the test command to run the defined tests under TestNg. The target for the tests is similar to existing Niagara tests: **all**, **<module>**, **<module>:<type>**. Single-method execution is not currently supported. The output will look something like this:

```

D:\niagara\r38\dev>test myModule
[TestNG] Running:
Command line suite

=====
myModuleTest_FunctionTypeTest
Total tests run: 5, Failures: 0, Skips: 0
=====

=====
Total Test Summary
Total tests run: 5, Failures: 0, Skips: 0
=====

```

Output verbosity can be set using the option **v:<n>**, where n is an integer from 1 to 10. The higher the number, the more TestNG prints out.

Any existing Niagara tests (now contained in testTest.jar) can be executed with the **-btest** option.

## Additional TestNg Capabilities

### Test Setup/Teardown

One big advantage of TestNg over JUnit is the flexible test configuration. These configurations are also accomplished with annotations. Setup and teardown methods can be established to run once per method, per class, per test group, or per test suite. The example below shows how to initialize and destroy a test station once for all test methods in a class, calling methods from BTest.

```
private TestStationHandler handler;
private BStation station;

@BeforeClass(alwaysRun=true)
public void setup()
    throws Exception
{
    handler = BTest.createTestStation();
    handler.startStation();
    station = handler.getStation();
}

@AfterClass(alwaysRun=true)
public void cleanup()
    throws Exception
{
    handler.stopStation();
    handler.releaseStation();
    handler = null;
}
```

### Groups, Dependencies and Sequencing

A set of tests may be grouped together with the **groups** annotation attribute. Groups naming is currently up to the developer. One use of groups is to identify a collection of tests to execute in a Continuous Integration (CI) environment (CI is not provided by Niagara, please go to [this link](#) for more information).

An example of the group attribute is below:

```
@Test(groups={"ci"})
public void ngTestSimple()
{ Assert.assertEquals(Lexicon.make("test").getText("fee.text"), "Fee"); }
```

You may declare dependencies between test methods and groups using **dependsOn\*** annotation attributes. For example, if you have a group of test that should run after other sets, just attach the dependsOnGroups attribute for each method in the group.

If you want to explicitly define a sequence of test method execution, use the **priority** annotation attribute. The value is a positive integer, and lower priorities will be scheduled first. See the TestNg documentation for additional information.

**Important:** If you implement **groups** and also use **BeforeClass/AfterClass** methods, be sure to attach the **(alwaysRun=true)** attribute to the BeforeClass/AfterClass annotations.

### Parameterized Tests

A set of similar test cases can be parameterized with a data source class that generates input to the test class. Again, the relationship is achieved with parameterized annotations. First you declare a data provider that creates an object array containing test method arguments for each instance of the test execution. In the example below, the test class takes two arguments, and each entry in the data provider array contains instances of those two argument types.

```

@DataProvider(name="operation")
public Object[][] createColumnData()
{
    return new Object[][] {
        { new Integer(BFunctionType.ADD),      BFunctionType.add },
        { new Integer(BFunctionType.SUBTRACT), BFunctionType.subtract },
        { new Integer(BFunctionType.MULTIPLY),  BFunctionType.multiply },
        { new Integer(BFunctionType.DIVIDE),    BFunctionType.divide }
    };
}

@Test(dataProvider = "operation")
public void testOperation(Integer i, BFunctionType ft)
{ Assert.assertEquals(ft, BFunctionType.make(i.intValue())); }

```

Note that the data provider argument types must be a Java Object (they cannot be primitives like boolean or int).

## Exception Testing

If your code can generate exceptions and you want to test these execution paths, you can tell a test method to expect particular exception types by using the **expectedExceptions** attribute with a list of exception classes. In the following test, an occurrence of a `NullPointerException` will successfully pass the test. Any other exception type will fail the test.

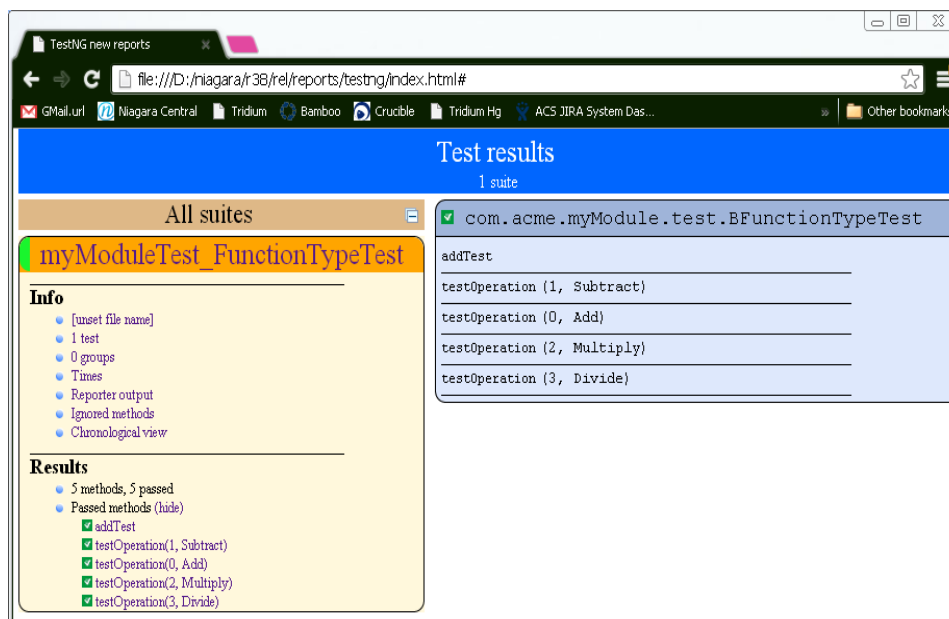
```

@Test(expectedExceptions={java.lang.NullPointerException.class})
public void ngTestException()
    throws Exception
{
    a = BExportSourceInfo.make(BOrd.make("station:|slot:/a"),
    BOrd.make("station:|slot:/b"), new BGridToText());
    BExportSourceInfo.make("foo:bar");
    a.decodeFromString("foo:bar");
}

```

## Reporting

TestNg will generate XML and HTML reports each time it runs. By default, creates these in a **(baja.home)/reports/testng** folder. The HTML report **index.html** contains detailed information about the test results. A **junitreports** folder contains XML reports that follow the same format created by Ant/JUnit. There is also a static XML report and an email-able static HTML report. The report location can be changed using the command line option **-output:<path>**.





## Eclipse Integration

There is an Eclipse plugin available for TestNg. If you are familiar with JUnit, test execution and reporting with TestNG plugin is very similar. Generally, it is not practical to execute Niagara framework test other than simple unit tests directly with the Eclipse plugin. The reason is that the Niagara class loading behavior and NRE initialization is not compatible with the stand-alone TestNG container.

## Additional Test Execution Options

The Niagara test executable supports several options for tailoring the execution of tests to you needs. The usage and options are outlined below:

```
usage:
  test <target> [testNGOptions]
target:
  all
  <module>
  <module>:<type>
  <module>:<type>.<method>
testNGOptions:
  -btest                Run tests based on BTest (not BTestNg)
  -v:<n>                Set TestNG output verbosity level (1 - 10)
  -groups:<a,b,c>       Comma-separated list of TestNG group names to
test                    -excludegroups:<a,b,c> Comma-separated list of TestNG group names to
skip                   -output:<path>         Set the location for TestNG output
```

Unit tests developed with the Niagara Test framework from 3.7 and earlier are still supported with the **-btest** option. TestNg groups can be included or excluded from tests.

# Virtual Components

## Overview

Refer to the [Virtual API](#) (available only in Niagara 3.2 and beyond).

The virtual components feature was originally driven by a common use case of most drivers in Niagara AX. However, since the original brainstorming for "phantom" components (later termed "virtual" components), it has since grown to cover a broader range of possible applications. This document (intended for developers) will focus its examples on driver applications, but the idea of transient, on-demand components can obviously reach to many other applications.

As mentioned, the term virtual components refers to transient, on-demand components in a station database that only exist when needed. Virtual components are created dynamically only when they are first required by the station (ie. enter a subscribed state), and then when they are no longer needed (ie. enter an unsubscribed state), they are automatically cleaned up from the station database (subject to virtual cache life constraints). This lifecycle for virtual components provides for efficiency. The key concepts that drive virtual components are their virtual [Ords](#) (Object Resolution Descriptors) and their existence within a virtual component space. The Ords for virtual components follow the [SlotPath](#) design (refer to [VirtualPath](#)) and must uniquely define virtual components (and provide enough information to create the virtual component at runtime). These unique, on-demand virtual components live within a [Virtual Component Space](#), which is different from the normal component space which manages components that are persisted in the station. The link between the normal component space and the virtual component space is through the [Virtual Gateway](#). There is a one-to-one relationship between a virtual gateway and its corresponding virtual component space, so it is possible to have multiple virtual gateways and virtual component spaces in the same running station. These concepts will be described in more detail in the class descriptions that follow.

From a drivers perspective, virtual components means that driver data can be addressed without premapping. Prior to this new feature, the old Niagara AX model used by drivers boiled down to a collection of BComponents used to normalize driver data. For example, most drivers contain a device network, devices, and proxy points (control points with proxy extensions). Proxy points are useful for modeling the smallest pieces of driver data ("point" information) and normalizing them for use in the Niagara AX environment. This model works well for linking proxy points to control logic for monitor and control. The problem with this model is that every piece of driver data that a user may want to visualize/configure in Niagara AX requires the overhead of a persistent component (i.e. proxy point) existing somewhere in the station's component space. The overhead of having persistent, premapped components limits the capacity of points that a station can monitor. This limitation especially becomes a problem on small embedded platforms (such as a JACE) where memory is limited.

There are two common driver use cases we identified where a user might want to have access to driver data, while not wanting the extra overhead of using persistent components. The first is that a user wants to build a Px view to look at device point data (simply for monitoring purposes). In this case, simply a polled value is sufficient to present the data to the user in the view only when it is needed (the view is open). The second use case is for configuration/commissioning a device in which the user wants to see a snapshot (i.e. property sheet) of the values within the device, and allow the user to monitor/modify these device values for one time configuration purposes. In both of these cases, building persistent components to model the driver data is not necessary and simply costs the user extra overhead. Instead, a transient display of the driver data is useful only when the user enters the view, but at all other times, the values are not needed and do not need to be consuming memory (i.e. not needed for linking to any other logic). Thus virtual components is a solution to both of these use cases.

**In general, linking in the virtual component space is not supported, as virtual components are not persisted (thus any user created links would be lost).**

## The Virtual API

The [javax.baja.virtual](#) package contains the base classes for supporting virtuals. The following gives a brief description of each class in this package:

### [BVirtualComponent](#)

A BVirtualComponent is a [BComponent](#), however it extends the functionality to support living in a virtual component space by keeping track of its last active ticks. The last active ticks are the clock ticks when the virtual component was last needed (ie. the moment the virtual component switches from a subscribed state back to an unsubscribed state, the last active ticks are updated to indicate the ticks when the virtual component was last in use\*). The last active ticks for each virtual component in the virtual component space are consistently monitored by the space's VirtualCacheCallbacks instance, which uses this information to determine when the virtual component is subject to auto-removal (clearing from the cache). Virtual Components can also be spared from auto removal if the instance is the root component of the virtual component space, or if the auto-removal behavior is specifically disabled for the virtual component (by subclassing and overriding the performAutoRemoval() callback). By default, virtual components also override the normal BComponent behavior to

specify their virtual nav Ord, enforce a few parent/child restrictions\*\*, and provide a convenient way to retrieve the parent BVirtualGateway instance, which is important because the gateway is the link between the normal component space and the virtual component space.

The BVirtualComponent class is the key structure to use for modeling objects in your virtual space. You can use BVirtualComponent (or a subclass of it) to model your data (or data groupings), and since BVirtualComponent is itself a BComponent, it supports all of the normal component life-cycle features. Just remember BComponent instances (those that aren't BVirtualComponents or BVectors) should not be used in the virtual component space, so keep this in mind when determining what types of frozen/dynamic slots your BVirtualComponents need to model the data.

\* **NOTE** - The last active ticks for a virtual component are also modified by a "touch" feature of the navigation tree in Workbench. Basically, for any virtual component's nav tree node currently in view in Workbench, there is a periodic message sent that "touches" the virtual component, in order to keep it active and prevent it from being auto cleaned. This is useful because a virtual component simply viewed in the nav tree is not guaranteed to be in a subscribed state.

\*\* **NOTE** - The general rule that should be followed is that the virtual component space should not contain BComponent instances that are not BVirtualComponents. So there are a few child/parent checks in place that attempt to enforce this rule. Of course, BVirtualComponent instances living within a virtual component space can contain other non-BComponent children, such as BSimple, BStructs, and there is even an exception made for BVectors. The reason you should keep non-virtual BComponent children out of the virtual component space is because it can break the virtual cache cleanup mechanism (discussed below for the VirtualCacheCallbacks class).

## **BVirtualComponentSpace**

The BVirtualComponentSpace is an extension of [BComponentSpace](#) which contains a mapping of BVirtualComponents (organized as a tree). The virtual component space is created at runtime when a BVirtualGateway instance is started in the station's component space. There is a one-to-one relationship between the virtual gateway and its virtual component space. The virtual component space has a few supporting *Callbacks* classes. In addition to those provided by BComponentSpace (LoadCallbacks, SubscribeCallbacks, and TrapCallbacks), BVirtualComponentSpace kicks off an instance of VirtualCacheCallbacks (described below). It is important to remember that the scope of the virtual component space is limited to its tree of virtual components, but it also has a reference to its BVirtualGateway instance which provides the link to the normal component space.

## **BVirtualGateway**

BVirtualGateway is an abstract subclass of BComponent designed to reside in the station component space and act as a "gateway" to its corresponding virtual component space. As mentioned previously, there is a one-to-one relationship between the virtual gateway and its virtual component space. For the virtual gateway, this means that the nav children displayed under the gateway in the nav tree will be the nav children for the root component of the virtual space. Just to clarify the point, the virtual gateway functions as the link between the normal (station) component space and its virtual space. Thus it overrides all of the nav methods to route to the virtual space's tree (of virtual components). In practice, you should *always avoid* adding frozen/dynamic slots as children of the virtual gateway directly, as the nav overrides will route users to the virtual space by default, thus making it difficult and confusing to view/change slots that are direct children on the virtual gateway itself.

The other important function of the virtual gateway is to provide the hooks for subclasses to load/create virtual components at runtime. This includes a few callback methods that the framework makes to the virtual gateway to tell it to load an individual virtual slot or load all of the virtual slots for a given virtual component. Two important factors to consider when subclassing BVirtualGateway and its methods are:

- By contract, whenever slots are added to virtual components, they should always be assigned a slot name that is the *escaped* virtual path name (ie. use `SlotPath.escape(virtualPathName)`). This is very important as virtual path names can be unescaped, but the contract is that their corresponding slot path name is simply the escaped version of the virtual path name. In order for virtual lookup to work correctly, this rule must be followed.
- Due to the possibility of a partial loaded state supported by virtuals, when you subclass BVirtualGateway (and even BVirtualComponent) and implement its methods, you should always be keenly aware of the present subscription state of the virtual components. For example, the BVirtualGateway load methods could be called and cause a new slot to be created for a parent virtual component while that parent is already in a subscribed state. So this could affect how the new virtual slot should be handled (ie. it may need to be added to a poll scheduler for updates). Subclasses should always be aware of this potential state and perform the proper checks to handle this case.

## **BVirtualScheme**

BVirtualScheme extends BSlotScheme and defines the "virtual" ord scheme ID. It works in close conjunction with VirtualPath for resolving virtual Ords (see below for further details).

## VirtualCacheCallbacks

This class is instantiated by `BVirtualComponentSpace` with a purpose to manage the virtual cache (ie. to determine when its appropriate to auto cleanup virtuals that are no longer in use). The default implementation of `VirtualCacheCallbacks` has a shared thread pool (used by multiple virtual component space instances) designed to monitor the virtual components in each registered virtual space, and check the min/max virtual cache life for any unused virtual components. The idea is that virtual components, when no longer needed, will remain in the cache for a certain cache life before they get automatically removed. The following static variables allow for tuning the performance of the virtual cache management (**all default values can be tweaked by making the appropriate settings in the system.properties file**):

`public static final BRelTime MAX_CACHE_LIFE` - Specifies the default virtual cache life maximum (default 45 seconds). When a virtual component expires, it will remain in memory for a maximum of this amount of time before it will be automatically cleaned up from the cache (assuming the virtual component is not re-activated in the meantime).

`public static final BRelTime MIN_CACHE_LIFE` - Specifies the default virtual cache life minimum (default 25 seconds). When a virtual component expires, it will remain in memory for a minimum of this amount of time before it will be subject to automatic clean up from the cache (assuming the virtual component is not re-activated in the meantime). This minimum cache life is only a factor when the virtual threshold limit has been exceeded (meaning that virtuals need to be cleaned up faster than normal). If the virtual threshold limit has not been exceeded, the maximum virtual cache life will be used (normal operation).

`public static final int VIRTUAL_THRESHOLD` - Specifies a global virtual threshold limit (default 1000), above which virtuals will start being auto cleaned from the cache quicker as space is needed (ie. the `MIN_CACHE_LIFE` will be used in the cache life determination when the number of virtuals in the station exceeds this threshold limit, otherwise the `MAX_CACHE_LIFE` will be used when the number of virtuals doesn't exceed this limit).

`public static final long VIRTUAL_THRESHOLD_SCAN_RATE` - Specifies the default time (in milliseconds) in which to perform a full scan of the station for virtuals, used for threshold level checking. The default is 1000, which means that every second, a full scan will occur. A value of zero disables the virtual threshold checking feature entirely.

`public static final int THREAD_POOL_SIZE` - Specifies the maximum number of worker threads in the thread pool shared by `VirtualCacheCallbacks` instances. There is a `VirtualCacheCallbacks` instance per virtual component space, however, the default implementation shares a common worker thread pool. Therefore, this setting determines the maximum number of virtual cleanup worker threads (10 default).

`public static final int SPACES_PER_THREAD` - Specifies the ideal number of virtual component spaces managed per worker thread in thread pool (this limit can be exceeded if all threads in the pool are already at capacity). The default is 5 virtual spaces (optimum) per thread.

## VirtualPath

`VirtualPath` extends `SlotPath` and allows for resolving `BVirtualComponents` (and their child slots) using unescaped slot names in the path (note that this is different from `SlotPath` which enforces the rule that only escaped slot names can be contained in the path). The '/', '|', '\$', and ':' characters are reserved and not allowed in a virtual path entry. Also, the "../" is reserved for backups.

The most common use case of `VirtualPath` follows the following format:

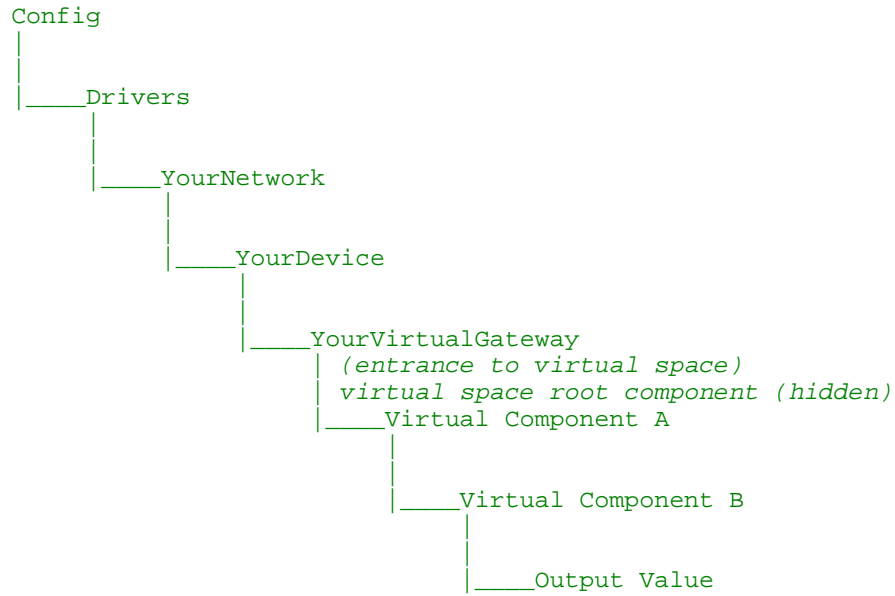
**host:|session:|space:|Ord to virtual gateway:|virtual:virtual path**

For example (disregard the line wrap):

```
local:|fox:|station:|slot:/Config/Drivers/YourNetwork/YourDevice/YourVirtualGateway
|virtual:/Virtual Component A/Virtual Component B/Output Value
```

This example shows how the virtual gateway is always the link point between the normal component space and the virtual space. The "|virtual:" in the example above indicates the jump to the virtual component space. When resolving such an Ord, once it starts parsing the virtual path, it will start from the left and work to the right (the "/" acts as the separator between virtual slots). So this means it will first check for the existence of a slot named "Virtual\$20Component\$20A" under the root component of the virtual space and return it if it exists (remember that by contract, virtual path names should be escaped to form the slot name). If it doesn't already exist, the virtual gateway will be given the opportunity to create a virtual object to represent it given the virtual path name and parent (subclasses will normally put enough information in the virtual path to know how to create the object). This process continues from left to right until the virtual path has resolved the last in the list.

The example above would be represented in the nav tree like this:



It is also worth noting that due to the virtual/slot path name contract, the following Ord is *functionally equivalent* to the example above (disregard the line wrap):

```

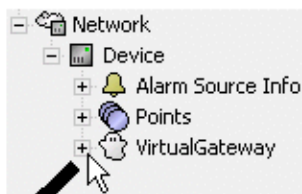
local:|fox:|station:|slot:/Config/Drivers/YourNetwork/YourDevice/YourVirtualGateway
|virtual:|slot:/Virtual$20Component$20A/Virtual$20Component$20B/Output$20Value

```

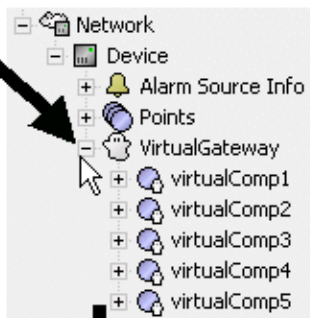
## Virtual Component Lifecycle

The following diagram attempts to show the common lifecycle of a virtual component.

User expands BVirtualGateway in the Nav tree...



If not fully loaded already, calls BVirtualGateway.loadVirtualSlots() to discover BVirtualComponent children



If BVirtualComponent opened in a view (ie. subscribed)



unsubscribe()

If BVirtualComponent only visible in Nav tree



**VirtualCacheCallbacks**  
monitors all BVirtual Components checking for expiration (inactive for cache life)

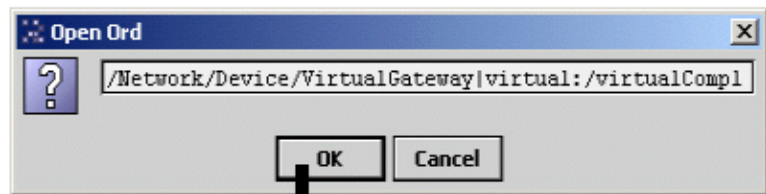
BVirtualComponents visible in the Nav tree receive touch() to stay active

BVirtualComponent expires



OR

A Virtual Ord is opened (ie. due to a Virtual Ord binding in an opened Px view), leading to the Virtual Ord resolution...



Calls BVirtualGateway.loadVirtualSlot()

BVirtualComponent doesn't exist

Calls BVirtualGateway.addVirtualSlot() to create the BVirtualComponent

BVirtualComponent already exists

## Building JavaScript Applications for Niagara

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### Introduction

In Niagara 4, the user interface is moving in a new direction with a heavy focus on HTML5 applications and open web technologies. Tridium provides a number of frameworks and utilities, intended to give developers the power to create their own web apps, from tiny field editors to powerful, full-featured full-screen views.

Developing in HTML5 and JavaScript is a different process from the familiar Java-based process for developing in the Niagara Framework. However, using the tools and techniques described in this document, you can create a JavaScript codebase that is robust, error-checked, and well-tested.

### Frameworks and Libraries

Before beginning HTML5 development in the Niagara Framework, you'll want to take a few moments to familiarize yourself with a few of the different libraries and frameworks available to you. These frameworks include [BajaScript](#), [bajaux](#), and other [open web technologies](#).



## Setting Up Your Environment

In order to most effectively develop Niagara web applications, you'll need to install a few external utilities for building, code analysis, and testing.

The toolchain described in this document is the one used by Tridium to develop all of its HTML5 web applications for Niagara 4. The tools described are free and open-source. The toolchain is separate from the Niagara Framework itself, so if you find that it does not suit your purposes, you are free to use a different set of development tools, or create your own.

To use the standard Tridium toolchain, you'll need to install the following utilities:

### Node.js

[Node.js](#) allows you to run JavaScript applications from the command line, without using a web browser. Tridium's open-source tools for developing Niagara web applications are all based upon Node.js.

### npm

npm is a utility used to download and install Node.js modules. It is automatically installed alongside Node.js.

### Grunt

[Grunt](#) is a task runner for JavaScript. You will use it to find errors, run tests, and analyze your code. Install it like this:

```
npm install -g grunt-cli
```

After that, you'll be able to run Grunt tasks for a web module by cd-ing into its directory and typing `grunt`.

### Git

[Git](#) is used to clone entire repositories of source code to your machine. This is mostly used internally by npm, but you might also need to clone some repositories manually.

## Build and Development Tools

### Open Source Niagara Development Utilities

In order to properly build and test JavaScript modules, there is some setup involved. npm libraries need to be downloaded and installed, configuration files need to be written, and code needs to be moved into the proper directories.

We have created a number of utilities to make this process as easy as possible. These are open-source Node.js modules, created and released by [Tridium](#). They will facilitate a fully automated, test-driven approach to creating functional, reliable, well-tested Niagara web modules.

#### grunt-init-niagara

`grunt-init` is a tool that streamlines the creation of a new JavaScript project. The process is similar to Wizards you might use in Workbench: it asks you a number of setup questions and generates a brand-new web module for you to



begin development.

`grunt-init-niagara` is Tridium's own `grunt-init` template which is Niagara-specific; it generates you a brand-new Niagara web module that can be built and run using standard Niagara tools. The module will be pre-configured with source code and test directories, configuration files, and everything necessary to start developing.

All of the modules described in the rest of this section will be automatically included in your new module with no further configuration necessary. Simply type `npm install` to download everything, then begin development.

While it's entirely possible to create a new web module without using `grunt-init-niagara`, we highly recommend that you use it for your first web module to learn about the recommended project structure and configuration.

### **grunt-niagara**

This is less of a development tool and more of a collection of smart defaults. Including `grunt-niagara` in your project will include [JSHint](#), [Karma](#), [Plato](#), and other development utilities, with configuration files pre-configured with settings Tridium has found to be optimal when developing web modules. The settings can be added to or changed in your own configuration files.

When creating a new module using `grunt-init-niagara`, you'll automatically have `grunt-niagara` installed and configured.

### **niagara-station**

This is a library that allows you to start and stop Niagara 4 stations using Node.js. It is most commonly used during the test process to start a station with BajaScript installed, so that the web module's unit tests can use a live BajaScript session to verify real-world behavior.

It also has some basic port configuration abilities. For example, if you are running tests on a machine that has port 80 already in use, `niagara-station` can reconfigure the station to run HTTP on port 8080 instead.

When using `grunt-init-niagara`, your web module will automatically receive a test station and a default `niagara-station` configuration.

### **niagara-test-server**

This module simply includes some utilities for logging into a running test station using JavaScript and triggering the browser to run tests. Again, it's automatically included by `grunt-init-niagara`.

## **JSHint**

Since JavaScript is an interpreted, not compiled, language, there is no compilation step to catch syntax errors before the code is run in the browser. This makes a static analysis tool like [JSHint](#) a necessity. It will find syntax errors (and some semantic errors as well) in your JavaScript code before it is run.

JSHint runs as a Grunt task as part of the standard development process.

## **Jasmine**

[Jasmine](#) is Tridium's unit testing framework of choice. All of our JavaScript libraries, like BajaScript and `bajaux`, are fully unit tested using Jasmine.

The Jasmine framework will be automatically configured when using `grunt-niagara`. It is possible to use other testing frameworks, but you will need to configure these manually.

## Karma

[Karma](#) actually runs your tests and generates the results. By default, it will start up an instance of [PhantomJS](#) - a headless browser - and run your full test suite. You can also connect any other browser to it, such as Chrome, Firefox, IE, or an iPhone, and run your tests in all of those browsers as well.

## Building and Compacting your JavaScript

When building your web module, the build process can use the [r.js optimizer](#) to compact all of your JavaScript code into a single file. Since network calls are the biggest factor affecting the loading time of your application, this is a crucial step in ensuring your app loads as quickly as possible.

This plugin also generates documentation for your app using JSDoc.

For more information, see the [Deploying Help](#) section.

## Developing in real time with moduledev mode

When developing a web module, it's a severe slowdown to have to rebuild your module and restart your station every time you want to test out a new change in your browser. It's much faster to simply change a file and refresh the browser to pick up the latest changes.

To facilitate this, Niagara 4 includes a moduledev mode that allows files from certain modules to be read directly from your hard drive instead of from a module JAR file. In order to enable this mode, you'll need to perform the following steps.

First, you'll need to ensure this feature is enabled in your Tridium license. You'll need the `developer` feature included in your license with the `moduleDev` property set to `true`. If your license does not include this feature, please contact your Tridium sales representative.

Next, add an entry to `system.properties`: `niagara.module.dev=true`. This is for the browser only; for Workbench, there is another setting: `niagara.module.dev.wb=true`.

Not every file type can be resolved in this way: by default, only JS, CSS, HTML, image files, and some other web-related file types are supported. If you wish to resolve some different file types, you can configure this list using this system property: `niagara.module.dev.supportedExtensions=js,css,vm,htm(...)`

Next, create a file `niagara_home/etc/moduledev.properties`. Each entry in this file maps a module name to the directory on your hard drive in which that module's source code lives. For instance, `myModule=d:/niagara/dev/myModule`.

Now, whenever a request is made for a file, with a supported extension, from your web module, it will be resolved from your hard drive instead of from the JAR. This way, hitting refresh in the browser will always load your up-to-date changes. Note that this mode should *never* be enabled in production - only in development.

## First Steps

Now that you've set up your environment and gotten a brief introduction to the various JavaScript libraries and frameworks available to you, it's time to start developing! This section will contain a full tutorial, from creating your first module using `grunt-init-niagara`, to writing your first test, to viewing the result in the browser.

## Creating a new module

Begin by installing [grunt-init-niagara](#) to your machine, following the instructions from [the Grunt website](#). Once installed, navigate in a console to your dev directory containing the source for your Niagara modules. Begin the process like so:

```
mkdir myWebModule
cd myWebModule/
grunt-init grunt-init-niagara
```

You'll be asked a series of questions. Leaving the answer to any question blank will accept the default (shown in parentheses). For this tutorial, we'll ask it to create a `bajaux Widget` for us to study and modify.

```
Please answer the following:
[?] Niagara module name (myWebModule)
[?] Shortened preferred symbol for your Niagara module (myWbMdl)
[?] Description of your Niagara module My First Web Module
[?] Author name (tridium)
[?] Would you like to create a bajaux Widget? (y/N) y
```

After completing all the questions (you can select default values for all additional questions not shown above), it will generate a `myWebModule-ux` directory, containing the generated sources for your web module. It should build and install using the normal build process: `gradlew :myWebModule-ux:jar`.

(To facilitate rapid development, ensure that you have enabled [moduledev mode](#) and added an entry for `myWebModule` to `moduledev.properties` at this time.)

Just to make sure everything is functional, let's install and run tests for our module.

```
cd myWebModule-ux/
npm install
grunt ci
```

Don't worry, I'll describe what's happening in just a moment. These commands should download and install all the necessary dependencies to run tests for your module, then it should actually run those tests. Hopefully, you'll see `SUCCESS` at the end of this process. Now let's take a look at a few of the individual steps in this process, and the relevant configuration files.

### package.json

This file is used by Node.js and npm. Most of it won't be relevant to you unless you decide to publish your module to the [npm repository](#). The important part is the `devDependencies` section, which describes which additional modules your module depends on. It will be pre-populated with those modules that are necessary to run unit tests for your Niagara web module.

Typing `npm install` will download these dependencies from npm and install them for you.

### Gruntfile.js

This file is used by Grunt. It describes all the automated tasks that are available for your module, and sets up configuration settings for each.

You will see at the bottom of the file that it loads tasks for the `grunt-niagara` module. This is a utility module that includes tasks that we at Tridium have found to be very useful when developing web applications. It sets up a default configuration for each one that we find to work well. You are free to override these configurations as you wish, but just leaving this file alone and working with the provided config is a great way to get started. (Later on, if you decide that `grunt-niagara` isn't right for you, you can leave it out completely and build your own toolchain as you see fit.)

To see the tasks that are available to you right out of the box, type `grunt usage`.

Another feature that `grunt-niagara` provides for you is the ability to pass in config flags on the command line when running tests. To see a list of all available flags, type `grunt flags`. A few flags you may find particularly useful are:

- `--testOnly`: if your test suite grows large, you may find it taking longer and longer to run all of your specs. You can use `testOnly` to limit which specs are run.
- `--station-http-port`: if your test station runs a different HTTP port, you can specify which port your tests should use to attempt to log into the station. Also works for HTTPS, FOX, and FOXS.
- `--override-station-ports`: used in conjunction with the previous flags, actually will inject the port number into the `config.bog` before starting the station to force it to run on a particular port.
- `--station-log-level`: configure how much detail from the station log is output to the console when running tests.

Many of these flags' default values are set using the `NIAGARA_HOME` and `NIAGARA_USER_HOME` environment variables.

## Watching - The Important Stuff

Let's start developing straight away by typing `grunt watch`. Your test station will be copied into your `stations/` directory and started up (note that the default credentials for the test station are user: admin, password: asdf1234), and an instance of Karma will be started as well. By default, a single instance of [PhantomJS](#) - a command-line, headless web browser - will start and get ready to run tests. (If you wish to run tests in other browsers, like Firefox or IE, it will print out instructions on how to connect those as well.)

What happens now is that every time you save a change to a file, the `grunt watch` task will immediately spring into action, running JSHint to detect syntax errors and other bugs, and then running your suite of tests in Karma to verify behavior. This allows for a very rapid TDD, red-green-refactor workflow.

Let's demonstrate the process. `grunt-init-niagara` should have generated you a file called `MyWebModuleWidget.js`. Out of the box, the code should pass all linting and tests, so we'll have to introduce some new errors to see how they are handled. Take a look at the `doLoad` function and you should see a line that looks like this:

```
that.$buildButtons(value);
```

Change it so that it looks like this:

```
that.$buildButtons(valve)
```

Now save the file. Grunt should detect your change and immediately go to work. The first step in the watch process is to run [JSHint](#) on your code. Our change introduced two errors in our code, and JSHint should have caught them both:

```
>> File "src\rc\MyWebModuleWidget.js" changed.
Running "jshint:src" (jshint) task

src\rc\MyWebModuleWidget.js
118 |     that.$buildButtons(valve)
    |                                ^ Missing semicolon.
118 |     that.$buildButtons(valve)
    |                                ^ 'valve' is not defined.
```

As you can see, whenever you introduce an error that JSHint can detect, you will immediately be alerted. Note that JSHint is a static code analysis tool; your code has not actually run at this point. JSHint looks for syntax errors, misspellings, code style problems, and similar categories of errors. It will not find logical errors in the execution of your code. That happens in the next step.

Back out the change we just made so that it looks like it did before:

```
that.$buildButtons(value);
```

Now, we'll demonstrate the unit testing capabilities of Karma. We're going to follow the traditional TDD method of red-green-refactor:

1. Write a new unit test and run it. It will fail, because you haven't yet written the code to make it pass. Unit tests should be small and focused. This is called the "red" phase because test failures usually are shown in red.
2. Write the bare minimum amount of code to implement the behavior that the test is verifying, then run it again. It should pass. This is called the "green" phase because test successes usually are shown in green. You should never

write production code without first having already written a failing test for it.

3. Once you have good test coverage by following steps 1 and 2 many times, you can refactor your code for greater readability and efficiency, without worrying about breaking old behavior. Just make sure that your refactoring doesn't introduce new behavior without accounting for it in the unit tests.

Take a look at the example page at <http://localhost/module/myWebModule/rc/myWebModule.htm> that `grunt-init-niagara` generated for us (remember that the default credentials for the test station are user: admin, password: asdf1234). You'll see that it creates a clickable button for every slot on a Component, and whenever we click one of the buttons, it updates to show the name of the slot we selected. For this next example, we want to change the widget's behavior slightly. Instead of just displaying the slot name, we'll add an exclamation mark just to properly convey our excitement.

The first step is to change the test. (If we were adding new behavior to the widget we'd add another test, but since we're changing existing behavior, we can just change the test.) Take a look at `srcTest/rc/MyWebModuleWidgetSpec.js`. This suite of unit tests is written using the [Jasmine](#) framework, which is Tridium's test framework of choice and the one automatically configured by `grunt-niagara`.

Look at the spec named `arms a handler to display selected slot name`. Since we're changing the way the slot name is displayed, this is also the spec that we will change. Towards the bottom of the spec, you will see the verification test that looks something like this:

```
runs(function () {
  expect(slotDom.text()).toBe('curlyJoe');
});
```

Change it so that it's expecting an exclamation point:

```
runs(function () {
  expect(slotDom.text()).toBe('curlyJoe!');
});
```

Save the file. Since `grunt watch` is running, the change will be immediately detected and your test suite will be run. You should see the spec fail:

```
nmodule/myWebModule/rc/MyWebModuleWidget #doInitialize() arms a handler to
display selected slot name FAILED
Expected 'curlyJoe' to be 'curlyJoe!'.
Executed 8 of 8 (1 FAILED) (0.562 secs / 0.567 secs)
```

This is the “red” phase of development: we have a failing unit test. By first having a failing test, we get visual proof that the behavior we're writing has correct test coverage behind it. To get back to green, we go into `src/rc/MyWebModuleWidget.js` and update the `$updateSlotText` function to add the exclamation point we need:

```
that.jq().find('.MyWebModuleWidget-selected-slot').text(slotName + '!');
```

Save the file and the test will automatically be run. This time, everything should pass.

Using these frameworks and techniques, you have the ability to implement a fully test-driven development process from beginning to end. It may seem like a large upfront time investment (isn't it twice as much code for the same functionality?) but a comprehensive suite of automated tests for your code is invaluable: short-term, it helps to ensure that the code you write actually does what you think it does; and long-term, it allows you to make changes, improvements, and refactorings to your code without worrying about breaking existing functionality.

## A note on Continuous Integration

Unit tests, as configured by `grunt-niagara`, will export their results in a JUnit-compatible XML format. This means that if your organization uses a Continuous Integration solution, like Bamboo or Jenkins, it can consume these XML files. Your JavaScript code can then be included in your CI process.

When invoking the Grunt process, use `grunt ci` to run CI-related tasks and generate these XML files. If needed, you can use the `--junit-reports-dir` flag to specify where the XML results go.

## Building your JavaScript into a Niagara module

Implementing your JavaScript-based widgets is only one part of the development process. They must also be built into your Niagara module so that they can be deployed to Niagara stations and supervisors.

### Compacting using the Gradle RequireJS Plugin

Build your module:

```
gradlew :myWebModule-ux:jar
```

As part of the build process, you'll notice that one of the build steps is to optimize your JavaScript using the Niagara RequireJS Gradle plugin. Let's take a closer look at how this works.

Examine `myWebModule.gradle` and take a look at the `niagaraRjs` section:

```
builds = [
    'myWebModule': [
        rootDir: 'src/rc',
        include: [
            'nmodule/myWebModule/rc/myWebModule',
            'nmodule/myWebModule/rc/MyWebModuleWidget'
        ]
    ]
]
```

This tells the Gradle build process to optimize your JavaScript using [r.js](#). The JavaScript modules specified in the `include` section will have all of their dependencies resolved and included in a single file: `myWebModule.built.min.js`. This allows you to download every JavaScript file in your Niagara module using a single network call. This is crucial on embedded devices where negotiating network connections can be slow.

### Implementing BIJavaScript

Often, your HTML5 web app will have an instance of some BajaScript value: a `Facets`, for instance, or a `DynamicEnum`, that you wish to present to the user in an editor. You could manually go and fetch the code for `FacetsEditor` or `DynamicEnumEditor`, then instantiate, initialize, and load it into your page. It would be much easier, though, to simply ask the framework for an editor that's appropriate to edit that value. Then, you'll be certain that you'll be provided the correct, most up-to-date version of that editor.

Also, consider the Property Sheet. If you have a custom Baja value and a custom field editor to edit that value, you'll need to create an association between the two so the Property Sheet knows how to show the correct editor for your custom value.

The way to do this is to create a simple Java class in your module. Its only job is to provide answers to these questions:

1. What JavaScript file represents the implementation of my editor?
2. What Types can I edit with this editor?

#### What JavaScript file defines my editor?

To let the Niagara framework know about the JavaScript file containing your editor, create a Java class that extends `BSingleton` and implements `javax.baja.web.js.BIJavaScript`. This simply creates a mapping between a Niagara Type and a JavaScript file.

```
public final class BMyWebModuleWidget
```

```

    extends BSingleton
    implements BIJavaScript, BFormFactorMini
{
    //private constructor, TYPE and INSTANCE as per BSingleton

    public JsInfo getJsInfo(Context cx) { return jsInfo; }

    private static final JsInfo jsInfo =
        JsInfo.make(
            BOrd.make( "module://myWebModule/rc/MyWebModuleWidget.js" ),
            BMyWebModuleJsBuild.TYPE
        );
}

```

As you can see, there is very little to a BIJavaScript class. It has only one method to implement, `getJsInfo()`, which lets the Niagara Framework know where the JavaScript implementation of your widget is located.

(Also notice the implemented interface `BFormFactorMini` - see the [bajaux](#) documentation for details on what this does.)

You can also see as part of the `JsInfo.make()` method, you can pass in an instance of `BJsBuild`. This performs a very similar function to `BIJavaScript`, but instead of providing the location of a single JavaScript module, it provides the location of an optimized JavaScript built file: e.g., `myWebModule.built.min.js` produced by the Gradle RequireJS plugin as described above.

The implementation of a `BJsBuild` class is also very simple:

```

public class BMyWebModuleJsBuild extends BJsBuild
{
    public static final BMyWebModuleJsBuild INSTANCE = new BMyWebModuleJsBuild(
        "myWebModule", //webdev ID
        new BOrd[] {
            BOrd.make( "module://myWebModule/rc/myWebModule.built.min.js" )
        }
    );

    //TYPE and private constructor
}

```

While optimizing your JavaScript and creating `BJsBuild` classes are strictly optional, they are highly recommended.

Don't forget that your `BIJavaScript` and `BJsBuild` classes are standard Niagara Types and should be included in `module-include.xml`.

### What Types can I edit with my editor?

Now that you've implemented a JavaScript editor and registered its existence with the framework, you can also declare it to be compatible with certain Types. For instance, `MyWebModuleWidget` might be able to load values of type `myWebModule:MyWebModuleComponent`. To declare this relationship, simply register your `BIJavaScript` as an agent on a Type. You can do this the usual way, in `module-include.xml`:

```

<type name="MyWebModuleWidget"
class="com.tridium.mywebmodule.BMyWebModuleWidget">
    <agent><on type="myWebModule:MyWebModuleComponent" /></agent>
</type>

```

Or the new annotation-based method available in Niagara 4:

```

@NiagaraType( agent=@AgentOn( types={ "myWebModule:MyWebModuleComponent" } ) )
public final class BMyWebModuleWidget

```



## Switching your Station into Web Development mode

One last thing to consider. At this point you have two files containing your editor's code: the one you've just created, with the human-readable JavaScript code (`MyWebModuleWidget.js`), and the built and minified version for conserving network traffic (`myWebModule.built.min.js`).

During normal usage, your station will only serve up the minified file. This is absolutely the correct behavior: on an embedded device, conservation of network traffic is key. But take a look at the minified file: it's completely incomprehensible. When developing and debugging, you really want to be able to see the original, human-readable code.

By enabling `webdev` mode for your module, the station will kick into debug mode: it will switch over to serving up the original file, so that you can open up the console in Chrome or Internet Explorer and trace through your actual code.

To enable `webdev` mode, simply go into the spy page for the station and visit the `webDevSetup` page. (You'll need to actually visit the web interface first - so the station serves up some files - for it to appear.) Enable `webdev` mode for the ID of your `BJSBuild`, and from then on, the unminified files from your module will be served to the browser. This is invaluable when debugging your code live in the browser. (To learn more about browser debugging, search the web for "{your browser name} console tutorial.")

## Moving Forward

Let's do a quick recap of what you've accomplished so far.

1. You've created a widget with JavaScript that can be used in the new Niagara 4 HTML5 web views (`MyWebModuleWidget.js`)
2. You've registered its existence with the framework (`BMyWebModuleWidget` implements `BIJavaScript`)
3. You've optimized it down within a single built JavaScript file to minimize network traffic (`niagaraRjs` configuration creates `myWebModule.built.min.js`)
4. You've registered the existence of the built file with the framework (`BMyWebModuleJsBuild` extends `BJSBuild`)
5. You've let the framework know to show you a `MyWebModuleWidget` when it tries to load an editor for a compatible Type (`BMyWebModuleWidget` is an Agent on `BMyWebModuleComponent`).

At this point, you have everything you need to go full-speed into developing HTML5 widgets and editors. Continue using the linting and testing tools provided by `grunt-init-niagara` to iterate over your widget until it is well tested, error-checked, and fully functional. (If you are developing a field editor intended for use in the HTML5 Property Sheet, definitely check out the [webEditors tutorial](#) for notes on this use case.)

Feel free to stop by the Niagara Central Forums to discuss any questions or problems.

Happy coding!



# Gx Graphics Toolkit

## Overview

The [gx](#) module defines the graphics primitives used for rendering to a display device. For example there implements for "painting" to computer screens and another for "painting" a PDF file. Many of the simple types used in the rest of the stack are defined in gx including [BColor](#), [BFont](#), [BPen](#), [BBrush](#), [BGeom](#), and [BTransform](#).

The gx APIs use a vector coordinate system based on x and y represented as doubles. The origin 0,0 is the top left hand corner with x incrementing to the right and y incrementing down. This coordinate system is called the logical coordinate space (sometimes called the user space). How the logical coordinate space maps to the device coordinate space is environment specific. Usually a logical coordinate maps directly into pixels, although transforms may alter this mapping.

## Color

[BColor](#) stores an RGBA color. It's string syntax supports a wide range of formats including most specified by CSS3:

- **SVG Keywords:** the full list of X11/SVG keywords is available by name and also defined as constants on BColor. Examples: red, springgreen, navajowhite.
- **RGB Function:** the rgb() function may be used with the red, green, and blue components specified as an integer between 0-255 or as a percent 0%-100%. Examples: rgb(0,255,0), rgb(0%,100%,0%).
- **RGBA Function:** the rgba() function works just like rgb(), but adds a fourth alpha component expressed as a float between 0.0 and 1.0. Example: rgba(0,100,255,0.5).
- **Hash:** the following hash formats are supported #rgb, #rrggbb, and #aarrggbb. The first two follow CSS rules, and the last defines the alpha component using the highest 8 bits. Examples: #0b7, #00bb77, #ff00bb77 (all are equivalent).

## Font

[BFont](#) is composed of three components:

- **Name:** a font family name stored as a String.
- **Size:** a point size stored as a double.
- **Style:** a set of attributes including bold, italics, and underline.

The format of fonts is "[italic || bold || underline] {size}pt {name}". Examples: "12pt Times New Roman", "bold 11pt sans-serif", "italic underline 10pt Arial". The BFont class also provides access to a font's metrics such as baseline, height, ascent, descent, and for calculating character widths.

## Brush

The [BBrush](#) class encapsulates how a shape is filled. The gx brush model is based on the SVG paint model. There are four types of brushes:

- **Solid Color:** the string format is just a standard color string such as "red"
- **Inverse:** uses an XOR painting mode
- **Gradients:** linear and radial gradients
- **Image:** based on a bitmap image file which may tiled or untiled

## Pen

The [BPen](#) class models how a geometric shape is outlined. A pen is composed of:

- **Width:** as double in logical coordinates
- **Cap:** how a pen is terminated on open subpaths - capButt, capRound, capSquare.

**Join:** how corners are drawn - `joinMiter`, `joinRound`, `joinBevel`

- **Dash:** a pattern of doubles for on/off lengths

## Coordinates

The following set of classes is designed to work with the gx coordinate system. Each concept is modeled by three classes: an interface, a mutable class, and an immutable BSimple version that manages the string encoding.

### Point

The [IPoint](#), [Point](#), and [BPoint](#) classes store an x and y location using two doubles. The string format is "x, y". Example "40,20", "0.4,17.33".

### Size

The [ISize](#), [Size](#), and [BSize](#) classes store a width and height using two doubles. The string format is "width,height". Examples include "100,20", "10.5, 0.5".

### Insets

The [IInsets](#), [Insets](#), and [BInsets](#) classes store side distances using four doubles (top, right, bottom, and left). The string format for insets follows CSS margin style: "top,right,bottom,left". If only one value is provided it applies to all four sides. If two values are provided the first is top/bottom and the second right/left. If three values are provided the first is top, second is right/left, and third is bottom. Four values apply to top, right, bottom, left respectively. Examples "4" expands to "4,4,4,4"; "2,3" expands to "2,3,2,3"; "1,2,3" expands to "1,2,3,2".

## Geom

The geometry classes are used to model rendering primitives. They all following the pattern used with Point, Size, and Insets with an interface, mutable class, and immutable BSimple. Geometries can be used to stroke outlines, fill shapes, or set clip bounds.

### Geom

The [IGeom](#), [Geom](#), and [BGeom](#) classes are all abstract base classes for the geometry APIs.

### LineGeom

The [ILineGeom](#), [LineGeom](#), and [BLineGeom](#) classes model a line between two points in the logical coordinate system. The string format of line is "x1,y1,x2,y2".

### RectGeom

The [IRectGeom](#), [RectGeom](#), and [BRectGeom](#) classes model a rectangle in the logical coordinate system. The string format of rectangle is "x,y,width,height".

### EllipseGeom

The [IEllipseGeom](#), [EllipseGeom](#), and [BEllipseGeom](#) classes model an ellipse bounded by a rectangle in the logical coordinate space. The string format is "x,y,width,height".

### PolygonGeom

The [IPolygonGeom](#), [PolygonGeom](#), and [BPolygonGeom](#) classes model a closed area defined by a series of line segments. The string format of polygon is "x1,y1 x2,y2,...".

### PathGeom

The [IPathGeom](#), [PathGeom](#), and [BPathGeom](#) classes define a general path to draw or fill. The model and string format of

a path is based on the SVG path element. The format is a list of operations. Each operation is denoted by a single letter. A capital letter implies absolute coordinates and a lowercase letter implies relative coordinates. Multiple operations of the same type may omit the letter after the first declaration.

- **Moveto:** move to the specified point. "M x,y" or "m x,y".
- **Lineto:** draw a line to the specified point: "L x,y" or "l x,y".
- **Horizontal Lineto:** draw a horizontal line at current y coordinate: "H x" or "h x".
- **Vertical Lineto:** draw a vertical line at the current x coordinate: "V y" or "v y".
- **Close:** draw a straight line to close the current path: "Z" or "z".
- **Curveto:** draws a Bezier curve from current point to x,y using x1,y1 as control point of beginning of curve and x2,y2 as control point of end of curve: "C x1,y1 x2,y2 x,y" or "c x1,y1 x2,y2 x,y".
- **Smooth Curveto:** draws a Bezier curve from current point to x,y. The first control point is assumed to be the reflection of the second control point on the previous command relative to the current point. "S x2,y2 x,y" or "s x2,y2 x,y".
- **Quadratic Curveto:** draws a quadratic Bezier curve from current point to x,y using x1,y1 as control point: "Q x1,y1 x,y" or "q x1,y1 x,y".
- **Smooth Quadratic Curveto:** draws a quadratic Bezier curve from current point to x,y with control point a reflection of previous control point: "T x,y" or "t x,y".
- **Arc:** draws an elliptical arc from the current point to x,y: "A rx,ry x-axis-rotation large-arc-flag sweep-flag x y" or "a rx,ry x-axis-rotation large-arc-flag sweep-flag x y".

Refer to the W3 SVG spec (<http://www.w3.org/TR/SVG/>) for the formal specification and examples.

## Transform

Transforms allow a new logical coordinate system to be derived from an existing coordinate system. The `gx` transform model is based on SVG and uses the exact string formatting. [BTransform](#) stores a list of transform operations:

- **Translate:** moves the origin by a tx and ty distance.
- **Scale:** scales the coordinates system by an sx and sy size.
- **Skew:** skew may be defined along the x or y axis.
- **Rotate:** rotate the coordinate system around the origin using a degree angle.

## Image

The [BImage](#) class is used to manage bitmap images. Image's are typically loaded from a list of ords which identify a list of files (GIF, PNG, and JPEG supported). When more than file is specified, the image is composited using alpha transparency from bottom to top (useful for "badging" icons). Images may also be created in memory and "painted" using the `Graphics` API.

The framework will often load images asynchronously in a background thread to maintain performance. Developers using `BImages` directly can poll to see if the image is loaded via the `isLoading()` method. Use the `sync()` method to block until the image is fully loaded. Animated GIFs require that the developer call `animate()` at a frame rate of 10frames/second. Typically developers should display images using `BLabel` which automatically handles async loading and animation.

The framework caches images based on their size and how recently they are used. You may use the [Image Manager](#) spy page to review the current cache.

## Graphics

Painting to a device is encapsulated by the [Graphics](#) class. The primitive paint operations are:

- **fill(IGeom):** filling a geometry involves painting a geometry's interior area with the current brush. Remember a brush can be a solid color, a gradient, or texture.
- **stroke(IGeom):** stroking a geometry is to draw its outline or line segments. Stroking uses the current pen to derive the "stroke geometry" based on the pen's width and style. Then the interior of the stroke is filled using the current brush.

**drawString()**: this draws a set of characters to the device. The shape of the characters is derived from the current font. The interior of the font is filled with the current brush. Note: we don't currently support stroking fonts like SVG.

- **drawImage()**: this draws an bitmap image to the device; the image may be scaled depending on the parameters and/or current transform.

All paint operations perform compositing and clipping. Compositing means that colors are combined as painting occurs bottom to top. For example drawing a GIF or PNG file with transparent pixels allows the pixels drawn underneath to show through. Alpha transparency performs color blending with the pixels underneath. Clipping is the processing of constraining paint operations to a specified geometry. Any pixels from a paint operation which would be drawn outside the clip geometry are ignored. Use the `clip()` method to clip to a specific region.

Often it is necessary to save the current state of the graphics to perform a temporary paint operation, and then to restore the graphics. An example is to set a clip region, paint something, then restore the original clip. The `push()` and `pop()` are used to accomplish this functionality by maintaining a stack of graphics state. You should always call `pop()` in a `try finally` block to ensure that your code cleans up properly.

# Bajau Widget Toolkit

## Overview

The [bajau](#) module contains a widget toolkit for building rich user interfaces. This toolkit is built using the Niagara component model. Widgets are `BComponents` derived from [BWidget](#). Widgets define basic UI functions:

- **Layout:** defines the layout model - how widget trees are positioned on the graphics device
- **Painting:** defines how widgets paint themselves using graphical composition and clipping
- **Input:** defines how user widgets process user input in the form of mouse, keyboard, and focus events
- **Data Binding:** defines how widgets are bound to data sources

Widgets are organized in a tree structure using the standard component slot model. Typically the root of the tree is a widget modeling a top level window such as [BFrame](#) or [BDialog](#).

## Layout

All widgets occupy a rectangular geometry called the bounds. Bounds includes a position and a size. Position is a x,y point relative to the widget parent's coordinate system. Size is the width and height of the widget. The widget itself defines its own logical coordinate system with its origin in the top left corner, which is then used to position its children widgets. Every widget may define a preferred size using `computePreferredSize()`. Layout is the process of assigning bounds to all the widgets in a widget tree. Every widget is given a chance to set the bounds of all its children in the `doLayout()` callback. When a layout refresh is needed, you may call `relayout()`. The relayout call is asynchronous - it merely enqueues the widget (and all its ancestors) for layout at some point in the near future.

## Panes

Widget's which are designed to be containers for child widgets derive from the [BPane](#) class. A summary of commonly used panes:

- [BCanvasPane](#): used for absolute positioning (discussed below);
- [BBorderPane](#): is used to wrap one widget and provide margin, border, and padding similar to the CSS box model.
- [BEdgePane](#): supports five potential children top, bottom, left, right, and center. The top and bottom widgets fill the pane horizontally and use their preferred height. The left and right widgets use their preferred width, and occupy the vertical space between the top and bottom. The center widget gets all the remainder space.
- [BGridPane](#): lays out its children as a series of columns and rows. Extra space in the rows and columns is configurable a number of ways.
- [BSplitPane](#): supports two children with a movable splitter between them.
- [BTabbedPane](#): supports any number of children - only one is currently selected using a set of tabs.
- [BScrollPane](#): supports a single child that may have a preferred size larger than the available bounds using a set of scroll bars.

## Absolute Layout

Every widget also has a frozen property called layout of type [BLayout](#). The `BLayout` class is used to store absolute layout. Widgets which wish to use absolute layout should be placed in a `BCanvasPane`. `BLayout` is a simple with the following string format "x,y,width,height". Each value may be a logical coordinate within the parent's coordinate space or it may be a percent of the parent's size. Additionally width and height may use the keyword "pref" to indicate use of preferred width or height. Examples include "10,5,100,20" "0,0,30%,100%", and "10%,10%,pref,pref".

Lastly the keyword "fill" may be used as a shortcut for "0,0,100%,100%" which means fill the parent pane. Fill is the default for the layout property which makes it easy to define layers and shapes.

## Painting

All widgets are given a chance to paint themselves using the `paint(Graphics)` callback. The graphics is always

translated so that the origin 0,0 is positioned at the top, left corner of the widget. The graphic's clip is set to the widget's size. Widget's with children, should route to `paintChild()` or `paintChildren()`. Painting follows the gx compositing rules. Alpha and transparent pixels blend with the pixels already drawn. Widgets are drawn in property order. So the first widget is drawn first (at the bottom), and the last widget drawn last (on the top). Note that hit testing occurs in reverse order (last is checked first). Effective z-order is reverse of property order (consistent with SVG).

## Input

User events are grouped into keyboard input, mouse input, and focus events. The following events are defined for each group:

### [BKeyEvent](#)

- `keyPressed`
- `keyReleased`
- `keyTyped`

### [BMouseEvent](#)

- `mouseEntered`
- `mouseExited`
- `mousePressed`
- `mouseReleased`
- `mouseMoved`
- `mouseDragged`
- `mouseDragStarted`
- `mouseHover`
- `mousePulse`
- `mouseWheel`

### [BFocusEvent](#)

- `focusGained`
- `focusLost`

## Design Patterns

Some complicated widgets have mini-frameworks all to their own. These include [BTable](#), [BTree](#), [BTreeTable](#), and [BTextEditor](#). All of these widgets use a consistent design pattern based on a set of support APIs:

- **Model:** defines the underlying logical model of the widget visualization
- **Controller:** processes all user input events, handles popup menus, and manages commands
- **Renderer:** responsible for painting the widget
- **Selection:** manages the current selection of the widget

## Commands

The `bajui` module provides a standard API for managing user commands using the [Command](#) and [ToggleCommand](#) classes. Commands are associated with one or more widgets which invoke the command. Typically this association happens by using a special constructor of the widget such as `BButton(Command cmd)` or using a `setCommand()` method. Commands are commonly used with [BButton](#) and [BActionMenuItem](#). `ToggleCommands` are commonly used with [BCheckBox](#), [BRadioButton](#), [BCheckBoxMenuItem](#), and [BRadioButtonMenuItem](#).

Commands provide several functions. First they provide a centralized location to enable and disable the command. It is common for a command to be available via a menu item, a toolbar button, and a popup menu. By enabling and disabling the command all the widgets are automatically enabled and disabled.

Commands also provide a standard mechanism used for localization via the lexicon APIs. If one of the module or lexicon

constructors is used the command automatically loads its visualization from a lexicon using a naming pattern: `keyBase+".label"`, `keyBase+".icon"`, `keyBase+".accelerator"`, and `keyBase+".description"`. The icon value should be an ord to a 16x16 png file. Widgets created with the Command will automatically set their properties accordingly.

The Command API also defines the basic framework for undo and redo. Whenever a command is invoked via the `invoke()` method, the Command can return an instance of [CommandArtifact](#) to add to the undo stack. Commands which don't support undo can just return `null`.

## Data Binding

All widgets may be bound to zero or more data sources using the [BBinding](#) class. Bindings are added to the widget as dynamic child slots. You may use the `BWidget.getBindings()` to access the current bindings on a given widget. Bindings always reference a data source via an ord. The [BBinding](#) API defines the basic hooks given to bindings to *animate* their parent widget.

The most common type of binding is the [BValueBinding](#) class. Value binding provides typical functionality associated with building real-time graphics. It supports mouse over status and right click actions. Additionally it provides a mechanism to animate any property of its parent widget using [BConverters](#) to convert the target object into property values. Converters are added as dynamic properties using the name of the widget property to animate. For example to animate the "text" property of a `BLabel` you might add a `ObjectToString` converter to the binding using the property name "text".

## Performance Tuning

The gx and bajaui toolkits are built using the AWT and Java2D. A key characteristic of performance is based on how widgets are double buffered and drawn to the screen. The following system properties may be used to tune widget rendering:

- **niagara.ui.volatileBackBuffer:** Defines whether the back buffer used for widget rendering uses `createVolatile()` or `createImage()`. Volatile back buffers can take advantage of Video RAM and hardware acceleration, non-volatile back buffers are located in system memory. Note: this feature is currently disabled.
- **sun.java2d.noddraw:** Used to disable Win32 DirectDraw. Often disabling DirectDraw can correct problems with flickering.

# Workbench

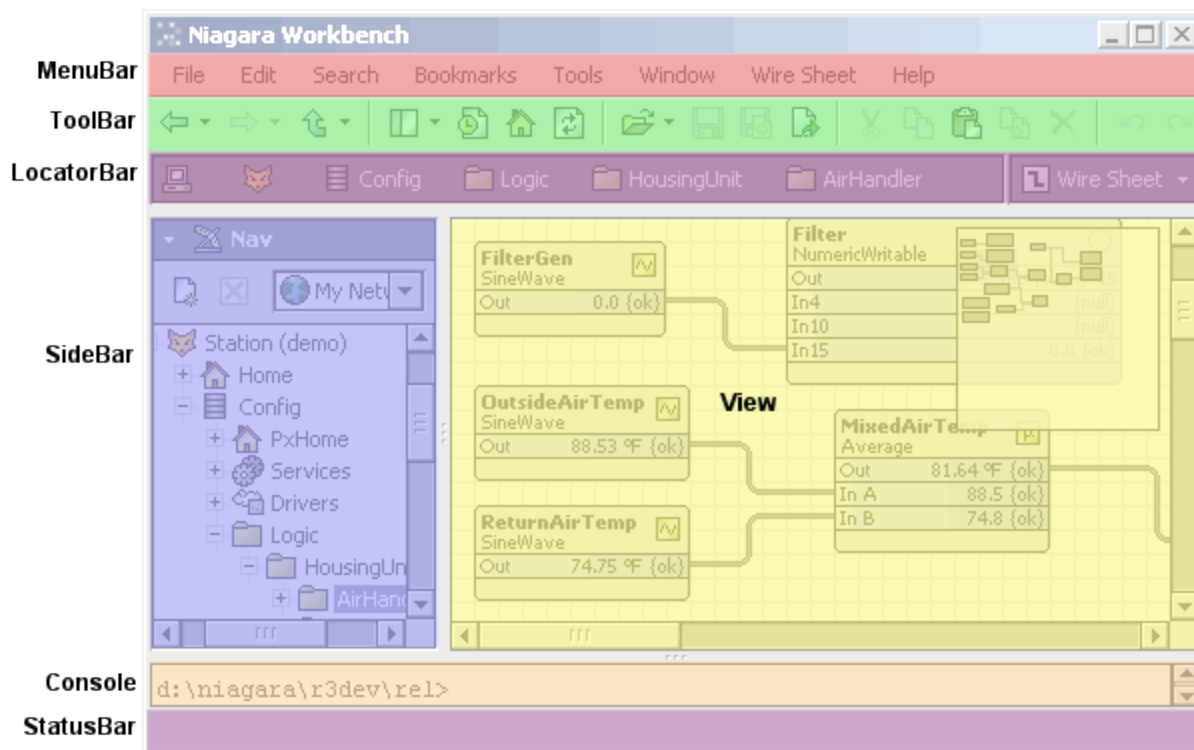
## Overview

The [workbench](#) module defines the framework for building standardized user interfaces. The workbench provides enhancements to the [bajau](#) widget toolkit:

- Standard layout with menu, toolbar, sidebars, and view;
- Standard browser based navigation model with an active ord, back, and forward;
- Bookmarking;
- Tabbed browsing;
- Options management;
- Plugin APIs;
- Ability to customize using WbProfiles;
- Enables both desktop and browser based applications;

Note: The term *workbench* applies both to the actual application itself as well as the underlying technology used to build customized applications. As you will see, all apps are really just different veneers of the same workbench customized using WbProfiles.

## Layout



The illustration above shows the key components of the Workbench layout:

- **MenuBar:** The bar of standard and view specific pulldown menus;
- **ToolBarBar:** The bar of standard and view specific toolbar buttons;
- **LocatorBar:** Visualization and controls for active ord;
- **SideBar:** Pluggable auxiliary bars including navigation and palette;
- **View:** The main tool currently being used to view or edit the active object;



- **Console:** Used to run command line programs such as the Java compiler;
- **StatusBar:** Standard location to display status messages;

The [BWbShell](#) class is used to model the entire workbench window (or the applet in a browser environment). The `getActiveOrd()` method provides access to the current location, and `hyperlink()` is used to hyperlink to a new ord.

## Browser Based Navigation

The fundamental navigation model of workbench is like a web browser. A web browser always has a current URL. As the current URL is changed, it fetches and displays the contents of that URL. A history of URLs is remembered allowing back and forward navigation. Most web browsers also allow the user to bookmark URLs for quick retrieval.

The workbench follows the same model. Instead of a URL to identify current location, the workbench uses an [ord](#). The ord currently being viewed is called the *active ord*. Every ord resolves to a BObject. The target of the active ord is called the *active object*.

[BWbViews](#) are the plugins used to work with the active object. Views are the primary content of the workbench and provide a user interface to view or edit the active object. The workbench discovers the available views by searching the registry for WbViews registered on the active object.

The workbench provides a ready to use bookmark system that allows users to save and organize ords as bookmarks. Bookmarks are also used to store NavSideBar and FileDialog favorites. The bookmark system provides a public API via the [javax.baja.ui.bookmark](#) package.

Workbench also provides tab based browsing similar to modern browsers such as Mozilla and FireFox. Most places in the interface which allow double clicking to hyperlink support Ctrl+double click to open the object in a new tab. Also see the File menu for the menu items and shortcuts used to manipulate and navigate open tabs.

## WbPlugins

The workbench is fundamentally a command and navigation shell, with all of its functionality provided by plugins. The plugins available to the workbench are discovered by searching the registry for the appropriate type (WbProfiles allow further customization). This means that installing a new workbench plugin is as simple as dropping in a module.

All plugins subclass [BWbPlugin](#), which is itself a BWidget. The following common plugins are discussed in the following sections:

- WbViews
- WbFieldEditor
- WbSideBars
- WbTools

## WbView

Views are the workhorses of the workbench. Views provide the content viewers and editors for working with the active objects. Views also have the unique ability to do menu and toolbar merging. To implementing a new view plugin follow these rules:

- Create a subclass of [BWbView](#), or if your view is on a BComponent, then subclass [BWbComponentView](#);
- Override `doLoadValue(BObject, Context)` to update the user interface with the active object.
- If your view allows editing of the object, then call `setModified()` when the user makes a change which requires a save.
- If your view allows editing and `setModified()` has been called, override `doSaveValue(BObject, Context)` to save the changes from the user interface back to the active object.
- Register your view as an agent on the appropriate object type (or types):

```
<type name="AlarmConsole" class="com.tridium.alarm.ui.BAlarmConsole">
  <agent requiredPermissions="r"><on type="alarm:ConsoleRecipient"/>
```

```

</agent>
</type>

```

Writing a view for a `BIFile` typically involved reading the file's content for display on `doLoadValue()`, and writing back the contents on `doSaveValue()`.

Writing a [BWbComponentView](#) for a `BComponent` typically involves subscribing to the necessary component or components on `doLoadValue()`, and saving back changes on `doSaveValue()`. The `WbComponentView` class provides a series of `registerX()` methods for managing the view's subscriptions. Remember that if working with remote components, batching resolves, subscribes, and transactions can make significant performance improvements. Refer to [Remote Programming](#) for more information.

## WbFieldEditor

Field editors are similar to views, except they typically are smaller editors used to edit a `BSimple` or `BStruct`. Unlike views, a field editor never fills the view content area, but rather is used inside views like the `PropertySheet`.

The rules for building a field editor are very similar to views:

- Create a subclass of [BWbFieldEditor](#).
- Override `doLoadValue(BObject, Context)` to update UI from object.
- Fire `setModified()` when the user makes a change.
- Override `doSaveValue(BObject, Context)` to update the object from the UI.
- Register your view as an agent on the appropriate object type (or type).

`BWbFieldEditor` also provides some convenience methods for displaying a dialog to input a specific `BObject` type. For example to prompt the user input a street address:

```

BStreetAddress addr = new BStreetAddress();
addr = (BStreetAddress)BWbFieldEditor.dialog(null, "Enter Address", addr);
if (addr != null) { /* do something! */ }

```

## WbSideBar

Sidebars are auxiliary tools designed to be used in conjunction with the active view. Sidebars are displayed along the left edge of the view. Multiple sidebars can be open at one time. Unlike views, sidebars are independent of the active ord.

The rules for building a sidebar:

- Create a subclass of [BWbSideBar](#).
- Provide display name and icon in your lexicon according to [TypeInfo](#) rules:

```

BookmarkSideBar.displayName=Bookmarks
BookmarkSideBar.icon=module://icons/x16/bookmark.png

```

## WbTool

Tools are plugins to the workbench Tools menu. Tools provide functionality independent of the active ord. Typically tools are dialogs or wizards used to accomplish a task. There are three types of tools:

- [BWbTool](#): is the base class of all tools. It provides a single `invoke(BWbShell shell)` callback when the tool is selected from the Tools menu. Often `invoke` is used to launch a dialog or wizard.
- [BWbNavNodeTool](#): is a tool which gets mounted into the ord namespace as "tool:{typespec}|slot:". Selecting the tool from the Tools menu hyperlinks as the tool's ord and then standard `WbViews` are used to interact with the tool. Typically in this scenerio the tool itself is just a dummy component used to register one or more views.
- [BWbService](#): is the most sophisticated type of tool. Services are `WbNavNodeTools`, so selecting them hyperlinks

to the tool's ord. Services also provide the ability to run continuously in the background independent of the active ord. This is useful for monitoring tools or to run drivers locally inside the workbench VM. Services can be configured to start, stop, and auto start via the WbServiceManager.

The rules for building a tool:

- Create a subclass of BWbTool, BWbNavNodeTool, or BWbService.
- Provide display name and icon in your lexicon according to [TypeInfo](#) rules:

```
NewModuleTool.displayName=New Module  
NewModuleTool.icon=module://icons/x16/newModule.png
```

## WbProfiles

The [BWbProfile](#) class provides the ability to create new customized versions of the workbench. WbProfile provides hooks to replace all of the standard layout components such as the MenuBar, ToolBar, LocatorBar, and StatusBar. Plus it provides the ability to customize which views, sidebars, and tools are available. Using WbProfiles you can quickly create custom applications that provide just the functionality needed for your domain.

You can launch workbench with a specific profile via a command parameter: `wb -profile:{typespec}`.

Note that if you wish to create an application that runs in the web browser you will need to subclass [BWbWebProfile](#).

# Web

## Overview

The [web](#) module is used to provide HTTP connectivity to a station via the [BWebService](#). The web module provides a layered set of abstractions for serving HTTP requests and building a web interface:

- **Servlet:** a standard `javax.servlet` API provides the lowest level of web integration.
- **ServletView:** is used to provide object views in a web interface.
- **Web Workbench:** is technology which enables the standard workbench to be run in a browser.
- **Hx:** is technology used to build web interfaces using only standards: HTML, JavaScript, and CSS.

## Servlet

Niagara provides a standard [javax.servlet](#) API to service HTTP requests. The [WebOp](#) class is used to wrap [HttpServletRequest](#) and [HttpServletResponse](#). [WebOp](#) implements `Context` to provide additional Niagara specific information. These APIs form the basis for the rest of the web framework.

The [BWebServlet](#) component is used to install a basic servlet which may be installed into a station database. The `servletName` is used to define how the servlet is registered into the URI namespace. A `servletName` of "foo" would receive all requests to the host that started with "/foo". Servlets are automatically registered into the URI namespace on their component started() method and unregistered on stopped(). The `service()` or `doGet()/doPost()` methods are used to process HTTP requests.

**Note:** The current `javax.servlet` implementation is based on version 2.4. The following interfaces and methods are not supported:

- **javax.servlet.Filter:** Unsupported interface
- **javax.servlet.FilterChain:** Unsupported interface
- **javax.servlet.FilterConfig:** Unsupported interface
- **javax.servlet.RequestDispatcher:** Unsupported interface
- **javax.servlet.ServletContext:** Unsupported methods
  - `getNamedDispatcher(String)`
  - `getRequestDispatcher(String)`
  - `getResource(String)`
  - `getResourceAsStream(String)`
  - `getResourcePaths(String)`
  - `getServlet(String)`
  - `getServlets()`
  - `getServletContextName(String)`
- **javax.servlet.ServletRequest:** Unsupported method
  - `getRequestDispatcher(String)`
- **javax.servlet.ServletRequestAttributeListener:** Unsupported interface
- **javax.servlet.ServletRequestListener:** Unsupported interface
- **javax.servlet.http.HttpSessionActivationListener:** Unsupported interface
- **javax.servlet.http.HttpSessionAttributeListener:** Unsupported interface
- **javax.servlet.http.HttpSessionListener:** Unsupported interface

## ServletView

The web framework follows an object oriented model similar to the workbench. The user navigates to objects within the station using ords. One or more web enabled views are used to view and edit each object.

When navigating objects using ords, Niagara must map ords into the URI namespace. This is done with the URI format of `"/ord?ord"`.

The [BServletView](#) class is used to build servlets that plug into the ord space using the "view:" scheme. For example if you wish to display an HTML table for every instance of component type "Foo", you could create a ServletView called "FooTable". Given an instance of "Foo", the URI to access that view might be `"/ord?slot:/foo3|view:acme:FooTable"`. The WebOp passed to `BServletView.service()` contains the target object being viewed (note WebOp subclasses from [OrdTarget](#)).

## Web Workbench

A nice feature of Niagara's web framework is the ability to run the entire workbench right in a browser. This *web workbench* technology allows almost any view (or plugin) to run transparently in both a desktop and browser environment. The following process illustrates how web workbench works:

1. User requests a workbench view for a specific object via its ord.
2. An HTML page is returned that fills the entire page with a small signed applet called wbapplet.
3. The wbapplet is hosted by the Java Plugin which must be preinstalled on the client's machine.
4. The wbapplet loads modules from the station as needed, and caches them on the browser's local drive.
5. The workbench opens a fox connection under the covers for workbench to station communication.
6. The workbench displays itself inside the wbapplet using the respective WbProfile and WbView.

Web workbench technology allows a sophisticated UI to be downloaded to a user's browser straight out of a Jace. It is downloaded the first time and cached - subsequent access requires only the download of wbapplet (13kb). Development for web versus desktop workbench is completely transparent. The only difference is that the [BWbProfile](#) used for a web interface must subclass from [BWbWebProfile](#). Some functionality is limited only to the desktop like the ability to access the console and Jikes compiler. Also note that web workbench session is limited to a specific station. So it doesn't make sense to navigate to ords outside that station such as `"local:|file:"`.

**Note:** in order for web workbench to be used, the client browser machine must have access to the station's fox port. This may require the fox port to be opened up in the firewall.

## Hx

There are cases where using the workbench is overkill or we don't wish to require the Java Plugin. For these use cases, Niagara provides the *hx* technology. Hx is a mini-framework used to build real-time web interfaces only with standard HTML, JavaScript, and CSS. See the [hx](#) chapter for details.

## WebProfileConfig

The web experience of a given user is controlled via the [BWebProfileConfig](#) class. WebProfileConfig is a MixIn added to every User component. The web profile determines whether web workbench or hx is used by specifying an WbProfile or HxProfile for the user.

# Px

## Overview

Px is a technology used to package a UI presentation as an XML file. A px file defines a tree of bajau widgets and their data bindings. Any [BWidget](#) and [BBinding](#) may be used, including those custom developed by you. Typically px files are created using a WYSIWYG tool called the PxEditor, although they can also be handcoded or auto-generated.

Px files are always given a ".px" extension, and modeled with the [file:PxFile](#) type.

## Px Views

A px file may be used in a UI via a variety of mechanisms:

- Navigating directly to a px file will display its presentation
- The px file may be attached to a component as a dynamic view
- Many px files can be automatically translated into HTML using hx

The `WbPxView` is the standard presentation engine for px files. `WbPxView` is the default view of `file:PxFile`, so you can use px files just like an HTML file - by navigating to one.

The [BPxView](#) class may be used to define *dynamic views* on components. Dynamic views are like dynamic slots, in that they are registered on an instance versus a type. A dynamic view is automatically available for every `BPxView` found in a component. Each `BPxView` provides an ord to the px file to use for that view. PxViews may be added through the workbench or programmatically. Since the bindings within a px file are always resolved relative to the current ord, you can reuse the same px file across multiple components by specifying bindings with relative ords.

If all the widgets used in a px file have a translation to hx, then the entire px file can be automatically translated into HTML for hx users. See [hx](#) for more details.

## PxMedia

As a general rule any `BWidget` is automatically supported when viewing a px file. However, viewing a px file in hx only supports a subset of widgets (those that have a hx agent). This means that you must target the lowest common denominator when creating px presentations. The target media for a px presentation is captured via the [BPxMedia](#) class. Both the px file and the `PxView` can store a `PxMedia` type. Currently there are only two available media types: `workbench:WbPxMedia` and `hx:HxPxMedia`. The PxEditor will warn you if you attempt to use widgets and bindings not supported by the target media.

## API

The bajau module provides a standard API for serializing and deserializing a widget tree to and from its XML representation. The [PxEncoder](#) class writes a widget tree to an XML document. [PxDecoder](#) is used to read an XML document into memory as a widget tree.

## Syntax

The bog XML format is optimized to be very concise with equal weight given to both read and write speed. The px XML format is designed to be more human usable. All px files have a root `px` element with a required `version` and optional `media` attribute. Within the root `px` element is an `import` element and a `content` element.

The `import` section contains a list of module elements. Each module specifies a Niagara module name using the `name` attribute. This module list is used to resolve type names declared in the `content` section.

The `content` section contains a single element which is the root of the px file's widget tree. Each component in the tree uses a type name as the element name. These type names are resolved to fully specified type specs via the import section.

Frozen simple properties of each component are declared as attributes in the component's start tag. Complex and dynamic slots are specified as children elements. The name of the slot inside the parent component may be specified using the name attribute. Dynamic simple properties specify their string encoding using the value attribute.

## Example

The following example shows a BoundLabel placed at 20,20 on a CanvasPane, which is itself nested in a ScrollPane. Note since the CanvasPane is the value of ScrollPane's frozen property content, it uses the name attribute. Note how frozen simple properties like viewSize, layout, and ord are defined as attributes.

```
<?xml version="1.0" encoding="UTF-8"?>
<px version="1.0" media="workbench:WbPxMedia">
  <import>
    <module name="baja"/>
    <module name="bajau"/>
    <module name="converters"/>
    <module name="gx"/>
    <module name="kitPx"/>
  </import>
  <content>
    <ScrollPane>
      <CanvasPane name="content" viewSize="500.0,400.0">
        <BoundLabel layout="20,20,100,20">
          <BoundLabelBinding ord="station:|slot:/Playground/SineWave"
statusEffect="none">
            <ObjectToString name="text"/>
          </BoundLabelBinding>
        </BoundLabel>
      </CanvasPane>
    </ScrollPane>
  </content>
</px>
```

# Hx

## Overview

The [hx](#) module defines the framework for building HTML-based user interfaces using HTML, CSS, JavaScript, and XmlHttp.

Hx is designed to approximate the same paradigms that exist for developing user interfaces in the Workbench environment, such as Views, FieldEditors, and Profiles. It's main goal is try and transparently produce lightweight HTML-only interfaces automatically based on the workbench views. Limited support exists for standard views like the Property Sheet, but [Px](#) is the main reuse target.

If you are not familiar with how interfaces are designed in workbench you should read the [Workbench](#) documentation before continuing.

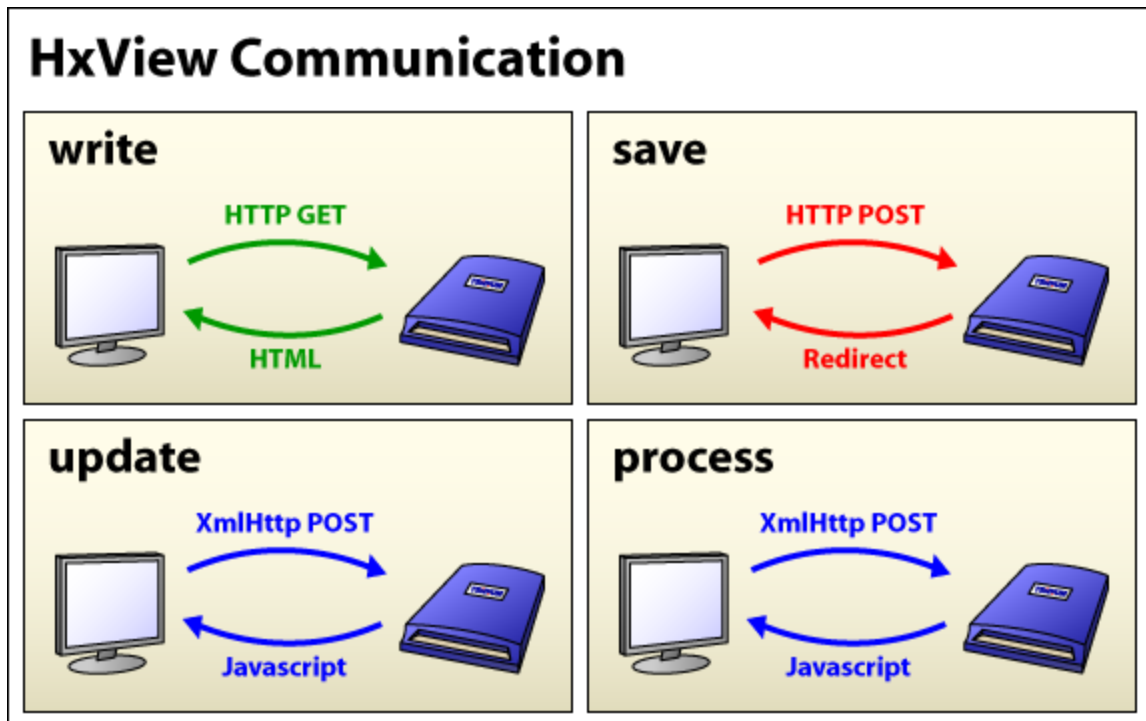
- [HxView](#) Details of HxView
- [HxOp](#) Details of HxOp
- [HxProfile](#) Details of HxProfile
- [Events](#) Detail of Events
- [Dialogs](#) Details of Dialogs
- [Theming](#) Details of Theming



# Hx - HxView

## HxView Overview

[HxView](#) provides the content viewers and editors for working with the active objects. As you have probably guessed, HxView is the Hx equivalent of WbView. HxView is designed to produce and interact with a snippet of HTML. [BHxProfile](#) takes one or more HxViews, adds some supporting markup plus some chrome, and produces a complete HTML page.



From the diagram, a HxView:

- Must have logic to render a HTML snippet from an object (write). This is synonymous to `BWbView.doLoadValue()`.
- May have logic to save changes back to the object (save). This is synonymous to `BWbView.doSaveValue()`.
- May have logic to periodically update the HTML snippet (update).
- May have logic to respond to client background requests (process).

The name in parenthesis at the end of each bullet is the corresponding method in HxView responsible for that behavior. Details on each method can be found below. The [HxProfile](#) is responsible for building the containing HTML around each HxView.

## Example

The details of each method can be found at the end of this document, but lets take a simple example to walk through the API:

```
public class BFooView extends BHxView
{
    public static final BFooView INSTANCE = new BFooView();
}
```

```

public Type getType() { return TYPE; }
public static final Type TYPE = Sys.loadType(BFooView.class);

protected BFooView() {}

public void write(HxOp op) throws Exception
{
    BFoo foo = (BFoo)op.get();
    HtmlWriter out = op.getHtmlWriter();
    out.w("Current name: ").w(foo.getName()).w("<br/>");
    out.w("<input type='text' name=''.w(op.scope("name")).w('');
    out.w(" value=''.w(foo.getName()).w('' /><br/>");
    out.w("<input type='submit' value='Submit' />");
}

public BObject save(HxOp op) throws Exception
{
    BFoo foo = (BFoo)op.get();
    foo.setName(op.getFormValue("name"));
    return foo;
}
}

// Register this view on BFoo in module-include.xml
<type name="FooView" class="bar.BFooView">
  <agent><on type="bar:Foo"/></agent>
</type>

```

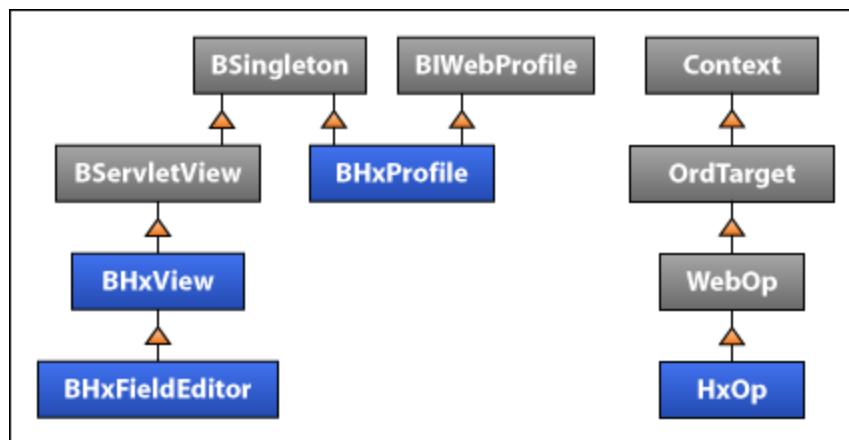
Assuming the current name in our BFoo object is "Peter Gibbons", the above code will produce the following HTML (ignoring the profile):

```

Current name: Peter Gibbons<br/>
<input type='text' name='name' value='Peter Gibbons' /><br/>
<input type='submit' value='Submit' />

```

If you are familiar with Niagara AX and HTML, this should be pretty straightforward. Let's walk through it though. Here's the class heirarchy of the main hx components:



The first thing to note is that **BHxView** extends [BServletView](#), which extends [BSingleton](#), which requires a `public static final INSTANCE` variable for all concrete implementations. If you have ever programmed Servlets

before, you'll know that a Servlet must be re-entrant, and HxViews follow the same model. The `INSTANCE` object is what will be used to handle requests. (The `protected` constructor is a convention used to enforce the singleton design pattern). Since HxView can't maintain state while its doing its thing, we need to stash stuff somewhere - that's where [HxOp](#) comes in. We won't get into the details of HxOp yet, just be aware that anything I need to know about my current request or response is very likely accessible via the `op`.

## Producing the HTML

Let's move on to the lifecycle of an HxView. The first thing a view will do is render its HTML to the client. This occurs in the `write()` method. By default Hx documents use the XHTML 1.0 Strict DOCTYPE. So you are encouraged to use valid XHTML in your `write` method. Since HxViews are designed to be chromable, and composable, you'll also only write the markup that directly pertains to this view in your `write` method. Here are the things you should take note of about `write`:

- Think `BWbView.doLoadValue()`
- Only write the HTML that directly pertains to this view.
- You should always use `op.scope()` when writing a form element name. We'll get to why you should do that in 'Writing Reusable HxViews' down below.
- This is just a plain old HTML form, so all the normal form elements are applicable. And of course any other HTML.
- Just like a plain HTML file, `<input type='submit' />` is used to submit changes back to the server. The Hx framework will take care of building the `form` tag so this request gets routed to your `save()` method.

## Saving Changes

Ok, my name is not "Peter Gibbons", so we need to be able to save something else back to the station. This is just as easy as writing my HTML, you simply implement a `save` method on your view. The request will automatically be routed, and all form data will be available from the `HxOp.getFormValue()` method.

So now if I view our example view in my browser, enter "Michael Bolton" and hit "Submit", the page will refresh to display:

```
Current name: Michael Bolton<br/>
<input type='text' name='name' value='Michael Bolton' /><br/>
<input type='submit' value='Submit' />
```

Technically, what happens, is the POST request gets routed to `save`, then Hx responds with a redirect back the same location. This forces the page contents to be requested on a GET request, avoiding double-posting problems.

## Writing Reusable HxViews

Hx is designed to allow for reusing and nesting HxViews within other HxViews. To accomplish this, we need some type of scoping mechanism to avoid naming conflicts. Luckily, Hx handles this quite cleanly. Each HxOp that gets created has a name (explicit or auto-generated), which when combined with its parent tree, creates a unique path to each "instance" of a HxView. So if you take the this code:

```
public void write(HxOp op) throws Exception
{
    HtmlWriter out = op.getHtmlWriter();
    out.w("<input type='text' name='" + op.scope("foo") + "' />");
    ...
}

public BObject save(HxOp op) throws Exception
{
    String foo = op.getFormValue("foo");
    ...
}
```

The resulting HTML could look something like this:

```
<input type='text' name='uid1.editor.uid5.foo' />
```

`HxOp.getFormValue()` will automatically handle the "unscoping" for you. This allows any `HxView` to be nested anywhere without knowing its context. However, this only works if you follow a few rules:

- Always give sub-views a sub-op using `HxOp.make()` - there should always be a 1:1 ratio between `HxOps` and `HxViews`. See "Managing Subviews" below.
- Always use `HxOp.scope()` when writing the name attribute for a form control.
- When using the auto name constructor of `HxOp`, names are created by appending the current counter value to a string ("uid0", "uid1", etc). So its very important that the order in which `HxOps` are created is always the same in write/save/update/process so the produced paths will always the same. Otherwise views will not be able to correctly resolve their control values.

## Managing Subviews

Hx does not contain any notion of containment, so composite views are responsible for routing all write/save/update/process requests to its children:

```
public class BCompositeView extends BHxView
{
    public void write(HxOp op) throws Exception
    {
        BSubView.INSTANCE.write(makeSubOp(op));
        ...
    }

    public BObject save(HxOp op) throws Exception
    {
        BFoo foo = BSubView.INSTANCE.write(makeSubOp(op));
        ...
    }

    public void update(HxOp op) throws Exception
    {
        BSubView.INSTANCE.update(makeSubOp(op));
    }

    public boolean process(HxOp op) throws Exception
    {
        if (BSubView.INSTANCE.process(makeSubOp(op)))
            return true;
        return false;
    }

    private HxOp makeSubOp(HxOp op)
    {
        BFoo foo;
        ...
        return op.make(new OrdTarget(op, foo));
    }
}
```

Don't forget to always create a sub-op to your child views so the Hx framework can strut its stuff.

## Writing HxView Agents for WbViews

Another feature of the hx framework is a transparent transition from the Workbench environment to the hx environment. For example, if you have created a WbView called WbFooView, all references to that view can be made to transparently map to your hx implementation. You just need to register your HxView directly on the WbView, and expect the input argument to be the same type as loaded into the WbView:

```
// Register WbView agents directly on the View
<type name="HxFooView" class="foo.BHxFooView">
  <agent><on type="foo:WbFooView"/></agent>
</type>

public void write(HxOp op)
    throws Exception
{
    // Assume object is what the corresponding WbView would
    // receive in its doLoadValue() method.
    BFoo foo = (BFoo)op.get();
    ...
}
```

Then this ord will work correctly in both environments:

```
station:|slot:/bar|view:foo:WbFooView
```

Also note that if your view is the default view on that object, the default ord will choose the correct view as well:

```
station:|slot:/bar
```

## Writing HxView Agents for Px Widgets

Similar to creating WbView agents, a BHxPxWidget is responsible for creating an hx representation of a BWidget used in a Px document. Note that BHxPxWidget works differently from a typical HxView in that op.get() will return the BWidget that this agent is supposed to model. The widget will already be mounted in a BComponentSpace and any bindings will already be active and leased. Also note that in module-include.xml this type should be registered as agent on the BWidget it is supposed to model.

```
// Register PxWidget agents directly on the Widget
<type name="HxPxLabel" class="com.tridium.hx.px.BHxPxLabel">
  <agent><on type="bajau:Label"/></agent>
</type>

public void write(HxOp op)
    throws Exception
{
    // OrdTarget is the widget we want to model
    BLabel label = (BLabel)op.get();

    HtmlWriter out = op.getHtmlWriter();
    out.w(label.getText());
}
```

## Uploading Files with Multi-part Forms

Hx supports file uploading by using the multi-part encoding for form submission. This capability is only supported for standard form submissions. You may upload one or more files along side the rest of your form. The files are stored in a temporary location on the station, and if not moved, will be automatically deleted at the end of the request.

- Must call `op.setMultiPartForm()` to change form encoding.
- Uploaded files are accessible from `op.getFile()`, where the control name designates which file you want.
- If the file is not explicitly moved to another location, it will be deleted at the end of the request.

Let's take an example:

```
public void write(HxOp op) throws Exception
{
    op.setMultiPartForm();
    out.w("<input type='file' name='someFile' />");
}

public BObject save(HxOp op) throws Exception
{
    BFile file = op.getFile("someFile");
    FilePath toDir = new FilePath("^test");
    BFileSystem.INSTANCE.move(file.getFilePath(), toDir, op);
    return op.get();
}
```

This code will upload a file to a temporary file, accessible as "someFile", and move it to another location so that it will not be deleted at the end of the request.

## HxView Methods in Detail

### write

Write is used to output the HTML markup for the current view. HxViews should only write the markup that directly pertains to itself. Avoid writing any containing markup - this is handled by the parent view or the profile. Especially avoid writing outer tags like `html`, `head`, and `body` - these are handled by the profile.

There is only one form tag in an hx page, and is written by the profile. HxViews should never write their own form blocks. So by design, the entire page content is encoded for `save` and `Events`. Naming collisions are handled automatically using the HxOp scoping rules (see 'Writing Reusable HxViews' above for more info on scoping).

The `write` method is always called on an HTTP GET request. However, if its written correctly (which typically means escaping quotes properly), it may be reused by `update` or `process` if it makes sense.

### save

Save is used to save changes made from the view back to the target object. This is usually just a standard response to a form post, where the form values are accessed using `HxOp.getFormValue()`. Views on `BSimple`s should return a new instance based on their new value. Views on `BComponents` should modify the existing instance and return that instance.

After a save is handled, a redirect is sent back to the browser to the current location. This is used to refresh the current page values, but more importantly to avoid double-posting problems. Content is always be requested on a GET request (and handled by `write`). You may choose to redirect back to a different URL using the `HxOp.setRedirect()` method.

The `save` method is always called on a standard HTTP POST form submit request. Both standard url-encoded and multi-part forms are supported. See 'Uploading Files with Multi-part Forms' above for info on multi-part forms.

### update

Update is automatically called periodically on all views if at least one view was marked as dynamic (via `HxOp`). This is a background request made using JavaScript and XmlHttp. The content returned to the browser must be executable JavaScript. For example:

```

public void write(HxOp op) throws Exception
{
    op.setDynamic();
    HtmlWriter out = op.getHtmlWriter();
    out.w("<div id='time'>Current Time</div>");
}

public void update(HxOp op) throws Exception
{
    HtmlWriter out = op.getHtmlWriter();
    out.w("var elem = document.getElementById('time');");
    out.w("elem.innerHTML = ").w(BAbsTime.now()).w(";");
}

```

Here, after the page is initially written, the browser will poll the station every five seconds running `update` on all the views. So this code will simply update the current time each time the station is polled.

## process

Process is used to handle non-update background requests. A process request is targeted and serviced by a single `HxView`. The default implementation for process handles routing events to the correct view. See [Events](#).

**Note:** If you override process, you must call super or event routing will fail.

# Hx - HxOp

## HxOp

[HxOp](#) maintains all the state for the current request, and provides the interface for creating and consuming a document. The original HxOp wraps the [WebOp](#) for the current request. Sub-views should be given a new HxOp from the current op via the `HxOp.make()` method. See 'Writing Reusable HxViews' in [HxView](#).

Note: There should always be a one-to-one mapping of HxOps to HxViews.

- [WebOp API](#)
- [HxOp API](#)
- [Servlet API](#)



# Hx - HxProfile

## HxProfiles

The [BHxProfile](#) is used to customize the HTML page around the current HxView. The profile is responsible for writing out the outer HTML tags (html, head, and body), any custom markup, and the current view. It is important that your profile respect the order HxOps are created in these methods: `writeDocument`, `updateDocument`, `processDocument`, and `saveDocument`. If any HxView uses the auto name constructor of HxOp to create a unique path name, it must be called in the exact same order in order to resolve correctly.

HxProfile exposes customization hooks through convenience methods, so there is no need to handle the boilerplate code:

```
public class BMyProfile
    extends BHxProfile
{
    public static final BMyProfile INSTANCE = new BMyProfile();

    public Type getType() { return TYPE; }
    public static final Type TYPE = Sys.loadType(BMyProfile.class);

    protected BMyProfile() {}

    public void doBody(BHxView view, HxOp op)
        throws Exception
    {
        BHxPathBar.INSTANCE.write(makePathBarOp(op));
        view.write(op);
        displayError(op);
    }

    public void updateDocument(BHxView view, HxOp op)
        throws Exception
    {
        BHxPathBar.INSTANCE.update(makePathBarOp(op));
        view.update(op);
    }

    public boolean processDocument(BHxView view, HxOp op)
        throws Exception
    {
        if (BHxPathBar.INSTANCE.process(makePathBarOp(op)))
            return true;
        return view.process(op);
    }

    public void saveDocument(BHxView view, HxOp op)
        throws Exception
    {
        BHxPathBar.INSTANCE.save(makePathBarOp(op));
        view.save(op);
    }

    protected HxOp makePathBarOp(HxOp op)
    {
        return op.make("pathbar", op);
    }
}
```

# Hx - Events

## Events

Hx uses [Events](#) to provide background interaction between the server and the browser. Events always originate from the client browser, and must return executable javascript as the response (you are not required to return content). The html form is encoded and sent for every event fire, so `op.getFormValue()` can be used to query the browser page state.

Events are implemented on top of the `HxView.process` method, and therefore use the `XmlHttp` support implemented in the major browsers.

[Command](#) extends `Event` to add some convenience methods and a display name property. By convention `Commands` are triggered by the user (maybe by clicking on a button), while `Events` are triggered programmatically. Though in reality they are interchangeable.

Note: `javax.baja.hx.Command` is not the same class as the `javax.baja.ui.Command`.

# Hx - Dialogs

## Dialogs

Support for modal dialog boxes is provided with [Dialog](#) and is typically used from an [Command](#):

```
class EditCommand extends Command
{
    public EditCommand(BHxView view)
    {
        super(view);
        dlg = new EditDialog(this);
    }

    public void handle(HxOp op) throws Exception
    {
        if (!dlg.isSubmit(op)) dlg.open(op);
        else
        {
            String name = op.getFormValue("name");
            String age  = op.getFormValue("age");

            BDude dude = (BDude)op.get();
            dude.setName(name);
            dude.setAge(Integer.parseInt(age));

            refresh(op);
        }
    }

    private EditDialog dlg;
}

class EditDialog extends Dialog
{
    public EditDialog(Command handler) { super("Edit", handler); }
    protected void writeContent(HxOp op) throws Exception
    {
        BDude dude = (BDude)op.get();
        HtmlWriter out = op.getHtmlWriter();

        out.w("<table>");
        out.w("<tr>");
        out.w(" <td>Name</td>");
        out.w(" <td><input type='text' name='".w(op.scope("name"));
        out.w("' value='".w(dude.getName()).w("' /></td>");
        out.w("</tr>");
        out.w("<tr>");
        out.w(" <td>Age</td>");
        out.w(" <td><input type='text' name='".w(op.scope("age"));
        out.w("' value='".w(dude.getAge()).w("' /></td>");
        out.w("</tr>");
        out.w("</table>");
    }
}
```

# Hx - Theming

## Theming

All styling in hx is handled with CSS. The core colors and fonts are defined in <module://hx/javax/baja/hx/default.css>. In order for your view to use the default theme, you should write your markup like this:

```
<div class="controlShadow-bg myCustomClass" style="...">
...
</div>
```

This order is important. The default class should always come first in the selector list, and before any style tag (though you should avoid using style directly in your view) - so that styles are overridden correctly.

**Note:** `HxProfiles` that override the theme should always place their custom stylesheet last to make sure it overrides any stylesheets loaded during the `write()` phase.

## Theme Modules Overview

The scope and capabilities of theme modules has been greatly expanded for Niagara 4. This document will describe the parts of the UI that are available for theming, the general process of creating a theme module, then provide details and tips regarding the individual parts and pieces of a theme.

## Niagara 4 UI Overview

Many more parts of the UI can have themes applied in Niagara 4.

- **bajau** is the Java user interface technology used by all parts of the Workbench UI in Niagara AX. This includes things like the Workbench nav tree, Px widgets, wizard dialogs, and any other UI elements carried forward from AX Workbench. It is styled using files written in a Niagara-specific syntax called NSS.
- **JavaFX** is a user interface technology that is distributed as part of Java 8 itself. It has a number of capabilities that bajau does not support, like rounded corners and drop shadows. It is styled using a specialized set of CSS rules. In Niagara 4, Workbench uses JavaFX to render certain elements like toolbars and menu buttons.
- **Hx** is a framework carried forward from Niagara AX. It runs in the station to generate web interfaces using HTML and JavaScript.
- **bajaux** is a new framework in Niagara 4, based on HTML and JavaScript. It is used to create browser-based Niagara applications like Property Sheet, Web Chart, and User Manager. It is styled using pure CSS.

A theme in Niagara 4 consists of a number of different parts, arranged into specified folders.

- `src/hx`: contains the CSS used to style Hx views, such as the Hx Property Sheet and HxPx graphics.
- `src/fx`: contains the CSS used to style JavaFX elements, like toolbars and menu buttons.
- `src/imageOverrides`: contains theme-specific replacements for icons from individual Niagara modules.
- `src/nss`: contains the NSS files used to style UI elements created with bajau. NSS syntax in 4.0 is exactly the same as it was in AX.
- `src/sprite`: contains a spritesheet image and CSS file used to minimize the number of network calls necessary to retrieve icons in web-based views.
- `src/ux`: contains the CSS used to style bajaux views, including the Shell Hx profile.

## Creating a theme module

Although it is possible to create a brand-new theme module from scratch, it will be much easier to select an existing theme that comes closest to your desired look, then copy and make modifications to that theme. As part of this tutorial, we will use `themeZebra-ux.jar` as a basis, copy and modify it, and save it as `themeOkapi-ux.jar` (we love our striped ungulate mammals here at Tridium).

The process of creating a theme module is very similar to creating any other Niagara module. The process outlined below will result in an exact copy of `themeZebra`, ready for modification.

- Create the folder structure for your module: `themeOkapi/themeOkapi-ux/`.
- Create a `src` directory in `themeOkapi-ux` and extract the contents of `themeZebra-ux.jar` into it.
- Included in the `src` directory are the files `cssTemplate.mustache`, `Gruntfile.js`, and `package.json`. These should be moved into the root of `themeOkapi-ux`, not the `src` directory. (`META-INF` can be deleted.) Ensure that any remaining references to `themeZebra` in these files are updated to reference `themeOkapi` instead.
- Create a standard `themeOkapi-ux.gradle` file, just like any other module. Ensure that all necessary files are included in the jar task.
- Create a `module-include.xml` file with the following contents, as described in the Workbench Theming knowledge base article:

```
<defs>
  <def name="themeName" value="themeOkapi" />
</defs>
```

Now, you should be able to build and install your theme module, then select it both in your users' web profiles and in Workbench options.

## NSS: Styling bajai elements and icons

The NSS syntax and method for overriding icons are unchanged since Niagara AX. This information is documented on Niagara Central:

<https://community.niagara-central.com/ord?portal:/blog/BlogEntry/235>

[https://community.niagara-central.com/ord?portal:/dev/wiki/Workbench\\_Theming](https://community.niagara-central.com/ord?portal:/dev/wiki/Workbench_Theming)

One difference from Niagara AX is that some widgets, such as menus and toolbar buttons, are now rendered using JavaFX instead of bajai. This means that styling menu, menu-item, and other toolbar-related nodes in the NSS will likely have no effect.

## JavaFX: Styling menus and toolbars

In Niagara 4, the Java runtime has been upgraded from 1.4 to 1.8. Java 8 includes a UI framework called JavaFX, which includes a number of UI widgets which have been integrated into parts of Workbench.

JavaFX widgets are styled using a Java-specific dialect of CSS. A reference for JavaFX CSS is available here:

<http://docs.oracle.com/javafx/2/api/javafx/scene/doc-files/cssref.html>

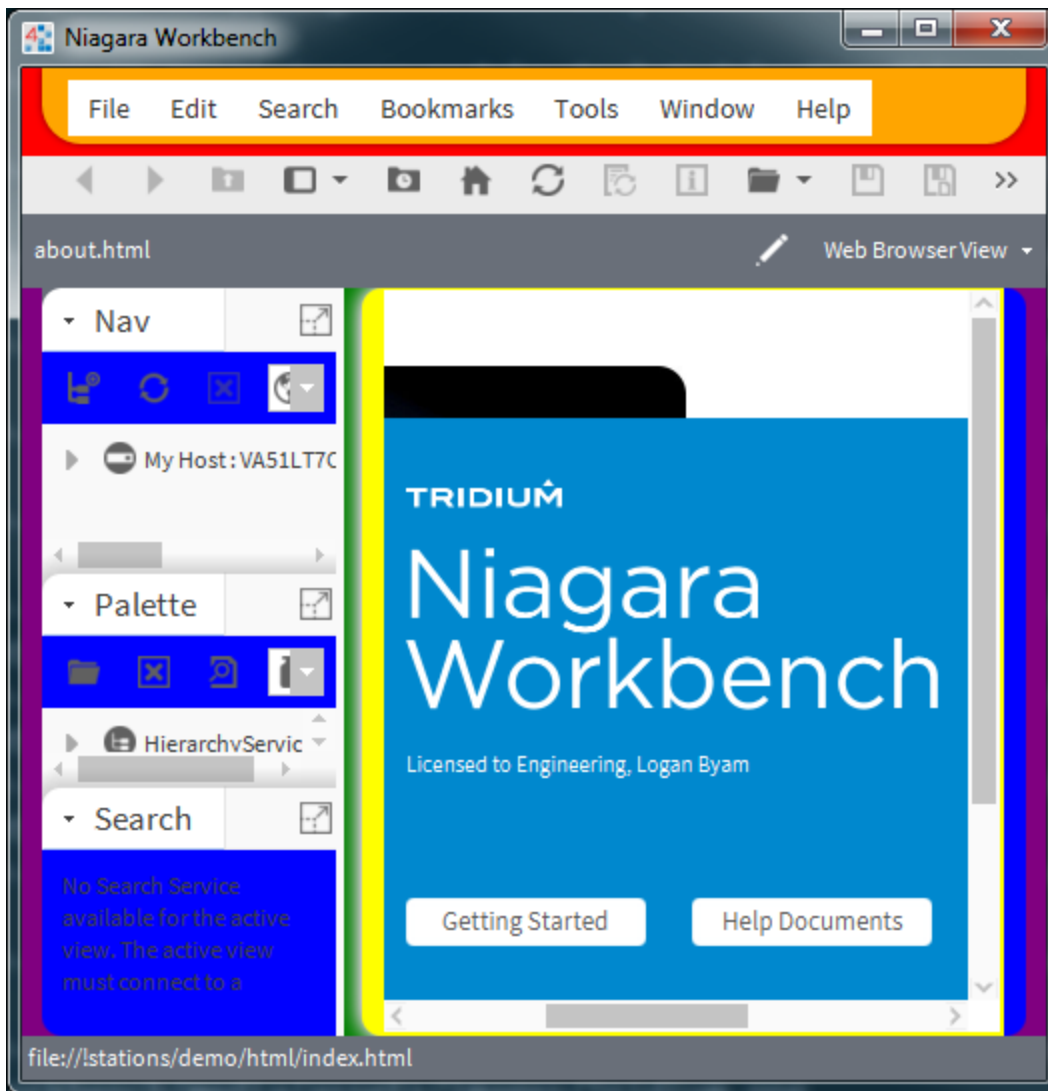
(Oracle's documentation on JavaFX CSS seems to have a few omissions, like the `.context-menu` class. We've already found a number of these missing classes and included them in the Zebra and Lucid themes.)

Workbench widgets that can be styled using JavaFX include the menu bar, toolbar, and scroll bars. These use the standard JavaFX class names: `menu`, `menu-item`, `tool-bar`, `scroll-bar`. To style these widgets, place a CSS file in your theme module at `src/fx/theme.css`.

Some common IDs to use in your CSS will include the following. Additional selectors may be added in the future if more widgets are converted from bajai to JavaFX.

- `#menu-bar-profile`: the topmost Workbench menu bar containing File, Edit, etc.
- `#menu-bar-profile-background-container`, `#menu-bar-profile-foreground-container`: wrap the upper toolbar in two separate containers for advanced border and shadow effects
- `#tool-bar-profile`: the topmost Workbench toolbar containing Back, Forwards, and Refresh buttons, etc.
- Foregrounds and backgrounds: primary areas of the UI are wrapped in two separate containers for advanced border and shadow effects.
  - `#menu-bar-profile-background-container`, `#menu-bar-profile-foreground-container`: topmost Workbench menu bar
  - `#view-profile-foreground`, `#view-profile-background`: the pane containing the primary Workbench view, such as Property Sheet
  - `#content-profile-foreground`, `#content-profile-background`: the pane containing all Workbench content south of the location bar (this includes the main view, sidebars, and console)

Example:



Niagara Framework > Niagara 4 Theme Module Creation > JavaFxIDs.png

- red: #menu-bar-profile-background-container
- orange: #menu-bar-profile-foreground-container
- yellow: #view-profile-foreground
- green: #view-profile-background
- blue: #content-profile-foreground
- purple: #content-profile-background

Note that these background colors will show through any elements configured without a background color of their own.

## Hx: Styling classic web views

Hx views can now be styled on a per-theme basis. The CSS file should go in your theme module at `src/hx/theme.css`.

These styles will apply on top of the default Hx styles in `default.css`.

## bajaux: Styling the new generation of Niagara web views

bajaux views use a common list of CSS classes, intended to be overridden by themes and to make it easy to apply global styles to bajaux widgets.

The base set of CSS classes lives in the web module at `module://web/rc/theme/theme.css`. Most `bajaux` widgets can be styled using these classes. You can view a visual demonstration of the different classes available by going to <http://localhost/module/web/rc/theme/test.html?theme=Zebra> (replacing `localhost` with the address of your station, if needed).

In order to create a `bajaux` theme, you can simply redefine these CSS classes in `src/ux/theme.css`.

`src/ux/theme.css` can also contain rules for any kind of `bajaux` widget, even those that might not use the base set of `ux` classes. There are several examples of this, which you can see in `themeZebra`'s `src/ux/theme.css` file, including dialogs, Property Sheet, charts, and other widgets. At the moment, adding additional rules to `src/ux/theme.css` is the only way to style these widgets in a theme. Future releases may include additional functions to apply styles in a more modular way.

## Developer notes on theming Hx and bajaux web views

### On using LESS

If you are building a theme using `themeZebra` as a base, you will notice a folder named `less` containing a number of `.less` files. LESS is a CSS compiler that brings the power of variables, functions, mixins, math, and other tools to CSS. For example, one benefit of using LESS is that we've chosen to store a base color palette in `palette.less`, so that they can be easily shared between the Hx and `bajaux` themes. In fact, you could simply change `palette.less` with no other changes, and instantly apply a new color scheme to both.

If you choose not to use LESS, you can simply edit `src/hx/theme.css` and `src/ux/theme.css` like any other CSS file. If you do want to give LESS a try, here are the steps you'll need to take:

- Install [Node.js](#).
- Install Grunt by typing `npm install -g grunt-cli`.
- Install PhantomJS by typing `npm install -g phantomjs`.
- In your `themeOkapi-ux` directory, type `npm install`.
- Still in your `themeOkapi-ux` directory, type `grunt watch:css`.
  - Now, whenever you save a change to a `.less` file, it will immediately be compiled into the corresponding CSS. Make your changes, hit reload in the browser, and immediately see those changes reflected in your Hx or `bajaux` views.
- To do a one-time compilation, just type `grunt less`.

### On sprites

In previous releases, icons were displayed simply by retrieving the individual icon files from the station and displaying them as `img` tags in the browser. On an embedded device, or with HTTPS turned on, minimizing the number of network calls becomes critical. So in the new Niagara 4 `bajaux` views, icons are now displayed using sprites.

A sprite is a number of different images, all concatenated together into one large image that forms a kind of mosaic. That large image is set as the background of an icon, but offset using CSS so that the particular icon you want is scrolled into view. The end result is that you can retrieve the entire icon set for a module using just two network calls: the sprite image, and the sprite CSS.

Due to this enhancement, if your theme module contains images, it *must* also contain a sprite. The sprite image should exist at `src/sprite/sprite.png` and the sprite CSS should be at `src/sprite/sprite.css`. You may generate your sprite using any tools you wish, but both `themeZebra` and `themeLucid` contain all the necessary configuration files to generate them for you. If you are using a stock theme as a base, you have everything you need.

A quick overview of the process follows.

- The default Grunt task performs three different steps: `sprite`, `imagemin`, and `concat`. (Simply typing `grunt` will do these three things in order.)
- `grunt sprite` uses a utility called `spritesmith` to generate the sprite image and sprite CSS files. These both go in `src/sprite`.
- `grunt imagemin` will losslessly compress `sprite.png` to save on space.



`grunt concat` adds the `@noSnoop` tag to the top of the CSS file. (Tech details: this disables the `SnoopHtmlWriter` in the station, which would otherwise break the direct `url` references in `sprite.css`.)

(`themeZebra-ux` does not actually contain any image overrides - it relies completely on the contents of the default `icons-ux` module. So `themeZebra`'s sprite will be empty. For an example of an actual generated sprite, try these steps with `themeLucid`.)

### The structure of a Niagara sprite CSS file, and how it's loaded into a theme

(This section is extremely techy. It's not necessary if all you want to do is create a new theme. Feel free to skip.)

Each icon in a Niagara module, when packed into a sprite, will have its own specified CSS class referenced in `sprite.css`. Each will look something like this:

```
.icon-icons-x16-add:before {
  display: inline-block;
  vertical-align: text-top;
  content: '';
  background: url(/module/themeLucid/sprite/sprite.png) -180px -494px;
  width: 16px;
  height: 16px;
}

.icon-icons-x16-add > img { display: none; }
```

This follows certain conventions relating to sprites in Niagara apps.

First, the CSS class of the HTML icon element is derived from the ORD of the icon itself. It begins with `.icon` and matches the ORD starting with the module name and omitting the file extension.

Second, it has an additional CSS rule indicating that any `img` tags inside of it are to be hidden. Why this rule? Well, for `bajaux` to correctly generate the HTML for the icon, it needs to know whether the icon is already represented in the spritesheet or not. If it's already in `sprite.png`, it would make no sense to download the actual `add.png` on top of that. But if the icon is not in the sprite, it still needs to be displayed.

So, a dummy element will be added to the DOM offscreen. It will have both the CSS class `.icon-icons-x16-add`, and an `img` tag inside of it. If it's in `sprite.css`, that CSS rule will hide the `img` tag, and by checking the `display` CSS property of that `img` we'll know if it's in the sprite or not. Slightly clumsy, but it works.

The RequireJS module `bajaux/icon/iconUtils` handles all of this logic and will generate the appropriate icon HTML for you.

## Known Limitations

### Incorporating premade widgets to stock themes

Say you have an HTML widget you've already built, completely outside the context of Niagara or `bajaux`, and you wish to port it over as a `bajaux` widget. You might want to apply one set of CSS rules to your widget for the Zebra theme, and a different set for Lucid.

At the moment, there is no way to do this. You will have to change the HTML structure of your widget so that it uses the standard set of `ux` classes, or else it will appear the same in all the default themes.

You can still style the widget as you wish using your own custom theme.

## Niagara Web Modules

In Niagara 4 standard Java Web Server technology can be used.

The Web Server currently being used is [Jetty](#). Jetty is built around the standard Java Servlet Specification.

Currently, the Jetty supports version 3 of the Java Servlet Specification. Currently we're not supporting the newer Servlet annotations; a Web XML descriptor must be used instead.

In Niagara AX, there are two other ways of creating Java Servlets. These are still supported in Niagara 4...

- [Servlet Views](#): create a view that is also a Servlet.
- [Web Servlet Components](#): create a component that's also a Servlet.

## Niagara 4

Please note that applications using [BWebServlet](#) and [BServletView](#) are still and will continue to be supported. From Niagara 4, we've additionally added support for adding standard Java Servlets that extend [javax.servlet.http.HttpServlet](#).

Please click [here](#) for more information on using Java Servlets.

### My First Niagara Web Module

Here's how you can create a Niagara Module that extends a standard `javax.servlet.http.HttpServlet` class...

- In your Niagara Module, add a class that extends `javax.servlet.http.HttpServlet`.
- Override `doGet` or any other HTTP verb related methods to handle implementation.
- There's no WebOp. If this Servlet is using Niagara Security, you can call the following `HttpServletRequest` methods...
  - `getUserPrincipal()`: cast this to a `BUser`.
  - `getLocale()`: returns a `java.util.Locale` object. Use the `forLanguageTag` and `toLanguageTag` methods to get the Locale to and from a String. Please note that `javax.baja.util.Lexicon` has a `make` method that takes a Locale object. Use a combination of these two methods to create an instance of `javax.baja.sys.BasicContext`. Please note, NCCB-7051 will address some of the issues concerning country and variant.
- In your module's src directory, add a directory called `WEB-INF`.
- In this folder, create a file called `web.xml`.
- In your module's gradle file, remember to add an entry to pick up the .xml files that will be created. For example...

```
jar {
    from('src') {
        ...
        include 'WEB-INF/*.xml'
    }
}
```

- Here's a sample `web.xml` file that plugs a Servlet into our new Web architecture...

```
<?xml version="1.0" encoding="UTF-8"?>
<web-app>
  <servlet>
    <servlet-name>testServlet</servlet-name>
    <servlet-class>mypackage.TestServlet</servlet-class>
  </servlet>
  <servlet-mapping>
    <servlet-name>testServlet</servlet-name>
    <url-pattern>/test/*</url-pattern>
  </servlet-mapping>
</web-app>
```

- The Servlet java class is plugged into the specified URL pattern. It's a URL pattern and not just a servlet name like

in Niagara AX. This gives developers far more flexibility.

- The \* in the pattern means that anything after /test/... will also be picked up by this Servlet. This is very useful if you're making a RESTful API. The XML listed here is all part of the J2EE standard. There's nothing specific to the Jetty implementation.

Now try building your module and starting up a Station. On Station start up, the Servlets will be automatically installed into the Web Server. No more configuration is required. Once the Station has started, the URL to access the Servlet would be in the following format...

```
http://localhost/moduleName/test
```

Or as we're also using a \* in the URI pattern...

```
http://localhost/moduleName/test/whatever/foobar
```

- By default, the name of the module is used for the Context Path.
- The Servlet Path is specified in the web.xml file. In this case it's 'test'. The path after the Servlet Path is known as the Path Info. Typically this is what you use in your Servlet. Please never call `HttpServletRequest#getRequestURI()` (as is typically done in AX). Servlets should be relative and reusable. Most of the time they really don't need to know about their precise plug point within a Web Server!

### Changing the Context Path

To change the Context Path of the Servlet we need to add one more XML file alongside web.xml called jetty-web.xml. This file configures functionality specific to the Jetty Web Server that can't be done via web.xml. By default, using the Niagara Module name is used for Context Path. This is a sound way to try and create a unique path mapping for a web application. This can be changed with the following jetty-web.xml file...

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<!DOCTYPE Configure PUBLIC "-//Jetty//Configure//EN"
"http://www.eclipse.org/jetty/configure.dtd">
<Configure id="webApp" class="org.eclipse.jetty.webapp.WebAppContext">
  <!-- Change the Context Path from the module name to something else -->
  <Set name="contextPath">/somethingelse</Set>
</Configure>
```

- Note the contextPath has been added to the file.
- Once built, the URI would change to `http://localhost/somethingelse/test/whatever`.

### Filters

As well as Servlets, developers can now use `javax.servlet.Filter`.

- A class that implements the `Filter` interface can intercept HTTP Requests before they get to their Servlet.
- They can also process the responses out of a Servlet.
- They can have initialization parameters.
- They can be plugged in via some web.xml.
- They're also great for monitoring and profiling Web Server performance.

Click [here](#) for more information on using Java Filters.

### How can I use a proper WAR file?

This isn't currently supported in Niagara 4.0.

## BServletView

### Overview

A [Servlet View](#) is Niagara view that typically generates HTML.

Alternatives to extending [BWebServlet](#) are...

- [BServletView](#): used by developers who want to create Web Views on Components.
- [Java Servlets](#): create standard Java Servlets.

Please note...

- [BHxView](#) extends [BServletView](#) and may be a preferred alternative. Click [here](#) for more information on creating Hx Views.
- In Niagara 4's new [Open Web architecture](#), you can create client side views in JavaScript. You may find this a better alternative than traditional Server Side Servlet programming for User Interfaces.

A developer creates a Servlet View in the following way...

- Extend `javax.baja.sys.BServletView`.
- Override `doGet` or any other HTTP verb related methods to handle implementation.
- Register the View as an Agent on the desired Niagara Type.

A few things to note about `BServletView`...

- `BServletView` extends `BSingleton`. Therefore, there's only ever one instance of a View.
- `BHxView` extends `BServletView`.

### Example

Here's an example of a Servlet View that will be rendered in a web browser when the user navigates to the `UserService`. Please note, in this case the view is declared as an Agent on `baja:UserService`.

```
public final class BMyFirstServletView extends BServletView
{
    private BMyFirstServletView() {}
    public static final BMyFirstServletView INSTANCE = new BMyFirstServletView();

    @Override
    public Type getType() { return TYPE; }
    public static final Type TYPE = Sys.loadType(BMyFirstServletView.class);

    @Override
    public void doGet(WebOp op) throws Exception
    {
        op.getWriter()
            .w("<!DOCTYPE html>").nl()
            .w("<html>").nl()
            .w("<head></head>").nl()
            .w("<body>").nl()
            .w("<h1>Hello World!</h1>").nl()
            .w("</body></html>");
    }
}
```

## BWebServlet

### Overview

A [Web Servlet](#) is a Component that can be added to a Station. Alternatives to creating a [Web Servlet](#) are [Servlet View](#) and standard [Java Servlets](#).

Once a Web Servlet has been added to a Station and is operational...

- The Servlet can be accessed from the Web Server via its Servlet name.
- The Servlet utilizes Niagara's Security Model. This is a great way to limit access to the Servlet.
- The Servlet Component can be removed from the Station. Once removed, the Servlet is no longer active.

To create a Web Servlet in Niagara AX, a developer has to...

- Extend [javax.baja.web.BWebServlet](#).
- Define a Servlet name.
- Override doGet or any other HTTP verb related methods to handle implementation.

A user adds the Servlet Component to a Station via a palette file.

### Example

This is a simple Web Servlet that can be accessed in a browser via <https://localhost/myFirstServlet...>

```
@NiagaraType
@NiagaraProperty(
    name = "servletName",
    type = "baja:String",
    flags = Flags.READONLY,
    defaultValue = "myFirstServlet"
)
public final class BMyFirstWebServlet extends BWebServlet
{
    /*+ ----- BEGIN BAJA AUTO GENERATED CODE ----- +*/
    /*@ $com.tridium.web.servlets.BMyFirstWebServlet(522312782)1.0$ @*/
    /* Generated Wed May 13 12:49:26 BST 2015 by Slot-o-Matic (c) Tridium, Inc.
    2012 */

    //////////////////////////////////////
    // Property "servletName"
    //////////////////////////////////////

    /**
     * Slot for the {@code servletName} property.
     * @see #getServletName
     * @see #setServletName
     */
    public static final Property servletName = newProperty(Flags.READONLY,
        "myFirstServlet",null);

    /**
     * Get the {@code servletName} property.
     * @see #servletName
     */
    public String getServletName() { return getString(servletName); }

    /**
     * Set the {@code servletName} property.
     * @see #servletName
     */
}
```

```

    public void setServletName(String v) { setString(servletName,v,null); }

    //////////////////////////////////////
    // Type
    //////////////////////////////////////

    @Override
    public Type getType() { return TYPE; }
    public static final Type TYPE = Sys.loadType(BMyFirstWebServlet.class);

    /*+ ----- END BAJA AUTO GENERATED CODE ----- +*/
    @Override
    public void doGet(WebOp op) throws Exception
    {
        op.getWriter().
            .w("<!DOCTYPE html>").nl().
            .w("<html>").nl().
            .w("<head></head>").nl().
            .w("<body>").nl().
            .w("<h1>Hello World!</h1>").nl().
            .w("</body></html>");
    }
}

```

## Apache Velocity

Apache Velocity is an open source web template engine that's now integrated into the Niagara framework. It provides users with the ability to script an HTML page together using a very simple scripting language.

For more information on understanding what Velocity is, please visit the Apache website [here](#).

The user guide for using Velocity can be found [here](#).

Velocity support was added to Niagara AX in version 3.7.

### Users

The Velocity API is not just for developers but can also be used by advanced users. Advanced users can take advantage of Velocity through Station Components that one can configure from the `axvelocity` palette.

### Velocity Station Components

*The AX Velocity Station Components require the 'axvelocity' license feature.*

There are multiple ways to use Velocity. Advanced users (who aren't necessarily fully trained Niagara developers) can configure a Station using Components from the `axvelocity` palette.

### Getting Started

- Create a new Station
  - Add a NumericWritable and BooleanWritable to the root of the Station.
  - Open the `axvelocity` palette and drag and drop the VelocityServlet into the Station.
- Double click the Servlet, this opens the Velocity Document Manager View.
- In this view, the name of the Servlet can be set and new Velocity Document Components can be created.
- Create a new Velocity Document Component.
  - Make sure the template file for the Document Component is `file:^test.vm`.
  - This text file will be located in the root of the Station's file system.
  - Create this file using Workbench but leave it blank for now.
  - Double click on the newly created Document Component, this will load the Velocity Context Element Manager View.
- Create two Velocity Context Ord Elements.
  - Set the ORD Property on one of the Elements to point to the NumericWritable you created earlier. The name of the Element should be `numPoint`.
  - Set the ORD Property of the other Element to point to the BooleanWritable you created earlier. The name of the Element should be `boolPoint`.
- Now edit the `vm` file you created earlier.
  - This file will contain the HTML for our web view as well as some VTL (Velocity Template Language) script to dynamically generate part of the web page.
  - We're now going to reference the two points (via the Velocity Context ORD Elements) we created earlier.
  - Use this HTML in the view...

```
<pre>
<!DOCTYPE html>
<html>
  <head>
    <title>My first Velocity test!</title>
  </head>
  <body>
    <p>Boolean Point: $boolPoint</p>
    <p>Numeric Point: $numPoint</p>
  </body>
</html>
```

```
</pre>
```

- Save the text file.
- Open a web browser and log on to Niagara. Logging on as admin will do.
- Change the URL to point to `http://localhost/velocity/test` (localhost can be changed to an IP address of your choice).
  - Note that `velocity` is the name of the servlet.
  - Note that `test` is the name of the Document Component you created earlier.
- The page should now load.
  - Note how the HTML typed in the `vm` file has been used for this view.
  - Note how `$boolPoint` and `$numPoint` has been replaced with real point data.

### Component Description

- **VelocityServlet:** the Servlet used by the Web Service to generate the web based view. The Servlet is accessed through a Web Browser by `http://yourIpAddress/velocity`. Please note the name of the Servlet can be changed from 'velocity' to something else in the Velocity Document Manager View. The Velocity Document Manager is the default view for this Component.
- **VelocityDoc:** a Document Component has a reference to a VM file and acts as a container for Velocity Context Elements. The VM file contains the HTML and VTL script used to generate a web page.
- **VelocityContextOrdElement:** this Component has an ORD Property that's used to point to another Component in the Station. The name of the Element is used in the VTL file so it can be referenced.
- **VelocityDocWebProfile:** this is a Web Profile a user can select for VelocityDoc Components. If the VelocityDoc Component has its `useProfile` Property set to true, this Profile will be used to generate the outer HTML page. For more information, please see the section on profiling.

### Security

Only a user with operator read permissions on a VelocityDoc Component can access that through the Velocity Servlet.

### Navigation

Accessing a particular VelocityDoc through a browser can be done in a variety of ways. For example...

*The velocity Servlet name can be changed by a user.*

- `http://localhost/velocity` - this will redirect to the first valid VelocityDoc that can be found for the user.
- `http://localhost/velocity/test` - this will load the VelocityDoc named `test`.
- `http://localhost/ord?station:%7Cslot:/VelocityServlet` - this will redirect to the first valid VelocityDoc that can be found for the user.
- `http://localhost/ord?station:%7Cslot:/VelocityServlet%7Cview:test` - this will redirect to the VelocityDoc named `test`.
- `station:|slot:/VelocityServlet|view:test` - an ORD that can be used as a hyperlink in a Px page. This will redirect to the VelocityDoc named `test`.

*Specifying the ORD to the Servlet Component in a NavFile is a really great way to get to your VelocityDoc using Niagara.*

### View parameters

Parameters can be passed into a view via a URI (or ORD that redirects to a URI). For instance...

- `http://localhost/velocity/test?param1=val1&param2=val2` - passes two parameters into a view.
- `station:|slot:/VelocityServlet|view:test?param1=val1;param2=val2` - an ORD that can be used as a hyperlink in a Px page. This will redirect to the VelocityDoc named `test` with the specified parameters.

The parameters can be picked up from VTL code. For example...

```
## Iterate through any query parameters used in the URL
#set( $parameters = $ax.op.getRequest().getParameterNames() )
#foreach ( $param in $parameters )
```



```
<p>
    Found parameter: $param - $ax.op.getRequest().getParameter($param)
</p>
#end
```

## Profiling

Profiling is an advanced feature of working with VelocityDoc Station Components. A Profile generates the outer HTML content while the VelocityDoc generates the inner.

### Getting Started

- Create a user who has their Default Web Profile set to Velocity Doc Web Profile.
  - Create a VM file for the profile (i.e. file: ^profile.vm). The VM file should have code similar to the following...
  - Set the Template File ORD on the Profile to this VM file.

```
<pre>
<!DOCTYPE html>
<html>
  <head>
    <title>Velocity Profile</title>
    #set($generateHeader = true)

    ## Parse the inner view for the header...
    #parse("$ax.viewTemplate")

    #set($generateHeader = false)
  </head>
  <body>
    <h2>Path: $ax.target.getPathInfo()</h2>

    ## Parse the inner view for the header...
    #parse("$ax.viewTemplate")

  </body>
</html>
</pre>

* The Profile creates the outer HTML and then calls
`#parse("$ax.viewTemplate")` to the inner HTML.
* Note how the `$generateHeader` flag is used to determine whether the header
of the body of the HTML document is being generated.
```

- Create a VelocityDoc Component that has its useProfile Property set to true.
  - When the VelocityDoc Component view is accessed through a browser (with the Profile we've just set up), the VelocityDoc will rely on the Profile generating the outer HTML.
  - If the VelocityDoc's useProfile Property is set to false, the VelocityDoc is responsible for generating the whole of the HTML document (just as before).
  - Here's an example of the VTL for the VelocityDoc's VM file...

```
<pre>
#if ($generateHeader)
  ## Anything for the header of the HTML page goes here.
#else
  ## Anything for the body of the HTML page goes here.
  <h3>This is from the body of the view</h3>
#end
</pre>
```

\*Note how the \$generateHeader (created by the Profile) is used to determine whether code is being generated for the HTML document's header or body.

*The 'Velocity Doc Web Profile' must always be used to access VelocityDoc views that have their 'useProfile' Property set to true!*

## Standard Velocity Java API

Velocity can be used by Java developers to create Velocity based views. A developer who uses this API should have been on the Developer Course and hence should be a fully trained Niagara Jedi.

### BVelocityView

BVelocityView extends BServletView. This class forms the basis for any Velocity based view. A view may or may not work in conjunction with a BVelocityWebProfile.

### Getting Started

- Create a new class that extends BVelocityView.
- Implement the `getTemplateFileMethod`.
  - This method will return an ORD to a file resource that contains the HTML and VTL (Velocity Template Language) used to generate the HTML.
  - For debugging, it might be easier to point this to a file in your local Station's file system.
  - For distribution, it's best to reference a file from a Niagara module (using the `module` ORD scheme).
- Override the `initVelocityContext` method.
  - Overriding this method allows a developer to inject new things into a VelocityContext.
  - Anything added to the VelocityContext can be referenced from VTL.

### BVelocityWebProfile

An interface used by any profile that wants to act as a Velocity Web Profile.

### BVelocityWebProfile

A Web Profile that implements BVelocityWebProfile.

A Velocity Web Profile has it's own VM file used to render the overall page. In the Velocity Context, there's a symbol called `$ax.viewTemplate` that be then be used by the profile VTL to render the underlying view.

### VelocityContextUtil

This is a useful library of functions that can be called via VTL. In VTL, this library can be referenced via '\$ax.util' or '\$util'. For more information on use please see Niagara VTL.

## Hx Velocity Views

To enhance Hx development, some Hx Velocity views have been added.

In Hx development, a developer would normally write out an Hx view's initial HTML by overriding BHxView's `write` method. In the following Velocity Hx classes, this method has already been overridden and will return output from Velocity.

### BVelocityHxView

This class extends BHxView.

This class follows the same design as BVelocityView.

*Note: the HxOp can be referenced from the VTL from `$ax.op`. For instance, `$ax.op.scope( ' idOrName ' )`.*

### BVelocityHxFieldEditor

An Hx Field Editor that uses Velocity.

### BVelocityHxPxWidget

An Hx Px Widget that uses Velocity.

## Niagara VTL

Common to all Velocity based views are some really useful Niagara related methods and properties that are accessed through the Velocity Context.

### Use Cases

There's a LOT we could add to the VelocityContext. However, to try and stem the tide, we've developed this feature around the following use cases...

\*For anything 'live', please consider using BajaScript. It does all of the 'live' things (like invoking an Action for instance) that Velocity isn't designed to do!

- To print out the value of a point. This includes any facets for units, precision etc.
- To resolve an ORD to a point and print out its value.
- To resolve an ORD with a base and print out its value.
- To resolve an ORD to a table.
  - To then be able to iterate through the results.
  - To generate an HTML table from the results.
  - To print out fully localized display Strings of each value in the table (i.e. that use any necessary units and precision).
- To create a hyperlink from an ORD or mounted Component.
- To print out translated values from a Lexicon.
- To print out translated values from a Lexicon (with parameters).
- To iterate through a Component's children.
  - To iterate through a Component's children of a specific Type.
- To test with a particular value is of a certain Type.
- To detect whether a Property should be hidden.
  - This includes checking for the hidden Slot flag as well as Types we never typically want the user to see (i.e. BLink, BNameMap (displayNames) and BWsAnnotation).
- To detect whether a user has appropriate read, write and invoke security permissions on a particular Slot or Component.
- To easily be able to include BajaScript into a Velocity View.
- To easily be able to include jQuery into a Velocity View.

### API

The core Niagara Velocity related methods and properties are part of the `$ax` namespace. Some sub-namespaces (i.e. `$ax.util`) are consider so useful that we've also added them to the global namespace (i.e. `$util`).

#### Core ax namespace

- `$ax.session`: the HttpSession being used to the current request.
- `$ax.target`: the OrdTarget for the current request.
- `$ax.cx`: the Context for the current request.
- `$ax.op`: the WebOp for the current request.
- `$ax.obj`: the resolved object for the current request (from `OrdTarget#get ( )`).
- `$ax.profile`: the web profile being used.
- `$ax.Flags`: `javax.baja.sys.Flags`.
- `$ax.lang`: the language for the current request.
- `$ax.user`: the user for the current request.

#### Util namespace

This can be accessed via `$ax.util` or `$util`.

All methods are fully listed (and commented) in `javax.baja.velocity.VelocityContextUtil`.

The methods are designed to be easy to use and in some cases can take a variety of argument Types (just like in JavaScript).

For convenience here's an overview...

### Value Access

- `$util.get("station:|slot:/")`: resolves an ORD returns the object. If the result is a mounted Component, it will be leased.
  - The argument can be a String or an BOrd.
  - If this ORD resolves to a table, then an array will be returned that can be iterated through.
- `$util.get("slot:BooleanWritable", "station:|slot:/")`: same as above except this can also take a base to help ORD resolution.
- Specifying a base is great for creating reusable VM files.
  - The base can be an BOrd, String (that get resolves as an BOrd) or a BObject that will get used to resolve the ORD.
- `$util.resolve("station:|slot:/")`: same as 'get' except this resolves to an OrdTarget.
- `$util.resolve("slot:BooleanWritable", "station:|slot:/")`: same as 'get' except this resolves to an OrdTarget.
- `$util.getChildren(complex)`: return an array of children of a BComplex.
  - The argument can be BComplex or a BOrd (or String) that resolves to a BComplex.
- `$util.getChildren(complex, "myModule:MyType")`: return an array of children from a Complex of a specific Type.
  - The first argument can be BComplex or a BOrd (or String) that resolves to a BComplex.
  - The second argument can be a Type or String to filter what children are returned.
- `$util.is(complex, "myModule:MyType")`: returns a boolean indicating whether the specified value is of the specified Type.
  - The second argument can be a Type or String.

### Misc

- `$util.ord("station:|slot:/", "bql:select * from baja:Component")`: creates a normalized ORD from a base and child. The argument can be BOrd or String.
- `$util.lex("bajau").get("dialog.ok")`: get a Lexicon value.
  - `$util.lex("bajau").getText("fileSearch.scanningFiles", "first", "second")`: get a Lexicon value with parameters.
  - Please note that `$util.lex("bajau")` simply returns the Lexicon for the given module name.
- `$util.requirejs()`: adds require js support. You need to add this at the top of the document if you want to use BajaScript or any of the new web technologies added to Niagara 4.

### Display

- `$util.getDisplay(complex)`: returns a display string for the given complex.
  - The argument can also be an BOrd (or String that get resolves as an BOrd) that resolves to a BComplex.
- `$util.getDisplay("slot:BooleanWritable", base)`: returns a display string for the given complex. If an ORD is specified as the argument then the base is used to help resolve it.
  - The first argument can also be an BOrd (or String that get resolves as an BOrd) that resolves to a BComplex.
  - The base argument can be a BOrd (or String that get resolves as a BOrd) or a BObject used to help resolve any ORDs.
- `$util.getDisplayFromProperty(complex, prop)`: returns a display string for the given complex and Property.
  - The first argument can also be an BOrd (or String that get resolves as an BOrd) that resolves to a BComplex.

The second argument can be a Property or a Property name (String).

- `$util.getDisplayFromProperty(complex, prop, base)`: returns a display string for the given complex and Property.
  - The first argument can also be a BOrd (or String that get resolves as an BOrd) that resolves to a BComplex.
  - The second argument can be a Property or a Property name (String).
  - The base argument can be a BOrd (or String that get resolves as a BOrd) or a BObject used to help resolve any ORDs.

### Slot Access

- `$util.isHidden(complex, slot)`: returns a boolean indicating whether the specified slot should be hidden.
  - The first argument can be a BComplex or a BOrd (or String) that resolves to a BComplex.
  - The second argument can be a Slot or a Slot name (String).
  - This method will also filter out Types that aren't typically shown on a Property Sheet (i.e. BWsAnnotation, BLink and BNameMap (displayNames)).
- `$util.canRead(component)`: returns a boolean whether the currently logged on user has read permissions on the specified Component.
  - The argument can be BComponent or BOrd (or String) that resolves to a BComponent.
- `$util.canRead(component, slot)`: returns a boolean whether the currently logged on user has read permissions to access the specified Slot.
  - The first argument can be BComponent or BOrd (or String) that resolves to a BComponent.
  - The second argument can be a Slot or a Slot name (String).
- `$util.canWrite(component, slot)`: returns a boolean whether the currently logged on user has write permissions to access the specified Slot.
  - The first argument can be BComponent or BOrd (or String) that resolves to a BComponent.
  - The second argument can be a Slot or a Slot name (String).
- `$util.canInvoke(component, slot)`: returns a boolean whether the currently logged on user has invoke permissions to access the specified Slot.
  - The first argument can be BComponent or BOrd (or String) that resolves to a BComponent.
  - The second argument can be a Slot or a Slot name (String).

### jQuery

- `$util.jquery()`: returns the HTML script tag to include jQuery.

## Velocity Px Views

This document follows on from the core [velocity](#) documentation.

In 3.8, a new feature was added that allows non-Java programmers to create dynamic Px Views (Px Views that are created on the fly). By using the Velocity, to create Px XML, customers have new flexibility in creating graphical views. This feature is intended for advanced Niagara users who want more dynamic graphics and navigation without having to use Java.

*This feature does require the 'axvelocity' license feature.*

### Getting Started

- In a Station, create a folder.
- Add some points to the folder.
- Go to create a new Px View on the folder.
- Click the Dynamic View option.
- Select the axvelocity:VelocityPxView option and click OK.
- Create a Px file on the file system.
- Using the Px Editor, create your basic template page.
- Exit the Px editor and rename the file to the extension pxvm.
- Please note that from this point onwards, the Px File can no longer be edited using the Px Editor.
- Using the Property Sheet, navigate to the newly created Velocity Px View.
- Set the Px Velocity Template File to point to the newly created pxvm file.
- Load the view and note how it's rendered the Px page.
- Now edit the Px view and add some VTL to script the creation of the Px file. Here's an example...

```
<pre>
<?xml version="1.0" encoding="UTF-8"?>
<!-- Niagara Presentation XML -->
<px version="1.0" media="workbench:WbPxMedia">
<import>
  <module name="baja"/>
  <module name="bajau"/>
  <module name="gx"/>
  <module name="converters"/>
</import>
<content>
  <ScrollPane>

    <CanvasPane name="content" viewSize="500.0,400.0" background="#c0c0ff">

      #set( $kids = $util.getChildren($ax.obj, "baja:Component") )

      <GridPane layout="10.0,10.0,480.0,380.0" columnCount="1" rowGap="20">

        #foreach($k in $kids)
          <Label>
            <ValueBinding ord="$k.getSlotPathOrd()"
hyperlink="$k.getSlotPathOrd()">
              <ObjectToString name="text" format="%displayName%: %.%"/>
            </ValueBinding>
          </Label>
        #end

      </GridPane>

    </CanvasPane>
  </ScrollPane>
</content>
</px>
```

```

    </ScrollPane>
  </content>
</px>
</pre>

```

This file will now create the navigation and labels for the points dynamically.

In conclusion, Velocity Px Views are very powerful but can be cumbersome without the initial use of the Px Editor to create the overall look and feel for the Px View.

## PxIncludes

In order to make the page more manageable, it's best to use this in conjunction with PxIncludes. The PxInclude Px file can then still be edited. For example, in this example the 'include.px' file can still be edited...

```

<pre>
  <?xml version="1.0" encoding="UTF-8"?>
  <!-- Niagara Presentation XML -->
  <px version="1.0" media="workbench:WbPxMedia">
    <import>
      <module name="baja"/>
      <module name="bajau"/>
      <module name="gx"/>
      <module name="converters"/>
    </import>
    <content>
      <ScrollPane>

        <CanvasPane name="content" viewSize="500.0,400.0" background="#c0c0ff">

          #set( $kids = $util.getChildren($ax.obj, "baja:Component") )

          <GridPane layout="10.0,10.0,480.0,380.0" columnCount="1" rowGap="20">

            #foreach($k in $kids)
              <PxInclude ord="file:^px/include.px" variables="val=s:$k.getName()" />
            #end

          </GridPane>

        </CanvasPane>

      </ScrollPane>
    </content>
  </px>
</pre>

```

## Querying the Media

The Px Media being used can be queried in Velocity. This is useful for dynamically creating Px Views for a Mobile experience that may require less Widgets...

```

<pre>
  #if ($ax.pxView.isMobileMedia())
    <Label text="Mobile Media is set!"/>
  #elseif ($ax.pxView.isHxMedia())
    <Label text="Hx Media is set!"/>
  #elseif ($ax.pxView.isReportMedia())
    <Label text="Report Media is set!"/>
  #elseif ($ax.pxView.isWorkbenchMedia())
    <Label text="Workbench Media is set!"/>
  #end
</pre>

```

## Why Velocity Px Views?

A Px file with Velocity code in allows graphics to be created on the fly without the aid of a Java programmer. Unfortunately, any Px file with VTL code can't be edited by the Px Editor. That's why PxIncludes are recommended to make this less cumbersome. The feature is intended for advanced users and covers the following use cases...

- Dynamically created navigation
- Reports



# Control

## Overview

The control module provides normalized components for representing control points. All control points subclass from the [BControlPoint](#) base class. Control points are typically used with the driver framework to read and write points in external devices.

There are four normalized categories of data matching the four `BStatusValue` types. Within each of the four categories is a readonly component and a writable component. These eight components are:

Type	Mode	Data
<a href="#">BBooleanPoint</a>	RO	Models boolean data with <code>BStatusBoolean</code>
<a href="#">BBooleanWritable</a>	RW / WO	Models boolean data with <code>BStatusBoolean</code>
<a href="#">BNumericPoint</a>	RO	Models numeric or analog data with <code>BStatusNumeric</code>
<a href="#">BNumericWritable</a>	RW / WO	Models numeric or analog data with <code>BStatusNumeric</code>
<a href="#">BEnumPoint</a>	RO	Models discrete values within a fixed range with <code>BStatusEnum</code>
<a href="#">BEnumWritable</a>	RW / WO	Models discrete values within a fixed range with <code>BStatusEnum</code>
<a href="#">BStringPoint</a>	RO	Models unicode strings with <code>BStatusString</code>
<a href="#">BStringWritable</a>	RW / WO	Models unicode strings with <code>BStatusString</code>

## Design Patterns

All control points use `BStatusValues` to represent their inputs and output. All points have one output called "out". The readonly points contain no inputs. Typically they model a value being read from a device via the driver framework.

The writable points all contain 16 inputs and a fallback value. These 16 inputs are prioritized with 1 being the highest and 16 being the lowest. The value to write is calculated by finding the highest valid input (1, 2, 3, down to 16). An input is considered valid if none of the following status bits are set: disabled, fault, down, stale, or null. If all 16 levels are invalid, then the fallback value is used. Note that the fallback value itself can have the null bit set in which case the point outputs null. The active level is indicated in the output as a status facet.

Each of the writable points reserves level 1 and level 8 for user invoked overrides. Level 1 is an emergency override which when invoked remains in effect permanently until the emergencyAuto action is invoked. Level 8 overrides are for normal manual overrides. Manual overrides may be timed to expire after a period of time, or may be explicitly canceled via the auto action. Whenever level 1 or 8 is the active level then the overridden status bit is set in the output. If a timed override is in effect then the `overrideExpiration` property indicates when the override will expire.

## Extensions

Extensions provide building blocks to extend and change the behavior of control points. Every extension must derive from [BPointExtension](#). They are added as dynamic properties on a control point. Extensions can process and modify the value of a control point whenever it executes. For example, an alarm extension can monitor the value and set the alarm

bit of the output's status if an alarm condition was detected. A list of extensions include:

- [BDiscreteTotalizerExt](#)
- [BNumericTotalizerExt](#)
- [BProxyExt](#)
- [BAlarmSourceExt](#)
- [BIntervalHistoryExt](#)
- [BCovHistoryExt](#)

Extensions are always invoked in the order they are declared in the slot list. They may be reordered using the standard reorder API and workbench commands.

When the execute method is invoked on a [BControlPoint](#), the `pointChanged(ControlPoint pt)` method is in turn invoked on each extension.

Note that when using extensions with driver proxy points, only the value being read is processed by extensions.

## History

### Overview

Refer to the [javax.baja.history](#) API.

The History module manages the storage, collection, and archiving of data logs (historical data). A data log in Niagara is often referred to as a Baja history (or history for short) and is an implementation of [BIHistory](#). Within Niagara, histories can be accessed locally or remotely (via Niagara's Fox communication). The History API provides the basis for creating, configuring, modifying, accessing, and deleting histories. The [Driver History](#) API provides the means for archiving histories (pulling/pushing histories from one station to another).

In order to provide support for a database of histories in a Niagara station, the History Service must be added ([BHistoryService](#)). It is responsible for creating the database and enables collection and storage of histories in the database. Once the History Service is in place, the basis for managing access to histories in the database is through the History Space ([BHistorySpace](#)). Whenever you wish to gain access to a history, it is handled by resolving through the [BHistorySpace](#). [BHistoryDatabase](#) is a local implementation of [BHistorySpace](#). It handles opening and closing history files as they are needed and also provides efficient access to these files.

### Access

As mentioned, in order to access histories in the database, you must first gain access to the database itself. This is done by resolving the history ord scheme (as defined by [BHistoryScheme](#)). The unique history scheme name is "history". Refer to the [Naming](#) documentation for details on Niagara's naming system. For example, if you want to access a history named "TestLog" in a station's database (the station being named "demo"), your ord would contain the query, "history:/demo/TestLog". You will notice that histories are organized by their source station (device), or [BHistoryDevice](#).

When a history is retrieved from the database, it is always an implementation of [BIHistory](#). [BIHistory](#) is used with a [HistorySpaceConnection](#) to provide access to the following:

- The history's identification. Histories are uniquely identified by a String identification composed of two parts, the source device name and the history name. This identification information is encapsulated in [BHistoryId](#). For example, if you have a history named "TestLog" and it is located under the local station named "demo", the history id would be the combination of device (station) name and history name: "demo/TestLog". *Note:* For convenience when importing/exporting histories between Niagara stations (refer to [Driver History](#)), you can use the shorthand character '^' to refer to the parent device name. For example, if you are exporting a local history generated by the local station, the shorthand representation for the previous example would be: "^TestLog".
- Summary information about the history. This information is encapsulated in [BHistorySummary](#). It provides such things as the history ID, number of records in the history, the timestamp of the first record in the history, and the timestamp of the last record in the history.
- The type of records in the history. This is normally a concrete type of [BHistoryRecord](#) which will be described in more detail later.
- The configuration of the history. This is defined in [BHistoryConfig](#) which will be described in more detail later.
- The data in the history itself. It provides support for scanning the records in the history, performing a time based query for records, and appending or updating records within the history.

A history contains records which are keyed by timestamp. A record is an instance of [BHistoryRecord](#) which supplies the timestamp key (records can always be identified by timestamp) and implements the [BIHistoryRecordSet](#) interface (always a set of 1 for a single history record). A [BTrendRecord](#) is a special extension of a [BHistoryRecord](#) which adds two more tidbits of information to a history record: trend flags ([BTrendFlags](#)) and status ([BStatus](#)). Trend flags are used to provide extra context information about the record data, such as the starting record, out of order records, hidden records, modified records, or interpolated records. The status ("ok", "alarm", "fault", etc.) is associated with the collected data value. The standard Niagara data value types are supported via extensions of [BTrendRecord](#): [BBooleanTrendRecord](#), [BEnumTrendRecord](#), [BNumericTrendRecord](#), and [BStringTrendRecord](#).

*Note:* When a [BIHistory](#) is scanned or queried for its data records, it most often returns a [Cursor](#) ([HistoryCursor](#)) or a [BICollection](#). When iterating through this [Cursor](#) or [BICollection](#), it is important to note that it returns the same instance of [BHistoryRecord](#) for each iteration. This is done for performance reasons. So, if you need to store the records for later use as you iterate through them, be sure to make a copy of the instance (you can use the `newCopy()` method).

You can also query the database via a history ordQuery as defined in [HistoryQuery](#). This allows you to find histories and filter the data returned.

## Configuration and Collection

When a user is ready to start logging data in Niagara, the most common way accomplish this is by adding a concrete instance of a history extension ([BHistoryExt](#)) to a control point. This is just like adding any point extension ([BPointExtension](#)) to a control point, extending its behavior. BHistoryExt is an extension of BPointExtension, however it also implements the [BIHistorySource](#) interface which allows it to be the creator of a history. BHistoryExt is an abstract class which provides the following among other things:

- The configuration of the history to create. This information is contained in a [BHistoryConfig](#) instance. It contains the following:
  - The unique identifier for the history within the entire system ([BHistoryId](#)).
  - The original source of the history.
  - The timezone where the history was originally collected.
  - The type of records contained in the history (i.e. [BBooleanTrendRecords](#), [BNumericTrendRecords](#), etc.).
  - The schema ([BHistorySchema](#)) for the records which allows the history to be read even if the original record type class has changed or is not available.
  - The amount of data that can be stored in the history ([BCapacity](#)).
  - The behavior when an attempt is made to write records to the (limited capacity) history that is already full ([BFullPolicy](#)).
  - The mechanism for storage of the history records ([BStorageType](#)).
  - The amount of time between records in the history ([BCollectionInterval](#)).
- The time period when the history extension should be collecting history records ([BActivePeriod](#)). This is normally a [BBasicActivePeriod](#) which allows the user to specify the days of the week and time of day that history records should be recorded.
- A definition of the pattern for deriving the name of the history created by the history extension. This property is of type [BFormat](#) and it can be static text or a simple pattern that allows the actual history name to be derived from the context.

There are two main types of BHistoryExts supported in the History module. These are the typed instances of [BCovHistoryExt](#) and [BIntervalHistoryExt](#). BCovHistoryExt provides support for collecting history records triggered on changes to the value of the parent control point while BIntervalHistoryExt provides support for collecting history records based on a user defined fixed interval.

## Compatibility

It is important to remember that there are two types of changes that an end user can make to a history extension (or BIHistorySource) to cause its history to be split (recreated with a new name). If the record type changes (i.e. a switch from numeric records to String records), this is an incompatible change. Another incompatible change is if the interval of collection changes. In both of these cases, the generated history will be split; the old history will keep its name, and the new history will have the same root name, but with a postfix ("\_cfg#") appended to the end of it. For example, if the history "TestLog" encounters an incompatible change, the old history will keep its records and the name "TestLog", while any new records will be placed in a new history named "TestLog\_cfg0". If yet another incompatible change occurs after the first, the next split will have the new history named "TestLog\_cfg1", and so on.

## Archiving

Refer to the [Driver History](#) documentation.

## History Exceptions

The History API defines a few standard history exceptions. These all extend from [HistoryException](#) which is a [BajaRuntimeException](#).

- A [ConfigurationMismatchException](#) is thrown when the properties of a BIHistory do not match the properties for that history that are stored in the actual database.

- A [DatabaseClosedException](#) is thrown when an operation is attempted on a history database that is not open.
- A [DuplicateHistoryException](#) is thrown when an attempt is made to create a history with an id that already exists.
- A [HistoryClosedException](#) is thrown when a history is closed at a time when it is expected to be open.
- A [HistoryDeletedException](#) is thrown when an attempt is made to access a history that has been deleted.
- A [HistoryNameException](#) is thrown when an attempt is made to create a history with an invalid name.
- A [HistoryNotFoundException](#) is thrown when a history cannot be found in the history database.
- An [IllegalConfigChangeException](#) is thrown when an attempt is made to reconfigure a history in an unsupported way.
- An [InvalidHistoryIdException](#) is thrown when an attempt is made to open a history without a valid history id.

## Changes From Niagara AX

In Niagara 4, the History API was re-factored to better support pluggable persistent storage. This allows for better scaling of the Niagara History Service since the JACE and the Supervisor are able to have different backing databases. The new API is connection oriented in order to better support the use to RDMS back-ends.

### javax.baja.history.BIHistory

The following methods have been moved to javax.baja.history.HistorySpaceConneciton and take a BIHistory as a parameter.

```
BHistorySummary getSummary()
int getRecordCount()
BAbsTime getFirstTimestamp()
BAbsTime getLastTimestamp()
BHistoryRecord getLastRecord()
void append(BIHistoryRecordSet)
void update(BHistoryRecord)
Cursor scan()
Cursor scan(boolean)
BITable timeQuery(BAbsTime, BAbsTime)
BITable timeQuery(BAbsTime, BAbsTime, boolean)
void flush()
```

### javax.baja.history.BHistorySpace

The following methods have been moved to javax.baja.history.HistorySpaceConneciton

```
boolean exists(BHistoryId)
void createHistory(BHistoryConfig)
void deleteHistory(BHistoryId)
void deleteHistories(BOrd[])
renameHistory(BHistoryId, String)
void clearAllRecords(BHistoryId, Context)
void clearAllRecords(BOrd[], Context)
void clearOldRecords(BHistoryId, Context)
void clearOldRecords(BOrd[], Context)
The following method was added to provide access to the HistorySpace
HistorySpaceConnection getConnection(Context)
```

### javax.baja.history.db.BHistoryDatabase

In addition to the methods from BHistorySpace, the following methods have been moved to javax.baja.history.db.HistoryDatabaseConnection

```
void doDeleteHistory(BHistoryId)
void doRenameHistory(BHistoryId, String)
void doCreateHistory(BHistoryConfig)
void recreateHistory(BHistoryConfig, boolean)
void resizeHistory(BHistoryId, BCapacity, BFullPolicy)
void reconfigureHistory(BHistoryConfig)
```

The following method was added to provide access to the HistoryDatabase

```
HistoryDatabaseConnection getDbConnection(Context)
```

### **javax.baja.history.HistorySpaceConnection**

The HistorySpaceConnection interface is AutoCloseable. It provides access to the HistorySpace and allows management of connection boundaries. Histories are obtained, queried and updated via the HistorySpaceConnection.

### **javax.baja.history.db.HistoryDatabaseConnection**

HistoryDatabaseConnection implements HistorySpaceConnection and provides additional methods and implementations for working with BHistoryDatabases.

## **Code Examples**

The following code examples highlight some of the History API changes between Niagara 4 and Niagara AX.

### **Add Records**

*Niagara AX*

```
BIHistory history = db.getHistory(historyId);
for (int i=0; i<records.length; i++)
{
    history.append(records[i]);
}
```

*Niagara 4*

```
try (HistoryDatabaseConnection conn = db.getConnection(cx))
{
    BIHistory history = conn.getHistory(historyId);
    for (int i=0; i<records.length; i++)
    {
        conn.append(history, records[i]);
    }
}
```

### **History Query**

*Niagara AX*

```
BIHistory history = db.getHistory(id);

BAbsTime startTime= history.getFirstTimestamp();
BAbsTime endTime = BAbsTime.make(2014, BMonth.JANUARY, 1);

BITable collection = history.timeQuery(startTime, endTime);
if (collection != null)
{
    Cursor cursor = collection.cursor()
    while (cursor.next())
    {
        BObject rec = cursor.get();
        if (rec instanceof BNumericTrendRecord)
        {
            displayRecord(rec);
        }
    }
}
```

*Niagara 4*

```
try (HistorySpaceConnection conn = db.getConnection(cx))
{
```

```

        BIHistory history = conn.getHistory(id);

        BAbsTime startTime = conn.getFirstTimestamp(history);
        BAbsTime endTime = BAbsTime.make(2014, BMonth.JANUARY, 1);

        BITable<BHistoryRecord> collection = conn.timeQuery(history, startTime,
endTime);
        if (collection != null)
        {
            try(Cursor<BHistoryRecord> cursor = collection.cursor())
            {
                while (cursor.next())
                {
                    BHistoryRecord rec = cursor.get();
                    if (rec instanceof BNumericTrendRecord)
                    {
                        displayRecord(rec);
                    }
                }
            }
        }
    }
}

```

## History Maintenance

### *Niagara AX*

```

        BHistoryConfig updatedConfig = makeNewConfig();

        // Update History Configs in target history
        if(db.getHistory(oldConfig.getId()) == null)
        {
            db.createHistory(updatedConfig);
        }
        else
        {
            db.reconfigureHistory(updatedConfig);
        }
    }
}

```

### *Niagara 4*

```

        BHistoryConfig updatedConfig = makeNewConfig();

        try (HistoryDatabaseConnection conn = db.getDbConnection(null))
        {
            // Update History Configs in target history
            if(conn.getHistory(oldConfig.getId()) == null)
            {
                conn.createHistory(updatedConfig);
            }
            else
            {
                conn.reconfigureHistory(updatedConfig);
            }
        }
    }
}

```

## Alarm

### Introduction

The Alarm module provides core functionality for lifecycle management of alarms within the Niagara Framework. Alarms are used to indicate that some value is not within an appropriate or expected range. Alarms may be routed from the system to a variety of external sources, be it email, a printer or a console application.

### Object Model

All alarms in the Niagara Framework are generated by objects implementing the [BAlarmSource](#) interface. Those alarms ([BAlarmRecord](#)) are then routed to the [BAlarmService](#). The service for storing and routing of alarms. Alarms are then routed to one or more recipients ([BAlarmRecipient](#)) via their [BAlarmClass](#).

### Alarm Sources

While [BAlarmSource](#) is an interface, most alarm sources are instances of `javax.baja.control.alarm.BAlarmSourceExt`, the alarm point extension. The alarm extension determines when it's parent point is in an alarmable condition, and uses the [AlarmSupport](#) class to take care of routing and issuing alarms to the alarm service. The alarm source updates the alarm when the parent point goes back to its normal condition as well as notifies the point that an acknowledgement has been received.

Objects implementing [BAlarmSource](#) that have a status ([BStatus](#)) should use the following rules when setting the status bits.

- Generate Offnormal alarm: set the `BStatus.ALARM` and `BStatus.UNACKED_ALARM` bits.
- Generate Fault alarm: set the `BStatus.ALARM`, `BStatus.UNACKED_ALARM` and `BStatus.FAULT` bits.
- AckAlarm methods is called: if the alarm is the last one generated clear the `BStatus.UNACKED_ALARM` bit.
- Generate Normal alarm: clear the `BStatus.ALARM` and `BStatus.FAULT` bits.

Note that `BStatus.UNACKED_ALARM` should only be set if the `BAlarmClass.ackRequired` bit is set for that transition in the AlarmSource's AlarmClass. This can easily be obtained if using the [AlarmSupport](#) class by calling `BAlarmSupport.ackRequired(BSourceState state)`.

### Alarm Service

The [BAlarmService](#) coordinates routing of alarms within the framework. It routes alarms from their source to the appropriate recipients, and alarm acknowledgements from the recipients back to the source. The alarm service routes individual alarms via their alarm class. All alarm classes available to the system are maintained as slots on [BAlarmService](#). The [BAlarmService](#) also maintains the Alarm Database. It is accessed though the `getAlarmDb()` method.

### Alarm Class

The alarm classes, as stated above, are maintained as slots on the alarm service and serve to route alarms with similar sets of properties along common routes - they serve as channels for like data. [BAlarmClass](#) manages the persistence of the alarms as needed via the alarm database. The [AlarmClass](#) manages the priority of an alarm and also which alarm require acknowledgement. Each alarm class can be linked to one or more alarm recipients.

### Alarm Recipients

Alarm recipients are linked to an alarm class (from the alarm topic on the alarm class to the `routeAlarm` action on [BAlarmRecipient](#).) Recipients may be configured to receive alarms only at certain times of day, certain days of the week, and receiving alarms of only certain transitions (eg. `toOffnormal`, `toFault`, `toNormal`, `toAlert`).

Three subclasses of [BAlarmRecipient](#) are worth noting: [BConsoleRecipient](#), [BStationRecipient](#) and [BEmailRecipient](#).



**BConsoleRecipient**

This recipient manages the transfer of alarms between the alarm history and the alarm console, i.e. it gets open alarms from the alarm history for the console and updates the history when they are acknowledged.

**BStationRecipient**

This recipient manages the transfer of alarms between the alarm service and a remote Niagara station.

**BEmailRecipient**

The email recipient is part of the [email](#) package. It allows alarms to be sent to users via email.

**Lifecycle**

Each alarm is a single BAlarmRecord that changes throughout its lifecycle. An alarm has four general states that it may be in:

1. New Alarm
2. Acknowledged Alarm
3. Normal Alarm
4. Acknowledged Normal Alarm

All alarms start as New Alarms and end as Acknowledged Normal Alarms. They may be acknowledged then go back to normal or go back to normal then be acknowledged.

An Alert is an alarm that does not have a normal state and thus its lifecycle consists of New Alarm and Acknowledged Alarm.

**Alarm Routing Overview***New Alarms*

1. BAlarmSource generates an offnormal alarm (or fault alarm).
2. It is sent to the BAlarmService.
3. BAlarmService routes it to its BAlarmClass.
4. The BAlarmClass sets the alarm's priority, ackRequired bit, and optional data.
5. It is then routed to any number of BAlarmRecipients.

The normal alarm is sent along this same path.

*Alarm Acks*

1. When a BAlarmRecipient acknowledges an alarm, the acknowledgement is sent to the BAlarmService.
2. The BAlarmService routes back to the BAlarmSource (if an ack is required).
3. The Alarm Acknowledgement is then routed to AlarmRecipients along the same path as a New Alarm.

**Usage****Setup**

The most basic piece needed is a control point. Then add an alarm extension from the alarm module palette. There are several types of extensions depending upon the type of point selected. The AlarmExtension are disabled by default. You must enable toOffnormal or toFault alarms and configure and enable the alarm algorithms.

An Alarm Service is also required. Depending on your needs, it may require some of the following slots:

- Any desired BAlarmClasses should be added.
- A BConsoleRecipient should be added if an alarm console is required.

Link any of the slots as needed. The alarm recipients must be linked to an alarm class in order to receive alarms from that alarm class.

To generate an alarm, go to a point with an alarm extension and put it an alarm condition.

### Console Recipient / Alarm Console

To view all of the outstanding alarms in the system, double click on the console recipient on the alarm service. The alarm console manages alarms on a per point basis. Each row in the alarm console is the most recent alarm from a point. To view all the current alarms from that point, double click the row.

To acknowledge an alarm, select the desired alarm and hit the ack button. An alarm is cleared from the alarm console when the alarm is acknowledged AND the point is in its normal state.

To view more information about an unacknowledged alarm, right click and select View Details.

### Station Recipient

A `BStationRecipient` allows sending alarms to remote Niagara stations. A remote station is selected from the stations you have configured in your Niagara Network. This recipient require that the remote station be properly configured in the Niagara Network.

### Printer Recipient

A `BPrinterRecipient` allows printing of alarms on an ink-jet or laser printer. This recipient is only available on Win32 Platforms. It supports both local and remote printers.

### Line Printer Recipient

A `BLinePrinterRecipient` allows printing of alarms on a Line Printer. This recipient is only available on Win32 Platforms. It supports both local and remote printers.

## Niagara AX to Niagara 4 API Changes

### Overview

The Alarm API has been re-factored to better support pluggable persistent storage. This will allow for better scaling of the Niagara Alarm Service since the JACE and the Supervisor will be able to have different backing databases. The new API is connection oriented in order to support the use to RDBMS and ODBMS back-ends.

[BAlarmDatabase](#) now extends [BSpace](#). This is now consistent with how other storage mechanisms are BSpaces with their Service defining the configuration of the space. As part of this change, database configuration properties on `BAlarmService` were refactored.

### BAlarmService & BAlarmDatabase

#### `javax.baja.alarm.BAlarmService.capacity` & `javax.baja.alarm.BAlarmDbConfig`

A [BAlarmDbConfig](#) property named `alarmDbConfig` was added to `BAlarmService`. This property will allow a greater flexibility in defining alarm storage configurations in the future. For the standard file-based Alarm Service, the capacity property was moved to the `BFileAlarmDbConfig` subclass of `BAlarmDbConfig`.

#### `javax.baja.alarm.BAlarmDatabase`

`BAlarmDatabase` now extends `BSpace` and implements [BIProtected](#). This allows the AlarmDatabase to appear in the Nav Tree as a peer to the History and System Databases and be categorized via the CategoryBrowser. Since `BAlarmDbConfig` now defines the configuration of the alarm database, the following method was added to `BAlarmDatabase` to handle changes to the configuration.

*BAlarmDatabase*

```

/**
 * Update the database with the new configuration.
 *
 * @param config new BAlarmDbConfig
 * @param p Property to update
 * @since Niagara 4.0
 */
public abstract void updateConfig(BAlarmDbConfig config, Property p)
    throws AlarmException;

```

The BAlarmDatabase gets a callback to updateConfig() for each property change on the BAlarmDbConfig object.

#### **javax.baja.alarm.BAlarmDbView & javax.baja.alarm.BAlarmDbMaintenanceView**

BAlarmDbView & BAlarmDbMaintenanceView have been moved to be views on BAlarmDatabase instead of BAlarmService.

#### **javax.baja.alarm.BAlarmRecord**

getSchema() and getRecordSize() methods were added to BAlarmRecord. These are currently placeholders for future use.

The default behaviour of the previously existing BAlarmRecord constructors was changed to not create a new [BUuid](#). New constructors were created accepting a BUuid as an argument.

### **Connection Oriented API**

#### **javax.baja.alarm.BAlarmSpace**

The BAlarmSpace interface was added to provide access to the Alarm Space via a connection oriented API. It provides the following method:

```
AlarmSpaceConnection getConnection(Context)
```

#### **javax.baja.alarm.BAlarmService**

The following methods have been moved to [javax.baja.alarm.AlarmSpaceConnection](#)

```

public void append(BAlarmRecord record)
public void update(BAlarmRecord record)
public int getRecordCount();
public BAlarmRecord getRecord(BUuid uuid)
public Cursor<BAlarmSource> getOpenAlarmSources()
public Cursor<BAlarmRecord> getOpenAlarms()
public Cursor<BAlarmRecord> getAckPendingAlarms()
public Cursor<BAlarmRecord> getAlarmsForSource(BOrdList alarmSource)
public Cursor<BAlarmRecord> scan()
public Cursor<BAlarmRecord> timeQuery(BAbsTime start, BAbsTime end)

```

The following methods have been moved to [javax.baja.alarm.AlarmDbConnection](#)

```

public abstract void clearAllRecords(Context cx)
public abstract void clearOldRecords(BAbsTime before, Context cx)
public abstract void clearRecord(BUuid uuid, Context cx)

```

The following method was added to provide access to the AlarmDatabase

```
AlarmDbConnection getDbConnection(Context)
```

#### **javax.baja.alarm.AlarmSpaceConnection**

The AlarmSpaceConnection interface is AutoCloseable. It provides access to the IAlarmSpace and allows management of connection boundaries. Alarms are obtained, queried and updated via the AlarmSpaceConnection.

**javax.baja.alarm.AlarmDbConnection**

AlarmDbConnection implements AlarmSpaceConnection and provides additional methods and implementations for working with BAlarmDatabases.

**Code Samples**

The following code examples demonstrate how to convert common alarm operations from the NiagaraAX Alarm API to the Niagara 4 Alarm API.

**Query Record by UUID**

*Niagara AX*

```
BUuid uuid = getAlarmUuid();
BAlarmRecord alarm = null;
BAlarmService alarmService = getAlarmService();
alarm = alarmService.getAlarmDb().getRecord(uuid);
```

*Niagara 4*

```
BUuid uuid = getAlarmUuid();
BAlarmRecord alarm = null;
BAlarmService as = getAlarmService();
try (AlarmDbConnection conn = alarmService.getAlarmDb().getDbConnection(null))
{
    alarm = conn.getRecord(uuid);
}
```

**Alarm Query**

*Niagara AX*

```
BAlarmDatabase alarmDb = alarmService.getAlarmDb();
Cursor cur = alarmDb.getOpenAlarms();
while (cur.next())
{
    BAlarmRecord alarm = (BAlarmRecord)cur.get();
}
```

*Niagara 4*

```
try (AlarmDbConnection conn = alarmService.getAlarmDb().getDbConnection(null))
{
    Cursor<BAlarmRecord> cur = conn.getOpenAlarms();
    while (cur.next())
    {
        BAlarmRecord alarm = cur.get();
    }
}
```

**Alarm Db Maintenance**

*Niagara AX*

```
BAbsTime before = getTimeOfLastRecordToKeep();
BAlarmService service = (BAlarmService)Sys.getService(BAlarmService.TYPE);
if (service != null)
{
    service.getAlarmDb().clearOldRecords(before, getSessionContext());
}
```

*Niagara 4*

```
BAbsTime before = getTimeOfLastRecordToKeep();
```

```
BAlarmService service = (BAlarmService)Sys.getService(BAlarmService.TYPE);
if (service != null)
{
    try (AlarmDbConnection conn = service.getAlarmDb().getDbConnection(null))
    {
        conn.clearOldRecords(before, getSessionContext());
    }
}
```

**Create New BAlarmRecord**

*Niagara AX*

```
BAlarmRecord record = new BAlarmRecord();
```

*Niagara 4*

```
BAlarmRecord recordWithNewUuid = new BAlarmRecord(BUuid.make());
BAlarmRecord recordWithDefaultUuid = new BAlarmRecord();
```

# Schedule

## Overview

A schedule is effective or it is not. When it becomes effective, it will do something like fire an event or change an output. When a schedule is not effective, it will have some default configurable behavior.

Most schedules will be a hierarchy of many schedules. Container schedules combine the effective state of their descendants to determine effectiveness. Atomic schedules use some internal criteria to determine effectiveness. An example of an atomic schedule is the month schedule. It can be configured to be effective in some months and not in others.

## Creating New Schedule Types

### [BAbstractSchedule](#)

All schedules subclass this.

**Subclassing.** To create a new schedule type, one simply needs to implement methods `isEffective(BAbsTime)` and `nextEvent(BAbsTime)`. See the API documentation for details.

**New Properties.** Properties on new schedule types should have the `user_defined_1` flag set. This is important for properties who when changed, should cause supervisor (master) schedules to update their subordinates (slaves).

**Output.** If the new schedule is going to be used in a control schedule, it will be necessary to assign an effective value to it. A control schedule finds output by searching child schedules, in order, for the first effective schedule with a dynamic property named "effectiveValue". The effectiveValue may be 10 levels deep, it will be found. Just remember the order of schedules in a composite is important.

### [BCompositeSchedule](#)

Composite schedules shouldn't need to be subclassed. However, they will be used (frequently) in building new schedule hierarchies.

These schedules perform a simple function, they determine their effective state by combining the effective state of their children. A composite can either perform a union or an intersection of it's children. A union means only one child has to be effective for the parent composite to be effective. An intersection means all children have to be effective.

## Using Existing Schedules

There are six preconfigured schedules. The weekly schedules look like control objects, the calendar schedule helps configure special events that will be used by multiple schedules. Lastly, the trigger schedule enables sophisticated scheduling of topics (events) which can be linked to actions on other components.

### [BBooleanSchedule](#), [BEnumSchedule](#), [BNumericSchedule](#) and [BStringSchedule](#)

These are all [BWeeklySchedules](#) whose output matches their name. There is one input who if linked and not null, completely overrides the schedule.

Example: Adding a special event

```
BDailySchedule specialEvent = new BDailySchedule(
    new BDateSchedule(5, BMonth.may, -1),
    BTime.make(11, 0, 0),
    BTime.make(12, 0, 0), //first excluded time
    BStatusBoolean.make(true));
myBooleanSchedule.addSpecialEvent(specialEvent);
```

Example: Adding to the normal weekly schedule

```
BDaySchedule day = myBooleanSchedule.get(BWeekday.monday);
```

```
day.add(BTime.make(11,0,0),BTime.make(12,0,0),BStatusBoolean.make(true));
```

Example: Retrieving all schedules in a normal weekday

```
BDaySchedule day = myBooleanSchedule.get(BWeekday.monday);
BTimeSchedule[] schedules = day.getTimesInOrder();
```

Example: Modifying the day schedule of a special event

```
BDailySchedule specEvent = (BDailySchedule)
myWeeklySchedule.getSpecialEvents().get("cincoDiMayo");
BDaySchedule day = specEvent.getDay();
```

Example: Retrieving all special events

```
BDailySchedule[] specEvents = myWeeklySchedule.getSpecialEventsChildren();
```

Legal special event schedule types:

[BDateSchedule](#)  
[BDateRangeSchedule](#)  
[BWeekAndDaySchedule](#)  
[BCustomSchedule](#)  
[BScheduleReference](#)

### **[BCalendarSchedule](#)**

This schedule has a boolean output. However, it's most common use is for special events in the four weekly schedules discussed above. The weekly schedule can store a special reference to any calendar in the same station and assign their own output to it.

Example: Adding a date schedule event

```
myCalendarSchedule.add("cincoDiMayo",aDateSchedule);
```

Legal event schedule types:

[BDateSchedule](#)  
[BDateRangeSchedule](#)  
[BWeekAndDaySchedule](#)  
[BCustomSchedule](#)

### **[BTriggerSchedule](#)**

This schedule fires an event when a schedule becomes effective. There is also an event signifying that a normal event has been missed.

Example: Add a date schedule event

```
myTriggerSchedule.getDates().add("cincoDiMayo",aDateSchedule);
```

Example: Add a trigger time

```
myTriggerSchedule.getTimes().addTrigger(11,00);
```

Legal event schedule types:

[BDateSchedule](#)  
[BDateRangeSchedule](#)  
[BWeekAndDaySchedule](#)  
[BCustomSchedule](#)

# Report

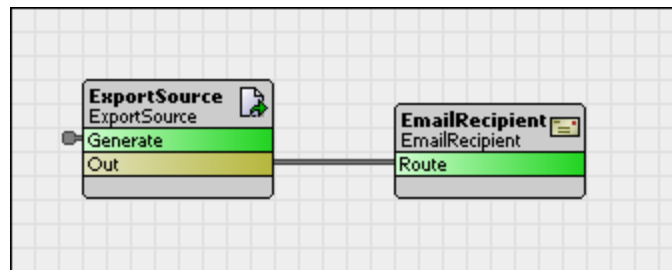
## Introduction

The Report module provides facilities for running periodic background reports on a station.

## ReportService

The ReportService provides a container for the components responsible for generating and routing reports. The process of generating a report is broken down into two components: [BReportSource](#) and [BReportRecipient](#).

## BReport Lifecycle



*(ExportSource and EmailRecipient are concrete implementations for ReportSource and ReportRecipient, respectively.)*

1. The generate action gets invoked on [BReportSource](#). The action can be invoked manually or automatically via the built-in schedule property.
2. ReportSource creates a new [BReport](#) object which gets propagated to the ReportRecipient.
3. [BReportRecipient](#) handles routing the report to some destination.



# BQL

## Introduction

The Baja Query Language (BQL) is an SQL-like query language that provides a mechanism for identifying various sets of data. It provides an ad hoc way to search for data based on some criteria. By including BQL in an ord, the results can be easily bookmarked or embedded in graphics views. This makes BQL an excellent tool for building reports.

## Select

The select query is the most common type of BQL query. It is very similar to the select statement in SQL. The syntax is as follows:

```
select <projection> from <extent> where <predicate> <having> <order by>
```

The select statement always returns a table even if the result is actually a single object.

## Extent

The first concept to understand about the above query is the extent. The extent is specified in the "from" clause of the query. The extent works together with the ord base to determine the general set of objects in the result. The rest of the query only narrows the general result. This is best explained with a few examples.

```
slot:/a/b/c|bql:select name, toString from control:ControlPoint
```

In the above query, the base of the "bql" query is the "slot" query. The slot scheme is used to access data in a Baja component tree. In this case, "slot:/a/b/c" identifies the root of the tree where the BQL query processing will start. From that point, the query will recursively search the tree for components of type "control:ControlPoint". So, when the base of the "bql" query is a slot path, the path identifies the subtree that will be searched by the query, and the extent identifies the type of component to search for. This query would get the name and toString for all control points under the /a/b/c in the component tree.

```
history:|bql:select timestamp, value, status from /myStation/myHistory
```

In this query, the base of the "bql" query is a "history" query. The history scheme is used to access data in the Baja history database. In this case, "history:" identifies the entire set of histories in the database. The query extent "/myStation/myHistory" identifies a specific history in the database. This query would get the timestamp, value, and status of all records in the history with the id "/myStation/myHistory".

## Projection

The projection is a comma separated list of the columns that will be returned in the result. Each element in the list must have a column specification and may have a display name specified with the 'as' clause. Beginning in Niagara 3.5, columns may be arbitrary expressions. The most frequent type of expression is a [path expression](#), but you can also call [scalar or aggregate functions](#).

```
select name, toString from baja:Component
select name as 'Point', out.value as 'Output Value', out.status from
control:NumericPoint
select MAX(out.value), MIN(out.value) from control:NumericPoint
select (out.value * 100) + '%' as 'Percent' from control:NumericPoint
```

In the second query, we know that all numeric points have an "out" property that is a StatusValue. A StatusValue is a structure that contains both a status and a value. In this query, we use a path to dive into the structure and extract the value and status individually.

In the third query, we use two aggregate functions, MAX and MIN, to find the largest and smallest value of all the control:ControlPoints in our query. The result will only have one row. See the section on [BQL functions](#) for more details.

In the fourth query, we perform a calculation on the out.value to make it a percent, and then append the '%' character to

the result so that the column values display with a percent sign. The column name is aliased as 'Percent'.

## Predicate

The predicate must be a boolean expression. Its purpose is to apply criteria for filtering objects out of the extent. Look at this query:

```
history:|bql:select timestamp, value from /weatherStation/outsideAirTemp
```

This query would retrieve the timestamp and value of all records in the specified history. That's often not a useful query and depending on how long the history has been collected, it may return a lot more data than we care to see. Instead, let's find all records where the value exceeds 80 degrees.

```
history:|bql:select timestamp, value from /weatherStation/outsideAirTemp
where value > 80
```

By adding the "where" clause with "value > 80", all records with a value less than 80 are filtered out of the result. To learn more about BQL expressions, see [BQL Expressions](#).

## Having

The "having" clause must be a boolean expression. The having clause has the same semantics as in SQL. You can use the having clause to filter the results of your query based on aggregate functions. Consider this query:

```
select displayName, SUM(out.value) from control:NumericPoint having
SUM(out.value) > 100
```

First, note that this query could return multiple rows since its projection contains both scalar columns ("displayName") and aggregate columns ("SUM(out.value)"). Each row will contain a distinct displayName, and the SUM of all the "out.value" values for the objects with that displayName. The HAVING clause will further restrict the result to only contain rows where the SUM of all the out.value values is greater than 100.

Note that if the above query had only asked for "SUM(out.value)" and did not ask for the displayName, there would only be one row in the result. It would contain the SUM of all the "out.value" values regardless of the object's displayName. It would not be very useful to include a HAVING clause in such a query.

## Order By

The "order by" clause can be used to sort the results of the bql query. It also has similar semantics to SQL. You can order by a path expression, a column alias, or column position (using a 1-based index). Further, you can specify whether you want the ordering to be done in ascending (ASC) or descending (DESC) order. ASC is assumed if not specified. For example,

```
select displayName, slotPath as 'Path' from control:NumericPoint order by
out.value, 1, 'Path' DESC
```

## Group By

BQL does not have a GROUP BY clause. If you mention *ANY* path expression in a query that contains aggregate functions, BQL implicitly defines a distinct grouping based on all the unique path expressions in your query. Consider:

```
select displayName, MAX(out.value) from control:NumericPoint where
isWritablePoint
```

This query will cause the bql engine to define an implicit grouping based on the "displayName" and "isWritablePoint" values.

## Simple Expressions

In some cases, it may be desirable to fetch a single value instead of a table of objects. You can accomplish that with BQL by using a simple BQL expression.

```
slot:/a/b/c|bql:handle
```

Putting a simple path expression in the BQL ord, causes the expression to be evaluated relative to the base. Resolving this ord just returns the value of the expression. In this case the result is the handle of the component identified by "/a/b/c". Note: If you run this query in Workbench, you will get a "No views are accessible" error since there are no views registered on the simple type "java.lang.String", which is the type of the "handle" path expression.

Beginning in Niagara 3.5, you can evaluate multiple expressions against the base and have the results returned in a table with a single row.

```
slot:/a/b/c|bql:{handle, out.value * 100, displayName + ' is my name'}
```

Each of the expressions in the list is evaluated against the component at "slot:/a/b/c". The result is a table with a single row with the result of evaluating each expression in its corresponding column.

Beginning in Niagara 3.6, you can alias the expressions. The column for that expression will have the alias as its display name in the resulting table.

```
slot:/a/b/c|bql:{handle as 'h', out.value / 2 as 'half', displayName}
```

## BQL Paths

BQL paths are an important element of any BQL query. A path can be used to specify column content or to filter the rows in a query result. In all cases, a path is relative to the set of objects defined by the extent.

A path is a dot-separated list of fields. Consider the following example:

```
slot:/a/b|bql:select name, historyConfig.capacity from history:HistoryExt
```

This retrieves the name and configured capacity of all history extensions under "/a/b". The extent tells me that I am only looking for history extensions. The second column specifier tells me to look inside the historyConfig and extract the value of the "capacity" property. The same concept can be applied in the "where" clause.

```
slot:/a/b|bql:select name, out from control:NumericPoint where out.value > 50
```

In this case, the extent tells me that I am only looking for numeric points. The where clause looks at the "value" property of the "out" property of each numeric point in "/a/b" and only includes the ones that are greater than 50.

Presenting a list of all available fields in a path is not feasible. The fields that can be accessed in a path include all frozen and dynamic properties of any component or struct (given sufficient security permissions) plus many of the methods on the target type. The Bajadoc reference is the best place to find this information for a particular type.

A method is accessible via a path if it is public and returns a non-void value and takes either no parameters or only a Context as a parameter. Methods that match the "getX" pattern are handled specially. To access a getter from BQL, the "get" is dropped and the next letter is changed to lowercase resulting in the name of the desired value rather than the method name for getting it.

```
getX -> x
getCurrentTemperature -> currentTemperature
```

A few methods are used particularly often. "name" gets the slot name of a value on its parent. "parent" gets the parent component. "parent" is useful because it allows you to look up the component tree.

```
slot:/foo/bar|bql:select parent.name, parent.slotPath from
schedule:BooleanSchedule
```

This query finds the name and path of all containers that contain a BooleanSchedule.

For more examples, see [BQL Examples](#).

For more information about expressions, see [BQL Expressions](#).

## Scalar and Aggregate Functions

BQL supports two types of function expressions: 1) scalar functions and 2) aggregate functions. Scalar functions operate on a single value and return a single value. In this respect they are similar to path expressions. Aggregate functions

operate on a set of values, and return a single, summarizing value. BQL also supports the ability for programmers to create their own scalar and aggregate functions. In all cases, the syntax for calling a function is

```
(<type spec>.)<function name>(<parameter list>)
```

The type spec is only required when the function is not part of the built-in BQL library. This is described in more detail in the sections below.

## Scalar Functions

BQL provides the following built-in scalar functions

- BBoolean slotExists(BString slotName): return true if an object has a slot with the given name.
- BBoolean propertyExists(BString propName): return true if an object has a property with the given name.
- BString substr(BString str, BNumber start, BNumber end): similar to Java substr() function.

```
select substr(displayName, 0, 1) from baja:Folder
select slotPath, displayName from baja:Component where slotExists('out')
```

The first query returns the first letter of all BFolders. The second query returns the slot path of every BComponent that has an 'out' slot.

## User-defined Scalar Functions

In this example, we show how to create a new scalar function "strlen" that returns the length of a BString. To create a new scalar function you simply define a new public static method in one of your BObjects where the first parameter is a BObject (the target object to work with), and the rest of the parameters match the type of the parameters for your method. The return type of all BQL functions must be a BObject.

```
public BLib extends BObject {
    /** Define the strlen function */
    public static BInteger strlen(BObject target, BString str) {
        return BInteger.make(str.getString().length());
    }

    public static final Type TYPE = Sys.loadType(BBLib.class);
    public Type getType() { return TYPE; }
}
```

That's it! Pretty straight-forward. Assuming this function was in a module called "MyBql", here is how you could use it to get the displayName and its length for every BFolder (note the use of the BTypeSpec to call the function):

```
select displayName, MyBql:Lib.strlen(displayName) from baja:Folder
```

## Aggregate Functions

BQL provides the following built-in aggregate functions:

1. COUNT(<expression>): count the number of items in the result set. Supports special syntax COUNT(\*).
2. MAX(<expression>): evaluates the expression for every item in the result set and returns the maximum value. The expression must evaluate to a BNumber or BStatusNumeric.
3. MIN(<expression>): evaluates the expression for every item in the result set and returns the minimum value. The expression must evaluate to a BNumber or BStatusNumeric.
4. SUM(<expression>): evaluates the expression for every item in the result set and returns the sum of all the values. The expression must evaluate to a BNumber or BStatusNumeric.
5. AVG(<expression>): evaluates the expression for every item in the result set and returns the average of all the values. The expression must evaluate to a BNumber or BStatusNumeric.

```
select MAX(out), MIN(out), AVG(out), SUM(out) from control:NumericWritable
select substr(displayName, 0, 1), COUNT(*) from baja:Folder
```

The first query returns the max, min, average, and sum of all the out properties of all control:NumericWritables. The resulting table will have a single row with four columns. The second query gets the first letter of every folder and then counts how many folders start with that letter.

### User-defined Aggregate Functions

**Note:** The ability to create user-defined aggregate functions is still considered experimental. The steps to create aggregate functions may change in the future.

In this example we show how to create and implement the AVG() aggregate function provided by BQL. Creating an aggregate function is a two-step process. The process is outlined below, and then a code example is provided.

- Step 1: Create the aggregator class
  - Create a class that extends BObject and implements the "marker" javax.baja.bql.BIAggregator interface. This interface has no methods, it just serves to signal the BQL engine that the class has aggregator semantics.
  - By convention, you must have a public void method called "aggregate" with a single parameter that is the type you want to aggregate on. This method will be called for each object in the result set. This is where the aggregating should be done.
  - By convention, you must have a "public <Type>" method called "commit()" that returns the aggregate value. This will be called on your class when all the objects have been aggregated. This gives you a chance to do any further calculation before returning the result.
- Step 2: Declare the aggregator in one of your module's classes so that BQL can find it when given a BTypeSpec invocation of the aggregate function.
  - Declare a public static final Type[] <function name> in one of your module's classes. The <function name> is the actual function name that would be used in a bql statement. If you have multiple implementations of the aggregate function (perhaps to support different argument types), include them all in the array. The BQL engine will search the list of implementing classes until it finds one that implements an "aggregate(<type>)" method that matches the type of the current object.

Here is an implementation of AVG that supports averaging BNumbers and BStatusNumerics. This code example shows how to implement step 1 above.

```
public final class BAverage extends BObject implements BIAggregator {

    /** Aggregate a BNumber */
    public void aggregate(BNumber value) {
        ++count;
        sum += value.getDouble();
    }

    /** Only aggregates if the status is valid. Otherwise it is skipped */
    public void aggregate(BStatusNumeric value) {
        if (value.getStatus().isValid()) {
            ++count;
            sum += value.getValue();
        }
    }

    /** Calculate the average and return the result */
    public BDouble commit() {
        if (count == 0)
            return BDouble.NaN;
        else
            return BDouble.make(sum/count);
    }

    public static final Type TYPE = Sys.loadType(BAvg.class);
    public Type getType() { return TYPE; }

    private double sum;
    private long count;
}
```

In the scalar example above, we created a class "BLib" in the "MyBql" module to create the "strlen()" function. Here is how we can modify that class to define the AVG function we just created. This shows how to implement step 2 from the outline above.

```
public BLib extends BObject {
    /** Define the strlen function */
    public static BInteger strlen(BObject target, BString str) {
        return BInteger.make(str.getString().length());
    }

    // Declare the AVG aggregate function (step 2)
    public static final Type[] avg = { BAverage.TYPE };

    public static final Type TYPE = Sys.loadType(BBLib.class);
    public Type getType() { return TYPE; }
}
```

Note that the name of the aggregate function is determined by its declaration in step 2, it is **NOT** the name of the class that implements the aggregation logic. Also, aggregate names are case-insensitive. Here is how you would call your implementation of the average aggregate function (note the use of the BTypeSpec)

```
select MyBql:Lib.avg(out) from control:NumericWritable
```

## BQL from Java

BQL query results can easily be displayed in a table or chart in a user interface. However, the results may also be examined in code using the Baja API. The result of a "select" query is always a [BITable](#). The items in the table depend on the query. If the projection is omitted, the result is a table of objects in the extent that matched the predicate requirements.

```
BOrd ord = BOrd.make("slot:/foo/bar|bql:select from control:NumericPoint");

BITable result = (BITable)ord.resolve(base).get();
Cursor c = result.cursor();
double total = 0d;
while (c.next())
{
    total += ((BNumericPoint)c.get()).getOut().getValue();
}
```

If the query has a projection, the result is a [BITable](#) and must be accessed that way to get the column data.

```
BOrd ord = BOrd.make("slot:/foo/bar|bql:select name, out.value from
control:NumericPoint");

BITable result = (BITable)ord.resolve(base).get();
ColumnList columns = result.getColumns();
Column valueColumn = columns.get(1);
TableCursor c = (TableCursor)result.cursor();
double total = 0d;
while (c.next())
{
    total += ((BINumeric)c.get(valueColumn)).getNumeric();
}
```

Since Niagara AX 3.5 you have been able to perform BQL queries against unmounted components. This is useful when

you are programmatically constructing component trees, and want to query the tree structure, but the components are not mounted in a station or bog. The example below illustrates how to do this.

```
// NOTE: using setOut() for numeric writables because set() doesn't work
when not mounted.
BFolder folder = new BFolder();
BNumericWritable nw1 = new BNumericWritable();
nw1.setOut(new BStatusNumeric(50.0));
folder.add("a", nw1);

nw1 = new BNumericWritable();
nw1.setOut(new BStatusNumeric(100.0));
folder.add("b", nw1);

String bql = "select sum(out.value) from control:NumericWritable";

// Create the unmounted OrdTarget using new "unmounted" factory method
OrdTarget target = OrdTarget.unmounted(folder);

// Query the unmounted folder to get the sum of all children
// control:NumericWritables out.value values.
BITable coll = (BITable)BqlQuery.make(bql).resolve(target).get();
```

# BQL Expressions

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BQL Expressions are used in the where clause of a BQL query to further qualify a result by narrowing the set of objects in the extent.

## Operator Precedence

BQL supports the following set of operators ordered by precedence:

!, not, -	logical not, numeric negation
*, /	multiplication, division
+, -	addition, subtraction
=, !=, >, >=, <, <=, like, in	comparisons
and, or	logical operators

Parentheses can be used to override the normal precedence.

## Typed Literals

All primitive types and BSimple types can be expressed as literals in BQL. The syntax for primitives types is:

**String** - single quoted string

Example: 'This is a string literal'

**number** - a numeric value, unquoted

Example: 10

**boolean** - true or false, unquoted

Example: true

**enum** - The enum type spec followed by the tag separated by a dot.

Example: alarm:SourceState.normal

Expressing other [BSimple](#) types in BQL is more verbose because a type specifier is required. The syntax for a BSimple value is the type spec (i.e. moduleName:typeName) followed by a string literal with the string encoding of the value (the result of encodeToString() for the type). Example: baja:RelTime '10000'

Baja types are expressed in BQL using the type spec. Any type spec that is not followed by a quoted string refers to the type itself.

Example: where out.type = baja:StatusNumeric



# BQL Examples

Back to [BQL Overview](#)

This document is a collection of example queries that illustrate how to identify some common sets of data with BQL. While each example in this document only presents a single solution, keep in mind that in most cases there are several different ways get the same result.

## All points

```
select slotPath, out from control:ControlPoint
```

The result is the slot path and output value of all control points. Since we specified "out" the result is the combination of value and status. If we wanted just the value, we would have used out.value. Or if we wanted value and status in separate columns we would have specified out.value and out.status.

## All points in alarm

```
select slotPath, out from control:ControlPoint where status.alarm
```

The result is the slot path and output value of all control points currently in the alarm state. In the where clause, the path "status.alarm" evaluates to true if the alarm status bit is set and false otherwise. This mechanism can be used to check the state of any of the status bits. See [BStatus](#) for more information on status flags.

## All points with "Meter" in their name

```
select slotPath, out from control:ControlPoint where name like '%Meter%'
```

The result is the slot path and output value of all points whose name includes the substring "Meter". BQL supports simple pattern matching. A '%' or '\*' matches zero or more characters. A '\_' matches exactly one character. The normal character matching is case sensitive.

## All points with a totalizer extension

```
select parent.slotPath, total from control:NumericTotalizerExt
```

The result is the slot path of every point that has a totalizer extension and the total for each totalizer. Note that the extent is the set of all totalizers. To get the point path, we look at the parent of each object in the extent.

## All current schedule output values

```
select slotPath, out from schedule:AbstractSchedule stop
```

The result is the slot path and output value of all schedules. Note the keyword "stop". The schedule component model makes the "stop" keyword necessary. All of the common schedule (BooleanSchedule, NumericSchedule, etc.) are actually composed of many more precise schedules. Without the "stop", the result would include all of the inner schedules in addition to the top level schedules that this query is actually looking for. The "stop" tells the query processor to stop the recursion when it reaches a component whose type matches the extent type.

## All points overridden at priority level 8

```
select slotPath, out from control:IWritablePoint
where activeLevel = control:PriorityLevel.level_8
```

The result is the slot path and output value of all writable points that are currently overridden at priority level 8. I know that every writable point is an instance of [IWritablePoint](#). All writable points provide access to their active level with a method called getActiveLevel(). Following the pattern for translating method names to BQL fields, I can access the active level on writable points using "activeLevel". In this case I know that active level is represented by a [PriorityLevel](#) enum. The level 8 value of the enum is specified by "control:PriorityLevel.level\_8".

## All points with units of degrees fahrenheit

```
select slotPath from control:NumericPoint
```

```
where facets.units.unitName = 'fahrenheit'
```

The key to this query is understanding how units are associated with a point. All control points have facets. For numeric points, the units are defined as a facet. So facets.units gets the units for the point. BUnit has a method called getUnitName() so "unitName" gets the result of that method.

#### All points linked to a specific schedule

```
select targetComponent.slotPath from baja:Link
where sourceSlotName = 'out' and
      sourceComponent.slotPath = 'slot:/app/MainSchedule'
```

This one is tricky. Because links are dynamic, they do not have a fixed name that we can search for. There is also no way to access just the links to a schedule output from BQL. Instead we have to look at all of the links and check the endpoints. So the extent is all links. Then we check for a source slot of "out". Finally we check the source slot path.

#### All points that generate alarms of a specific class

```
select parent.slotPath from alarm:AlarmSourceExt where alarmClass = 'hvac'
```

The result is the slot path of all control points that generate alarms for the "hvac" alarm class. The extent is all alarm source extensions. We find the extensions that specify "hvac" for the alarm class and get the parent slot path from those. The parent of an alarm source extension is always a control point.

#### All points with a history extension

```
select parent.slotPath from history:HistoryExt
```

This one is simple. We find all of the history extensions by using history:HistoryExt as the extent. Then we just get the slot path of the parent. The parent of a history extension is always a control point.

#### All points that collect a history with a capacity greater than 1000 records.

```
select parent.slotPath, historyConfig.capacity from history:HistoryExt
where historyConfig.capacity.isUnlimited or
      historyConfig.capacity.maxRecords > 1000
```

For this query you have to understand how history extensions are configured. The capacity is a property of [HistoryConfig](#). However, [Capacity](#) is not a simple numeric value. To exceed 1000 records of capacity, the configured capacity may either be unlimited or limited to a value greater than 1000. So first we check for unlimited and then we check for a limit of more than 1000 records.

#### The number of unacked alarms in all alarm classes

```
select name, unackedAlarmCount from alarm:AlarmClass
```

This query just looks at all of the [alarm classes](#) and for each one returns the name and the unackedAlarmCount. In this case, it will be much more efficient to narrow the search by making the alarm service be the query base. All alarm classes must be children of the [AlarmService](#). So it is much better to only search the AlarmService container.

```
slot:/Services/Alarm|bql:select name, numberOfUnackedAlarms from
alarm:AlarmClass
```

# Driver Framework

## Overview

The driver framework provides a common model for abstracting how information is imported and exported from the station VM. The model is built upon the following concepts

- [BDeviceNetwork](#): This models a physical or logical network of devices.
- [BDevice](#): This models a physical or logical device such as a fieldbus device or an IP host.
- [BDeviceExt](#): This models a functional integration at the device level which imports and/or exports a specific type of information such a points, histories, alarms, or schedules.
- [BNetworkExt](#): This models an functional extension at the network level.

## Driver Hierarchy

Drivers are always structured according to a fixed slot hierarchy as illustrated the [Driver Hierarchy Diagram](#):

- **DriverContainer**: Typically all drivers are located in this folder directly under the station root.
- **DeviceNetwork**: Models the specific driver's protocol stack.
- **DeviceFolder**: Zero or more levels of DeviceFolder can be used to organize the driver's Devices.
- **Device**: Devices model the physical or logical device of the driver. Devices are descendents of the DeviceNetwork either as direct children or inside DeviceFolders.
- **DeviceExt**: DeviceExts are always direct children of Devices, typically declared as frozen slots.

Within each DeviceExt, there is usually a well defined hierarchy. For example the PointDeviceExt follows a similar model with PointDeviceExt, PointFolders, ControlPoints, and ProxyExt.

## Status

A key function of the driver framework is providing normalized management of status. The follows semantics are defined for status flags:

- **Disabled**: the user manually disabled the driver component
- **Fault**: a configuration, hardware, or software error is detected
- **Down**: a communication error has occurred
- **Stale**: a situation has occurred (such as elapsed time since a read) which renders the current value untrustworthy

The driver framework provides a standard mechanism to manage each of these status flags. A component is disabled when a user manually sets the enabled property to false. Disable automatically propagates down the tree. For example setting the network level disabled automatically sets all devices and points under it disabled.

The fault status is typically a merge of multiple fault situations. The driver framework does its own fault detection to detect fatal faults. Fatal faults typically occur because a device or component has been placed inside the wrong container (such as putting a ModbusDevice under a LonworksNetwork). Licensing failures can also trigger fatal faults. Driver developers can set their own fault conditions in networks and devices using the `configFail()` and `configOk()` methods. A `faultCause` method provides a short description of why a component is in fault. Fault conditions automatically propagate down the tree.

The down status indicates a communication failure at the network or device level. Down status is managed by the ping APIs using `pingFail()` and `pingOk()`. Ping status is maintained in the health property. The driver framework includes a `PingMonitor` which automatically pings devices on a periodic basis to check their health. The `PingMonitor` can generate alarms if it detects a device has gone down.

## DeviceExts

The following standard device extensions provide a framework for working specific types of data:

- [Point](#): For reading and writing proxy points.
- [History](#): For importing and exporting histories.
- [Alarm](#): For routing incoming and outgoing alarms.
- [Schedule](#): Used to perform master/slave scheduling.

## User Interfaces

The driver framework provides a comprehensive set of APIs for building tools for managing configuration and learns based on the [AbstractManager](#) API. Also see the [Driver Learn](#) illustration.

# Point Devicelet Framework

## Overview

The [javax.baja.driver.point](#) API is used to perform point IO with logical or physical control points. Drivers use the standard control points found in the [control](#) module. But each driver provides a specialization of [BProxyExt](#) for driver specific addressing, tuning, and IO.

Refer to [Architecture - Driver Hierarchy](#) for an illustration of the component slot hierarchy.

Refer to [Architecture - ProxyExt](#) for an illustration of the design.

## Point Modes

There are three modes which a proxy point may operate in:

- **Readonly:** These points are read from the device, but never written.
- **ReadWrite:** These are points which the driver can both read from and write to.
- **Writeonly:** These are points which the driver can write to, but cannot read.

A ProxyExt must indicate which mode it is operating by overriding the `getMode()` method

## Proxy Ext

The ProxyExt component contains two properties used for managing read and write values.

The `readValue` property indicates the last value read from the device. For writeonly points this is the last value successfully written. This value is used to feed the parent point's extensions and out property. If numeric, it is in device units.

The `writeValue` property stores the value currently desired to be written to the device. If numeric, it is in device units.

## Framework to Driver Callbacks

Driver developers have three callbacks which should be used to manage reads and writes:

- `ProxyExt.readSubscribed()`: This callback is made when the point enters the subscribed state. This is an indication to the driver that something is now interested in this point. Drivers should begin polling or register for changes.
- `ProxyExt.readUnsubscribed()`: This callback is made when the point enters the unsubscribed state. This is an indication to the driver that no one is interested in the point's current value anymore. Drivers should cease polling or unregister for changes.
- `ProxyExt.write()`: This callback is made when the framework determines that a point should be written. The tuning policy is used to manage write scheduling.

**Note:** All three callbacks should be handled quickly and should never perform IO on the callers thread. Instead drivers should use queues and asynchronous threads to perform the actual IO.

## Driver to Framework Callbacks

The ProxyExt contains a standard API which the driver should call once a read or write operation has been attempted.

If a read operation completes successfully then `readOk()` method should be called with the value read. If the read fails then call the `readFail()` method.

If a write operation completes successfully then the `writeOk()` method should be called with the value written. If the write fails for any reason then call `writeFail()`.

## Tuning

All `ProxyExt`s contain a `Tuning` property that manages how read and writes are tuned. All drivers which implement proxy points should create a "tuningPolicies" property of type `TuningPolicyMap` on their `DeviceNetwork`. The `Tuning` structure on each `ProxyExt` identifies its `TuningPolicy` within the network by slot name. `TuningPolicies` allow users to configure which state transitions result in a `write()` callback. `TuningPolicies` may also be used to setup a `minWriteTime` to throttle writes and a `maxWriteTime` to do rewrites.

## Utilities

The driver framework provides a suite of APIs to aid developers in building their drivers:

- [BPollScheduler](#): This is a prebuild component that manages polling the points using a set of configurable buckets. To use this feature have your `ProxyExt` implement the [BPollable](#) interface.
- [ByteBuffer](#): This class provides a wealth of methods when working with byte buffers such as reading and writing integers using big or little endian.

# History Devicelet Framework

## Overview

Refer to the [javax.baja.driver.history](#) API.

History device extensions manage exporting and importing histories (data logs) to and from remote devices for archiving purposes. For more information on Niagara histories, refer to the [History](#) documentation.

The [BHistoryDeviceExt](#) component is the container for archive descriptors which specify the details for importing/exporting histories. A concrete implementation of this component can be placed under a device (concrete implementation of [BDevice](#)) to specify the export/import behavior of histories to and from the device. The actual descriptions of each history export/import are contained in a subclass of [BArchiveDescriptor](#) which supplies the unique [History Id](#) for the history exported/imported. Since it is a [BDescriptor](#), among other things it supplies the execution time for performing the export/import. Two subclasses of [BArchiveDescriptor](#) are available: [BHistoryExport](#) is used for exporting or pushing a history to a remote device (referred to as a history export descriptor), and [BHistoryImport](#) is used for importing or pulling a history from a remote device (referred to as a history import descriptor). Currently these are the only two options, or active history descriptors. At present there are no passive history descriptors (i.e. history exported descriptor or history imported descriptor). Also, in the concrete Niagara Driver implementation, the code prevents a history export from occurring when there already exists a history import for a matching history id.

The [BHistoryNetworkExt](#) component manages network level functions for the history transfers. Its primary purpose is to be the container of the configuration rules ([BConfigRules](#)) that specify how the configuration of a history should be changed when a history is pushed (exported) into a Niagara station. Configuration rules are applied when an exported history is created. Changing a rule has no effect on existing histories. A [BConfigRule](#) entry has two String parameters used for matching a pushed history's device and history name, and once a match is found (the configuration rules are iterated in slot order, and the first match will be used), any override rules (properties) will be used in place of the corresponding properties on the incoming history's configuration ([BHistoryConfig](#)). For example, if you wanted to increase the history capacity on a history that has been received from an export for archiving purposes, you could supply an override property on a configuration rule to increase the capacity.

# Alarm Devicelet Framework

The [BAlarmDeviceExt](#) handles the sending and receiving of alarms to and from remote devices. It is both an alarm source, implementing [BIRemoteAlarmSource](#), and an alarm recipient, implementing [BIRemoteAlarmRecipient](#).

## Receiving Alarms

BAlarmDeviceExt is used for receiving alarms from a remote device. The BAlarmDeviceExt should be used as the source for all incoming alarms. If more detail is needed about the actual source, the BAlarmRecord.SOURCE\_NAME or additional fields in the BAlarmRecord's alarmData can be used. Alarm Ack Request will be routed back to the BAlarmDeviceExt when it is set as the source.

In Niagara Offnormal and Normal alarms are not two separate alarms as is found in some systems. In Niagara Offnormal and Normal are two states of the same alarm. This is important to keep in mind is not using the AlarmSupport class as each offnormal alarm generated will need its source state set to Normal when its source goes back to the normal state.

## Sending Alarms

Sending alarms from the Niagara system to a remote device is accomplished by implementing a BAlarmRecipient. The BAlarmRecipient's handleAlarm method should route alarms from the Niagara system to the remote device and the originating source. The actual sending of alarms to the device network should be done on a separate thread so as to not block the control engine thread. The DeviceExt should not attempt to send alarms to Devices which are down or disabled.



# Schedule Device Extensions

## Overview

Schedule device extensions manage remote schedule synchronization. A subordinate schedule is a read-only copy of a supervisor schedule. Subordinate schedules must be children of the schedule device extension.

Refer to the [javax.baja.schedule.driver](#) API.

## [BScheduleDeviceExt](#)

Container of supervisor schedule export descriptors and subordinate schedules.

### Subscription

At a random time after station startup and within the subscribeWindow property value, all subordinate schedules who have not communicated with their supervisor will have their execute action invoked. For drivers where remote supervisors do not persist information about local subordinates, the subscribe window should be some small value rather than the default of a day.

### Retries

Periodically the execute action of all BScheduleExports and BScheduleImportExts who are in fault is invoked. The retry interval is controlled by the retryTrigger property.

### Subclasses

- Implement makeExport(String supervisorId) to create BScheduleExport objects for incoming subscription requests from remote subordinates.
- Implement makeImportExt() to create the schedule extension for new subordinate schedules.
- Can call processImport() to handle requests from remote subordinates.
- Can call processExport() to handle updates from remote supervisors.

## [BScheduleExport](#)

Maps a local supervisor to a remote subordinate. Will be a child of a BScheduleDeviceExt.

### Execution

The execute action is where the the local supervisor schedule configuration is sent to the remote subordinate. It is only invoked if the local supervisor schedule has been modified since the last time it was sent to the remote subordinate. The executionTime property controls when the local supervisor version is compared to the remote subordinate.

### Subclasses

- Implement doExecute() to upload the supervisor schedule configuration.
- Implement postExecute() to enqueue the execute action on an async thread.
- Always call getExportableSchedule() before encoding a schedule for transmission. This inlines schedule references.

## [BScheduleImportExt](#)

Maps a local subordinate to a remote supervisor. Will be a child of the subordinate schedule.

### Execution

The execute action is where the local subordinate makes a request to the remote supervisor for a configuration update. The executionTime property controls when execute is invoked but it is turned off by default. Since

BScheduleImportExt.execute will always result in a message to the remote supervisor, it is more efficient to have the supervisor push changes only when necessary.

When the schedule device extension performs subscription, it is simply invoking the execute action on BScheduleImportExt.

### Subclasses

- Implement doExecute() to download the supervisor schedule configuration.
- Implement postExecute() to enqueue the execute action on an async thread.
- Can call processExport() to handle configuration updates from the remote supervisor.

### [BScheduleExportManager](#)

This is the manager view for local supervisor schedules. This is a convenience and can be ignored.

### Subclasses

- Subclass [ScheduleExportModel](#) to add MgrColumns for properties added to your BScheduleExport.
- Override makeModel() to return your new model.
- Make the manager an agent on your schedule device extension.

### [BScheduleImportManager](#)

This is the manager view for local subordinate schedules. This is a convenience and can be ignored.

### Subclasses

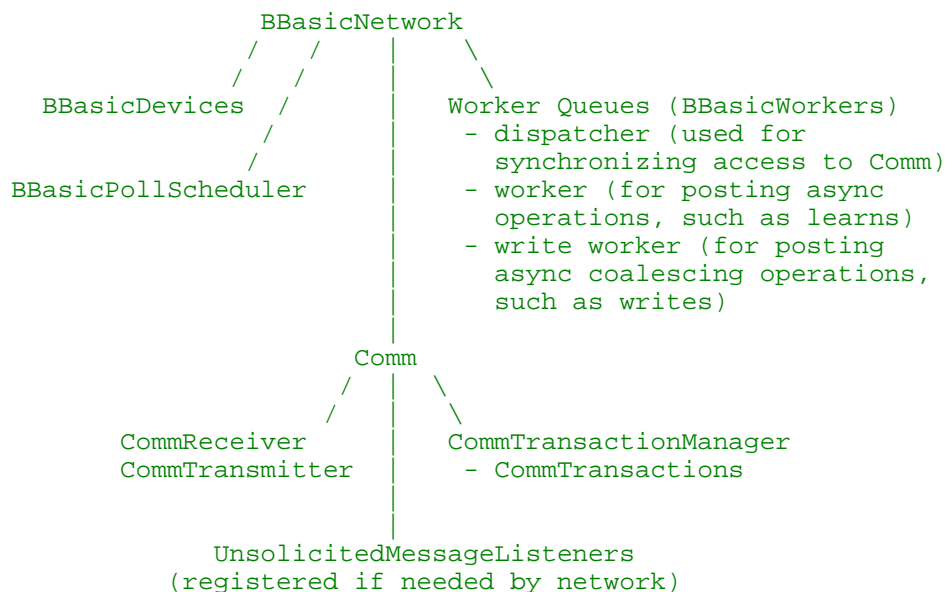
- Subclass [ScheduleImportModel](#) to add MgrColumns for properties added to your BScheduleImportExt.
- Override makeModel() to return your new model.
- Make the manager an agent on your schedule device extension.

# Basic Driver

## Overview

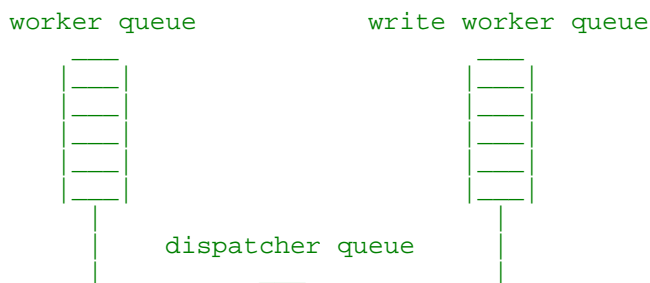
Refer to the [Basic Driver API](#).

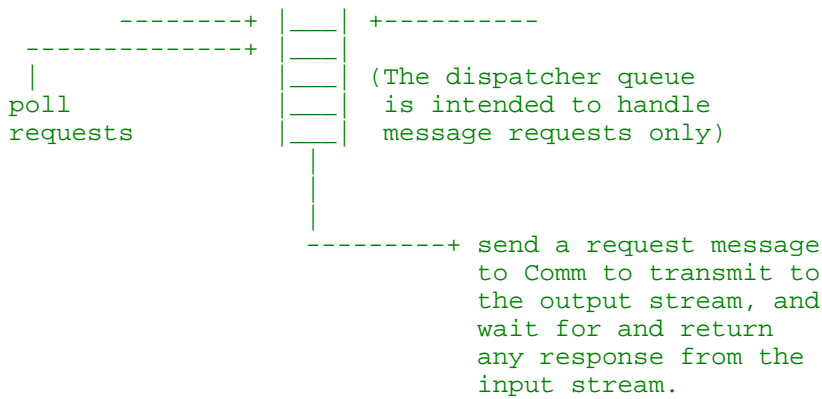
This package provides some basic classes that may be useful to developers building a new driver (i.e. field bus driver). These classes can be used (or subclassed) to provide some basic driver functionality, such as worker (queue) management, basic poll schedule handling, basic messages and management of these basic messages through request/response transactions (as well as unsolicited message handling), etc. It also provides a serial implementation ([com.tridium.basicdriver.serial](#)) which can be subclassed by drivers that use a serial port for communication. Here is an overview of basicDriver's structure:



The abstract class [BBasicNetwork](#) is the root component of basicDriver. It is the base container for [BBasicDevice](#) objects, and it provides a basic poll scheduler where objects implementing the [BIBasicPollable](#) interface can register to be polled (i.e. points, devices). It also provides three worker threads (queues) for handling asynchronous operations and synchronization of request messages to the [Comm](#) for transmission to the output stream (the following outlines the INTENDED use of these worker queues):

Asynchronous operations should be posted onto either the worker queue or write worker queue (coalescing). Write operations should always go to the write worker queue so they will be coalesced. Most other asynchronous operations, such as learns, should be posted to the worker queue to keep the write worker queue free for write operations. As these async operations are processed (dequeued), they should post any necessary message requests to the dispatcher queue, which synchronizes access to the Comm (Comm is ultimately responsible for sending the request message to the output stream via the CommTransmitter and receiving the response message from the input stream via the CommReceiver). Other threads may also post directly to the dispatcher queue (for example, the poll thread can post poll message requests directly to the dispatcher queue).





## Supporting Classes

BBasicNetwork also handles initialization, starting, and stopping the Comm, or communication handler. Comm is used to manage request/response message transactions for the network, handles the interaction between the low-level transmitter and receiver, and routes any unsolicited received messages to the appropriate listener. Comm uses the following supporting classes to accomplish its tasks:

- [CommTransactionManager](#): provides a pool of [CommTransaction](#) objects that are used for request/response message matching. Matching a request message to a response message is determined through an Object tag on the Message (discussed below).
- [CommReceiver](#): an abstract class implementing Runnable which handles receiving and forming ReceivedMessages from the input stream. Subclasses must override the `receive()` abstract method to read and return a complete ReceivedMessage. CommReceiver will loop and continuously call `receive()` in order to receive messages. Once a complete ReceivedMessage is received, this class routes the ReceivedMessage back up to the Comm for further processing. The returned ReceivedMessage may also need to contain data for request/response message matching (tag data) and unsolicited message listener processing (unsolicited listener code).
- [CommTransmitter](#): provides access and synchronization for writing Messages (and/or bytes) to the output stream.
- [UnsolicitedMessageListener](#): Comm can store a list of objects implementing this interface in order to process unsolicited received messages. UnsolicitedMessageListener objects can be registered to the Comm with an unsolicited listener code key. Then when a ReceivedMessage is received and determined to be unsolicited, it can match the unsolicited listener code to determine which UnsolicitedMessageListener instance should handle the ReceivedMessage.
- [MessageListener](#): This is a helper interface that should be implemented by objects that wish to receive a response Message. When using the `sendAsync()` or `sendAsyncWrite()` convenience methods of BBasicNetwork, they require a parameter of type MessageListener in order to determine where to route the response Message.

## Messages

The [com.tridium.basicdriver.message](#) package contains classes useful for building driver messages (using the Message abstract class), allowing these Messages to be written to the output stream, and formatting a response received (ReceivedMessage) into a proper Message.

- [Message](#): an abstract class for wrapping a driver message and providing some methods necessary for handling a response to this message. At a minimum, subclasses will need to provide the implementation for writing the message to the output stream and determine how a response (ReceivedMessage) should be interpreted and formed into a Message.
- [ReceivedMessage](#): an abstract class for wrapping a received driver message and providing some methods for determining if it is unsolicited and/or the unsolicited listener code to use for finding the correct UnsolicitedMessageListener if the message is determined to be unsolicited. Subclasses should provide a means to serve the appropriate data to form a complete Message.

## Utility Classes

The [com.tridium.basicdriver.util](#) package contains utility classes useful to most drivers.

- [BasicException](#): an extension of [BajaRuntimeException](#), a `BasicException` can be thrown when an error occurs in the driver.
- [BBasicWorker](#): an extension of [BWorker](#), it manages a basic worker thread for a queue. Used by the `BBasicNetwork` for the asynchronous worker.
- [BBasicCoalescingWorker](#): an extension of `BBasicWorker`, it manages a basic worker thread for a coalescing queue. Used by the `BBasicNetwork` for the asynchronous write worker.
- [BBasicPollScheduler](#): an extension of [BPollScheduler](#), it handles subscribing, unsubscribing, and polling of `BIBasicPollable` objects.
- [BIBasicPollable](#): an extension of [BIPollable](#), this interface should be implemented by any objects that wish to register to receive poll requests from the `BBasicPollScheduler`. Subclasses of `basicDriver` can use this to poll any devices, points, etc. as needed.

## Serial Driver

The [com.tridium.basicdriver.serial](#) package contains classes useful to most serial drivers (with the communication handler, `Comm`, at the network level).

- [BSerialNetwork](#): an extension of `BBasicNetwork` that supports serial communication on a single configurable serial port. This abstract class can be subclassed to provide a frozen property of type [BSerialHelper](#). This property, called 'Serial Port Config', provides an end user the ability to configure a serial port and its settings (i.e. baud rate, data bits, etc.) to use for communication with devices on the serial network.
- [SerialComm](#): an extension of `Comm` that handles opening the user selected serial port as well as the input and output streams to that port. It is used by the `BSerialNetwork` to handle synchronization of the serial communication.

# BACnet Driver

## Overview

The Niagara AX BACnet driver provides both client and server side BACnet functionality. On the server side, the Niagara station is represented as a BACnet device on the network. Certain objects in Niagara can be exposed as BACnet Objects. Niagara will respond to BACnet service requests for these objects, according to the BACnet specification. On the client side, Niagara can represent other BACnet devices in the Framework. Properties of BACnet objects can be brought into Niagara as BACnet Proxy Points. In addition, the BACnet driver provides client side schedule and trend log access. The BACnet objects can also be viewed as a whole, using the Config views. Both client-side and server-side alarm support is provided, using the intrinsic alarming mechanism. The basic components in the BACnet driver are

- [BBacnetNetwork](#): This represents the BACnet network in Niagara.
- [BLocalBacnetDevice](#): This represents Niagara as a BACnet device.
- [BBacnetDevice](#): This models a remote BACnet device.

## Server

The server side functionality of the driver is accomplished by using **export descriptors** to map Niagara objects as BACnet Objects. The Local BACnet Device contains an export table from where all of the export descriptors are managed. The [javax.baja.bacnet.export](#) package contains the standard export descriptors. The base interface for an export descriptor, which must be implemented by all export descriptors, is [BIBacnetServerObject](#). This contains the methods that are used by the comm stack and export mechanisms to access the BACnet Object properties of whatever Niagara object is being exported. The primary classes implementing this interface are

- [BBacnetPointDescriptor](#) and its subclasses - for exporting control points.
- [BBacnetScheduleDescriptor](#) and its subclasses - for exporting schedules.
- [BBacnetTrendLogDescriptor](#) and [BBacnetNiagaraHistoryDescriptor](#) - for exporting native BACnet trend logs and Niagara histories, respectively.
- [BBacnetFileDescriptor](#) - for exporting file system files.
- [BBacnetNotificationClassDescriptor](#) - for exporting Niagara BAlarmClasses as Notification Class objects.

Wherever a BACnet property is available directly from the exported Niagara object, this property is used. In some cases, a BACnet-required property is not available on the Niagara object being exported. In those cases, the property is defined within the export descriptor itself.

To export an object, the Bacnet Export Manager is used. A BQL query is made against the station to find components of a particular type, and the results are displayed. When a decision is made to add an export descriptor for a particular component, the registry is searched for export descriptors that are registered as agents on the component's Type. If any are found, these are presented to the user in the Add dialog.

For accepting writes, the BACnet driver requires that a BACnet user be defined in the User Service. The password for this user is not important, except for Device Management functions such as DeviceCommunicationControl and ReinitializeDevice. The permissions assigned for this user define what level of access is allowed for BACnet devices. Reads are always allowed; writes and modifications (such as AddListElement) are governed by the permissions of the BACnet user. If no BACnet user is defined, writes are not allowed.

The main area where the server side of the BACnet driver is extensible is through the creation of new export descriptor types. To create export descriptors for object types that are not currently exportable (such as a String Point), you simply need to create a class that implements [BIBacnetServerObject](#). You may find that you want to subclass one of the base export descriptor classes mentioned above, or you may find it easier to create your own, using these classes as a guide.

## Client

The client side functionality of the driver is accomplished with the [BBacnetDevice](#) and its device extensions. There are extensions for each of the normalized models

- [BBacnetPointDeviceExt](#) - for modeling properties of BACnet objects into Niagara control points.
- [BBacnetScheduleDeviceExt](#) - for representing BACnet Schedules as Niagara schedules for monitor or control.
- [BBacnetHistoryDeviceExt](#) - for representing BACnet Trend Logs as Niagara histories for configuration and archiving.
- [BBacnetAlarmDeviceExt](#) - for managing BACnet alarms from the device.
- [BBacnetConfigDeviceExt](#) - for viewing and modifying BACnet Objects in their native model - as an entire object, rather than by individual properties.

BACnet Proxy Points are configured by using a [BBacnetProxyExt](#). There are four subclasses of this, one for each type of Niagara control point. The extensions are polymorphic, in that they know how to convert data from any of the primitive data types to the data type of their parent point. Any proxy point can be written to if it is of the proper type. The BACnet proxy extensions manage writes for both priority-array and non-prioritized points.

BACnet client-side Scheduling can be accomplished in two ways

- [BBacnetScheduleExport](#) - This descriptor is used when Niagara is the supervisor, driving the schedule in the device. It contains the object identifier of the remote schedule, and the ord to the Niagara schedule that is to be the source of scheduling data. At configurable times this data is written down to the remote schedule.
- [BBacnetScheduleImportExt](#) - This extension is used when the remote schedule is the source of data, and Niagara is simply reading scheduling information from the device. The schedule is queried at configurable times to update the Niagara schedule.

BACnet client-side Trending is accomplished by using the [BBacnetHistoryImport](#). This descriptor periodically archives data from the Trend Log object in the remote device for storage by the Niagara station.

The operation of BACnet objects is sometimes easier to understand when the object is viewed as a whole, with all of its properties viewed together. For this reason, the Config device extension is provided. This allows you to view, for example, all of the properties of an Analog Input object together, without having to create proxy points for all of them. The expected use case is initial configuration or commissioning. The base object for representing BACnet Objects is [BBacnetObject](#). Specific subclasses for BACnet standard object types exist in [javax.baja.bacnet.config](#).

The main areas where the client side of the BACnet driver is extensible are

1. **BBacnetDevice**. For specialized device behavior, the `BBacnetDevice` can be subclassed. This is not for adding additional BACnet properties; the device object properties are contained in the [BBacnetDeviceObject](#). Each `BBacnetDevice` has an enumeration list which contains all of the extensions known to that device. Specific device classes might have preconfigured entries for these enumerations, that allow it to better interpret and represent proprietary enumeration values received from this device.
2. **BBacnetObject**. For specialized object types, such as a representation of a proprietary object type, the `BBacnetObject` class should be subclassed. This includes any specific device object properties, which would be contained in a subclass of [BBacnetDeviceObject](#).
3. **proprietary data types**. If any proprietary data types are created, they can be modelled corresponding to the data types in [javax.baja.bacnet.datatypes](#). Primitive data types are generally modelled as simples. Constructed data types are generally modelled as a subclass of `BComplex`. The data type must implement [BIBacnetDataType](#).
4. **proprietary enumerations**. Proprietary enumerations can also be created. If a property in an object is of an extensible enumeration, it should be modelled as a dynamic enum whose range is defined by the specified frozen enum. Examples of both extensible and non-extensible enumerations exist in [javax.baja.bacnet.enum](#).

For additional information, refer to the [BACnet API](#).

# Lonworks Driver

## Overview

The [Lonworks API](#) provides the means to model lonwork networks and devices for configuration and run time control. A network is a collection of connected lonworks devices and routers.

Basic components

- [BLonNetwork](#): Is the top level container for BLonDevices. It provides manager views for commissioning, binding and trouble shooting.
- [BLonDevice](#): Provides a database model for lonDevices to facilitate configuration and access to run time data.
- [BLonProxyExt](#): Customizes proxy points for data elements on lonDevices. Proxy points provide the mechanism to interface point data in devices with Niagara control logic and graphics

Misc components

- [BLonRouter](#): Contains the database model needed for network management of lonworks router.

## LonDevice

A BLonDevice contains [BDeviceData](#) and the means to manage a collection of [BLonComponents](#) and [BMessageTags](#).

BLonComponents are database representation of specific components in a device. They contain one or more data elements (see LonDataModel below) and specific config information. There are three types: [BNetworkVariable](#), [BNetworkConfig](#), [BConfigParameter](#).

BMessageTags are only for linking. There is no behavior implemented in message tags in the station.

[BLonDevice](#) is an abstract class and is the root class for all lonworks devices. There are two flavors of BLonDevice implemented in the lonworks drivers:

- [BLocalLonDevice](#) is a final class which provides the means to manage the local neuron. It is a frozen slot on BLonNetwork.
- [BDynamicDevice](#) provides support for dynamically building the devices data and BLonComponents. There are two actions to accomplish this: **learnNv** uses the self documentation in the device, **importXLon** uses an xml file containing a representation of the device.

## Lon Data Model

Each [BLonComponent](#) contains one or more data elements which mirror the data structure of the component in the device. These data elements are managed by [BLonData](#) which handles conversion between the database representation and the devices binary format. BLonData can also contain other BLonData components allowing for nested data types.

NOTE: BLonData has been folded into BLonComponent. The effect is to place the data elements at the same tree level as the LonComponent config properties. This was done to improve efficiency in the workbench. The getter setter methods in BLonComponent access LonData as though it were contained by the LonComponent. The `getData()` method will return the BLonComponent as a BLonData. The `setData()` method will replace the current data elements with the new elements passed in data argument.

Each data element is modeled as a [BLonPrimitive](#). There are BLonPrimitives for each primitive datatype.

- [BLonBoolean](#) models a boolean element
- [BLonEnum](#) models an enumeration element
- [BLonFloat](#) models a numeric element
- [BLonString](#) models a string element



## Special element types

- [BLonInteger](#) models a numeric element when full 32 bits of data is needed
- [BLonByteArray](#) is used in special cases to model data when can not be meaningfully modeled as primitive elements
- [BLonSimple](#) is used in special cases to model data which has been represented by a simple. The simple must implement [BILonNetworkSimple](#).

## Proxy points

Proxy points are standard Niagara control points used to access data elements in foreign devices. Proxy points have a driver specific ProxyExt that handles addressing data elements in a specific device and data conversion needed to present the data in a normalized format. The inputs and outputs of proxies can be linked to other control logic or graphical points.

A [BLonProxyExt](#) in a Proxy point makes it a lonworks proxy point. There are different [BLonProxyExt](#)s for each primitive data type. These can be seen in [javax.baja.lonworks.proxy](#).

Lon Proxy Points are managed by LonPointManager which is a view on the points container in each [BLonDevice](#).

## Network Management

Implements a set of standard lonworks network management functions. The user has access to these functions through the following manager view.

- DeviceManager - provides support for discovering and adding lonwork devices to the database, for managing device addresses, and downloading standard applications to devices.
- RouterManager - provides support for discovering and adding lonwork routers to the database, and for managing device addresses
- LinkManagar - provides means to manage link types and bind links.
- LonUtilitiesManager - provides a set of utilities useful for managing a lon network

## LonComm

The lonworks communication stack can be accessed through a call to [BLonNetwork.lonComm\(\)](#). [LonComm](#) is provides APIs which allow the user to send LonMessages with one of the LonTalk service types (unacknowledged, acknowledged, unacknowledged repeat, request response).

[LonComm](#) also provides a means to receive unsolicited messages by registering a [LonListener](#) for a specified message type from an optional subnetNode address.

## LonMessage

[LonMessage](#) is the base class for all messages passed to/from LonComm APIs.

Users should subclass LonMessage if they wish to create a new explicit message type.

A set of LonTalk defined messages is provide in [com.tridium/lonworks/netmessages](#). The definition of these message is found in Neuron Chip Data Book Appendix B, Lonworks Router User's Guide, and EIA/CEA-709.1-B.

## Mapping ProgramId to Device Representation

A mechanism is provided to associate an xml or class file with a particular device type. The device type is identified by its ProgramId as described in LonMark Application-Layer Interoperability Guidelines. The association is created by putting "def" entries in a modules module-include.xml file. This association is used during the learn process to determine the appropriate database entity for discovered devices.

A "def" entry consists of name and value attribute. The name has the formate "lonworks:programId" where programId is

the devices ProgramId represented as 8 hex encoded bytes with leading zeros and <space> delimiter. Multiple mappings are allowed for the same programId. Any nibble can be replaced with an '\*' to indicate a range of programIds mapped to the same object. The value field can reference a class or xml file.

The formate for a class is cl=module:cname. The module is the niagara module containing the class and the cname is the name as defined in the module-include.xml for that module. The class must be a sub class of BLonDevice or BDynamicDevice.

The formate for an xml file is xml=module/xname. The module is the niagara module containing the xml file and the xname is the name of the file containing the device representation. The xml file formate is described in [Lon Markup Language](#).

Examples of def entries in lon device module-include.xml file.

```
<defs>
  <def name="lonworks.80 00 0c 50 3c 03 04 17" value="cl=lonHoneywell:Q7300"
/>
  <def name="lonworks.80 00 16 50 0a 04 04 0a"
value="xml=lonSiebe/Mnlrv3.lnml"/>
  <def name="lonworks.80 00 8e 10 0a 04 0* **"
value="xml=lonCompany/dev.lnml"/>
</defs>
```

For further information refer to the [Lonworks API](#).

# Lon Markup Language

## Overview

This document defines the content of a lon XML interface file. Basic syntax: The xml interface file represents a collection of objects. These objects may contain predefined elements and/or undefined elements. LonDevice contains the predefined element deviceData and any number of undefined NetworkVariables. As a general rule, elements which are not a defined element of the parent must have a type attribute. Defined elements must provide a value "v" attribute or contain defined elements.

```
<name type="XLonXmlType">
<name v="value">
```

Example:

```
<T7300h type="XLonDevice">
  <!-- Defined element deviceData with no type specified -->
  <deviceData
    <!-- Defined element with value -->
    <programID v="80 0 c 50 3c 3 4 17"/>
    . . .
  </deviceData>

  <!-- Undefined element with specified type -->
  <nviRequest type="XNetworkVariable">
    <index v="0"/>
  </nviRequest>
</T7300h type="XLonDevice">
```

The set of valid LonXmlTypes are: XLonXMLInterfaceFile, XLonDevice, XEnumDef, XTypeDef, XNetworkVariable, XNetworkConfig, XConfigProperty, XMessageTag

## LonXMLInterfaceFile

The root type is LonXMLInterfaceFile. It may contain EnumDefs, TypeDefs, and LonDevices. It may also reference other LonXMLInterfaceFiles to allow for EnumDefs, and TypeDefs to be shared. The file attribute indicates the element is an included file

```
<!-- Example with reference to other interface files. -->
<T7300h type="XLonXMLInterfaceFile">
  <HwTherm file="datatypes\HwTherm.lnml"/>
  <HwCommon file="datatypes\HwCommon.lnml"/>
  <T7300h type="XlonDevice">
  </T7300h>

  <!-- Example with enumDefs and typeDefs included in single file. -->
  <T7300h type="XLonXMLInterfaceFile">
    <HwThermAlarmEnum type="XenumDef"> . . . </HwThermAlarmEnum>
    <HwThermAlarm type="XTypeDef"> . . . </HwThermAlarm>
    <T7300h type="XLonDevice"> . . . </T7300h>
  </T7300h>
```

## TypeDefs

EnumDefs and TypeDefs elements are needed to define the data portion of nvs, ncis, and config properties. An EnumDef contains a set of tag/id pairs where the name of the element is the tag and the value is the id.

```
<HwThermAlarmEnum type="XEnumDef">
  <NoAlarm v="0"/>
  <T7300CommFailed v="2"/>
  <AlarmNotifyDisabled v="255"/>
```

```
</HwThermAlarmEnum>
```

A TypeDef contains a set of data elements. Each data element contains a name and set of qualifiers. The "qual" attribute contains a type field(u8, s8, b8, e8 ..), type restrictions (min,max) and encoding (resolution, byteOffset, bitOffset, len) information. For a description of valid element values see Appendix B. If an element is an enumeration then the enumDef attribute must be included to specify the name of the EnumDef used.

```
<HwThermAlarm type="XTypeDef">
  < elem n="subnet" qual="u8 res=1.0 off=0.0"/>
  < elem n="type" qual="e8" enumDef="HwThermAlarmEnum"/>
</HwThermAlarm>
```

A TypeDef element may also include "default" and "engUnit" attributes.

```
<HwThermConfig type="XTypeDef">
  <TODOffset qual="u8 byt=0 bit=0 len=4 min=0.0 max=15.0 "
    default="0" engUnit="F"/>
  <DeadBand qual="ub byt=0 bit=4 len=4 min=2.0 max=10.0 "
    default="2" engUnit="F"/>
</HwThermConfig>
```

A TypeDef may have nonstandard features which require a software implementation. This is the case for typedefs with unions. Unions are not currently supported. A typeSpec attribute can be used to specify a class file in a baja module as the implementation of the TypeDef. The class must be a subclass of [BLonData](#) and provide overrides to `byte[] toNetBytes()` and `fromNetBytes(byte[] netBytes)`.

```
<FileStatus type="XTypeDef">
  < typeSpec v="lonworks:LonFileStatus"/>
</FileStatus>
```

## LonDevice

A LonDevice consists of a defined element deviceData and sets of 0 or more of each XNetworkVariable, XNetworkConfig, XConfigProperty, and XMessageTag type elements.

```
<T7300h type="XLonDevice">
  <deviceData> . . . </deviceData>
  <nviRequest type="XNetworkVariable"> . . . </nviRequest>
  <nvoAlarmLog type="XNetworkVariable"> . . . </nvoAlarmLog>
  <nciApplVer type="XNetworkConfig"> . . . </nciApplVe>
  <ScheduleFile type="XConfigProperty"> . . . </ScheduleFile>
  <fx_explicit_tag type="XMessageTag"> . . . </fx_explicit_tag>
</T7300h>
```

## DeviceData

DeviceData is a defined set of values need to describe or qualify a lonworks device. A complete list of elements and their default values provided later.

```
<deviceData>
  <majorVersion v="4"/>
  <programID v="80 0 c 50 3c 3 4 17"/>
  <addressTableEntries v="15"/>
  . . .
</deviceData>
```

## NVs, NCIs, ConfigProps

NetworkVariable, NetworkConfig (nci), and ConfigProperty elements share a common structure. Each one consists of a set of defined elements and a data definition. See Appendix A for a complete list of defined elements and their default values.

The data definition can take one of three forms:

1. for standard types a snvtType(for nv/nci) or scptType(for nci/cp) element
2. a typeDef element to specify the XTypeDef containing the data elements
3. a set of elem entries contained in the nv,nci,cp with the same definition as used for TypeDef

```
<nvoAlarmLog type="XNetworkVariable">
  <index v="38"/>
  <direction v="output"/>
  <typeDef="HwThermAlarmLog"/>
</nvoAlarmLog>

<nviRequest type="XNetworkVariable">
  <index v="0"/>
  <snvtType v="objRequest"/>
  . . .
</nviRequest>

<nciSetpoints type="XNetworkConfig">
  <index v="17"/>
  <snvtType v="tempSetpt"/>
  . . .
</nciSetpoints>

<bypassTime type="XConfigProperty">
  <scptType v="CpBypassTime"/>
  <scope v="object"/>
  <select v="0"/>
  . . .
</bypassTime>
```

## File Attribute

There will be cases where it is desirable to nest interface files. This will provide a means to share type definitions between multiple device interface files. It may also ease the process of auto generating the files when the data is contained in multiple forms (i.e. xif files, resource files, ...).

To include a file an element with the "file" attribute is included in the root. The path in the file attribute entry is specified relative to the containing file.

The following is an example of nested files. File #1 contains enum definitions, File #2 contains type definitions which use the enumDefs and file #3 contains the device definition which may use both.

File #1 ..\honeywell\enum\ HwThermEnum.xml

```
<?xml version="1.0" encoding="UTF-8"?>
<HwThermEnum type="XLonXMLInterfaceFile">
  <HwThermAlarmEnum type="XEnumDef">
    <NoAlarm v="0"/>
    <InvalidSetPtAlrm v="1"/>
    . . .
  </HwThermAlarmEnum>
  . . .
</HwThermEnum>
```

File #2 ..\honeywell\datatypes\ HwTherm.xml

```
<?xml version="1.0" encoding="UTF-8"?>
<HwTherm type="XLonXMLInterfaceFile">
  <HwThermEnum file="..\enum\HwThermEnum.xml"/>
  <HwThermAlarm type="XTypeDef">
    <elem n="subnet" qual="us res=1.0 off=0.0"/>
```

```

    <elem n="node" qual="us res=1.0 off=0.0 "/>
    <elem n="alarmType" qual="en " enumDef="HwThermAlarmEnum"/>
  </HwThermAlarm>
  . . .
</HwTherm>

```

File #3 ..\honeywell\

```

<?xml version="1.0" encoding="UTF-8"?>
<T7300h type="XLonXMLInterfaceFile">
  <HwTherm file="..\datatypes\HwTherm.xml"/>
  <T7300h type="XLonDevice">
    <nvoAlarm type="XNetworkVariable" >
      <typeDef="HwThermAlarm"/>
      <index v="36"/>
      <direction v="output"/>
    ...
  </nvoAlarm>
</T7300h>
</T7300h>

```

## XDeviceData Definition

XDeviceData definition: see LonMark External Interface File Reference Guide 4.0B

Type	Name	Default	Valid Values
int	majorVersion	0	-
int	minorVersion	0	-
byte[]	programID	0 0 0 0 0 0 0	-
int	domains	2	-
int	addressTableEntries	0	-
boolean	handlesIncomingExplicitMessages	false	-
int	numNvDeclarations	0	-
int	numExplicitMessageTags	0	-
int	networkInputBuffers	0	-
int	networkOutputBuffers	0	-
int	priorityNetworkOutputBuffers	0	-
int	priorityApplicationOutputBuffers	0	-
int	applicationOutputBuffers	0	-
int	applicationInputBuffers	0	-
int	sizeNetworkInputBuffer	0	-
int	sizeNetworkOutputBuffer	0	-
int	sizeAppOutputBuffer	0	-
int	sizeAppInputBuffer	0	-
String	applicationType	unknown	unknown,mip,neuron,hostSelect,hostNISelect
int	numNetworkVariablesNISelect	0	-

int	rcvTransactionBuffers	0	-
int	aliasCount	0	-
boolean	bindingII	false	-
boolean	allowStatRelativeAddressing	false	-
int	maxSizeWrite	11	-
int	maxNumNvSupported	0	-
int	neuronChipType	0	-
int	clockRate	0	-
int	firmwareRevision	0	-
int	rcvTransactionBlockSize	0	-
int	transControlBlockSize	0	-
int	neuronFreeRam	0	-
int	domainTableEntrySize	0	-
int	addressTableEntrySize	0	-
int	nvConfigTableEntrySize	0	-
int	domainToUserSize	0	-
int	nvAliasTableEntrySize	0	-
boolean	standardTransceiverTypeUsed	true	-
int	standardTransceiverTypeId	0	-
int	transceiverType	0	-
int	transceiverInterfaceRate	0	-
int	numPrioritySlots	0	-
int	minimumClockRate	0	-
int	averagePacketSize	0	-
int	oscillatorAccuracy	0	-
int	oscillatorWakeupTime	0	-
int	channelBitRate	0	-
boolean	specialBitRate	false	-
boolean	specialPreambleControl	false	-
String	specialWakeupDirection	input	input,output
boolean	overridesGenPurposeData	false	-
int	generalPurposeData1	0	-
int	generalPurposeData2	0	-
int	generalPurposeData3	0	-
int	generalPurposeData4	0	-
int	generalPurposeData5	0	-
int	generalPurposeData6	0	-

int	generalPurposeData7	0	-
int	rcvStartDelay	0	-
int	rcvEndDelay	0	-
int	indeterminateTime	0	-
int	minInterpacketTime	0	-
int	preambleLength	0	-
int	turnaroundTime	0	-
int	missedPreambleTime	0	-
int	packetQualificationTime	0	-
boolean	rawDataOverrides	false	-
int	rawDataClockRate	0	-
int	rawData1	0	-
int	rawData2	0	-
int	rawData3	0	-
int	rawData4	0	-
int	rawData5	0	-
String	nodeSelfID	""	-

NetworkVariable and Network Config common elements

Type	Name	Default	Valid Values
String	snvtType	"xxx"	from SNVT Master List. "SNVT_angle_vel" becomes "angleVel".
int	index	-1	-
int	averageRate	0	-
int	maximumRate	0	-
int	arraySize	1	-
boolean	offline	false	-
boolean	bindable	true	-
String	direction	"input"	input,output
String	serviceType	"unacked"	acked, repeat, unacked, unackedRpt
boolean	serviceTypeConfigurable	true	-
boolean	authenticated	false	-
boolean	authenticatedConfigurable	true	-
boolean	priority	false	-
boolean	priorityConfigurable	true	-

NetworkVariable only elements

Type	Name	Default	Valid Values
------	------	---------	--------------



String	objectIndex	""	-
int	memberIndex	-1	-
int	memberArraySize	1	-
boolean	mfgMember	false	-
boolean	changeType	false	-

NetworkConfig only elements

Type	Name	Default	Valid Values
String	scptType	""	-
String	scope	"node"	node,object,nv
String	select	""	If for node select=-1. Possible formats are n n~m n-m n.m n/m
String	modifyFlag	"anytime"	anytime, mfgOnly, reset, constant, offline, objDisable, deviceSpecific
float	max	Float.NaN	-
float	min	Float.NaN	-
boolean	changeType	false	-

ConfigParameter elements

Type	Name	Default	Valid Values
String	scptType	""	-
String	scope	"node"	node,object,nv
String	select	""	If for node select=-1. Possible formats are n n~m n-m n.m n/m
String	modifyFlag	"anytime"	anytime, mfgOnly, reset, constant, offline, objDisable, deviceSpecific
int	length	0	-
int	dimension	1	-
float	max	Float.NaN	-
float	min	Float.NaN	-
String	principalNv	""	if the scope is object and the scpt is inherited then this specifies the memberNumber of the principalNv in the selected object. Prefixed with '#' if mfgDefined member ' ' if standard member.

## Element Qualifier

The format for an element attribute is:

```
qual="Type [qualifier=xx]"
example: qual="u8 res=0.1 min=5 max=12"
```

Type	Device Data Type	Valid Qualifiers
c8	character - 1 byte	-
s8	signed short - 1 byte	res, off, min, max, invld
u8	unsigned short - 1 byte	res, off, min, max, invld

s16	signed long - 2 byte	res, off, min, max, invld
u16	unsigned lon - 2 byte	res, off, min, max, invld
f32	float - 4 byte	res, off, min, max, invld
s32	signed int - 4 bytes	res, off, min, max, invld
b8	boolean - 1 byte	-
e8	enumeration - 1 byte	-
bb	boolean in bit field	byt, bit, len
eb	enumeration in bit field	byt, bit, len
ub	unsigned int in bit field	byt, bit, len, min, max, invld
sb	signed int in bit field	byt, bit, len, min, max, invld
st	string	len
na	no type - byte array	len

Qualifier Code	Description	Default
res	resolution float	1.0
off	Offset	0.0
min	Minimum legal value	Not specified
max	Maximum legal value	Not specified
invld	Invalid value	Not specified
byt	Byte offset - 0 based	-1
bit	Bit offset - 0 based, 7 for msb, 0 for lsb	0
len	Number of bytes(na), char(st) or bits(bb,eb,ub)	1

## Build

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### Overview

Niagara 4 contains many architecture and functionality improvements. One area Tridium is improving on is the Niagara system's support for standard software development tools. The intent is that there will be minimal changes required in your development environment to compile modules in Niagara 4, while providing a better and more standard user experience for our Java developer customers.

One change being made is to incorporate Gradle into our build tool chain and migrate away from the proprietary build

system used in Niagara AX. This should enable a more standard setup of development projects and provide more standard integration with Java IDEs (specifically Eclipse or IntelliJ).

Additional information on Gradle can be found by following the links below. It is not expected that Niagara developers become experts in Gradle, but there is a lot of information available on the web, as well as several books available for those who wish to learn more.

[Gradle home page](#)  
[Gradle user guide](#)  
[Gradle language reference](#)

Also, a number of example Gradle projects are provided as part of the Niagara 4 installer. After extracting the installer .zip file, check inside the dev folder, right next to the installer .exe files.

## Gradle Configuration

There is some configuration required to run Gradle to compile module source code, build a module jar file, and assemble module a javadoc jar file. For single module projects, a basic `build.gradle` script is required to actually build the module, and a `gradlew.bat` script is required to install Gradle, set up the environment, and initiate the build process.

Build scripts for single module projects or the main project of a multi-project build should be executed with the `gradlew.bat`. The first time it is run it will install Gradle for you, so there is no installation required by the developer. It also sets up the build environment (Java classpath, etc.) for a Gradle project to use during execution. The

The `build.gradle` script contains the actual Domain Specific Language (DSL) code used by Gradle to run the module build task. It contains the same basic information as a `build.xml` file has for Niagara AX modules, like the module name, version, vendor, and dependencies. More details of the elements defined in the `build.gradle` and a mapping of `build.xml` elements to a `build.gradle` script are located in the [Build Script Elements](#) section below.

For multi-project builds, a single `gradlew.bat` file and a `build.gradle` script is needed for the main project of the build. Each module will have a `gradle` file containing module-specific configuration elements.

For large multi-project builds, Gradle includes a Configuration On Demand mode that improves build performance by only configuring projects that are relevant for the required tasks. To enable this feature, add it to your Gradle properties file:

- In your home folder, create a `.gradle\gradle.properties` file. Your home folder is typically `C:\Users\<username>` in windows7
- Insert the line `org.gradle.configureondemand = true` into the file

Other elements can be configured here, including `org.gradle.daemon = true`. Enabling the daemon element can improve build times, but will keep the JVM binary locked on Windows. You can read more about Gradle configuration on the [Gradle web site](#).

Note: Certain network configurations may require setting proxy information in the `gradle.properties` file in the user's home folder. More information on how this is configured can be found on the [Gradle web site](#).

## Project Setup

### Project Configuration Files

In addition to the `gradlew.bat` and `build.gradle` files, a `module-include.xml` file is required, and the `module.palette` and `module.lexicon` files are optional. If you have test classes for your module, a `moduleTest-include.xml` is needed. The contents of these files are described in a later section of this document. Note that the Niagara AX `build.xml` file is no longer needed to build Niagara 4 modules.

### Project Source Code Layout

Gradle locates source code through a configuration called `sourceSets`. The default source set configuration for Niagara projects is for the source code to be in a folder called `src` and for test source code to be in `srcTest`. This folder structure is used during compile to allow Gradle to locate source code and during module jar creation to enable Gradle to

locate any files to include in the module. See the build script for examples of include files for main and test modules - the `from(...)` syntax. More details on setting up tests can be found in the [TestNG Support in Niagara 4](#) document.

### Stand-alone Module Project

```
\<module name> - Top level source directory
|- build.gradle - Gradle script file
|- module.lexicon - Default lexicon file
|- module.palette - Defines Palette information for the module
|- module-include.xml - Declares Types, Defs, etc. for the module
|- moduleTest-include.xml - Declares Types, Defs, etc. for the test module
|- src\ - Folder containing module packages, source files, and resource files
|- srcTest\ - Folder containing test packages, source files, and resource files
```

### Multi-project Module Set

```
\<some folder name> - Top level directory
|- build.gradle - Main Gradle script file
|- vendor.gradle - Define the group (vendorName) and version here - they will be used
  in all modules
|- settings.gradle - Gradle script containing the names of all modules or folders
  containing modules
|- <module 1 name>\ - Folder containing Module 1
|   |- <module 1 name>.gradle - Module 1 Gradle script file
|   |- module.lexicon - Default lexicon file for module 1
|   |- module.palette - Defines Palette information for module 1
|   |- module-include.xml - Declares Types, Defs, etc. for module 1
|   |- moduleTest-include.xml - Declares Types, Defs, etc. for test module 1
|   |- src\ - Folder containing module 1 packages, source files, and resource files
|   |- srcTest\ - Folder containing test 1 packages, source files, and resource files
|- <module 2 name>\ - Folder containing Module 2
|   |- <module 2 name>.gradle - Module 2 Gradle script file
...

```

## Running Gradle

### Gradle Task Resolution

Part of the reason for using Gradle is that it includes a DSL (Domain Specific Language) for building Java projects. A small amount of script configuration results in a powerful set of tasks for compiling, assembling, testing, and publishing software. When you run `gradlew <taskName>`, Gradle will apply that task to all projects that declare that task. For example, `gradlew clean` will clean all modules in a multi-project configuration. If you want to execute a task against a specific project, use the `gradlew :path:to:project:<taskName>` syntax. If your multi-project module set is organized as described above, you can run Gradle tasks for a single module using `gradlew :<moduleName>:<taskName>`. For example, to clean the `componentLinks` module in the developer examples under the `dev` folder, run `gradlew :componentLinks:clean`. When you execute `gradlew` for the first time, it will download the Gradle framework required to complete task execution. This will take a few moments, but will only be needed once.

### Common Gradle Tasks

```
gradlew tasks - List the Gradle tasks available for execution
gradlew jar - Compile module source code, assemble the module jar, and copy it to the installation location
gradlew javadocJar - Generate javadoc files and assemble them into a jar file
gradlew moduleTestJar - Compile, jar, and install test module code
gradlew clean - Clean compiled artifacts from the module folder
gradlew :<moduleName>:jar - Compile, jar, and install a single
gradlew -p <moduleName> jar - Compile, jar, and install a single
```

## Additional Gradle Options

Gradle provides tasks to generate Eclipse and IntelliJ project files from script configurations.

**Set Up IntelliJ IDEA for Niagara 4 Development**

1. Open a command prompt console and execute `gradlew cleanIdea idea` in your main project folder to generate the necessary IDEA project files.
  - `cleanIdea` will clean any previous project files out, then `idea` will rebuild them.
2. Run IntelliJ. At the welcome screen, select “Open Project”.
3. Browse to your project folder and select `niagara4.ipr`.

**Set Up Eclipse for Niagara 4 Development**

1. Open a command prompt console and execute `gradlew cleanEclipse eclipse` in your main project folder to generate the necessary eclipse project files.
  - `cleanEclipse` will clean any previous project files out, then `eclipse` will rebuild them.
2. Run Eclipse. Select “Import...” for each module.
3. Navigate to the module folder in the Import wizard.

**External Dependencies**

In Niagara AX, if you had an external dependency on a third-party jar (like Apache commons-pool) and choose not to convert it to a module, then you included it in the `extdirectory` of your module source and `build.jar` would take care of including it in your generated module. This process is typically called creating an “uberjar” or “fatjar”.

In Niagara 4, using Gradle we take a slightly different approach. You declare all your external dependencies in your Gradle script using a special uberjar dependency configuration. Any dependencies declared against the uberjar configuration will be automatically included in the generated module. Also, in Niagara 4 we are moving towards pulling external dependencies from a central repository. Gradle includes support for the central Maven repository, which is a commonly used repository for software artifacts. Gradle will download the dependency automatically from the central Maven repository and include it in the generated module. The Gradle build scripts will no longer look for dependencies in the `ext` directory of your module.

NOTE: Internet connectivity is required for accessing the central Maven repository.

**Gradle Build Scripts**

The Gradle script files contain elements similar to those in the Niagara AX `build.xml` file, configured for Gradle. The specific configuration will depend on the type of project (stand-alone or multi-project) required by the developer. For a stand-alone module, the Gradle script file is `build.gradle`. For a multi-project build environment, there will be one `build.gradle` for the main project, and each module within the project will have a `<module>.gradle` file. The developer examples found in the `dev` folder contain script files for both configurations. See the description of stand-alone and multi-project configurations for details on the two project types.

Each `build.gradle` script, either stand-alone or multi-project, will have an associated `gradlew.bat` Gradle wrapper file.

**Gradle Wrapper Script - `gradlew.bat`**

A gradle wrapper file is available in the `bin` folder of the Niagara installation. It sets up the build environment for compiling Niagara modules, including Java class paths and Gradle configuration settings. The first time it is used to compile a module, it will download the Gradle runtime libraries and any external dependencies needed to compile. It should be used every time modules are compiled, as it enables a Gradle daemon to improve compile efficiency.

Additional information about the Gradle wrapper is available on the [Gradle web site](#). More advanced users may choose to modify the wrapper script as needed, but it is likely that this will not be necessary.

**Build Script Elements - `build.gradle`**

Several Gradle properties must be declared in the appropriate script file in order for the module to compile, jar, and test correctly. The examples shown later in this document and the source examples in the `dev` folder contain the commonly used properties that will need to be defined for each module. Use them as templates for your stand-alone modules. There are other elements in these examples that should be left as they are; these are noted by comments in the Gradle scripts. Some common elements used in Gradle build scripts are described below. The specific Gradle file containing these

elements depends on which configuration being used (stand-alone or multi-project). Refer to the examples for guidance on where to locate these elements in your projects.

`ext {}` - This namespace is used to declare extra properties within the project.  
`buildscript {}` - Configures the classpath used by the build script for this project.  
`repositories {}` - Gradle uses these to resolve and download dependency artifacts. The default configurations for Niagara 4 projects uses Maven and local flat file repositories for providing dependencies.  
`dependencies {}` - Specific artifacts required by particular phases of the build sequence (r.g. compile, test, etc.).  
`jar {}` - Enables the jar task to locate additional files to include in the jar file.  
`apply` - Include shared Gradle code into the current project.  
`sourceSets {}` - Configurations for source file locations.  
`niagaraModule {}` - Provided by the niagara-module plugin to enable construction of a Niagara 4 compliant jar file.  
`moduleTestJar {}` - Provided by the niagara-module plugin to enable construction of a Niagara 4 compliant test jar file.

NOTE: The examples in the dev folder contain configurations for both project types. You only need to configure one of these (stand-alone or multi-project).

### Gradle Dependency Notation

Your modules will generally have a dependency on one or more Niagara 4 modules. These dependency declarations are declared in the module build Gradle file. The first element in the dependency declaration is the configuration name. The standard Gradle configuration for compiling Java code is `compile`. A second configuration used for test classes in Niagara 4 is `niagaraModuleTestCompile`. The second element in the dependency declaration is the dependency notation. The notation used in the example modules for external dependencies uses the String notation format. The notation contains the group (vendorName), name (module), and version, each separated by a colon (:). So the notation for declaring a dependency on the `baja.jar` module is `"Tridium:baja:4.0"`.

One advantage of using Gradle is that it does transitive dependency resolution automatically. This means that you only need to declare direct dependencies on modules or external libraries that your code directly references. If these direct dependencies have their own compile-time dependencies (i.e. transitive dependencies), Gradle will resolve these automatically.

Other notation formats are possible. See the [Gradle documentation](#) for additional information on dependency management.

### Convert Niagara AX build.xml to Niagara 4 build.gradle

In the Niagara AX Developer Guide, the section on Build provides an overview of the elements available for inclusion in the `build.xml` file. This includes a definition of XML element and attributes that can be used in `build.xml`. There are four XML elements described in the documentation: module (the root element), dependency, package, and resources. Most of the element and attribute mappings from `build.xml` to the Gradle script are straightforward. Pay particular attention to the dependency declarations. Gradle contains a more sophisticated approach to dependency resolution described above, and has a standard way of declaring and resolving dependencies that has been adopted in Niagara 4.

### Mapping Summary

The table below contains a mapping of common elements used in the `build.xml` to declarations in a corresponding Gradle script.

build.xml	Gradle Script
<b>Root &lt;module&gt; Attributes</b>	<b>ext or niagaraModule Elements</b>
<code>name = "foo"</code>	<code>ext { name = "foo" }</code>
<code>vendor = "X"</code>	<code>ext { project.group = "X" }</code>
<code>vendorVersion = "1.5.0"</code>	<code>ext { project.version = "1.5.0" }</code>
<code>description = "X foo"</code>	<code>ext { project.description = "X foo" }</code>
<code>preferredSymbol = "x"</code>	<code>niagaraModule { preferredSymbol = "x" }</code>
<code>bajaVersion = "0"</code>	<code>niagaraModule { bajaVersion = "0" }</code> (optional)
<b>&lt;dependency&gt; Tag</b>	<b>dependencies Elements</b>
<code>name="bar" vendor="X" vendorVersion="4.0"</code>	<code>dependencies { compile "X:bar:4.0" }</code>
<b>&lt;resources&gt; Tag</b>	<b>jar Elements</b>

name="/com/example/icons/*.png"	jar { from("src") { include "/com/example/icons/*.png" } }
<b>&lt;dependency&gt; Tag for Test</b>	<b>dependencies Elements</b>
name="baz" vendor="X" vendorVersion="4.0"	dependencies { niagaraModuleTestCompile "X:baz:4.0" }
test="true"	
<b>&lt;resources&gt; Tag for Test</b>	<b>moduleTestJar Elements</b>
name="com/example/test/*.bog" test="true"	moduleTestJar { from("srcTest") { include "com/example/test/*.bog" } }

## Example Conversion

### build.xml

```
<module
  name = "componentLinks"
  bajaVersion = "0"
  preferredSymbol = "cl"
  description = "Example of checking and creating Links programmatically"
  vendor = "Tridium"
>
  <dependency name="baja" vendor="Tridium" vendorVersion="4.0" />
  <dependency name="kitControl" vendor="Tridium" vendorVersion="4.0" />
  <dependency name="control" vendor="Tridium" vendorVersion="4.0" />
  <dependency name="bajai" vendor="Tridium" vendorVersion="4.0" test="true" />

  <package name="com.examples.componentLinks" />

  <resources name="com/examples/icons/*.png" />
  <resources name="com/examples/test/bogs/*.bog" test="true" />
</module>
```

NOTE: The module version is retrieved from the devkit.properties file

### build.gradle

```
//use default niagara configurations for modules
apply from: "${System.getenv('niagara_home')}/etc/gradle/niagara.gradle"
ext {
  // Declare module name and project properties
  name = "componentLinks"
  project.version = "5.0.1"
  project.group = "Tridium"
  description = "Example of checking and creating Links programmatically"
}

// Declare niagaraModule properties
niagaraModule {
  preferredSymbol = "cl"
  // The runtime profile indicates the minimum Java runtime support required
  for this module jar
  runtimeProfile = "rt"
  // The moduleName is registered with the Niagara runtime engine.
  // In Niagara 4, it is possible for a module to have multiple jar files for
  separate runtimeProfile values.
  moduleName = "componentLinks"
}

// Declare compile and test dependencies
dependencies {
  compile "Tridium:baja:4.0.0"
  compile "Tridium:kitControl-rt:4.0.0"
  compile "Tridium:control-rt:4.0.0"

  niagaraModuleTestCompile "Tridium:bajai:4.0.0"
```



```

    }

    // Include additional files in module jar
    jar {
        from("src") {
            include "com/examples/icons/*.png"
        }
    }

    // Include additional files in the test jar
    moduleTestJar {
        from("srcTest") {
            include "com/examples/test/bogs/*.bog"
        }
    }
}

```

## Other Module Files

### module-include.xml

This file is placed directly under the module's root directory. If it is declared, then the build tools automatically include it in the module's manifest as META-INF/module.xml. Its primary purpose is to allow developers to declare def, type, and lexicon elements.

### module.palette

The module.palette file is an optional file that is placed directly under the module's root directory. If included it is automatically inserted into the module jar file, and accessible in the module as /module.palette. The module.palette file should contain the standard palette of public components provided by the module. The format of the file is the same as a standard .bog file.

### module.lexicon

The module.lexicon file is an optional file that is placed directly under the module's root directory. If included it is automatically inserted into the module jar file. The lexicon file defines the name/value pairs accessed via the [Lexicon API](#).

### moduleTest-include.xml

Put any Niagara def, type, and lexicon elements used in your test classes in this file.

## Single Module Project

### Project Setup

A stand-alone module not part of a multi-project build needs to have only the build.gradle and gradle.bat files in the top level folder to support building the module with Gradle. The module-include.xml is still required, and the module.lexicon and module.palette files can be included if needed. A moduleTest-include.xml is needed for any test classes. Here is the file structure for a stand-alone project.

```

\<module name> - Top level source directory
| - build.gradle - Gradle script file
| - gradlew.bat - Gradle wrapper file
| - module.lexicon - Default lexicon file
| - module.palette - Defines Palette information for the module
| - module-include.xml - Declares Types, Defs, etc. for the module
| - moduleTest-include.xml - Declares Types, Defs, etc. for the test module
| - src\ - Folder containing module packages, source files, and resource files
| - srcTest\ - Folder containing test packages, source files, and resource files

```

### Project Build

Gradle commands will be run from a Windows command prompt. For a single module, navigate to the folder containing the module source and configurations. The Gradle tasks for separate phases of the build sequence are below.

```
gradlew tasks - List the Gradle tasks available for execution
gradlew jar - Compile module source code, assemble the module jar, and copy it to the installation location
gradlew slotomatic - Run slot-o-matic on the module source code creating boiler plate slot code
gradlew javadocJar - Generate javadoc files and assemble them into a jar file
gradlew moduleTestJar - Compile, jar, and install test module code
gradlew clean - Clean compiled artifacts from the module folder
```

## Multiple Module Project

### Project Setup

A multi-project set of module jar files will have a `build.gradle` and `gradlew.bat` in the top-level folder. There will also be a `settings.gradle` and `vendor.gradle` files containing Gradle elements that will be applied to all module builds. Each module jar will require a `<moduleName>.gradle` file containing Gradle configurations specific to that module. The `module-include.xml` is required for each module jar, and the `module.lexicon` and `module.palette` are included as needed. A `moduleTest-include.xml` is needed for any module jar containing test classes.

Niagara 4 supports multiple runtime profiles for a single Niagara module. To take advantage of this runtime configuration, there will be a separate module jar file for each profile. By convention, the gradle build file for a module jar file will be `<moduleName>-<profile>.gradle` and the runtime profile will be declared in that file as part of the Gradle build configuration. Profiles include **rt**, **ux**, **wb**, **se**, and **doc**. Here is the file structure for a project containing multiple modules.

```
\<some folder name> - Top level directory
| - build.gradle - Main Gradle script file
| - gradlew.bat - Gradle wrapper file
| - vendor.gradle - Define the group (vendorName) and version here - they will be used in all modules
| - settings.gradle - Gradle script containing the names of all modules or folders containing modules
| - <module 1 name>\ - Folder containing Module 1
|   | - <module 1 name>.gradle - Module 1 Gradle script file
|   | - module.lexicon - Default lexicon file for module 1
|   | - module.palette - Defines Palette information for module 1
|   | - module-include.xml - Declares Types, Defs, etc. for module 1
|   | - moduleTest-include.xml - Declares Types, Defs, etc. for test module 1
|   | - src\ - Folder containing module 1 packages, source files, and resource files
|   | - srcTest\ - Folder containing test 1 packages, source files, and resource files
| - <module 2 name>\ - Folder containing Module 2
|   | - <module 2 name>.gradle - Module 2 Gradle script file
|   | - module-include.xml - Declares Types, Defs, etc. for module 2
| ...
```

### Project Build

Gradle commands will be run from a Windows command prompt. For a multi-module project, navigate to the main project folder. The Gradle tasks for separate phases of the build sequence are below.

```
gradlew tasks - List the Gradle tasks available for execution
gradlew jar - Compile source code, assemble jars, and installation for all modules
gradlew slotomatic - Run slot-o-matic on the all source code.
gradlew javadocJar - Generate javadoc files and assemble them into jar files for all modules
gradlew moduleTestJar - Compile, jar, and install test code for all modules
gradlew clean - Clean compiled artifacts for all modules
gradlew :<moduleName>:jar - Compile, jar, and install a single
gradlew :<moduleName>:slotomatic - Run slot-o-matic on the source code.
```

This same module-specific syntax can be also used for the rest of the Gradle tasks.

## Example Gradle Scripts

### build.gradle (for the project)

```

ext {
    niagaraHome = System.getenv("niagara_home")
    if (niagaraHome == null) {
        logger.error("niagara_home environment variable not set")
    }
}

//to enable idea/intellij or eclipse support, un-comment the lines below
// apply from: "${System.getenv("niagara_home")}/etc/gradle/idea.gradle"
// apply from: "${System.getenv("niagara_home")}/etc/gradle/eclipse.gradle"

gradle.beforeProject { p ->
    configure(p) {
        def vendorSettings = file("${rootDir}/vendor.gradle")
        if (vendorSettings.exists()) {
            apply from: vendorSettings
        }
        apply from: "${System.getenv("niagara_home")}/etc/gradle/niagara.gradle"
    }
}

tasks.addRule("""
Pattern: [jar[Test]|clean|<any gradle task>]/[path]: Run a Gradle task against
a set of modules rooted at path.
""") { String taskName ->
    def matcher = taskName =~ /(.*?)(Test)?\/(.*)/
    if (matcher) {
        def command = matcher.group(1)
        def includeTestModules = matcher.group(2) == "Test"
        def path = file("${projectDir}/${matcher.group(3)}").toPath()
        assert path.toFile().exists()
        def targetProjects = subprojects.findAll {
it.projectDir.toPath().startsWith(path) }
        // default is build command and build is an alias for Gradle's jar task
        if (command.isEmpty() || command == "build") { command = "jar" }
        // Create task for subproject
        task(taskName, dependsOn: targetProjects.tasks[command])
        if (includeTestModules && command == "jar") {
            tasks[taskName].dependsOn targetProjects.moduleTestJar
        }
    }
}

```

### vendor.gradle

```

// Vendor name applied to all modules
group = "Tridium"
// Major, minor, and build version
def moduleVersion = "5.0.1"
// Patch version can be declared
// For example, to patch envCtrlDriver module as 5.0.1.1
// moduleVersionPatch.'envCtrlDriver' = ".1"
def moduleVersionPatch = [:]
// Final version property applied to all modules
version = "${moduleVersion}${moduleVersionPatch.get(project.name, '')}"

```

### settings.gradle

```

import groovy.io.FileVisitResult
import groovy.io.FileType

```

```

def discoveredProjects = [:] as Map

ext {
    // Configure your sub-project folders here
    // This will include ALL sub-folders as sub-projects.
    niagaraRoots = ["."]
    // To explicitly define sub-project folders, name them in the array like this

    // niagaraRoots = ["componentLinks", "envCtrlDriver"]

    // Configure any directories to exclude from search for nested sub-projects
    excludeDirs = [".hg", "build", "out", "src", "srcTest"]
}

// niagaraRoots configuration - do not modify
niagaraRoots.collect({ file(it) }).findAll({ it.exists() }).each { File
projectRoot ->
    projectRoot.traverse(
        type: FileType.DIRECTORIES,
        preRoot: true,
        preDir: { File projectDir ->
            def projectName = projectDir.name
            if (excludeDirs.contains(projectName)) {
                return FileVisitResult.SKIP_SUBTREE
            }

            File buildScript = new File(projectDir, "${projectName}.gradle")
            if (buildScript.exists()) {
                discoveredProjects[projectName] = projectDir

                if (projectDir != projectRoot) {
                    include projectName
                    return FileVisitResult.SKIP_SUBTREE
                }
            }
        }
    )
}

// Set up the project tree - no need to modify
rootProject.name = "niagara"
rootProject.children.each { project ->
    project.projectDir = discoveredProjects[project.name]
    project.buildFileName = "${projectName}.gradle"
    assert project.projectDir.isDirectory()
    assert project.buildFile.isFile()
}

```

## External Library Dependencies

### Project Setup

Modules may depend on 3rd party libraries that implement some desired functionality. These dependencies are configured much like Niagara module dependencies, but are contained in a configuration called `uberJar`. For example, if a module has a direct dependency on the Apache Velocity library and the `baja` module, the dependency declaration would look like:

```

// Declare compile and test dependencies
dependencies {
    compile "Tridium:baja:4.0.0"
    uberJar "org.apache.velocity:velocity:1.7"
}

```

Libraries compiled with the `uberJar` configuration will cause the classes of the dependency to be included in the

resulting module jar file. This makes it straightforward to distribute modules with external dependencies.

Note that the string used to identify a particular library follows a specific convention of `group:name:version`. So in the above example, the group is `org.apache.velocity`, the name is `velocity`, and the version is `1.7`. This information relates to the Maven information for that library, and it will be verified and downloaded from a central Maven repository. See the [Gradle documentation on dependency management](#) for more information on external library dependency naming and the central Maven repository.

# Deploying Help

## Overview

Help documentation is deployed as a set of files zipped up in a module jar. With the introduction of module parts in Niagara 4, help content should be contained in a part with a runtime profile of **doc**. See [Modules](#) for a description of modules and runtime profiles. Help content can be any MIME typed file. The primary content types are:

- *HTML*: Niagara 4 provides support for HTML 5. This is the main format used to distribute help content.
- *Bajadoc*: These are an XML-based file type used to distribute Java API reference documentation. Niagara provides a special view for this file type, which allows users to view the documentation. Bajadoc files are generated from Javadoc comments in source code, using configuration specified in the build script.

There are three steps in help content creation:

1. The module developer supplies help content files and help structure files. Most of help content will be in form of HTML files, optionally with some graphics to enhance the presentation. As a general rule, you, as developer, should not concern yourself with anything but the content itself, providing HTML files with defined title and body that contains only content-related information. Developers should also include guide help for all their views. This view documentation is in the form of standard HTML files, located in the “doc” directory using a naming convention of “module-TypeName.html”. A [table of contents](#) file should be provided, to specify the logical order of the help files.
2. (Optional) The developer supplies a lexicon key to point to module containing help. Guide help (Guide on Target) will look for the HTML file defined above in the doc directory of its module if the help.guide.base is not defined in its lexicon. You can supply this key to point to another module. As an example, most core modules point to `docUser: help.guide.base=module: //docUser/doc`.
3. Build the module. The module part containing the help content is built using the same tools as other module parts. See [the build documentation](#) for more information on this. During this step, the help content is indexed for the full text search purposes.

## Build script

A doc module part’s build script should have the ‘docmodule.gradle’ script applied to it, as follows:

```
apply from: "${System.getenv('niagara_home')}/etc/gradle/docmodule.gradle"
```

This will cause several things to happen when the module is built:

- HTML files in the /doc folder and referenced in the table of contents will be enhanced with a link to the standard help style sheet. This style sheet is not user configurable.
- A copyright notice will be applied to the HTML, if specified.
- Navigation links, based on the table of contents, will be inserted at the top and bottom of the document. There are three navigation links generated:
  - *Index* - always points to `index.html`.
  - *Prev* - points to the previous file in TOC, or is disabled if this is the first file in the TOC.
  - *Next* - points to the next file in TOC, or disabled if this is the last file in the TOC.

In order for the HTML enhancement processing to insert the style sheet and navigation links in the correct positions, the `<head>`, `<body>` and `</body>` elements in the document HTML should start on new lines. It is also required that HTML documentation files in the module are encoded with the UTF-8 character set.

The copyright text applied to the HTML can be specified in the project’s build script as an extra property named `copyright` on the project. For example, the build script could include the following extra property:

```
ext.copyright = 'Copyright © 2000-2015 Tridium Inc. All rights reserved.'
```

This will apply the copyright text to a single module part. For multi-project builds, the copyright text can also be specified in the `vendor.gradle` file, again as an extra property. This will ensure that the same copyright text is applied to all doc

module parts under the root Niagara project.

## Generating Bajadocs

When optionally generating Bajadoc API documentation, there will be one or more projects containing the Java code to be documented - these projects will have runtime profiles such as 'rt' or 'wb'. There will also be a project with a 'doc' runtime profile. This will be the project configured to contain user documentation relating to the other projects, and also to generate the Bajadocs from the source code in the other projects:

```
\<some folder name> - Top level directory
|
| - build.gradle
| - vendor.gradle
| - settings.gradle
|
| - <project name-rt>\ - Folder containing project name-rt`
|   | - <project name-rt>.gradle - rt Project Gradle script file`
|   |
|   - <project name-wb>\ - Folder containing project name-wb`
|     | - <project 2 name-wb>.gradle - wb Project Gradle script file`
|     |
|     - <project name-doc>\ - Folder containing project name-doc`
|       | - <project name-doc>.gradle - doc Project Gradle script file`
```

The application of the `docmodule.gradle` script will add a dynamic method named `bajadoc()` to the `doc` project. This method is called to generate Java API documentation for a project, with the resulting documentation being included into the 'doc' module part the script is applied to.

Several configuration values can be passed to the method:

- **source** This is the project containing the code to be documented. This is always required. A project can be referenced by calling the `project()` method, passing the name of the project, prefixed with a colon. Example: `source project(":myDriver-rt")`
- **includePackage** This can be used to pass the name of a single Java package to be documented. There are two further configuration properties required here (see below for an example):
  - **name** = The name of the Java package.
  - **bajaOnly** = A boolean value, which, if true, will only generate API documentation for the properties, actions and topics of Niagara types. Methods, functions and regular Java classes will *not* be documented.
- **includePattern** This can be used to include code files via an ANT style include pattern. The pattern should target '.java' files relative to the project's `/src` directory. Example: `includePattern "com/mycompany/mydriver/messages/*.java"`
- **excludePattern** This can be used to exclude files via an ANT style exclude pattern. The pattern should target '.java' files relative to the project's `/src` directory. This might be used to exclude certain classes that need to be in a documented package, but are not considered part of the public API and therefore can be ignored. Example: `excludePattern "com/mycompany/mydriver/**/*Util.java"`

The `bajadoc` declaration must contain at least one usage of `includePackage` or `includePattern` in order to have a set of source files to generate the documentation from. Note that `includePackage` specifies a *single package name*, while `includePattern` and `excludePattern` specify *file paths*, which could potentially match more than one Java package.

The 'doc' part's build script should invoke the `bajadoc()` method for each project to be documented, referencing the other project as the source. The following example is an extract from a build script for a project with a 'doc' runtime profile, which calls `bajadoc()` to generate class documentation for a project named "myDriver-rt". It references the project containing the source code, and passes configuration such that two packages are documented, and classes with names ending "Util" are excluded.

myDriver-doc.gradle:

```
niagaraModule {
    preferredSymbol = "mydriv"
    moduleName = "myDriver"
    runtimeProfile = "doc"
}

bajadoc {
```

```

source project(":myDriver-rt")
includePackage {
    name = "com.mycompany.mydriver.core"
    bajaOnly = true
}
includePackage {
    name = "com.mycompany.mydriver.messages"
    bajaOnly = false
}
excludePattern "com/mycompany/mydriver/**/*.Util.java"
}

```

## Generating JavaScript Documentation

In addition to the Bajadoc feature for documenting Java source code, documentation may also be generated for JavaScript code by specifying a `jsdocBuilds` configuration with the Niagara rjs plugin. This will generate HTML-based documentation from comments in the source code using the JSDoc tool. See the [JSDoc](#) site for details on the syntax of documentation comments.

To enable this functionality, the plugin needs to be applied in the project's build script:

```
apply plugin: "niagara-rjs"
```

The build script can then specify one or more projects to generate HTML documentation from. For each project, there are several options that can be configured:

- **rootDir:** This string specifies a path to the root folder of the JavaScript code for the project. This will include all .js files it finds, but will exclude built and minified files.
- **source:** As an alternative to the 'rootDir' option, a file tree containing the JavaScript files to be documented can be specified. This option allows the set of documented source files to be refined by the use of ANT style include and exclude patterns.
- **destinationDir:** Specifies the directory to receive the JSDoc output. If it isn't already, this directory should be added to the includes for the project's jar task.
- **options:** This optional configuration value allows a list of string values to be passed to JSDoc command line. Tutorials can be specified via this option; see the command line options for JSDoc [here](#).

The following is an example of the usage of these options to document the JavaScript for two projects:

```

niagaraRjs {
    jsdocBuilds = [
        ModuleA: [
            source: project(":moduleA-ux").fileTree(".") {
                include "src/rc/**/*.js"
                include "README.md"
                exclude "src/rc/**/*.buil*.js"
            },
            destinationDir: "$buildDir/jsdoc/moduleA-ux"
        ],
        ModuleB: [
            rootDir: project(":moduleB-ux").projectDir.path + "/src/rc",
            destinationDir: "$buildDir/jsdoc/moduleB-ux"
        ]
    ]
}

jar {
    // Include generated JS docs into the jar
    from (new File("$buildDir/jsdoc")) {
        include '**/*.js'
        into 'doc/jsdoc/'
    }
}

```



```
}
```

## Help Side Bar

The help side bar has three tabs: Table of Contents, API and Search.

- Table of Contents, a.k.a. TOC, is used for presenting help content as a structured tree, in some logical order.
- API is used for presenting Bajadoc API documentation, organized by module part.
- Search allows full text search of the help content based on some search criteria.

## Table Of Contents (TOC)

As a general rule, you should provide a TOC with your help content. This should be an XML file, named `toc.xml`, located in the `src/doc/` directory. This file is required for a module to appear in the help table of contents. The DTD for this file is as follows:

```
<!ELEMENT toc (tocitem*)>
  <!ATTLIST toc version CDATA #FIXED "1.0">
  <!ATTLIST toc xml:lang CDATA #IMPLIED>

<!-- an item -->
<!ELEMENT tocitem (#PCDATA | tocitem)*>
  <!ATTLIST tocitem xml:lang CDATA #IMPLIED>
  <!ATTLIST tocitem text CDATA #IMPLIED>
  <!ATTLIST tocitem image CDATA #IMPLIED>
  <!ATTLIST tocitem target CDATA #IMPLIED>
```

It should have `<toc>` as its root element, and a list of files that you want to include in the final TOC, in the logical order. Although the TOC structure can be many levels deep, the most likely case will be a flat list of files. Each file is included via the `<tocitem>` element, and has two important attributes: `text` and `target`. The `text` attribute is used to specify the label text of the node as it appears in the TOC tree, while the `target` attribute specifies the relative URL of the help content file associated with this TOC item. It is required that at least one of the `target` or `text` attributes is present.

The `target` attribute:

- Must be a sub-path relative to the project's `src/doc/` directory.
- Must not contain backup characters: `..`

You may use `tocitem` elements with only the `text` attribute defined as a way of grouping TOC nodes. If you want to define a TOC node associated with some help content, you must provide the `target`. If you provide the `target` only, the `text` will be generated as the name of the target file, without path and extension.

The following is an example TOC file:

```
<toc version="1.0">
  <tocitem text="Index" target="index.html" />
  <tocitem text="User Guide" target="userGuide.html" />
  <tocitem text="Developer Guide" target="devGuide.html" />
</toc>
```

## API

This is a tree of module parts that have Bajadoc API documentation available. Packages and types within a module part can be viewed by expanding the items in the tree.

## Search

This is a search view, used to search for occurrences of text. Enter the search term in the *'Find:'* box, and click the *'Search'* button. Matching results will be displayed in a list below the search box.

# Slot-o-matic

## Overview

The **Slot-o-matic** is a java source code preprocessor which generates java source code for Baja slots based on a predefined comment header block. The generated code is placed in the same source file, and all other code in the original source is not modified in any way.

## Usage

### Invocation

Slot-o-matic is invoked by the executable `slot.exe`. To get help invoke:

```
D:\>slot -?

usage: slot [-f] [-?] <dir | file ...>
-f force recompile of specified targets
-? provides additional help.

slot compiles Baja object files.

For a file to be compiled, it must have a name
  of the form B[A-Z]*.java.

slot will happily recurse any and all directory arguments.
```

Slot-o-matic will compile any file that meets the following conditions:

1. The file name is of format *B[A-Z]\*.java*, e.g. *BObject.java* or *BSystem.java*, but not *Ball.java*.
2. The source code has a comment block delimited by `/* - */`.

When Slot-o-matic compiles a file, it reads the comment block and generates new java source code based on the contents of that block. The new source is placed in the file being compiled immediately **after** the Baja comment block. If any errors are found, the contents of the file are not altered in any way. The source file may (and indeed probably must) have any other source code required to implement the class in the source file, as with normal java source. The **only** difference between a normal java source file and one usable by Slot-o-matic is the `/* - */` comment block.

Compiling a file is simple:

```
D:\>slot D:\niagara\r3dev\fw\history\javax\baja\history\BHistoryService.java
  Compile BHistoryService.java
Compiled 1 files

D:\>
```

As is a directory:

```
D:\>slot D:\niagara\r3dev\fw\history
  Compile BHistoryService.java
Compiled 1 files

D:\>
```

Slot-o-matic works like `make` in that it will only compile files whose `/* - */` comment block's content has changed since the last compile. To force recompile, use the `-f` flag on a file or directory:

```
D:\>slot -f D:\niagara\r3dev\fw\history\src\javax\baja\history\
Compile BBooleanHistory.java
Compile BFloatHistory.java
Compile BHistory.java
Compile BHistoryDevicelet.java
Compile BHistoryJoin.java
Compile BHistoryPeriod.java
Compile BHistoryService.java
Compile BHistorySync.java
Compile BStorageType.java
Compiled 9 files

D:\>
```

## Slot file format

As stated above, Slot-o-matic will compile only files that meet certain conditions. In addition to having an appropriate file (and by extension class) name, the source code in the file must contain a comment block that describes the slots on the object to be compiled.

### Examples

#### Class Example

This example class would resolve in a file named *BImaginaryObject.java*.

```
/*-
class BImaginaryObject
{
    properties
    {
        imaginaryName: String
        -- The imaginary name for the imaginary object.
        default {[ "imaginaryName" ]}
        size: int
        -- The size of the imaginary object.
        flags { readonly, transient }
        default {[ 0 ]}
    }
    actions
    {
        imagine(arg: BComponent)
        -- Imagine something
        default {[ new BComponent() ]}
        create(): BSystem
        -- Create a new imaginary system.
    }
    topics
    {
        imaginationLost: BImaginaryEvent
        -- Fire an event when the object loses its imagination.
    }
}
-*/
```

There are blocks for each of the major slot types: properties, actions, and topics. None of the blocks needs to be present.

#### Properties Block

Each property has a name and a data type. Comments are specified via the "--" tag per line of comment. All comments

are transferred to the javadoc headers of the generated source code but are of course optional. A default value for all properties **must** be specified. The default block is delineated by { [ ] } and may have any sequence of java code inside it. Flags on the property may also optionally be specified. For more information on the available flags, see the [Flags bajadoc](#). Slot-o-matic will generate all get and set methods for the property.

### Actions Block

Each action may have 0 or 1 input (formal) arguments, and may optionally return a value. Actions are commented like properties. The input argument, if present, **must** have a default value as with a property. Slot-o-matic will generate the action invocation code; the implementor of the class must provide a do<actionName> method that provides the action implementation.

### Topics Block

Each topic specifies a name and an event type that it sends when fired. Slot-o-matic generates code to fire the event.

### Enum Example

This example class would resolve in a file named *BImaginaryEnum.java*.

```
/*-
enum BImaginaryEnum
{
    range
    {
        good,
        bad,
        ugly
    }

    default { [ bad ] }
}
-*/
```

Each member of the enumeration is specified.

### BNF

The formal BNF of the format is as follows:

```
Unit ::= ( Annotation )? ( Class | Enum )
Class ::= "class" Identifier "{" ( Singleton )? ( PropertyBlock | ActionBlock |
    TopicBlock )* "}"
Singleton ::= "singleton"
PropertyBlock ::= ( Annotation )* "properties" "{" ( Property )* "}"
Property ::= ( Annotation )* Identifier ":" BajaType ( Default | Flags | SlotFacets
    )*
ActionBlock ::= ( Annotation )* "actions" "{" ( Action )* "}"
Action ::= ( Annotation )* Identifier "(" ( FormalParameter )? ")" ( ":" BajaType
    )? ( Default | Flags | SlotFacets )*
FormalParameter ::= Identifier ( ":" BajaType )?
```

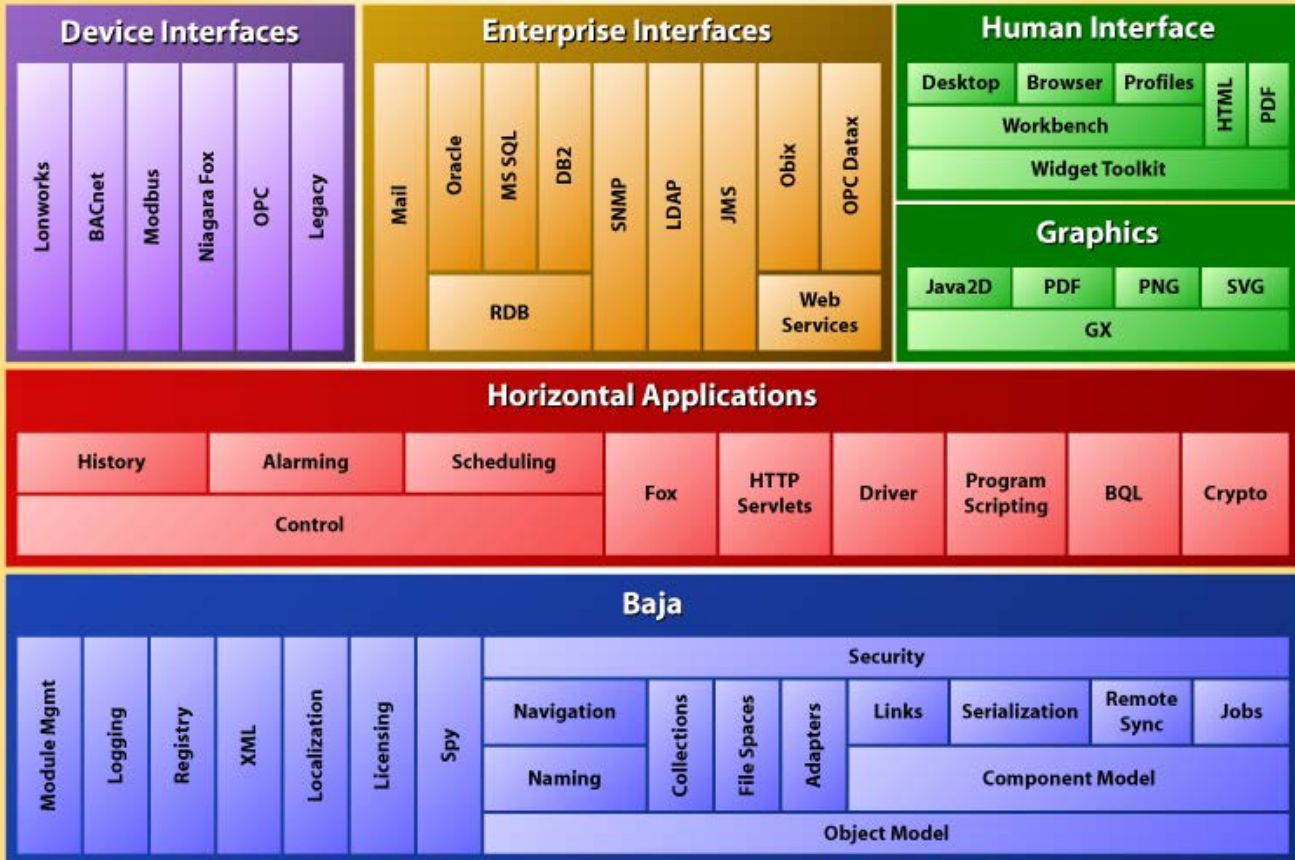
```

TopicBlock ::= ( Annotation )* "topics" "{" ( Topic )* "}"
    Topic ::= ( Annotation )* Identifier ( ":" BajaType )? ( Flags | SlotFacets )*
    Enum ::= "enum" Identifier "{" RangeBlock EnumDefault "}"
RangeBlock ::= "range" "{" ( Range ( "," Range )* )? ( "," )? "}"
    Range ::= Identifier ( "=" JavaExpression )?
EnumDefault ::= "default" "{" "[" JavaExpression "]" "}"
    Flags ::= "flags" "{" ( Identifier ( "," Identifier )* )? ( "," )? "}"
    Default ::= "default" "{" "[" JavaExpression "]" "}"
SlotFacets ::= "slotfacets" "{" "[" ( Facets ( "," Facets )* )? ( "," )? "]" "}"
    Facets ::= ( BajaName "=" )? JavaExpression
Identifier ::= <IDENTIFIER>
BajaType ::= ( BajaPrimitive | BajaName )
BajaPrimitive ::= ( "boolean" | "int" | "long" | "float" | "double" )
BajaName ::= Identifier ( "." Identifier )*
Annotation ::= "@" Identifier ( NormalAnnotation | SingleAnnotation )?
SingleAnnotation ::= "(" ( JavaExpression | JavaExpressionList ) ")"
NormalAnnotation ::= "(" KeyValue ( "," KeyValue )* ")"
    KeyValue ::= Identifier "=" ( JavaExpression | JavaExpressionList )
JavaExpressionList ::= "{" JavaExpression ( "," JavaExpression )* ( "," )? "}"
JavaExpression ::= <JAVA_EXPRESSION>

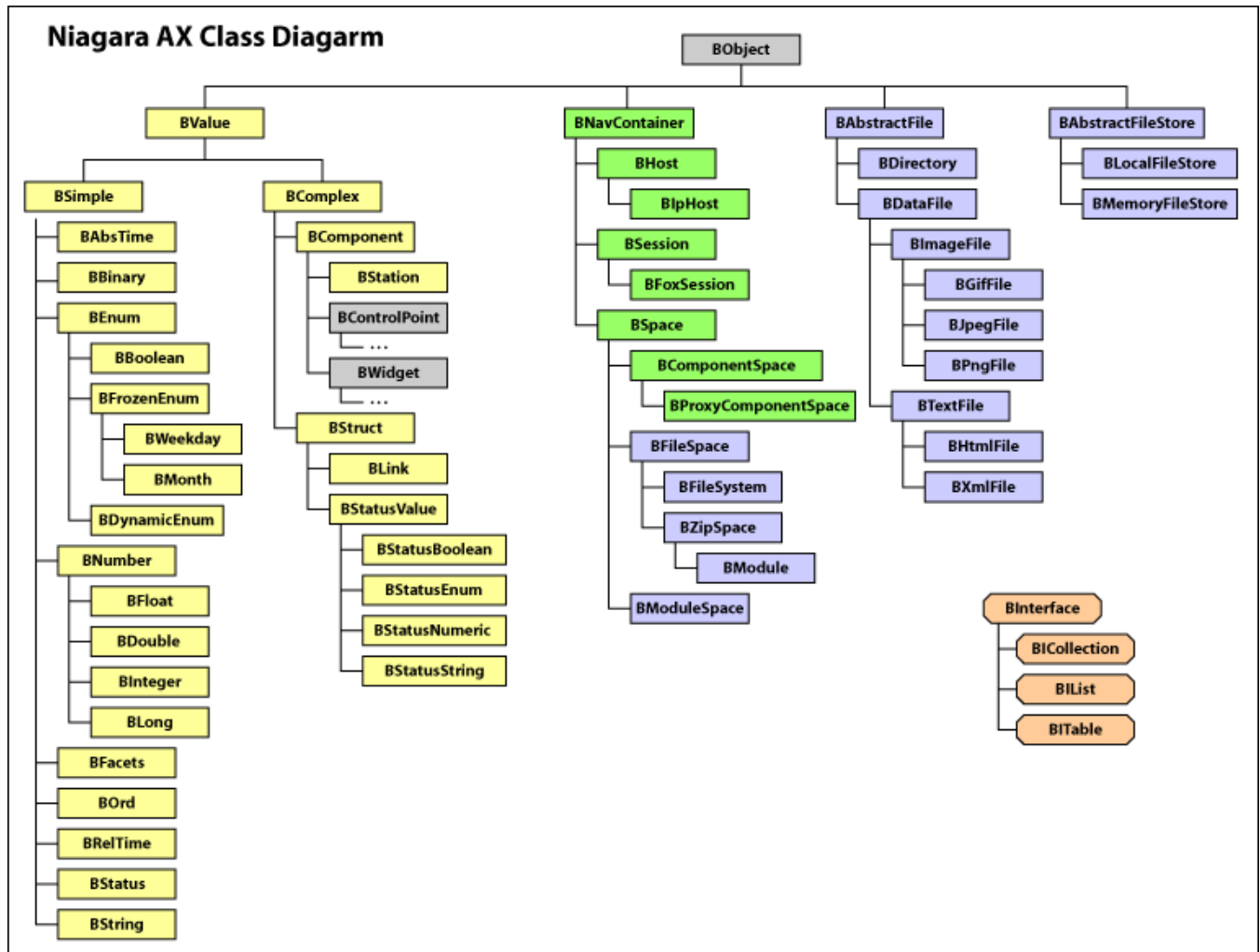
```

# Architecture - Software Stack

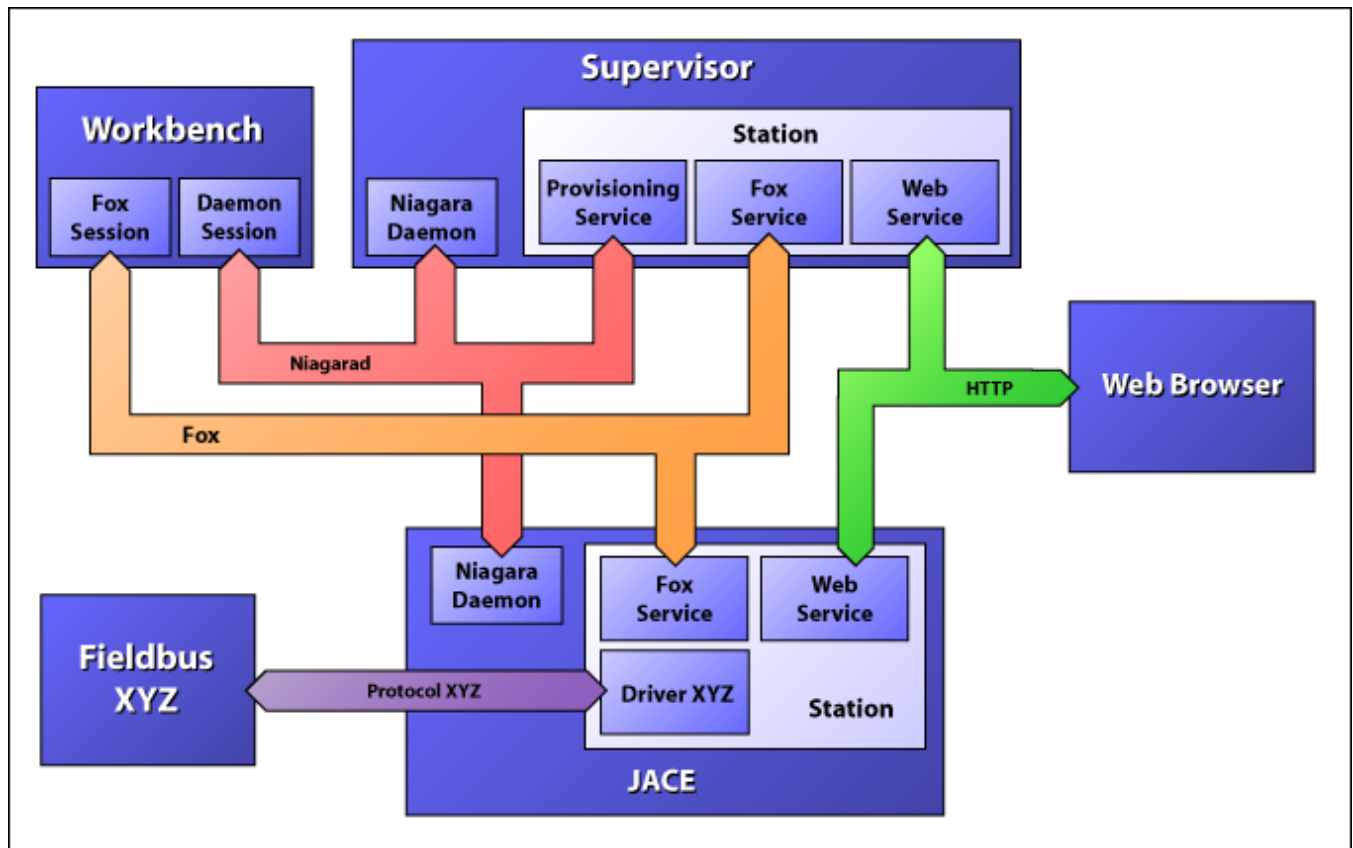
## Niagara AX Software Stack



# Architecture - Class Diagram

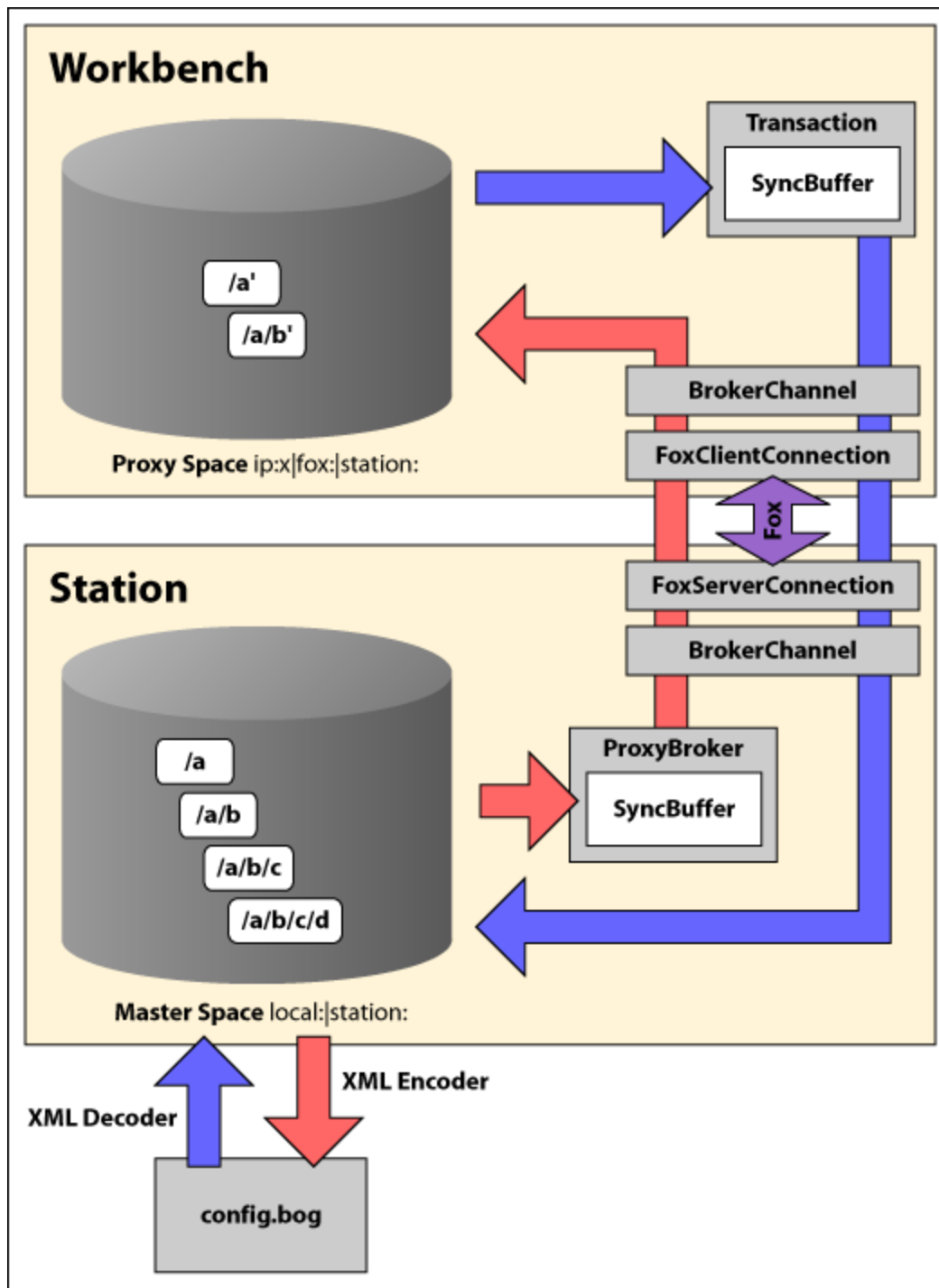


# Architecture - Communication

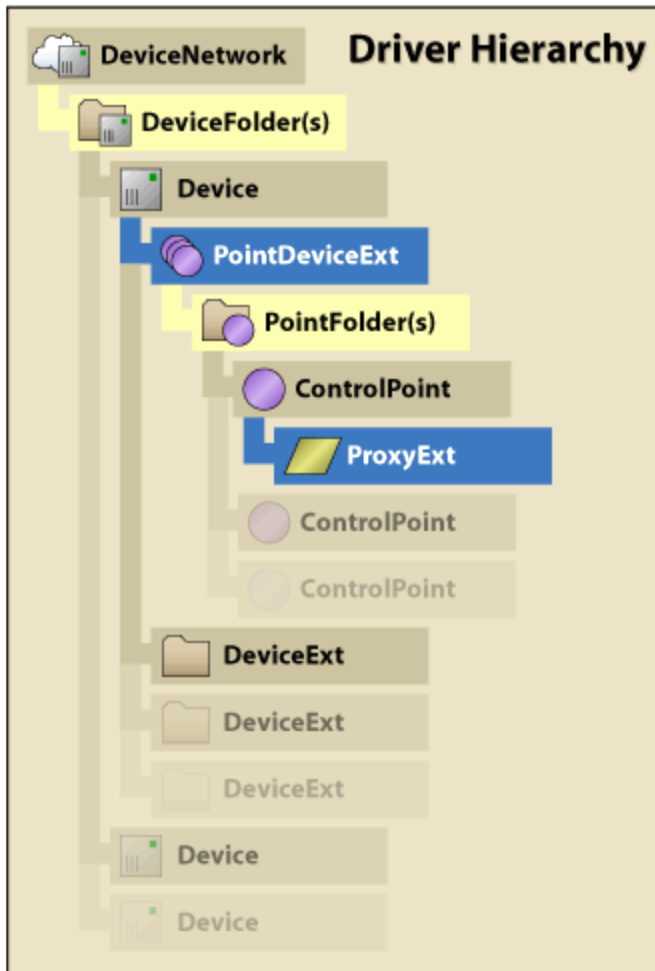




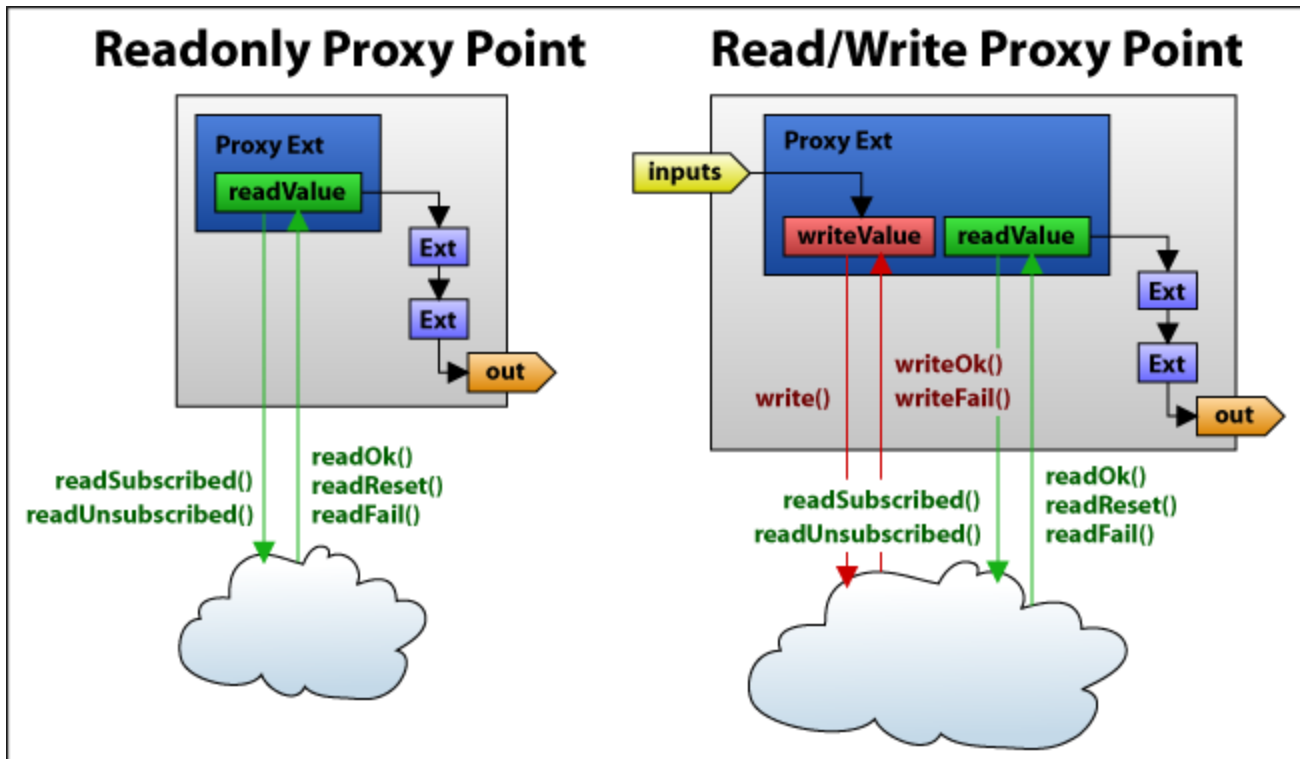
## Architecture - Remote Programming



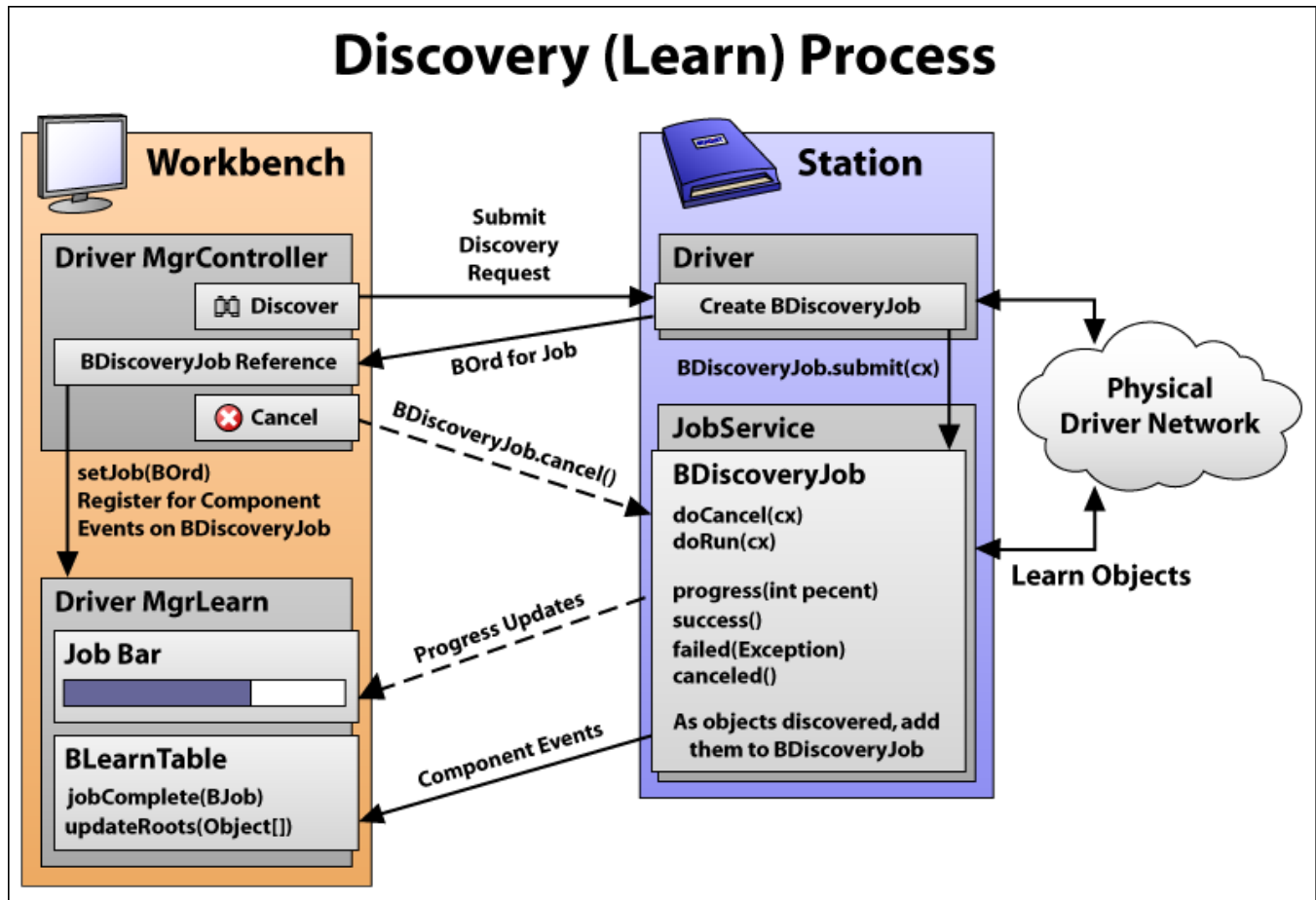
# Architecture - Driver Hierarchy



# Architecture - ProxyExt



## Architecture - Driver Learn



## Working with Series Schema

The data schema concept is heavily relied upon throughout the transform framework. A data schema defines the structure of some piece of data. An everyday example of a data schema is a BStruct or BComponent that defines frozen property slots. These frozen slots are guaranteed to be present for each instance of the defining struct or component object, and so other applications may reliably make use of these frozen slots.

In the series transform framework, the record schema is defined much the same way. However, rather than dealing with frozen slots on a defined component object, the transform framework defines the schema as the *dynamic* property slots that *will be present* on the record cursor object at the time the graph is resolved.

### Schema Composition

A series transform schema is a collection of field names with each field name associated with a BTypeSpec to represent the data type and BFacets to represent metadata for the field.

#### The Schema Field

Each schema field is stored in a **BSeriesSchema** instance as a dynamic property. The schema field name is the name of the Property slot. The data type of the schema field, the type of data that is represented by the field, is the value of the Property slot. This value is a **BTypeSpec** to allow the value to be stored in a property slot.

When a graph node is resolved to a cursor, the schema information is used to construct the record BComponent object that is returned from the **Cursor.get()** method. The record component properties are the same properties of the schema, with the exception that the value of the properties are data values of the Type represented by the schema field's BTypeSpec value.

#### Key Field

Each schema includes a key field. The key field is the data field that will include a unique value for each data row at the time that the graph node cursor is resolved. The key field is akin to the primary key field used in relational databases.

In the case of histories, the key field is the Timestamp field. Each record returned by a history is guaranteed to have a unique Timestamp value. By using the Timestamp field as the key field, the transform framework can perform tasks such as grouping a collection of records together in five minute intervals. This is possible because key field allows the framework to uniquely identify each cursor record, or "table row", as a unique record.

### Input and Output Schema

Each graph node deals with two separate schemas: the schema, or schemas, of the data source or sources for the graph node, and the schema of the record data that the graph node cursor will return.

The Incoming schema data is defined by the outgoing schema of the node source. In cases where a graph node has multiple incoming schemas, such as the Composite graph node, the schemas should be namespaced by the name of the graph node that the schema originates from.

The BGraphNode base class includes the **getSources()** method which returns an array of BGraphNode objects that are the inputs of the current graph node instance. This method is used to obtain the incoming schema of the graph node. Below is a code snippet from the composite editor that is used to create the fields available for selection to configure the composite node:

```
private String[] getCompositeFields()
{
    Set srcFields = new HashSet();

    //get the input sources for our node
    BGraphNode[] sources = srcNode.getSources();
    for( int i = 0 ; i < sources.length; i++ )
    {

        BGraphNode src = sources[i];
        String srcNodeName = src.getName();
```

```

        BSeriesSchema nodeSchema = src.getSchema();

        String keyField = nodeSchema.getKeyField();

        String[] fieldNames = nodeSchema.getFieldNames();
        for( int j = 0; j < fieldNames.length; j++ )
        {
            String fieldName = fieldNames[j];
            if( fieldName.equals(keyField)) continue;
            String colName = srcNodeName + "." + fieldName;
            srcFields.add(colName);
        }

        return (String[])srcFields.toArray(new String[]{});
    }
}

```

In the above example, the schema fields are obtained from all schemas associated with the composite node. These fields are later used to build the composite editor interface.

The output schema is the result of configuring the incoming schema or schemas in conjunction with the functionality of the transform graph node. In the case of the Composite node, the output schema is the collection of renamed input schema fields that are composited together to create a new data structure. The output schema is the representation of the dynamic properties of the BComponent that will be returned by the **CompositeCursor.get()** method.

It is not possible to know the composition of a series cursor record until the graph node of the cursor is resolved. This is a direct result of the end user's ability to dynamically alter data structures through the transform graph. The schema is absolutely necessary to grant each graph node cursor the knowledge of how to handle the incoming data.

## BSeriesSchema

The BSeriesSchema is the framework component that represents the schema for a graph node. The series schema component stores the schema fields as dynamic Property slots. By definition, this requires that each schema field has a unique name in the schema.

The series schema offers several convenience methods for working with the schema in an intuitive manner.

The **getKeyField()** method returns the key field for the entire schema. The key field is the data field that will include a unique value for each data row at the time that the graph node cursor is resolved. The key field is akin to the primary key field used in relational databases.

The **getFieldNames()** returns all schema field names. Each schema field name is unique and is the name of the Property Slot that will be set on the series cursor record BComponent returned from the cursor's **get()** method.

The facets and type information for each field is retrieved using the **getFieldFacets()** and **getFieldType()** methods. Each method takes a string Field name as the method argument.

Below is a code snippet demonstrating how to create a cursor template record using a series schema supplied from a graph node:

```

    public static BComponent createTemplateRecord(BSeriesSchema
recordSchema)
    {
        //make sure our composite Template includes the time stamp column
        BComponent templateRecord = new BComponent();

        //use our schema to initialize our template
        String[] fieldNames = recordSchema.getFieldNames();
        for( int i = 0; i < fieldNames.length; i++)
        {
            String fieldName = fieldNames[i];

```

```
BTypeSpec fieldType = recordSchema.getFieldType(fieldName);
BFacets fieldFacets = recordSchema.getFieldFacets(fieldName);
BValue defaultValue = getDefaultValue(fieldType.getResolvedType());

    templateRecord.add(fieldName,defaultValue,0,fieldFacets,null);
}

return templateRecord;
}
```

Note that once the field names are obtained from the schema, the field type and field facets information is retrieved for each field name to construct the dynamic properties of the template BComponent record.

## Creating a Graph Component

Transform Graphs are made of a series of Graph Nodes. These nodes interconnect to represent data transformations. These transformations may include scaling the data, reconstructing the schema of the data, performing mathematical transformations on the data to produce new data, and so on.

A graph node has two separate states that must be considered at time of implementation: the **design time** configuration state and the graph **resolve time** state.

The configuration state includes setting custom properties of the graph node and defining both the data input schema that defines the structure of the data that will be processed by the node at graph resolve time, and the output data schema the describes the structure of the data returned by the node at resolve time.

New Graph Nodes can be created and integrated into the transform graph framework by following these simple steps:

- [Create a BComponent that extends the BGraphNode abstract base class.](#)
- [Create a concrete implementation of the BSeriesTransformTable class.](#)
- [Create a Cursor implementation.](#)
- Optionally provide a [wiresheet popup editor](#) for the graph node component.



## Extending the Graph Node

All graph node implementations must extend from `BGraphNode`. This base class provides several key elements necessary to integrate with the transform graph.

### Graph Properties

Each graph node includes 4 properties which are used by the transform graph as follows:

- **Status** - Provides the configuration status of the graph node. If the node is currently misconfigured due to a change in the incoming [series schema](#) or node property settings made by the end user, this status should be set to fault.
- **faultCause** - The fault cause provides a description of why the node is currently in a fault state. This message should provide a description of what settings of the node are incorrectly set to assist the end user in properly configuring your graph node within the transform graph.
- **transformInputs** - The transform inputs property is a target property to allow the end user to connect one or more data input [schemas](#) to your graph node. An input source will most often be the output of another graph node.

This property defines the flow of data from a data source to a graph node and also defines the structure of data that the graph node can expect when processing the data at graph resolve time.

By default, this property does not declare the `fanIn` flag. You can set the `fan in` flag, or any other flag, on this property in the constructor of your graph node using the following code snippet:

```
Slot slot = getSlot(transformInputs.getName());
if( null != slot)
    setFlags(slot, Flags.TRANSIENT|Flags.SUMMARY|Flags.FAN_IN);
```

- **transformOutput** - The transform output is a target property that allows an end user to connect the output [schema](#) of the node as a data source to another node.

While these 4 properties may not be overridden, a graph node implementation may include as many additional properties as desired.

Node properties should be thought of as **design time** configuration settings for the graph node. These settings will be used at the time that the graph is resolved to determine how the incoming data for the node should be processed.

### Abstract Methods

When extending the `BGraphNode` base class, a handful of methods must be overridden and implemented.

#### `getSchema()`

This method allows the node to return the expected output [data schema](#) of the record object produced by the resolve time cursor. The schema is returned as a `BSeriesSchema` object.

Returning the schema via method call rather than a property on the node allows the schema to be built dynamically at the time the schema is requested based on the node configurations.

#### `doCheckSchema()`

This method is called by the transform framework to allow the graph node to check the current incoming [schema](#) or schemas against its current outgoing schema configuration. In cases where the input schemas are no longer sufficient to support the configuration of the output schema, a `ConfigurationException` should be thrown and the node placed in fault to notify the end user that the node is currently misconfigured.

This should be implemented by calling `getSchema()` on the source input nodes of the graph node and comparing that input schema to the configurations of the graph node. If the graph node configurations are supported by the incoming schemas we return from our method.

Below is a snippet from the BScaleNode class that shows how the incoming schema is checked against the current scale node configuration. What is important to node is that the method first retrieves all the input sources for the node using the **getSources()** method of BGraphNode, then retrieves the schema for each input node calling **getSchema()** on each source node. Each field of the schema that is used in the Scale Node's configuration is then checked to ensure that the value represented by the schema field is a numeric type.

```
//get the sources for our node by calling BGraphNode.getSources()
BGraphNode[] sources = getSources();

//get the configuration of our node. In the case of the Scale Node,
//the configuration is stored as a collection of BScaleFactor
//objects. Each scale factor is a simple mapping of an incoming
//schema field with a numeric scale factor.
BScaleFactors scaleFactorContainer = getScaleFactors();
Object[] factors =
    scaleFactorContainer.getChildren(BScaleFactor.class);

//check if we have any sources
if( sources.length == 0)
{
    //if we have factors but no sources, we are in fault
    if( factors.length > 0)
    {
        getTransformInputs().setStatus(BStatus.fault);
        getTransformInputs().setValue(
            lex.getText(SCHEMA_FAULT_UNMATCHED_FIELD));
    }
    return;
}

BGraphNode src = sources[0];
src.lease();
BSeriesSchema srcSchema = src.getSchema();

// brute force check of all schema inputs to make sure that all our
// scale maps use schema values that are still present
Set fields = getScaleInputFields();
String keyField = srcSchema.getKeyField();

for( int i = 0 ; i < factors.length; i++)
{
    BScaleFactor factor = (BScaleFactor)factors[i];
    String fieldName = factor.getInputFieldName();

    //ignore our key field
    if( fieldName.equals(keyField)) continue;

    //check that the incoming schema field exists in our set. If
    //the field is not present in our set of configured fields,
    //throw an exception indicating that the schema does not
    //correspond with our configuration.
    if( !fields.contains(fieldName) )
    {
        purge.add(factor);
        getTransformInputs().setStatus(BStatus.fault);
        getTransformInputs().setValue(
            lex.getText(SCHEMA_FAULT_INVALID_FIELD,
                new Object[] {fieldName}));

        continue;
    }

    //check that the type value of the field is numeric
}
```

```

        BTypeSpec fieldType = srcSchema.getFieldType(fieldName);
        if( !fieldType.getTypeInfo().is(BINumeric.TYPE)){
            getTransformInputs().setStatus(BStatus.fault);
            getTransformInputs().setValue(
                lex.getText(SCHEMA_FAULT_INVALID_TYPE,
                    new Object[]{
                        fieldType.toString(),
                        fieldName,
                        BScaleNode.TYPE.toString()
                    }
                )
            );
        }
        continue;
    }
}

```

### **doResolve( BSeriesTransformTable[], GraphNodeParams, BOrd )**

This method is called when the graph node is resolved to a data cursor. This is the method which brings together the Series Table defined for our graph node, the node Cursor, and the configurations of the node itself.

When this method is called, the graph node is expected to return an array of BSeriesTable objects. This array will usually consist of one series table value.

When creating the series table instance or instances to return, the method will use the configuration data of the node to generate the table instance. This configuration data is gathered in one of two ways in the following order:

1. The configuration data is obtained from the GraphNodeParams object passed into the method. This object is map of the properties of the graph node to a value passed in at run time. This value overrides the current property setting for this node.
2. If no value is present for the property in the GraphNodeParams object, the value currently set for the node property is used.

Below is a code snippet from the BHistorySourceNode class that demonstrates overriding the doResolve method. Note that the GraphNodeParams object is first checked to see if it contains a value for the given property name. If not, the value is obtained directly from our property.

```

protected BSeriesTransformTable[] doResolve(
    BSeriesTransformTable[] inputs,
    GraphNodeParams args,
    BOrd base) throws TransformException
{
    ...

    //Attempt to construct a history ORD from our node settings. First
    //attempt to retrieve the value from our graph node args. If the
    //value is not present, return the value found in our graph node
    //property.
    BOrd schemaOrd = BOrd.NULL;
    BFormat relativeSource =
        (BFormat)args.get(dataSource.getName(), getDataSource());
    BDynamicTimeRange range =
        (BDynamicTimeRange)args.get(dateRange.getName(), getDateRange());
    String historyOrdParams = getHistoryOrdParams(range);

    //construct our ORD from our format string and date range

    ...
}

```

```

// If we have a source ORD, process the source
if( schemaOrd != BOrd.DEFAULT )
{
    //get our Ord Target
    BObject object = schemaOrd.get(base.get());
    if( object instanceof BICollection)
    {
        BICollection c = (BICollection)object;

        //create our quantization cursor for this source
        BITable table = c.toTable();
        BSeriesInterval interval = getQuantInterval();
        BSeriesTransformTable table;
        if( interval.getDesc() == BSeriesIntervalEnum.none)
        {
            table = new BNonQuantizedTable(getName(),
                                           getSchema(),
                                           table));
        }
        else
        {
            table = new BQuantizationTable( getName(),
                                           getSchema(),
                                           interval,
                                           table) );
        }

        return new BSeriesTransformTable[]{table};
    }
}

//If we reach this point, we have an invalid data source
throw new SourceException(INVALID_DATA_SRC);
}

```

## Creating a Series Transform Table

All graph node implementations are expected to return a `BSeriesTransformTable` implementation. The Series Transform Table is an abstract implementation of the `BITable` interface that includes additional series data information.

When creating a series transform table, two pieces of information are required: the [Series Schema](#) of the records that will be returned by the table's cursor, and the **Series Name** of the data.

The schema data is the same schema data that is returned for the graph node's `getSchema()` method. This schema is the format of the data of each record that will be returned by the Cursor returned by the table instance.

The Series Name is name of the graph node that creates the table instance. The series name is used to handle name space issues when combining data from multiple input sources.

```
public BCompositeTable(String seriesName, BSeriesSchema schema,
                      CompositeMapping[] mappings, IFilter filter)
{
    super(seriesName, schema);
    this.mappings = mappings;
    setFilter(filter);

    //Perform other initialization operations as necessary
    ...
}
```

The only required method implementation is the `cursor()` method. This method will return a **Cursor** that performs the data transformations as intended by the graph node. Below is an example implementation of the cursor method for the `BCompositeTable` class.

```
public Cursor cursor()
{
    return new CompositeCursor(getSchema(), mappings, getFilter());
}
```

## Creating the Series Cursor

Each series transform table must return a Cursor implementation. The Cursor is responsible for retrieving data in the form of records from an input source (one or more Cursors) and performing operations on the data before returning the transformed data in a component record format.

### Creating a Cursor

The only requirement of implementing a Cursor for use with the Series Transform Table is to create an object that implements the **Cursor** interface.

As the Cursor interface requires a number of method implementations, the transform framework provides the **SeriesCursor** base class as a convenience base class for implementing a Series cursor. This document will focus on extending the Series Cursor base class.

The Series Cursor requires two method implementations: the **get()** method and the **next()** method.

The **get()** method will return a **BComponent** record. It is important to note that this method *should not create a new record instance* when it is called. Instead, the cursor should create a single instance of the record component at the time of initialization and load the record with new data each time the **get()** method is called, returning that record instance. This prevents an out of memory exception when iterating over large data sets.

The **next()** method is responsible for incrementing the cursor to the next record. If the cursor record cannot be incremented, due to lack of data or other causes, this method should return **false**.

### Cursor Implementation

When implementing a transform cursor, there are a few considerations to take into account.

The most important rule is that the **get()** method must return a reference to the same BComponent record each time it is called. It should **never create a new instance** of the component record. This implies that the Cursor will have a single BComponent instance instantiated and initialized at the time of class construction and returned whenever the **get()** method is called.

A second and equally important rule is that the BComponent record must conform to the [Series Schema](#) defined for the graph node that the Cursor represents. The component record must include a set of dynamic Property slots that conform to the Series Schema of the graph node.

Both of these rules are readily accomplished by creating a BComponent instance that is a record template and makes use of the Series Schema defined by the represented graph node as shown in the following code snippet.

```
public class CompositeCursor
extends SeriesCursor
{
    public CompositeCursor(BSeriesSchema schema, CompositeMapping[]
                                compositeMappings, IFilter filter)
    {
        keyField = schema.getKeyField();
        this.filter = null;
        this.templateRecord = makeTemplate (schema);
        createSubCursors(compositeMappings);
    }

    public static BComponent makeTemplate( BSeriesSchema recordSchema)
    {
        //create our template instance
        BComponent templateRecord = new BComponent();

        //use our schema to initialize our template
        String[] fieldNames = recordSchema.getFieldNames();
        for( int i = 0; i < fieldNames.length; i++)
```

```

        {
            String fieldName = fieldNames[i];

            BTypeSpec fieldType = recordSchema.getFieldType(fieldName);
            BFacets fieldFacets = recordSchema.getFieldFacets(fieldName);
            BValue defaultValue =
                getDefaultValue(fieldType.getResolvedType());

            templateRecord.add(fieldName,defaultValue,0,fieldFacets,null);
        }

        return templateRecord;
    }

    public BObject get()
    {
        //return our template instance
        return templateRecord;
    }

    public boolean next()
    {
        //get record values from our internal cursors. In the case of the
        //composite cursor, these internal cursors are passed in as part
        //of the constructors CompositeMapping values.
        ...

        //after retrieving our internal data from our sub cursors,
        // copy the composite properties to the composite record
        Set dstPropNames = propMappings.keySet();
        for( Iterator dstIt = dstPropNames.iterator(); dstIt.hasNext(); )
        {
            String dstPropName = (String)dstIt.next();
            String srcPropName = (String)propMappings.get(dstPropName);
            Property property = templateRecord.getProperty(dstPropName);

            BFacets facets = property.getFacets();
            BValue value = record.get(srcPropName);
            templateRecord.set(dstPropName, value);
            Slot slot = templateRecord.getSlot(dstPropName);
            templateRecord.setFacets(slot, facets);
        }

    }

    //our only record instance
    private BComponent templateRecord;
}

```

## Wrapping Cursors

The concept of wrapping cursors is simple. When a series cursor is instantiated, one or more cursors are passed into the cursor constructor. How the cursor is passed in is determined by the implementation.

In the case of the Scale Cursor, the data cursor is passed into the constructor by passing in the BSeriesTransformTable that is the data source that the scale cursor will operate against. Remember that a Series Transform table is a specific implementation of the BITable. Each time the scale cursor is initialized, we want to ensure that the scale cursor gets a new cursor by calling the cursor() method of the underlying data source, the series transform table.

```

public class ScaleCursor
    extends SeriesCursor

```

```

{
    public ScaleCursor(BSeriesSchema schema, BSeriesTransformTable table,
                      Map scaling, IFilter filter)
    {
        fieldNames = schema.getFieldNames();
        this.scaleFactors = scaling;
        this.innerCursor = table.cursor();
        this.filter = filter;
    }
    ...
    private Cursor innerCursor;
}

```

The series transform table passed into the cursor constructor is itself passed into the BScaleTable constructor and used when creating the ScaleCursor.

```

public class BScaleTable
extends BSeriesTransformTable
{
    //////////////////////////////////////
    // Type
    //////////////////////////////////////

    public Type getType() { return TYPE; }
    public static final Type TYPE = Sys.loadType(BScaleTable.class);

    public BScaleTable(String seriesName, BSeriesSchema schema,
                      BSeriesTransformTable table, Map scaleFactors)
    {
        this(seriesName,schema,table,scaleFactors,null);
    }

    public BScaleTable(String seriesName, BSeriesSchema schema,
                      BSeriesTransformTable table, Map scaleFactors,
                      IFilter filter)
    {
        super(seriesName,schema);
        this.scaleFactors = scaleFactors;
        this.table = table;
        this.setFilter(filter);
    }

    public Cursor cursor()
    {
        return new ScaleCursor(getSchema(), table, scaleFactors,
                               getFilter());
    }

    public BICollection filter(IFilter filter)
    {
        return new BScaleTable(getSeriesName(),getSchema(), table,
                               scaleFactors, filter);
    }

    private Map scaleFactors;
    private BSeriesTransformTable table;
}

```



```
}
```

Finally, the series transform table that is the data source for the Scale Cursor is passed into the BScaleTable at the time the scale table is instantiated: in the **doResolve()** method of the BScaleNode.

```
protected BSeriesTransformTable[] doResolve(
    BSeriesTransformTable[] inputs,
    GraphNodeParams params, BOrd base)
throws TransformException
{
    // get our scale factors
    Map scaleFactors = convertScaleFactorsToMap();

    BSeriesTransformTable[] results =
        new BSeriesTransformTable[inputs.length]

    // create a scale table for each input table
    for(int i = 0; i < inputs.length; i++)
    {
        BSeriesTransformTable table = inputs[i];

        // pass in the transform table into our new scale table
        BScaleTable scaleTable = new BScaleTable( getName(), getSchema(),
                                                    table, scaleFactors);
        results[i] = scaleTable;
    }
    return results;
}
```

## Creating a Rounded Popup Editor

A new feature included with Niagara AX 3.7 is the wiresheet popup editor. This editor, if defined for a BComponent type in the wiresheet, is displayed in lieu of the Property Sheet for the component.

It is important to note that the Property Sheet view is still available for the component; the end user must select the view from the available views on the component.

The popup editor allows the application to create a **BWbEditor** for the component as a whole, rather than for each field in a component as is required by the Property Sheet.

To create a popup editor, simply create a class which extends the BWbEditor base abstract class and implements the new BIPopupEditor interface. The editor should be implemented as any other Workbench editor and will display whenever the component is clicked in the workbench wiresheet.

## Creating Aggregate Functions

The Aggregate and Rollup graph nodes provide a few base functions for aggregating or performing a "rollup" on the incoming data. Additional functions can be created and will automatically be included by the Aggregate and Rollup graph nodes by extending the **BTransformFunction** base class.

Of the five required method implementations, four of these are required to integrate with the GUI workbench editors. These methods provide a name and description of the function as well as acceptable argument types (numeric, Boolean, etc.) and the return type.

The method of most importance is the **applyFunction( )** method. This method is called by the aggregate and rollup cursors to perform the data calculation for each data record or set of records in a cursor iteration.

### The applyFunction Method

The method includes four arguments: a map of series names to records lists an array of source property names, the destination property where the final calculated value will be stored, and the result record that the calculated value in which the value will be stored.

#### The Series Map

The **series** argument is a map of BComponent records contained in a **java.util.List** object that is keyed by the String name of the series that the records are associated with. Each source property name contained in the array of source property names is namespaced with the name of the series that the property is associated with.

The list of records associated with a value in the source property array can be obtained using the **getSeriesRecords** method available in the transform function API:

```
for( int i = 0; i < srcProps.length; i++)
{
    String name = srcProps[i];

    //get our records for the series associated with this input field
    List records = getSeriesRecords(series, getSeriesName(name));

    ...
}
```

#### The Source Properties Array

The **srcProps** array is an array of String values that represent the arguments for the transform function. Each String value contains the name of the Property containing the argument value and the name of the series that contains the record from which to pull the value. Each String value in the array of source properties uses the following format:

```
SeriesName.PropertyName
```

Prefixing the source property name with the associated series name allows implementing transform function to pull data from multiple input sources at cursor resolve time.

#### Example Implementing applyFunction

The following code snippet is an example of implementing the **applyFunction** method using the methods available in the Transform Function API. This example uses the Max function from the transform framework:

```
public void applyFunction(Map series, String[] srcProps,
```

```

                                Property destProp, BComplex resultRecord)
throws TransformException
{
    BNumber maxValue = null;

    // Use the getUnits static method of the Transform Function to get
the
    // Unit metadata of the destination property.
    BUnit dstUnits = getUnits(destProp);

    // iterate through each argument property name. For each argument,
    // get the series that contains the list of records that the property
    // is associated with and the name of the property.
    for( int i = 0; i < srcProps.length; i++)
    {
        String name = srcProps[i];

        // Use the getSeriesRecord method to retrieve the list of records
        // associated with this input argument. The static getSeriesName
        // method parses the series name from the argument name.
        List records = getSeriesRecords(series, getSeriesName(name));

        // iterate over our list of records and find our max for the
        // given field value
        if( null == records)continue;
        for( Iterator it = records.iterator(); it.hasNext();)
        {
            BComplex record = (BComplex)it.next();
            Property field = record.getProperty(getFieldName(name));

            // calculate our current maximum value, taking into account our
            // previous maximum and the source and destination Unit
information
            maxValue = getMaxValue(maxValue, field, dstUnits, record);

            // In the case of working with numeric data, if we have an
            // an invalid value returned as our maximum, we quit all attempts
            // to recalculate the max value and return the NaN to signify
that
            // invalid data is included in the data set.
            if( maxValue == BDouble.NaN) break;
        }
    }

    // if we have no records, we have no max
    if( null == maxValue)
        maxValue = BDouble.NaN;

    // Use the setRecordValue method to handle setting facet information
    // and creating a new dynamic property in the BComponent if
necessary.
    setRecordValue(resultRecord, destProp, maxValue);
}

```

## Helper Functions

The BTransformFunction abstract base class includes several useful static functions that may be used when implementing the applyFunction method.

**getUnits( javax.baja.sys.Property )**

This method retrieves the **BUnit** facet data from the given Property slot. If no unit facet information is found, the method returns BUnit.NULL.

**convertToUnits( javax.baja.sys.BNumber , javax.baja.units.BUnit sourceUnit, javax.baja.units.BUnit targetUnit)**

This method converts the given number from the source unit type to the destination unit type. An example is when the source unit value is defined in Fahrenheit while the target unit type for the destination property in the result record is Celsius. This method will convert the numeric value from the source unit to the destination unit, returning the value in the format of the target unit.

**getSeriesName( String )**

This method assumes that the String value given is as namespaced function argument of the following format:

`SeriesName.PropertyName`

This method parses the String value and returns the series name.

**getFieldName( String )**

This method assumes that the String value given is as namespaced function argument of the following format:

`SeriesName.PropertyName`

This method parses the String value and returns the Property name.

# Security

## Overview

Security in the Niagara framework covers a couple of broad topics:

- **Authentication:** Logging in and verifying a user;
- **Encryption:** When and how to use cryptography to secure data;
- **Categories:** Categorizing objects we wish to protect via the security model;
- **Permissions:** Configuring and verifying user permissions on objects through categories;
- **Auditing:** Logging user actions to create an audit trail;

The following steps are used to setup a Niagara security model:

1. First we have to define the users, which are modeled as BUsers.
2. We have to authenticate users, to make sure they are who they say they are. This is done via a login, with a username and password or other credentials appropriate to the user's authentication scheme.
3. We have to determine what each user can do with each object. The objects we typically wish to protect are Components, Files, and Histories. Each of these objects is categorized into one or more categories.
4. We grant each user a set of permissions in each category. This defines exactly what each user can do with each object in the system.
5. Last we audit anything a user does for later analysis.

## Users

The [BUser](#) component models security principles in a Niagara system. Typically, BUsers map to human users, but can also be used to represent machine accounts for machine to machine logins.

The [BUserService](#) is used to store and lookup BUsers during login. The BUserService simply stores the system users as dynamic slots.

BUser is used to store the authentication credentials, roles, as well as any other required meta-data for each user. As a developer, if you wish to add additional meta-data to users, then you might consider declaring your own [BIMixin](#).

## Authentication

For a detailed look at the BAuthenticationService, and how to create new [BAuthenticationSchemes](#), see the [authentication documentation](#).

All authentication in the Niagara framework is based on the [BUserService](#) and the BAuthenticationService configured for a station database.

The BAuthenticationService determines what BAuthenticationSchemes a station supports. These BAuthenticationSchemes are then assigned to each user in the BUserService

The BUserService is used to lookup [BUsers](#) by username during login, to determine what BAuthenticationScheme to use. This determines what types of credentials to acquire from the user, and how to acquire them. The credentials are then compared to the credentials stored in the BUserService.

There are three primary authentication points in the Niagara system:

1. **Fox Workbench to Station:** When a connection is made from workbench to a station, the user is prompted for a username and credentials which are used to authenticate the Fox connection.
2. **Fox Station to Station:** When a connection is made from a station to another station, preconfigured credentials are used to authenticate the Fox connection. These credentials are stored in the NiagaraStation.clientConnection component.
3. **HTTP Browser to Station:** When a browser hits a station URL, an HTTP authentication mechanism is used to

validate the user.

## Authentication and Communication Protocols

Niagara 4 supports authentication over fox and over HTTP. However, not all `BAuthenticationSchemes` support both protocols. For example, the `HTTPBasicAuthenticationScheme` only works over HTTP. Pick a `BAuthenticationScheme` appropriate for the user's requirements.

Details about what a `BAuthenticationScheme` needs to support authentication over fox or HTTP are described in the [authentication documentation](#).

## Categories

All objects designed to be protected by the security model implement the [BIProtected](#) interface. The `BIProtected` interface extends from the [BICategorizable](#) interface. An `ICategorizable` object has the ability to be assigned to one or more categories. In essence a category is just a number: Category 1, Category 2, Category 3, etc. You can give meaningful names categories by mapping category numbers to a [BCategory](#) component within the [BCategoryService](#). Most objects of interest implement the `BIProtected` interface including `BComponent`, `BIFile`, and `BIHistory`.

Categories are just arbitrary groups - you can use categories to model whatever your imagination dreams up. Typically for security they will map to some type of role, for example any device associated with lighting may be assigned to a "lighting" category. But that same device may also be assigned to a "floor3" category.

Categories are implemented as variable length bit strings with each bit representing a category number: bit 1 for Category 1, bit 2 for Category 2, etc. This bit mask is encapsulated via the [BCategoryMask](#) class. `CategoryMasks` are stored and displayed as hex strings, for example the mask for membership in category 2 and 4 would be "a". There are two special `CategoryMasks`, the "" empty string represents the NULL mask (membership in no categories) and "\*" represents the WILDCARD mask (membership in all categories).

The `BICategorizable` interface provides a `getCategoryMask()` method to get the *configured category mask* for the object. However most objects support the notation of category inheritance, where the configured mask is null and the applicable category mask is inherited from an ancestor. This is called the *applied category mask* and is accessed via the `getAppliedCategoryMask()` method.

## Permissions

Once a user has been authenticated, the user is granted or denied permissions for each protected object in the system using the user's configured [BPermissionsMap](#). This map grants the user permissions for each category, thereby granting the user permissions for objects assigned to that category. Users may be configured as *super users* by setting their permissions map to `BPermissionsMap.SUPER_USER`. Super users are automatically granted every permission in every category for every object.

### Permission Levels

Niagara defines two *permission levels* called **operator** and **admin**. Each slot in a `BComponent` is assigned to be operator or admin based on whether the `Flags.OPERATOR` bit is set.

### Permissions

Each slot is defined as admin or operator level. Six *permissions* are derived to control access to slots:

- **Operator-Read:** Allows the user to view operator level information;
- **Operator-Write:** Allows the user to change operator level information;
- **Operator-Invoke:** Allows the user to view and invoke operator level operations;
- **Admin-Read:** Allows the user to view admin level information;
- **Admin-Write:** Allows the user to change admin level information;
- **Admin-Invoke:** Allows the user to view and invoke admin level operations;

The [BPermissions](#) class is used to store a bitmask of these six permissions.

## Component Permission Semantics

The following are the standard semantics applied to BComponents:

Operation	On Slot	Permission Required
read	operator non-BComponent properties	operatorRead
write	operator non-BComponent properties	operatorWrite
read	admin non-BComponent properties	adminRead
write	admin non-BComponent properties	adminWrite
read	operator BComponent properties	operatorRead on child
read	admin BComponent properties	operatorRead on child
invoke	operator actions	operatorInvoke
invoke	admin actions	adminInvoke
read	operator topics	operatorRead
read	admin topics	adminRead

Note that the permissions required to access a property containing a BComponent are based on the child BComponent regardless of access to its parent or whether the containing slot is marked operator or admin.

## File Permission Semantics

BIFiles use the operatorRead permissions to check read access for the file and operatorWrite to check write access. For a directory operatorRead is required to list the directory, and operatorWrite to create a new file.

## Computing Permissions

To check the permissions available for a specific object use the `BIProtected.getPermissions(Context)` method. If working with an [OrdTarget](#), then it is preferable to use `OrdTarget.getPermissionsForTarget()`, which computes the permissions once and then caches the result.

The standard mechanism to compute permissions by an `IProtected` object is:

1. If the Context is null or doesn't specify a user, then return `BPermissions.all`
2. Route to `BUser.getPermissionsFor()`. Note: don't use this method directly, because it might by-pass special cases within `IProtected.getPermissionsFor()` (see below).
3. Get the object's mask using `getAppliedCategoryMask()`.
4. Map the category mask to a permissions mask via `BPermissionsMap.getPermissions(BCategoryMask)`, which is a logical "OR" of each permission assigned to the configured categories.

There are a couple special cases to note. First is that BComponent access requires access to the entire ancestor tree. For example to access "c" in "/a/b/c", requires at least operatorRead access to "a" and "b". The system will automatically grant operatorRead to all ancestors of a component which a user has at least one permission on. Note that this calculation is only done periodically, but can be forced using the `CategoryService.update` action.

Another special case is BIFile which applies these special rules for file system protection:

1. Files in a BModule are automatically granted operatorRead (this does not include .class files which are never mapped into the ord name space).
2. If the user is not a super user, automatically deny any permissions outside of the station home directory
3. Any remaining cases map to user's configured permissions via the file's categories



## Checking Permissions

Permission checks are built-in at several layers of the framework:

- Checked on the BComponent modification methods.
- Checked on all Fox network traffic.
- Access in Workbench.

Each of these checks is discussed in detail.

### BComponent Modification

The following methods will check user permissions if a non-null Context is passed with a non-null BUser. If the permission is not available then a `PermissionException` is thrown.

- **set()**: If the property is operator, then must have operator write, otherwise admin write of the containing BComponent.
- **setFlags()**: Must have admin write of containing BComponent.
- **add()**: Must have admin write.
- **remove()**: Must have admin write.
- **rename()**: Must have admin write.
- **reorder()**: Must have admin write.
- **invoke()**: If the action is operator, then must have operator invoke, otherwise admin invoke.

Developers should take care to use the proper version of the method with a user context when applicable.

### Fox Traffic

Fox is the primary protocol used for workbench-to-station and station-to-station communication. Fox automatically performs all permission checks on the server side before sensitive data can be accessed or modified by a client. By the time a BComponent reaches the client Fox ensures the following:

- Dynamic slots which the user lacks permission to read are never sent across the network and will never appear in the client.
- Frozen slots which the user lacks permission to read/invoke will automatically have the hidden flag set.
- Frozen properties which the user lacks permission to write will automatically have the readonly flag set.

Furthermore all attempts to modify components are checked by the server being committed.

### Workbench Access

Each view declares the permissions a user is required to have on a given BComponent in order to access the view. These permissions are usually declared in the module manifest (module-include). By default views require `adminWrite`. To override the default:

```
<type name="PropertySheet"
class="com.tridium.workbench.propsheet.BPropertySheet">
  <agent requiredPermissions="r"><on type="baja:Component" /></agent></type>
```

Note that required permissions for a dynamic `PxViews` are configured via the `BPxView.requiredPermissions` property.

## Auditing

One of the important aspects of security is the ability to analyze what has happened after the fact. The Niagara component model is designed to audit all property modifications and action invocations. Auditable actions include:

- Property changed
- Property added

- Property removed
- Property renamed
- Properties reordered
- Action invoked

Component modifications are only audited when the modification method is passed a non-null Context with a non-null BUser. The history module includes a standard implementation of an audit trail stored to a history database file.

## Code Samples

In order to check if a BUser has a operator read permission on specified component:

```
target.getPermissionsFor(user).has(BPermissions.operatorRead) // BUser
implements Context
```

This snippet of code will throw a PermissionException if the user lacks the admin invoke permission:

```
user.check(target, BPermissions.adminInvoke)
```

To filter a list of INavNode children for security:

```
BINavNode[] kids = node.getNavChildren();
kids = BNavContainer.filter(kids, context);
```

Use an AccessCursor to automatically skip slots that a user lacks permission to read/invoke:

```
SlotCursor c = AccessSlotCursor.make(target.getSlots(), user)
while(c.next()) {}
```

## Security Manager

### Overview

One of the changes implemented in Niagara 4 is the activation of the Java Security Manager. The Security Manager allows us to restrict who can call what code using permissions. By default, *no one has any permissions*. Any code that requires a permission check will fail, with an `AccessControllerException`. Each permission must be granted explicitly, using a policy file.

This allows us to ensure that certain sensitive calls can only be made by trusted code or individuals – for example, we can limit who can read, write, delete or execute specific files or folders, using a [java.io.FilePermission](#). This way, we can protect sensitive files like the contents of the security folder, ensuring that only modules that absolutely need to access those files have permissions to do so.

As a developer, this means that you may encounter access control issues and defects, caused by the new Security Manager. In this document, we will show how to deal with these issues by:

- [Identifying Access Control Issues](#)
- [Disabling the Security Manager](#)
- [Reporting Security Manager Issues](#)

### Identifying Access Control Issues

When using Niagara 4 with the Security Manager enabled, you may come across issues where certain features are no longer functioning as expected. These problems may or may not be related to the Security Manager. To identify whether it truly is an access control issue, you have a number of options. We will go over each of these options in the sections below.

#### Inspect Output and Stack Traces

If you run across an issue you think may be related to the Security Manager, the first thing to do, as for any other issue, is to inspect the output for either the station or workbench, as appropriate. Typically, issues caused by the Security Manager will include one of the following in the output or stack trace:

```
AccessControllerException: access denied (<required permission>)
    access denied (<required permission>)
```

The presence of either of these two lines indicates a Security Manager issue, which should be reported.

#### Enable Security Manager Debug Output

Not all issues (Security Manager related or otherwise) generate a stack trace or other output, making it a little trickier to determine if the issue you are seeing is related to the Security Manager or not. In these cases, there are logs that may be turned on to obtain additional debug information.

##### Niagara Debug Output

For some basic debug output, you can go to the **DebugService** in the station, or to **Tools > Logger Configuration** in workbench, and turn on the “security.niagaraPolicy” log. Different settings will give different levels of detail:

- **FINE**. Logs failed permission checks, including the permission name and code base that failed the check.
- **FINER**. Logs successful permission checks for certain Niagara-specific permissions, including the permission name and the Niagara permission that granted it.
- **FINEST**. Logs successful permission checks for all permissions.

This is very basic information and is good for quickly determining the source of the problem in simple situations. For more complex situations, the built-in Java debug output can be used.

##### Built-in Java Debug Output

If you can start your station or workbench from the command line, Java offers a command line property to enable debugging on the Security Manager, allowing you to precisely identify access control issues. To enable Security Manager debug output, add the following (shown in green) to the command line:

```
station <stationname> -@Djava.security.debug=access,failure
```

Note that this will produce a LOT of output, which may be difficult to view from the console. If you would like to stream this output to a file, use the following (shown in green):

```
station <stationname> -@Djava.security.debug=access,failure > D:\tmp\debug.txt 2>&1
```

where D:\tmp\debug.txt is the file you want to stream your output to. The path and file can be changed, and the path *must* exist.

#### Note

The full debug output may only completely stream to the file once the application stops. The best way to test Security Manager issues, if possible is to start your application, attempt to reproduce the issue as soon as possible, then close the program and inspect the debug output.

#### Note

The Security Manager debug feature produces a lot of output, a lot of which you don't need to worry about if you're looking for access denied issues. You can filter out a lot of output if you use a text editor which allows a search and replace based on regular expressions, such as Notepad++. Simply use find and replace with:

Find: ". \*access allowed. \*\r\n"

Replace with: " "

### Disable the Security Manager and Try Again

If you have an issue and don't see any debug output, and cannot start your station or workbench from the command line, you do have another option available. If you know you can reproduce the issue consistently with the Security Manager on, you can stop the application and then disable the Security Manager, then restart the application. If you're still seeing the issue, it's not related to the Security Manager. If you aren't seeing it anymore, it may be Security Manager related.

See the following section for instructions on how to disable the Security Manager.

## Disabling the Security Manager

Enabling the Security Manager was a change with a massive scope. The Security Manager can potentially affect any and all features. As a result, it was not possible to identify every single potential issue before enabling it. In order to allow work to continue even when issues come up, we have provided the ability to disable the Security Manager when a blocking issue is found.

**The first requirement to disable the security manager is to have the "smDeveloperMode" license feature.** *If you don't have this license feature, you will not be able to disable the Security Manager even if you follow one of the methods described below.*

Once you have the "smDeveloperMode" license feature, you need to request to your application that it run without the Security Manager. There are three ways to do this, which we will go over in the sections below.

### Use the Command Line Argument

If you can start your application using the command line, the simplest way to request to disable the Security Manager is using the command line argument. Simply add the following (shown in green) to the command line:

```
station <stationname> -@Dniagara.security.manager.disable
```

### Set a System Property

If you can't start your application from the command line, you can request to disable the Security Manager by setting the `niagara.security.manager.disable` system property. The system property needs to be present at boot, so you

should include it in your `<niagara.user.home>/etc/system.properties` file.

## Enable the no-security-manager Flag (QNX)

In QNX, if you can't start your application from the command line, you can request to disable the Security Manager by opening an SSH connection to the JACE and issuing the following command:

```
touch /etc/no-security-manager
```

This will disable the Security Manager for both niagarad and stations.

## Reporting Security Manager Issues

Security Manager issues should be reported the same way as any other issue you come across. To help get the issue resolved more quickly, however, there are some additional details you can include.

- When describing how the issue occurs, **precise reproduction steps** are *extremely* important with Security Manager issues. The order of operations can affect whether the issue occurs at all, as can any change from default settings, or the presence of a new Service, etc...
- If you used the Security Manager command line debug argument, please include the entire debug output captured (before or after filtering the "access allowed" lines) in your issue report.
- If the issue caused a stack trace or other output in the console, please include the entire stack trace in your issue report.

Having all this information from the start will allow issues to be dealt with much more quickly, and will reduce the need for follow ups.

## Fixing Access Control Issues

Currently, the ability for third party developers to fix access control issues is limited. We do, however, allow the following:

- As (read/write/delete/execute) access to files is a restricted action requiring a specific permission for the file in question, third party modules that try to access the file system may run into issues. To address this, we have added shared directories that all modules have read/write/delete access to in the following locations:
  - Under the station. This location is now called `station_home`, and can be obtained via `Sys.getStationHome()`.
  - Under `niagara_user_home`. This location can be obtained via `Sys.getNiagaraSharedUserHome()`.

# Authentication

## Overview

In Niagara 4, the Authentication Service manages how users can log in to the station. It supports using multiple Authentication Schemes at once, so that different users can log in using different methods appropriate to the type or sensitivity of the account. Developers can create additional Authentication Schemes if desired.

# Authentication Service Model

## Overview

In Niagara 4, all authentication (that is, how users prove who they are to the station) is managed by the Authentication Service. In a Niagara 4 station, all authentication requests are routed through the Authentication Service. The types of authentication a station supports (both for fox and web) is determined solely by the Authentication Service. This results in a more robust authentication framework. Functionality that can be centralized is handled by the service itself, avoiding duplication of code. Functionality that cannot be centralized is handled by specialized handlers, which can be reused.

In this section, we describe how the Authentication Service works, and what steps are required to create new authentication schemes.

## Authentication Schemes

The most important element of the Niagara 4 Authentication Service is the Authentication Scheme. An Authentication Scheme determines how the client authenticates to the server. For example, with the `HTTPBasicAuthenticationScheme`, a username and password are sent over in plaintext; with the `DigestAuthenticationScheme`, multiple messages are passed back and forth to prove the client knows the password, without ever actually sending the password.

A station can support multiple authentication schemes. Each user account is tied to a specific scheme. This allows more sensitive accounts to use a more secure scheme (e.g. digest or two-factor), while still allowing other accounts to use other schemes such as LDAP. This is done via the `authenticationSchemeName` property on the `BUser`, which allows you to choose any Authentication Scheme configured in the Authentication Service and assign it to that user.

New schemes are added to the Authentication Service and configured as needed (e.g. the LDAP scheme will require certain parameters like the URL of the LDAP server to which you wish to connect). Only schemes added to the Authentication Service are supported by that station.

## Using the Authentication Service

In this section, we'll discuss how to set up a station to use the Authentication Service.

### Add the Authentication Service

Each station needs an Authentication Service. New stations are created with an `AuthenticationService` already in the "Services" container. If you have accidentally removed the `AuthenticationService`, you can manually add one from the "baja" palette into the "Services" container.

### Add the Desired Authentication Schemes

A station may support multiple Authentication Schemes. Which ones you want depends entirely on what you need your station to do.

Authentication Schemes should be added to the `AuthenticationService's AuthenticationSchemes` folder. Only schemes in that folder are supported by the station.

Each station is created with the `DigestAuthenticationScheme` and `AXDigestAuthenticationScheme` in the `AuthenticationSchemes` folder. This way, any Niagara 4 station can do digest authentication with both N4 and AX

clients.

Additional Schemes can be found in the `baja` and `ldap` palettes. Schemes may be added or removed from the `AuthenticationSchemes` folder, but be aware that removing a scheme may leave your users with an invalid reference to a non-existent scheme, and unable to log in.

### Assign Authentication Schemes to Users

In Niagara 4, each user is assigned its own `AuthenticationScheme`. This allows different users to use different schemes appropriate to the user type. For example, the `DigestScheme` is appropriate for human users, whereas the `HTTPBasicScheme` is more appropriate for devices that can't do digest.

A user's `AuthenticationScheme` can be changed via the user's `authenticationSchemeName` property in the user's property sheet. Simply select the desired scheme from the drop down list.

Once these setup steps are complete, the station should be ready for authentication. Note that by default, each new station comes with the `Digest` scheme installed, which is assigned to all users by default, so that in simple cases no additional setup is required.

### Creating an Authentication Scheme

When creating a new authentication scheme, there are a few things to take into consideration:

- The station must know how to gather information from the client.
- The client must know how to provide the server with information.
- The station must know how to process the information it gathers.
- Multiple protocols (e.g. fox or web) may need to be supported.

For each new authentication scheme created, a number of handlers may also need to be created to ensure that communication is possible between the client and the server. In this section, we will go over all the different objects that must be created when implementing a new authentication scheme.

- Step 1: Create a [BAuthenticationScheme](#) subclass
- Step 2: Create a [LoginModule](#)
- Step 3: Create the `BAuthenticationScheme` building blocks
  - `CallbackHandlers`
  - `Fox`
    - [BFoxCallbackHandler](#)
    - [BFoxClientAuthnHandler](#)
  - `Workbench`
    - [BWbDialogHandler](#)
  - `Web`
    - [BWebCallbackHandler](#)
    - [BILoginHTMLForm](#)

#### Step 1: Create a `BAuthenticationScheme` subclass

Each new authentication scheme must be a subclass of `BAuthenticationScheme`. A `BAuthenticationScheme` is essentially a wrapper for a JAAS (Java Authentication and Authorization Service) `LoginModule`. Each subclass must implement the following methods:

- `getSchemeName()`. This should return a `String` containing a **unique** name for the authentication scheme (e.g. "n4digest" or "n4HTTPBasic"). This name will be used by the server to inform the client which scheme is being used.
- `getLoginConfiguration()`. This should return a `JAAS login Configuration` that indicates which login module(s) to use, whether they are required, and what options to use. In most cases, a new `NiagaraLoginConfiguration` can be created with the appropriate `LoginModule` name, the `LoginModuleControlFlag.REQUIRED` flag, and whatever options are appropriate to the scheme (e.g. LDAP server name).

`BAuthenticationScheme` subclasses must also be declared as agents on `BAuthenticationScheme`.

## Step 2: Create a `LoginModule`

One of the most important pieces of a new Authentication Scheme is its corresponding JAAS [LoginModule](#). The `LoginModule` decides what information it needs from the user, delegates the task of acquiring it to the various handlers described in step 3, and then processes that information to determine whether authentication was successful or not.

For example, an authentication scheme for a basic authentication scheme could acquire the username and password from the user, and then compare the password to the stored hash to determine if the supplied password was correct. An LDAP scheme, on the other hand, might acquire the username and password from the user in the same way, but would then turn around and authenticate to the LDAP server rather than compare to an internally stored password.

A full discussion of how to create a JAAS `LoginModule` is beyond the scope of this document. For more information, see Oracle's [LoginModule Developer's Guide](#).

## Step 3: Create the `BAuthenticationScheme` building blocks

In order to keep `BAuthenticationSchemes` modular and easily extensible, authentication functionality is separated into a number of building blocks. Each building block provides a different piece of completely self-contained functionality.

Depending on what you want your `BAuthenticationScheme` to support, some of the building blocks may not be required. For example, an Authentication Scheme meant only to be used only over fox does not need any of the web building blocks. Note that this would mean that users using this scheme would not be able to log in via the web.

The building blocks are described in the following sections, grouped by functionality.

### CallbackHandlers

As mentioned in Step 2, the `LoginModule` delegates the task of acquiring user information to a JAAS `CallbackHandler`. In essence, the `LoginModule` doesn't care how the information it needs is acquired, so long as it is acquired. Different `CallbackHandlers` can acquire the same information in different ways.

This is particularly important for Niagara – it means that the same `LoginModule` can be used for both fox and web authentication, or any other protocol we might want to use. The only thing that needs to be added is a new `CallbackHandler` for each required protocol. It also means that different `LoginModules` that happen to require the same information can get it using the same `CallbackHandlers`, and can then process it differently.

In Niagara 4, we have two `CallbackHandler` superclasses defined, one for fox (`BFoxCallbackHandler`) and one for web (`BWebCallbackHandler`). Each `BAuthenticationScheme` must be associated to a subclass of these in order for authentication over that protocol to be possible.

### Fox

For `BAuthenticationSchemes` intended to communicate over Fox, both the `BFoxCallbackHandler` and `BFoxClientAuthnHandler` must be implemented.

### `BFoxCallbackHandler`

All `CallbackHandlers` intending to acquire information over fox for a scheme's `LoginModule` **must** be a subclass of `BFoxCallbackHandler`. Each subclass **must** implement JAAS's `CallbackHandler.handle(Callback[] callbacks)` method, which will send and receive messages over fox to acquire information from the client, and fill in the `callbacks` array with the appropriate information.

It **may** override `BFoxCallbackHandler.init(FoxSession session)`, which is called before starting the `LoginModule` login process. If it is overridden, `super(session)` **must** be called, as it ties the `BFoxCallbackHandler` to a specific `FoxSession`, allowing it to send messages to the client.

**To associate a `BFoxCallbackHandler` to a specific `BAuthenticationScheme`, it must be declared as an agent on that scheme.**

### `BFoxClientAuthnHandler`



The `BFoxClientAuthnHandler` is the client counterpart to the server's `BFoxCallbackHandler`. Although the client doesn't specifically need a `CallbackHandler` (which is only required for JAAS `LoginModules`), it does need to know what messages to expect from the server and how to respond to them. Therefore, each new `BAuthenticationScheme` must be associated with a subclass of `BFoxClientAuthnHandler`, which is "paired" to a `BFoxCallbackHandler`.

Subclasses of `BFoxClientAuthnHandler` **must** implement `handleAuthentication(FoxSession session, BICredentials credentials)`, which is responsible for sending and receiving messages over fox, to give the station the information it needs for authentication. The messages it receives should correspond to the messages sent by the corresponding `BFoxCallbackHandler`, and vice-versa.

**To associate a `BFoxClientAuthnHandler` to a specific `BAuthenticationScheme`, it must be declared as an agent on that scheme.**

### Workbench

If your `BAuthenticationScheme` will be used for users logging in via Workbench, a `BWbDialogHandler` **must** be created.

### BWbDialogHandler

Different `BAuthenticationSchemes` may require the user to supply different credentials. For example, digest authentication requires only a username and password. Two-factor authentication, on the other hand, requires a username and password, as well as an additional token. Workbench needs to know which dialog to present to the user in order to collect the appropriate information.

The `BWbDialogHandler` is responsible for building the appropriate dialogs when Workbench attempts to log in to a station.

Subclasses of `BWbDialogHandler` **must** implement `getPaneForStep(AuthenticationRealm realm, int step, BIOBJECT seedInfo)`, which constructs and returns an appropriate `BCredInputPane` for the given authentication step. While many authentication schemes will only have a single step, some may require multiple passes to enter additional credentials; since these steps may require different credentials from the user, a different pane can be built for each step.

The `BIOBJECT seedInfo` argument can be used to pre-populate the pane. For example, if the username and password have previously been stored, they can be pre-filled for the user.

### Web

If your `BAuthenticationScheme` is meant for users who will be logging in via the web interface, a `BWebCallbackHandler` **must** be implemented. *For users logging in via the browser*, a `BILoginHTMLForm` **must** be implemented.

### BWebCallbackHandler

All `CallbackHandlers` intending to acquire information over HTTP for a scheme's `LoginModule` **must** be a subclass of `BWebCallbackHandler`. Each subclass **must** implement `BWebCallbackHandler.handleRequest(HttpServletRequest req, HttpServletResponse resp)`, which is responsible for acquiring information from the user by processing HTTP requests and sending HTTP responses.

Each subclass **must** also implement JAAS's `CallbackHandler.handle(Callback[] callbacks)` method, which uses the data acquired from the user in `handleRequest()` to fill in the callbacks array.

Note that the mechanism for acquiring information is slightly different for `BFoxCallbackHandler` and `BWebCallbackHandler`. While fox allows us to send multiple messages within a single call to `handle(Callback[] callbacks)`, the servlet request handling process does not allow us to make multiple requests and responses within a single method. Since `LoginModules` don't support a partial login process, we are forced to gather all the user information before we start the login process at all. Therefore, `handleRequest()` will continue to be called until it returns a state of `BWebCallbackHandler.READY`, indicating that it has all the information it needs to process a `handle()` call, at which point the `LoginModule`'s login process will begin.

**To associate a `BWebCallbackHandler` to a specific `BAuthenticationScheme`, it must be declared as an agent on**

that scheme.

### BILoginHTMLForm

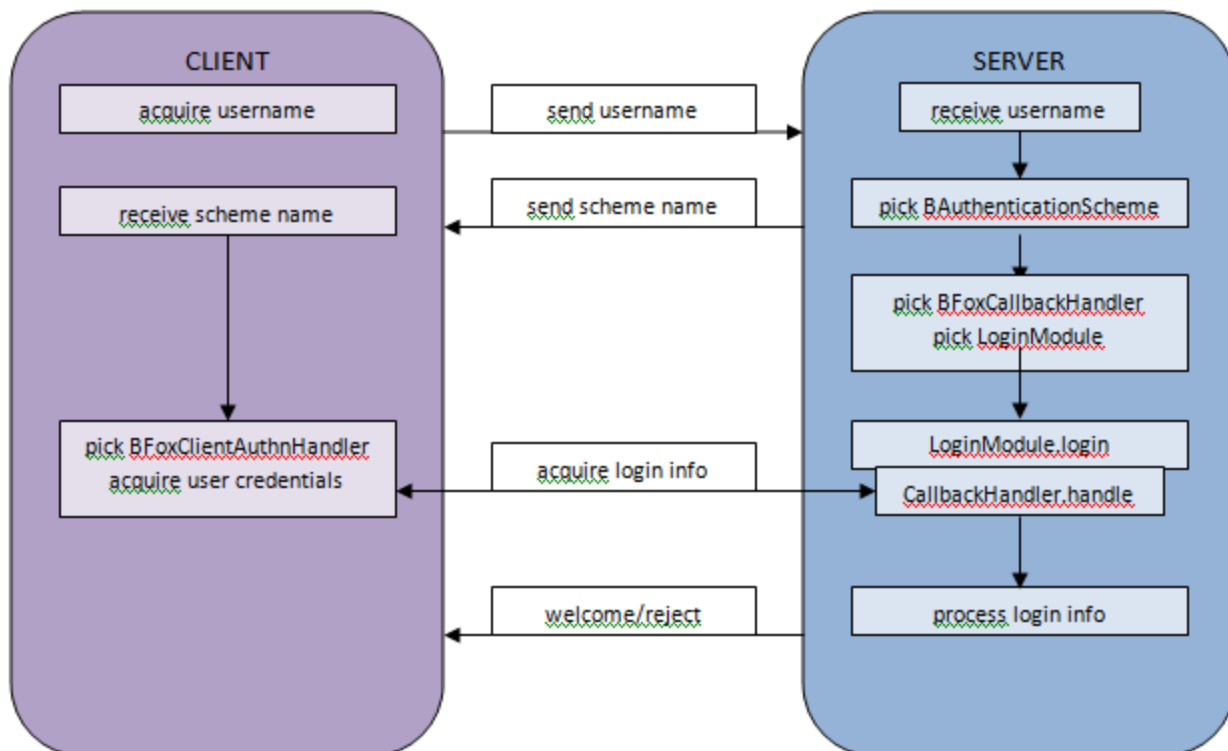
Just as we need to let a fox client know how to handle fox authentication messages, we also need to ensure that a web client knows what information to acquire from the user, how to acquire it, and how to send it back to the server. We do this by ensuring that each `BAuthenticationScheme` can create its own customizable HTML login form – each `BAuthenticationScheme` must be associated with a class implementing the `BILoginHTMLForm` interface.

Classes implementing the `BILoginHTMLForm` interface must implement the `getLoginFormHTML(Context context)` method. This method is responsible for creating an HTML snippet containing any input fields, buttons, or additional information the login form might require. The context argument can be used to pass in a `Locale`, or any other customizable information supported by the `BILoginHTMLForm` (`BDigestLoginHTMLForm`, for example, allows the username, password and login labels to be customized via the context argument).

**To associate a `BILoginHTMLForm` to a specific `BAuthenticationScheme`, it must be declared as an agent on that scheme.**

### Process Overview

This figure outlines the login process over fox, and how the various pieces (`BAuthenticationScheme`, `LoginModule`, `BFoxCallbackHandler` and `BFoxClientAuthnHandler`) fit together.



## Niagara AX to Niagara 4 API Changes

### Overview

In Niagara AX, authentication is handled by a number of different services and agents. The Fox Service, Web Service and User Service all determine in part what type of authentication the station supports. Not all possible configurations are valid, and this can lead to confusion and reduced security. What's more, because authentication is handled in so many different places, the authentication system tends to be fairly fragile.

In Niagara 4, the authentication model has been changed so that all authentication functionality goes through a single service, the Authentication Service. This helps centralize common functionality like auditing or approving or rejecting

authentication, and allows us to easily create and integrate new authentication schemes.

For more information about the Niagara 4 Authentication Service, view the [Authentication Service Model](#) section. As a result of these changes, some modifications were made to the API. These are described below.

## Who is Impacted

Any custom authentication implementation using `BAuthAgents` or subclasses of `BUserService` will be affected.

## What Changed

A number of things have changed with the new Authentication Service implementation:

- `BAuthAgents` are no longer used for authentication. Any implementation of a `BAuthAgent` will need to be refactored into the appropriate `BFoxCallbackHandler`, `BWebCallbackHandler`, `BFoxClientAuthHandler` and `BILoginHTMLForm` components.
- All `BAuthAgents` have been removed. Any code that uses or implements `BAuthAgent` will not compile.
- The methods `BUserService.getAuthAgent()` and `BUserService.authenticateBasic()` have been removed.
- The `authenticationPolicy` and `legacyAuthentication` properties has been removed from `BFoxService`.
- The `authenticationScheme` property has been removed from `BWebService`.
- `javax.baja.web.BAuthenticationType` has been removed.
- All stations must have an Authentication Service for authentication to be possible.
- There is no longer any need to subclass `BUserService` if an alternate authentication scheme is desired.

## Resolution

Any custom `BAuthAgent` should be replaced by the various components described in the [Authentication Service Model](#) section.

Subclasses of `BUserService` are no longer required to implement alternate authentication schemes. Authentication specific elements of the `BUserService` subclasses should be moved to the appropriate `BAuthenticationScheme` component (e.g. the scheme's `LoginModule`).