The JBoss 4 Application Server J2EE Reference

JBoss AS 4.0.5

Release 2

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The JBoss JMX Microkernel

Modularly developed from the ground up, the JBoss server and container are completely implemented using component-based plug-ins. The modularization effort is supported by the use of JMX, the Java Management Extension API. Using JMX, industry-standard interfaces help manage both JBoss/Server components and the applications deployed on it. Ease of use is still the number one priority, and the JBoss Server architecture sets a new standard for modular, plug-in design as well as ease of server and application management.

This high degree of modularity benefits the application developer in several ways. The already tight code can be further trimmed down to support applications that must have a small footprint. For example, if EJB passivation is unnecessary in your application, simply take the feature out of the server. If you later decide to deploy the same application under an Application Service Provider (ASP) model, simply enable the server's passivation feature for that web-based deployment. Another example is the freedom you have to drop your favorite object to relational database (O-R) mapping tool, such as TOPLink, directly into the container.

This chapter will introduce you to JMX and its role as the JBoss server component bus. You will also be introduced to the JBoss MBean service notion that adds life cycle operations to the basic JMX management component.

1.1. An Introduction to JMX

The success of the full Open Source J2EE stack lies with the use of JMX (Java Management Extension). JMX is the best tool for integration of software. It prov ides a common spine that allows the user to integrate modules, containers, and plug-ins. Figure 1.1 shows the role of JMX as an integration spine or bus into which components plug. Components are declared as MBean services that are then loaded into JBoss. The components may subsequently be administered using JMX.

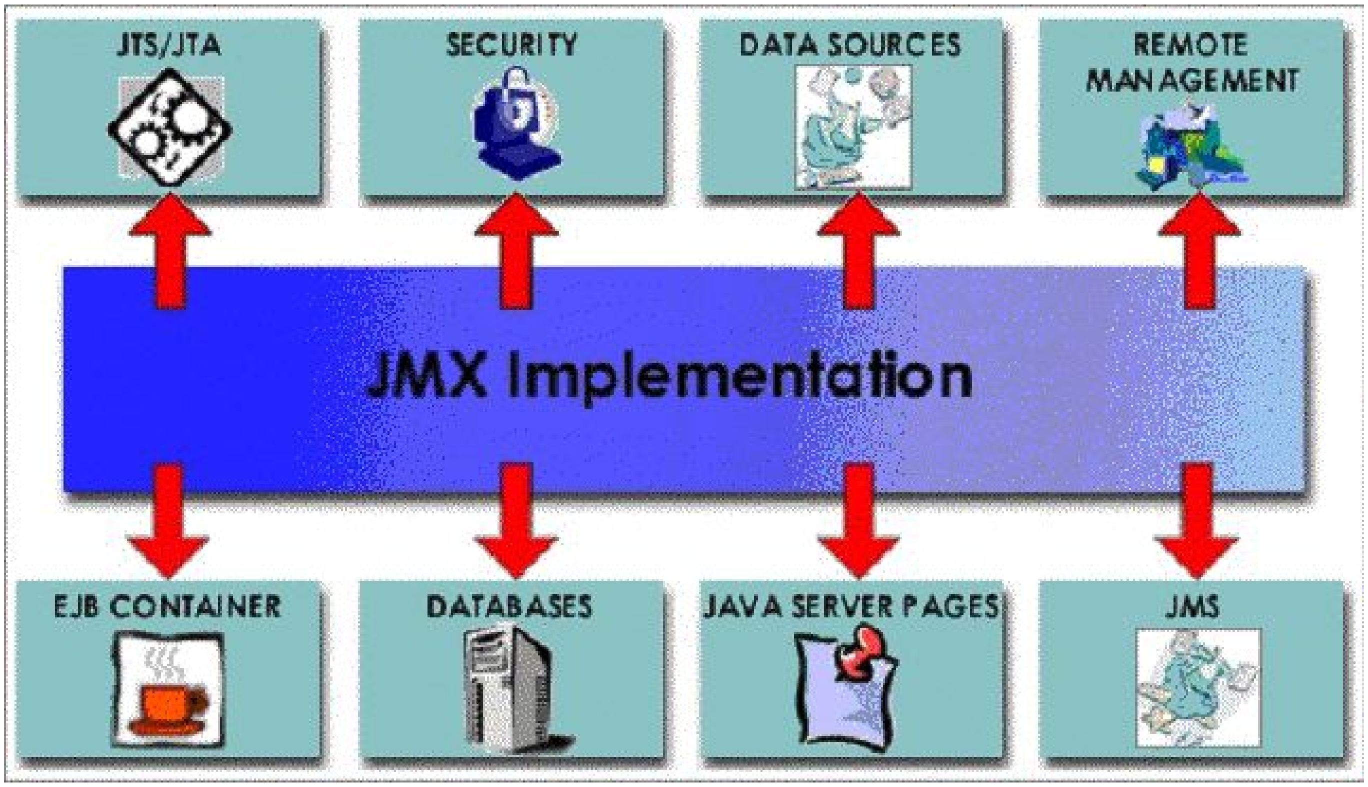


Figure 1.1. The JBoss JMX integration bus and the standard JBoss components

Before looking at how JBoss uses JMX as its component bus, it would help to get a basic overview what JMX is by touching on some of its key aspects.

JMX components are defined by the Java Management Extensions Instrumentation and Agent Specification, v1.2, which is available from the JSR003 Web page at http://jcp.org/en/jsr/detail?id=3. The material in this JMX overview section is derived from the JMX instrumentation specification, with a focus on the aspects most used by JBoss. A more comprehensive discussion of JMX and its application can be found in *JMX: Managing J2EE with Java Management Extensions* written by Juha Lindfors (Sams, 2002).

JMX is a standard for managing and monitoring all varieties of software and hardware components from Java. Further, JMX aims to provide integration with the large number of existing management standards. Figure 1.2 shows examples of components found in a JMX environment, and illustrates the relationship between them as well as how they relate to the three levels of the JMX model. The three levels are:

- **Instrumentation**, which are the resources to manage
- **Agents**, which are the controllers of the instrumentation level objects
- **Distributed services**, the mechanism by which administration applications interact with agents and their managed objects

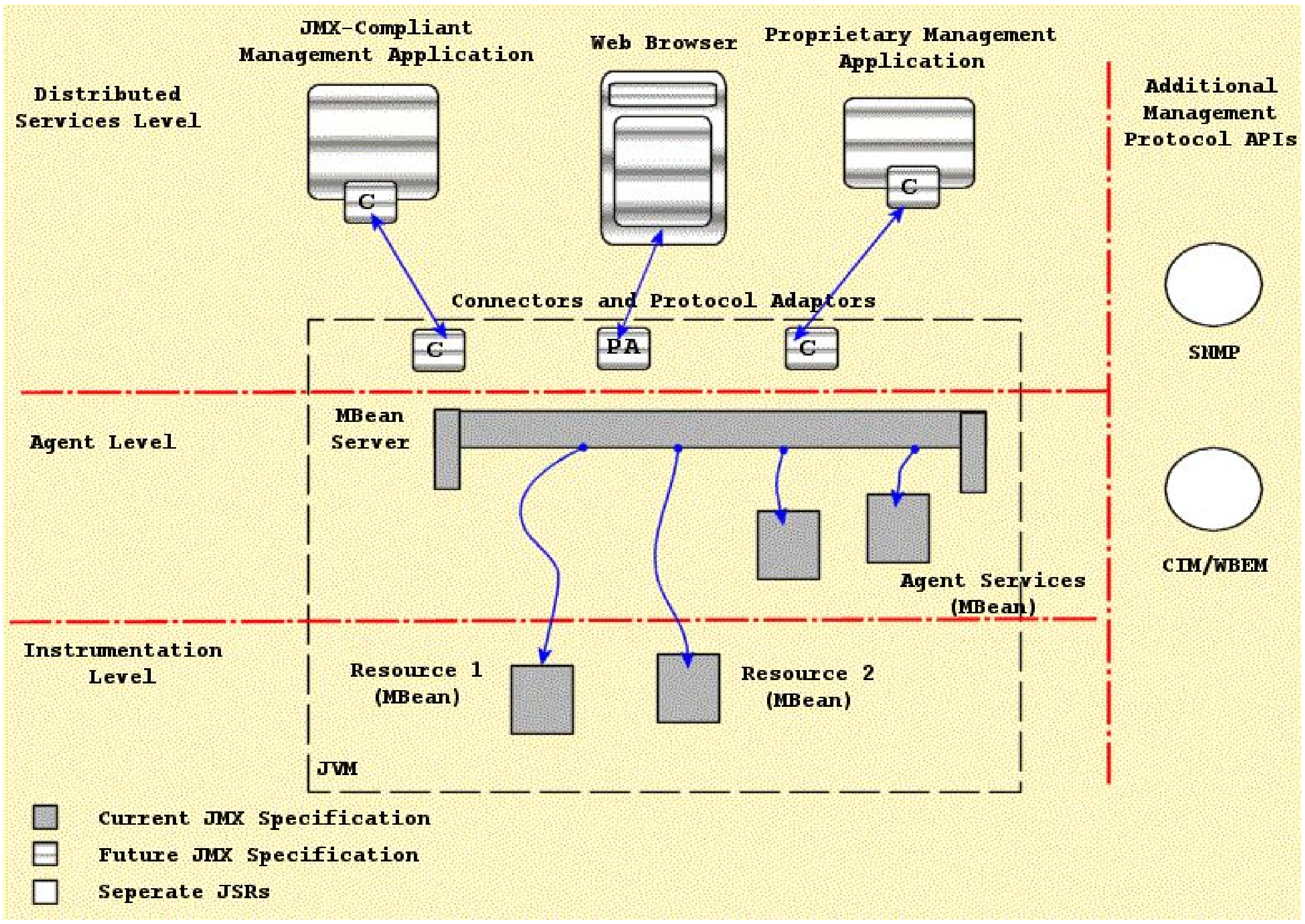

JMX-Compliant Management Application
Web Browser
Proprietary Management Application
Additional Management Protocol APIs
Distributed Services Level
C
C
Connectors and Protocol Adaptors
C
PA
C
SNMP
Agent Level
MBean Server
CIM/WBEM
Agent Services (MBean)
Instrumentation Level
Resource 1 (MBean)
Resource 2 (MBean)
JVM
Current JMX Specification
Future JMX Specification
Seperate JSRs

Figure 1.2. The Relationship between the components of the JMX architecture

1.1.1. Instrumentation Level

The instrumentation level defines the requirements for implementing JMX manageable resources. A JMX manageable resource can be virtually anything, including applications, service components, devices, and so on. The manageable resource exposes a Java object or wrapper that describes its manageable features, which makes the resource instrumented so that it can be managed by JMX-compliant applications.

The user provides the instrumentation of a given resource using one or more managed beans, or MBeans. There are four varieties of MBean implementations: standard, dynamic, model, and open. The differences between the various MBean types is discussed in Managed Beans or MBeans.

The instrumentation level also specifies a notification mechanism. The purpose of the notification mechanism is to allow MBeans to communicate changes with their environment. This is similar to the JavaBean property change notification mechanism, and can be used for attribute change notifications, state change notifications, and so on.

1.1.2. Agent Level

The agent level defines the requirements for implementing agents. Agents are responsible for controlling and exposing the managed resources that are registered with the agent. By default, management agents are located on the same hosts as their resources. This collocation is not a requirement.

The agent requirements make use of the instrumentation level to define a standard MBeanServer management agent, supporting services, and a communications connector. JBoss provides both an html adaptor as well as an RMI adaptor.

The JMX agent can be located in the hardware that hosts the JMX manageable resources when a Java Virtual Machine (JVM) is available. This is how the JBoss server uses the MBeanServer. A JMX agent does not need to know which resources it will serve. JMX manageable resources may use any JMX agent that offers the services it requires.

Managers interact with an agent's MBeans through a protocol adaptor or connector, as described in the Section 1.1.3 in the next section. The agent does not need to know anything about the connectors or management applications that interact with the agent and its MBeans.

1.1.3. Distributed Services Level

The JMX specification notes that a complete definition of the distributed services level is beyond the scope of the initial version of the JMX specification. This was indicated by the component boxes with the horizontal lines in Figure 1.2. The general purpose of this level is to define the interfaces required for implementing JMX management applications or managers. The following points highlight the intended functionality of the distributed services level as discussed in the current JMX specification.

- Provide an interface for management applications to interact transparently with an agent and its JMX manageable resources through a connector
- Exposes a management view of a JMX agent and its MBeans by mapping their semantic meaning into the constructs of a data-rich protocol (for example HTML or SNMP)
- Distributes management information from high-level management platforms to numerous JMX agents
- Consolidates management information coming from numerous JMX agents into logical views that are relevant to the end user's business operations
- Provides security

It is intended that the distributed services level components will allow for cooperative management of networks of agents and their resources. These components can be expanded to provide a complete management application.

1.1.4. JMX Component Overview

This section offers an overview of the instrumentation and agent level components. The instrumentation level components include the following:

- MBeans (standard, dynamic, open, and model MBeans)
- Notification model elements
- MBean metadata classes

The agent level components include:

- MBean server
- Agent services

1.1.4.1. Managed Beans or MBeans

An MBean is a Java object that implements one of the standard MBean interfaces and follows the associated design patterns. The MBean for a resource exposes all necessary information and operations that a management application needs to control the resource.

The scope of the management interface of an MBean includes the following:

- Attribute values that may be accessed by name
- Operations or functions that may be invoked
- Notifications or events that may be emitted
- The constructors for the MBean's Java class

JMX defines four types of MBeans to support different instrumentation needs:

- **Standard MBeans**: These use a simple JavaBean style naming convention and a statically defined management interface. This is the most common type of MBean used by JBoss.

- **Dynamic MBeans**: These must implement the `javax.management.DynamicMBean` interface, and they expose their management interface at runtime when the component is instantiated for the greatest flexibility. JBoss makes use of Dynamic MBeans in circumstances where the components to be managed are not known until runtime.

- **Open MBeans**: These are an extension of dynamic MBeans. Open MBeans rely on basic, self-describing, user-friendly data types for universal manageability.

- **Model MBeans**: These are also an extension of dynamic MBeans. Model MBeans must implement the `javax.management.modelmbean.ModelMBean` interface. Model MBeans simplify the instrumentation of resources by providing default behavior. JBoss XMBeans are an implementation of Model MBeans.

We will present an example of a Standard and a Model MBean in the section that discusses extending JBoss with your own custom services.

1.1.4.2. Notification Model

JMX Notifications are an extension of the Java event model. Both the MBean server and MBeans can send notifications to provide information. The JMX specification defines the `javax.management` package `Notification` event object, `NotificationBroadcaster` event sender, and `NotificationListener` event receiver interfaces. The specification also defines the operations on the MBean server that allow for the registration of notification listeners.

1.1.4.3. MBean Metadata Classes

There is a collection of metadata classes that describe the management interface of an MBean. Users can obtain a common metadata view of any of the four MBean types by querying the MBean server with which the MBeans are registered. The metadata classes cover an MBean's attributes, operations, notifications, and constructors. For each of these, the metadata includes a name, a description, and its particular characteristics. For example, one characteristic of an attribute is whether it is readable, writable, or both. The metadata for an operation contains the signature of its parameter and return types.

The different types of MBeans extend the metadata classes to be able to provide additional information as required. This common inheritance makes the standard information available regardless of the type of MBean. A management application that knows how to access the extended information of a particular type of MBean is able to do so.

1.1.4.4. MBean Server

A key component of the agent level is the managed bean server. Its functionality is exposed through an instance of the `javax.management.MBeanServer`. An MBean server is a registry for MBeans that makes the MBean management interface available for use by management applications. The MBean never directly exposes the MBean object itself; rather, its management interface is exposed through metadata and operations available in the MBean server interface. This provides a loose coupling between management applications and the MBeans they manage.

MBeans can be instantiated and registered with the MBeanServer by the following:

- Another MBean
- The agent itself
- A remote management application (through the distributed services)

When you register an MBean, you must assign it a unique object name. The object name then becomes the unique handle by which management applications identify the object on which to perform management operations. The operations available on MBeans through the MBean server include the following:

- Discovering the management interface of MBeans
- Reading and writing attribute values
- Invoking operations defined by MBeans
- Registering for notifications events
- Querying MBeans based on their object name or their attribute values

Protocol adaptors and connectors are required to access the MBeanServer from outside the agent's JVM. Each adaptor provides a view via its protocol of all MBeans registered in the MBean server the adaptor connects to. An example adaptor is an HTML adaptor that allows for the inspection and editing of MBeans using a Web browser. As was indicated in Figure 1.2, there are no protocol adaptors defined by the current JMX specification. Later versions of the specification will address the need for remote access protocols in standard ways.

A connector is an interface used by management applications to provide a common API for accessing the MBean server in a manner that is independent of the underlying communication protocol. Each connector type provides the same remote interface over a different protocol. This allows a remote management application to connect to an agent transparently through the network, regardless of the protocol. The specification of the remote management interface will be addressed in a future version of the JMX specification.

Adaptors and connectors make all MBean server operations available to a remote management application. For an agent to be manageable from outside of its JVM, it must include at least one protocol adaptor or connector. JBoss currently includes a custom HTML adaptor implementation and a custom JBoss RMI adaptor.

1.1.4.5. Agent Services

The JMX agent services are objects that support standard operations on the MBeans registered in the MBean server. The inclusion of supporting management services helps you build more powerful management solutions. Agent services are often themselves MBeans, which allow the agent and their functionality to be controlled through the MBean server. The JMX specification defines the following agent services:

- **A dynamic class loading MLet (management applet) service**: This allows for the retrieval and instantiation of new classes and native libraries from an arbitrary network location.
- **Monitor services**: These observe an MBean attribute's numerical or string value, and can notify other objects of several types of changes in the target.
- **Timer services**: These provide a scheduling mechanism based on a one-time alarm-clock notification or on a repeated, periodic notification.
- **The relation service**: This service defines associations between MBeans and enforces consistency on the relationships.

Any JMX-compliant implementation will provide all of these agent services. However, JBoss does not rely on any of these standard agent services.

1.2. JBoss JMX Implementation Architecture

1.2.1. The JBoss ClassLoader Architecture

JBoss employs a class loading architecture that facilitates sharing of classes across deployment units and hot deployment of services and applications. Before discussing the JBoss specific class loading model, we need to understand the nature of Java's type system and how class loaders fit in.

1.2.2. Class Loading and Types in Java

Class loading is a fundamental part of all server architectures. Arbitrary services and their supporting classes must be loaded into the server framework. This can be problematic due to the strongly typed nature of Java. Most developers know that the type of a class in Java is a function of the fully qualified name of the class. However the type is also a function of the `java.lang.ClassLoader` that is used to define that class. This additional qualification of type is necessary to ensure that environments in which classes may be loaded from arbitrary locations would be type-safe.

However, in a dynamic environment like an application server, and especially JBoss with its support for hot deployment are that class cast exceptions, linkage errors and illegal access errors can show up in ways not seen in more static class loading contexts. Let's take a look at the meaning of each of these exceptions and how they can happen.

1.2.2.1. ClassCastExceptions - I'm Not Your Type

A `java.lang.ClassCastException` results whenever an attempt is made to cast an instance to an incompatible type. A simple example is trying to obtain a `String` from a `List` into which a `URL` was placed:

```
ArrayList array = new ArrayList();
array.add(new URL("file:/tmp"));
String url = (String) array.get(0);

java.lang.ClassCastException: java.net.URL
at org.jboss.book.jmx.ex0.ExCCEa.main(Ex1CCE.java:16)
```

The `ClassCastException` tells you that the attempt to cast the array element to a `String` failed because the actual type was `URL`. This trivial case is not what we are interested in however. Consider the case of a JAR being loaded by different class loaders. Although the classes loaded through each class loader are identical in terms of the bytecode, they are completely different types as viewed by the Java type system. An example of this is illustrated by the code shown in Example 1.1.

Example 1.1. The ExCCEc class used to demonstrate ClassCastException due to duplicate class loaders

```
package org.jboss.book.jmx.ex0;

import java.io.File;
import java.net.URL;
import java.net.URLClassLoader;
import java.lang.reflect.Method;

import org.apache.log4j.Logger;

import org.jboss.util.ChapterExRepository;
import org.jboss.util.Debug;

/**
 * An example of a ClassCastException that
 * results from classes loaded through
 * different class loaders.
 * @author Scott.Stark@jboss.org
 * @version $Revision: 1.2 $
 */
public class ExCCEc
{
    public static void main(String[] args) throws Exception
    {
        ChapterExRepository.init(ExCCEc.class);

        String chapDir = System.getProperty("chapter.dir");
        Logger ucl0Log = Logger.getLogger("UCL0");
        File jar0 = new File(chapDir+"/j0.jar");
        ucl0Log.info("jar0 path: "+jar0.toString());
        URL[] cp0 = {jar0.toURL()};
        URLClassLoader ucl0 = new URLClassLoader(cp0);
        Thread.currentThread().setContextClassLoader(ucl0);
        Class objClass = ucl0.loadClass("org.jboss.book.jmx.ex0.ExObj");
        StringBuffer buffer = new
            StringBuffer("ExObj Info");
        Debug.displayClassInfo(objClass, buffer, false);
        ucl0Log.info(buffer.toString());
        Object value = objClass.newInstance();

        File jar1 = new File(chapDir+"/j0.jar");
        Logger ucl1Log = Logger.getLogger("UCL1");
        ucl1Log.info("jar1 path: "+jar1.toString());
        URL[] cp1 = {jar1.toURL()};
        URLClassLoader ucl1 = new URLClassLoader(cp1);
        Thread.currentThread().setContextClassLoader(ucl1);
        Class ctxClass2 = ucl1.loadClass("org.jboss.book.jmx.ex0.ExCtx");
        buffer.setLength(0);
        buffer.append("ExCtx Info");
        Debug.displayClassInfo(ctxClass2, buffer, false);
        ucl1Log.info(buffer.toString());
        Object ctx2 = ctxClass2.newInstance();

        try {
            Class[] types = {Object.class};
            Method useValue =
                ctxClass2.getMethod("useValue", types);
            Object[] margs = {value};
            useValue.invoke(ctx2, margs);
        } catch(Exception e) {
            ucl1Log.error("Failed to invoke ExCtx.useValue", e);
            throw e;
        }
    }
}
```

Example 1.2. The ExCtx, ExObj, and ExObj2 classes used by the examples

```
package org.jboss.book.jmx.ex0;

import java.io.IOException;
import org.apache.log4j.Logger;
import org.jboss.util.Debug;

/**
 * A classes used to demonstrate various class
 * loading issues
 * @author Scott.Stark@jboss.org
 * @version $Revision: 1.2 $
 */
public class ExCtx
{
    ExObj value;

    public ExCtx()
        throws IOException
    {
        value = new ExObj();
        Logger log = Logger.getLogger(ExCtx.class);
        StringBuffer buffer = new StringBuffer("ctor.ExObj");
        Debug.displayClassInfo(value.getClass(), buffer, false);
        log.info(buffer.toString());
        ExObj2 obj2 = value.ivar;
        buffer.setLength(0);
        buffer = new StringBuffer("ctor.ExObj.ivar");
        Debug.displayClassInfo(obj2.getClass(), buffer, false);
        log.info(buffer.toString());
    }

    public Object getValue()
    {
        return value;
    }

    public void useValue(Object obj)
        throws Exception
    {
        Logger log = Logger.getLogger(ExCtx.class);
        StringBuffer buffer = new
```

```
            StringBuffer("useValue2.arg class");
        Debug.displayClassInfo(obj.getClass(), buffer, false);
        log.info(buffer.toString());
        buffer.setLength(0);
        buffer.append("useValue2.ExObj class");
        Debug.displayClassInfo(ExObj.class, buffer, false);
        log.info(buffer.toString());
        ExObj ex = (ExObj) obj;
    }

    void pkgUseValue(Object obj)
        throws Exception
    {
        Logger log = Logger.getLogger(ExCtx.class);
        log.info("In pkgUseValue");
    }
}
```

```
package org.jboss.book.jmx.ex0;

import java.io.Serializable;

/**
 * @author Scott.Stark@jboss.org
 * @version $Revision: 1.2 $
 */
public class ExObj
    implements Serializable
{
    public ExObj2 ivar = new ExObj2();
}
```

```
package org.jboss.book.jmx.ex0;

import java.io.Serializable;

/**
 * @author Scott.Stark@jboss.org
 * @version $Revision: 1.2 $
 */
public class ExObj2
    implements Serializable
{
}
```

The `ExCCEc.main` method uses reflection to isolate the classes that are being loaded by the class loaders `ucl0` and `ucl1` from the application class loader. Both are setup to load classes from the `output/jmx/j0.jar`, the contents of which are:

```
[examples]$ jar -tf output/jmx/j0.jar
...
org/jboss/book/jmx/ex0/ExCtx.class
org/jboss/book/jmx/ex0/ExObj.class
org/jboss/book/jmx/ex0/ExObj2.class
```

We will run an example that demonstrates how a class cast exception can occur and then look at the specific issue with the example. See Appendix A for instructions on installing the examples accompanying the book, and then run the example from within the examples directory using the following command:

```
[examples]$ ant -Dchap=jmx -Dex=0c run-example
```

```
...
     [java] java.lang.reflect.InvocationTargetException
     [java]     at sun.reflect.NativeMethodAccessorImpl.invoke0(Native Method)
     [java]     at sun.reflect.NativeMethodAccessorImpl.invoke(NativeMethodAccessorImpl.java:39)
     [java]     at sun.reflect.DelegatingMethodAccessorImpl.invoke(DelegatingMethodAccessorImpl
                .java:25)
     [java]     at java.lang.reflect.Method.invoke(Method.java:585)
     [java]     at org.jboss.book.jmx.ex0.ExCCEc.main(ExCCEc.java:58)
     [java] Caused by: java.lang.ClassCastException: org.jboss.book.jmx.ex0.ExObj
     [java]     at org.jboss.book.jmx.ex0.ExCtx.useValue(ExCtx.java:44)
     [java]     ... 5 more
```

Only the exception is shown here. The full output can be found in the `logs/jmx-ex0c.log` file. At line 55 of `ExCCEc.java` we are invoking `ExcCCECtx.useValue(Object)` on the instance loaded and created in lines 37-48 using `ucl1`. The `ExObj` passed in is the one loaded and created in lines 25-35 via `ucl0`. The exception results when the `ExCtx.useValue` code attempts to cast the argument passed in to a `ExObj`. To understand why this fails consider the debugging output from the `jmx-ex0c.log` file shown in Example 1.3.

Example 1.3. The jmx-ex0c.log debugging output for the ExObj classes seen

```
[INFO,UCL0] ExObj Info
org.jboss.book.jmx.ex0.ExObj(f8968f).ClassLoader=java.net.URLClassLoader@2611a7
..java.net.URLClassLoader@2611a7
....file:/Users/orb/proj/jboss/jboss-docs/jbossas/j2ee/examples/output/jmx/j0.jar
++++CodeSource: (file:/Users/orb/proj/jboss/jboss-docs/jbossas/j2ee/examples/output/
                 jmx/j0.jar <no signer certificates>)
Implemented Interfaces:
++interface java.io.Serializable(41b571)
++++ClassLoader: null
++++Null CodeSource
[INFO,ExCtx] useValue2.ExObj class
org.jboss.book.jmx.ex0.ExObj(bc8e1e).ClassLoader=java.net.URLClassLoader@6bd8ea
..java.net.URLClassLoader@6bd8ea
....file:/Users/orb/proj/jboss/jboss-docs/jbossas/j2ee/examples/output/jmx/j0.jar
++++CodeSource: (file:/Users/orb/proj/jboss/jboss-docs/jbossas/j2ee/examples/output/
                 jmx/j0.jar <no signer certificates>)
Implemented Interfaces:
++interface java.io.Serializable(41b571)
++++ClassLoader: null
++++Null CodeSource
```

The first output prefixed with `[INFO,UCL0]` shows that the `ExObj` class loaded at line `ExCCEc.java:31` has a hash code of `f8968f` and an associated `URLClassLoader` instance with a hash code of `2611a7`, which corresponds to ucl0. This is the class used to create the instance passed to the `ExCtx.useValue` method. The second output prefixed with `[INFO,ExCtx]` shows that the `ExObj` class as seen in the context of the `ExCtx.useValue` method has a hash code of `bc8e1e` and a `URLClassLoader` instance with an associated hash code of `6bd8ea`, which corresponds to `ucl1`. So even though the `ExObj` classes are the same in terms of actual bytecode since it comes from the same `j0.jar`, the classes are different as seen by both the `ExObj` class hash codes, and the associated `URLClassLoader` instances. Hence, attempting to cast an instance of `ExObj` from one scope to the other results in the `ClassCastException`.

This type of error is common when redeploying an application to which other applications are holding references to classes from the redeployed application. For example, a standalone WAR accessing an EJB. If you are redeploying an application, all dependent applications must flush their class references. Typically this requires that the dependent applications themselves be redeployed.

An alternate means of allowing independent deployments to interact in the presence of redeployment would be to isolate the deployments by configuring the EJB layer to use the standard call-by-value semantics rather than the call-by-reference JBoss will default to for components collocated in the same VM. An example of how to enable call-by-value semantics is presented in Chapter 4

1.2.2.2. IllegalAccessException - Doing what you should not

A `java.lang.IllegalAccessException` is thrown when one attempts to access a method or member that visibility qualifiers do not allow. Typical examples are attempting to access private or protected methods or instance variables. Another common example is accessing package protected methods or members from a class that appears to be in the correct package, but is really not due to caller and callee classes being loaded by different class loaders. An example of this is illustrated by the code shown in Example 1.5.

Example 1.4. The ExIAEd class used to demonstrate IllegalAccessException due to duplicate class loaders

```
package org.jboss.book.jmx.ex0;

import java.io.File;
import java.net.URL;
import java.net.URLClassLoader;
import java.lang.reflect.Method;

import org.apache.log4j.Logger;

import org.jboss.util.ChapterExRepository;
import org.jboss.util.Debug;

/**
 * An example of IllegalAccessExceptions due to
 * classes loaded by two class loaders.
 * @author Scott.Stark@jboss.org
 * @version $Revision: 1.2 $
 */
public class ExIAEd
{
    public static void main(String[] args) throws Exception
    {
        ChapterExRepository.init(ExIAEd.class);

        String chapDir = System.getProperty("chapter.dir");
        Logger ucl0Log = Logger.getLogger("UCL0");
        File jar0 = new File(chapDir+"/j0.jar");
        ucl0Log.info("jar0 path: "+jar0.toString());
        URL[] cp0 = {jar0.toURL()};
        URLClassLoader ucl0 = new URLClassLoader(cp0);
        Thread.currentThread().setContextClassLoader(ucl0);

        StringBuffer buffer = new
            StringBuffer("ExIAEd Info");
        Debug.displayClassInfo(ExIAEd.class, buffer, false);
        ucl0Log.info(buffer.toString());

        Class ctxClass1 = ucl0.loadClass("org.jboss.book.jmx.ex0.ExCtx");
        buffer.setLength(0);
        buffer.append("ExCtx Info");
        Debug.displayClassInfo(ctxClass1, buffer, false);
        ucl0Log.info(buffer.toString());
        Object ctx0 = ctxClass1.newInstance();

        try {
            Class[] types = {Object.class};
            Method useValue =
                ctxClass1.getDeclaredMethod("pkgUseValue", types);
            Object[] margs = {null};
            useValue.invoke(ctx0, margs);
        } catch(Exception e) {
            ucl0Log.error("Failed to invoke ExCtx.pkgUseValue", e);
        }
    }
}
```

The `ExIAEd.main` method uses reflection to load the `ExCtx` class via the `ucl0` class loader while the `ExIEAd` class was loaded by the application class loader. We will run this example to demonstrate how the `IllegalAccessException` can occur and then look at the specific issue with the example. Run the example using the following command:

```
[examples]$ ant -Dchap=jmx -Dex=0d run-example
Buildfile: build.xml
...
[java] java.lang.IllegalAccessException: Class org.jboss.book.jmx.ex0.ExIAEd
  can not access a member of class org.jboss.book.jmx.ex0.ExCtx with modifiers ""
[java]     at sun.reflect.Reflection.ensureMemberAccess(Reflection.java:65)
[java]     at java.lang.reflect.Method.invoke(Method.java:578)
[java]     at org.jboss.book.jmx.ex0.ExIAEd.main(ExIAEd.java:48)
```

The truncated output shown here illustrates the `IllegalAccessException`. The full output can be found in the `logs/jmx-ex0d.log` file. At line 48 of `ExIAEd.java` the `ExCtx.pkgUseValue(Object)` method is invoked via reflection. The `pkgUseValue` method has package protected access and even though both the invoking class `ExIAEd` and the `ExCtx` class whose method is being invoked reside in the `org.jboss.book.jmx.ex0` package, the invocation is seen to be invalid due to the fact that the two classes are loaded by different class loaders. This can be seen by looking at the debugging output from the `jmx-ex0d.log file`.

```
[INFO,UCL0] ExIAEd Info
org.jboss.book.jmx.ex0.ExIAEd(7808b9).ClassLoader=sun.misc.Launcher$AppClassLoader@a9c85c
..sun.misc.Launcher$AppClassLoader@a9c85c
...
[INFO,UCL0] ExCtx Info
org.jboss.book.jmx.ex0.ExCtx(64c34e).ClassLoader=java.net.URLClassLoader@a9c85c
..java.net.URLClassLoader@5d88a
...
```

The ExIAEd class is seen to have been loaded via the default application class loader instance `sun.misc.Launcher$AppClassLoader@a9c85c`, while the `ExCtx` class was loaded by the `java.net.URLClassLoader@a9c85c` instance. Because the classes are loaded by different class loaders, access to the package protected method is seen to be a security violation. So, not only is type a function of both the fully qualified class name and class loader, the package scope is as well.

An example of how this can happen in practice is to include the same classes in two different SAR deployments. If classes in the deployment have a package protected relationship, users of the SAR service may end up loading one class from SAR class loading at one point, and then load another class from the second SAR at a later time. If the two classes in question have a protected access relationship an `IllegalAccessError` will result. The solution is to either include the classes in a separate jar that is referenced by the SARs, or to combine the SARs into a single deployment. This can either be a single SAR, or an EAR that includes both SARs.

1.2.2.3. LinkageErrors - Making Sure You Are Who You Say You Are

Loading constraints validate type expectations in the context of class loader scopes to ensure that a class `X` is consistently the same class when multiple class loaders are involved. This is important because Java allows for user defined class loaders. Linkage errors are essentially an extension of the class cast exception that is enforced by the VM when classes are loaded and used.

To understand what loading constraints are and how they ensure type-safety we will first introduce the nomenclature of the Liang and Bracha paper along with an example from this paper. There are two type of class loaders, initiating and defining. An initiating class loader is one that a `ClassLoader.loadClass` method has been invoked on to initiate the loading of the named class. A defining class loader is the loader that calls one of the `ClassLoader.defineClass` methods to convert the class byte code into a `Class` instance. The most complete expression of a class is given by $<C,Ld>^{Li}$, where `C` is the fully qualified class name, `Ld` is the defining class loader, and `Li` is the initiating class loader. In a context where the initiating class loader is not important the type may be represented by `<C,Ld>`, while when the defining class loader is not important, the type may be represented by C^{Li} . In the latter case, there is still a defining class loader, it's just not important what the identity of the defining class loader is. Also, a type is completely defined by `<C,Ld>`. The only time the initiating loader is relevant is when a loading constraint is being validated. Now consider the classes shown in Example 1.5.

Example 1.5. Classes demonstrating the need for loading constraints

```
class <C,L1> {
    void f() {
        <Spoofed, L1>^{L1}x = <Delegated, L2>^{L2}
        x.secret_value = 1; // Should not be allowed
    }
}
```

```
class <Delegated,L2> {
    static <Spoofed, L2>^{L3} g() {...}
    }
}
```

```
class <Spoofed, L1> {
    public int secret_value;
}
```

```
class <Spoofed, L2> {
    private int secret_value;
}
```

The class `C` is defined by `L1` and so `L1` is used to initiate loading of the classes `Spoofed` and `Delegated` referenced in the `C.f()` method. The `Spoofed` class is defined by `L1`, but `Delegated` is defined by `L2` because `L1` delegates to `L2`. Since `Delegated` is defined by `L2`, `L2` will be used to initiate loading of `Spoofed` in the context of the `Delegated.g()` method. In this example both `L1` and `L2` define different versions of `Spoofed` as indicated by the two versions shown at the end of Example 1.5. Since `C.f()` believes `x` is an instance of `<Spoofed,L1>` it is able to access the private field `secret_value` of `<Spoofed,L2>` returned by `Delegated.g()` due to the 1.1 and earlier Java VM's failure to take into account that a class type is determined by both the fully qualified name of the class and the defining class loader.

Java addresses this problem by generating loader constraints to validate type consistency when the types being used are coming from different defining class loaders. For the Example 1.5 example, the VM generates a constraint $\texttt{Spoofed}^{L1}=\texttt{Spoofed}^{L2}$ when the first line of method `C.f()` is verified to indicate that the type `Spoofed` must be the same regardless of whether the load of `Spoofed` is initiated by `L1` or `L2`. It does not matter if `L1` or `L2`, or even some other class loader defines `Spoofed`. All that matters is that there is only one `Spoofed` class defined regardless of whether `L1` or `L2` was used to initiate the loading. If `L1` or `L2` have already defined separate versions of `Spoofed` when this check is made a `LinkageError` will be generated immediately. Otherwise, the constraint will be recorded and when `Delegated.g()` is executed, any attempt to load a duplicate version of `Spoofed` will result in a `LinkageError`.

Now let's take a look at how a `LinkageError` can occur with a concrete example. Example 1.6 gives the example main class along with the custom class loader used.

Example 1.6. A concrete example of a LinkageError

```
package org.jboss.book.jmx.ex0;
import java.io.File;
import java.net.URL;

import org.apache.log4j.Logger;
import org.jboss.util.ChapterExRepository;
import org.jboss.util.Debug;

/**
 * An example of a LinkageError due to classes being defined by more
 * than one class loader in a non-standard class loading environment.
 *
 * @author Scott.Stark@jboss.org
 * @version $Revision: 1.2 $
 */
public class ExLE
{
    public static void main(String[] args)
        throws Exception
    {
        ChapterExRepository.init(ExLE.class);

        String chapDir = System.getProperty("chapter.dir");
        Logger ucl0Log = Logger.getLogger("UCL0");
        File jar0 = new File(chapDir+"/j0.jar");
        ucl0Log.info("jar0 path: "+jar0.toString());
        URL[] cp0 = {jar0.toURL()};
        Ex0URLClassLoader ucl0 = new Ex0URLClassLoader(cp0);
        Thread.currentThread().setContextClassLoader(ucl0);
        Class ctxClass1  = ucl0.loadClass("org.jboss.book.jmx.ex0.ExCtx");
        Class obj2Class1 = ucl0.loadClass("org.jboss.book.jmx.ex0.ExObj2");
        StringBuffer buffer = new StringBuffer("ExCtx Info");
        Debug.displayClassInfo(ctxClass1, buffer, false);
        ucl0Log.info(buffer.toString());
        buffer.setLength(0);
        buffer.append("ExObj2 Info, UCL0");
        Debug.displayClassInfo(obj2Class1, buffer, false);
        ucl0Log.info(buffer.toString());

        File jar1 = new File(chapDir+"/j1.jar");
        Logger ucl1Log = Logger.getLogger("UCL1");
        ucl1Log.info("jar1 path: "+jar1.toString());
        URL[] cp1 = {jar1.toURL()};
        Ex0URLClassLoader ucl1 = new Ex0URLClassLoader(cp1);
        Class obj2Class2 = ucl1.loadClass("org.jboss.book.jmx.ex0.ExObj2");
        buffer.setLength(0);
        buffer.append("ExObj2 Info, UCL1");
        Debug.displayClassInfo(obj2Class2, buffer, false);
        ucl1Log.info(buffer.toString());

        ucl0.setDelegate(ucl1);
        try {
            ucl0Log.info("Try ExCtx.newInstance()");
            Object ctx0 = ctxClass1.newInstance();
            ucl0Log.info("ExCtx.ctor succeeded, ctx0: "+ctx0);
        } catch(Throwable e) {
            ucl0Log.error("ExCtx.ctor failed", e);
        }
    }
}
```

```
package org.jboss.book.jmx.ex0;

import java.net.URLClassLoader;
import java.net.URL;

import org.apache.log4j.Logger;

/**
 * A custom class loader that overrides the standard parent delegation
 * model
 *
 * @author Scott.Stark@jboss.org
 * @version $Revision: 1.2 $
 */
public class Ex0URLClassLoader extends URLClassLoader
{
    private static Logger log = Logger.getLogger(Ex0URLClassLoader.class);
    private Ex0URLClassLoader delegate;

    public Ex0URLClassLoader(URL[] urls)
    {
        super(urls);
    }

    void setDelegate(Ex0URLClassLoader delegate)
    {
        this.delegate = delegate;
    }

    protected synchronized Class loadClass(String name, boolean resolve)
        throws ClassNotFoundException
    {
        Class clazz = null;
        if (delegate != null) {
            log.debug(Integer.toHexString(hashCode()) +
                      "; Asking delegate to loadClass: " + name);
            clazz = delegate.loadClass(name, resolve);
            log.debug(Integer.toHexString(hashCode()) +
                      "; Delegate returned: "+clazz);
        } else {
            log.debug(Integer.toHexString(hashCode()) +
                      "; Asking super to loadClass: "+name);
            clazz = super.loadClass(name, resolve);
            log.debug(Integer.toHexString(hashCode()) +
                      "; Super returned: "+clazz);
        }
        return clazz;
    }

    protected Class findClass(String name)
```

```
        throws ClassNotFoundException
    {
        Class clazz = null;
        log.debug(Integer.toHexString(hashCode()) +
                  "; Asking super to findClass: "+name);
        clazz = super.findClass(name);
        log.debug(Integer.toHexString(hashCode()) +
                  "; Super returned: "+clazz);
        return clazz;
    }
}
```

The key component in this example is the `URLClassLoader` subclass `Ex0URLClassLoader`. This class loader implementation overrides the default parent delegation model to allow the `ucl0` and `ucl1` instances to both load the `ExObj2` class and then setup a delegation relationship from `ucl0` to `ucl1`. At lines 30 and 31. the `ucl0` `Ex0URLClassLoader` is used to load the `ExCtx` and `ExObj2` classes. At line 45 of `ExLE.main` the `ucl1` `Ex0URLClassLoader` is used to load the `ExObj2` class again. At this point both the `ucl0` and `ucl1` class loaders have defined the `ExObj2` class. A delegation relationship from `ucl0` to `ucl1` is then setup at line 51 via the `ucl0.setDelegate(ucl1)` method call. Finally, at line 54 of `ExLE.main` an instance of `ExCtx` is created using the class loaded via `ucl0`. The `ExCtx` class is the same as presented in Example 1.2, and the constructor was:

```
public ExCtx()
    throws IOException
{
    value = new ExObj();
    Logger log = Logger.getLogger(ExCtx.class);
    StringBuffer buffer = new StringBuffer("ctor.ExObj");
    Debug.displayClassInfo(value.getClass(), buffer, false);
    log.info(buffer.toString());
    ExObj2 obj2 = value.ivar;
    buffer.setLength(0);
    buffer = new StringBuffer("ctor.ExObj.ivar");
    Debug.displayClassInfo(obj2.getClass(), buffer, false);
    log.info(buffer.toString());
}
```

Now, since the `ExCtx` class was defined by the `ucl0` class loader, and at the time the `ExCtx` constructor is executed, `ucl0` delegates to `ucl1`, line 24 of the `ExCtx` constructor involves the following expression which has been rewritten in terms of the complete type expressions:

$<\text{ExObj2,ucl0}>^{\text{ucl0}}$ obj2 = $<\text{ExObj,ucl1}>^{\text{ucl0}}$ value * ivar

This generates a loading constraint of $\texttt{ExObj2}^{\text{ucl0}}$ `=` $\texttt{ExObj2}^{\text{ucl1}}$ since the `ExObj2` type must be consistent across the `ucl0` and `ucl1` class loader instances. Because we have loaded `ExObj2` using both `ucl0` and `ucl1` prior to setting up the delegation relationship, the constraint will be violated and should generate a `LinkageError` when run. Run the example using the following command:

```
[examples]$ ant -Dchap=jmx -Dex=0e run-example
Buildfile: build.xml
...
[java] java.lang.LinkageError: loader constraints violated when linking
           org/jboss/book/jmx/ex0/ExObj2 class
[java]     at org.jboss.book.jmx.ex0.ExCtx.<init>(ExCtx.java:24)
[java]     at sun.reflect.NativeConstructorAccessorImpl.newInstance0(Native Method)
[java]     at sun.reflect.NativeConstructorAccessorImpl.newInstance(NativeConstructorAccessor
           Impl.java:39)
[java]     at sun.reflect.DelegatingConstructorAccessorImpl.newInstance(DelegatingConstructor
           AccessorImpl.java:27)
[java]     at java.lang.reflect.Constructor.newInstance(Constructor.java:494)
[java]     at java.lang.Class.newInstance0(Class.java:350)
[java]     at java.lang.Class.newInstance(Class.java:303)
[java]     at org.jboss.book.jmx.ex0.ExLE.main(ExLE.java:53)
```

As expected, a LinkageError is thrown while validating the loader constraints required by line 24 of the `ExCtx` constructor.

1.2.2.3.1. Debugging Class Loading Issues

Debugging class loading issues comes down to finding out where a class was loaded from. A useful tool for this is the code snippet shown in Example 1.7 taken from the org.jboss.util.Debug class of the book examples.

Example 1.7. Obtaining debugging information for a Class

```
Class clazz =...;
StringBuffer results = new StringBuffer();

ClassLoader cl = clazz.getClassLoader();
results.append("\n" + clazz.getName() + "(" +
               Integer.toHexString(clazz.hashCode()) + ").ClassLoader=" + cl);
ClassLoader parent = cl;

while (parent != null) {
    results.append("\n.."+parent);
    URL[] urls = getClassLoaderURLs(parent);

    int length = urls != null ? urls.length : 0;
    for(int u = 0; u < length; u ++) {
        results.append("\n...."+urls[u]);
    }

    if (showParentClassLoaders == false) {
        break;
    }
    if (parent != null) {
        parent = parent.getParent();
    }
}

CodeSource clazzCS = clazz.getProtectionDomain().getCodeSource();
if (clazzCS != null) {
    results.append("\n++++CodeSource: "+clazzCS);
} else {
    results.append("\n++++Null CodeSource");
}
```

The key items are shown in bold. The first is that every Class object knows its defining `ClassLoader` and this is available via the `getClassLoader()` method. The defines the scope in which the `Class` type is known as we have just seen in the previous sections on class cast exceptions, illegal access exceptions and linkage errors. From the `ClassLoader` you can view the hierarchy of class loaders that make up the parent delegation chain. If the class loader is a `URLClassLoader` you can also see the URLs used for class and resource loading.

The defining `ClassLoader` of a `Class` cannot tell you from what location that `Class` was loaded. To determine this you must obtain the `java.security.ProtectionDomain` and then the `java.security.CodeSource`. It is the `Code-`

Source that has the URL p location from which the class originated. Note that not every Class has a CoPdeSource. If a class is loaded by the bootstrap class loader then its CodeSource will be null. This will be the case for all classes in the java.* and javax.* packages, for example.

Beyond that it may be useful to view the details of classes being loaded into the JBoss server. You can enable verbose logging of the JBoss class loading layer using a Log4j configuration fragment like that shown in Example 1.8.

Example 1.8. An example log4j.xml configuration fragment for enabling verbose class loading logging

```
<appender name="UCL" class="org.apache.log4j.FileAppender">
    <param name="File" value="${jboss.server.home.dir}/log/ucl.log"/>
    <param name="Append" value="false"/>
    <layout class="org.apache.log4j.PatternLayout">
        <param name="ConversionPattern" value="[%r,%c{1},%t] %m%n"/>
    </layout>
</appender>

<category name="org.jboss.mx.loading" additivity="false">
    <priority value="TRACE" class="org.jboss.logging.XLevel"/>
    <appender-ref ref="UCL"/>
</category>
```

This places the output from the classes in the org.jboss.mx.loading package into the ucl.log file of the server configurations log directory. Although it may not be meaningful if you have not looked at the class loading code, it is vital information needed for submitting bug reports or questions regarding class loading problems.

1.2.2.4. Inside the JBoss Class Loading Architecture

Now that we have the role of class loaders in the Java type system defined, let's take a look at the JBoss class loading architecture. Figure 1.3.

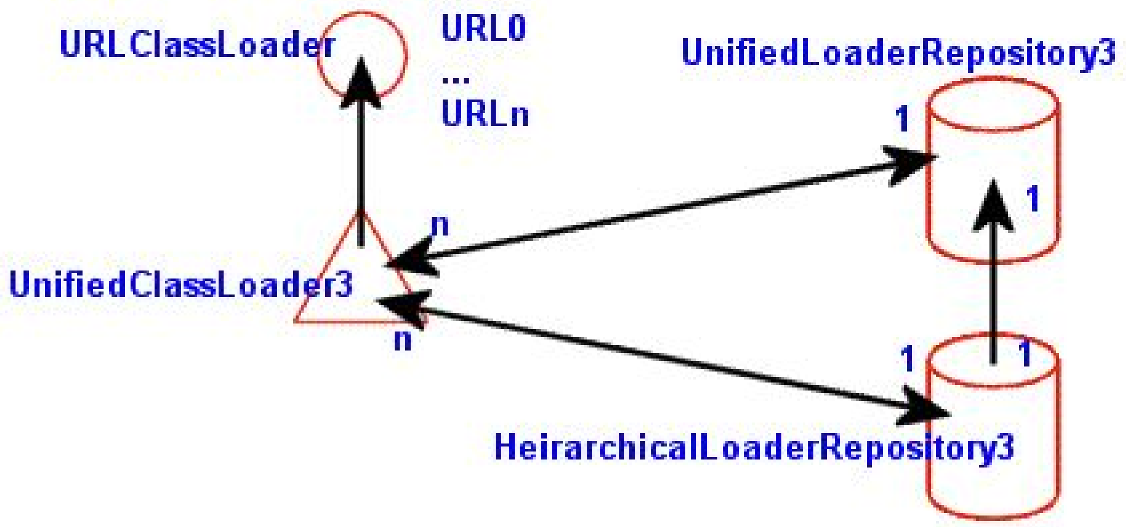


Figure 1.3. The core JBoss class loading components

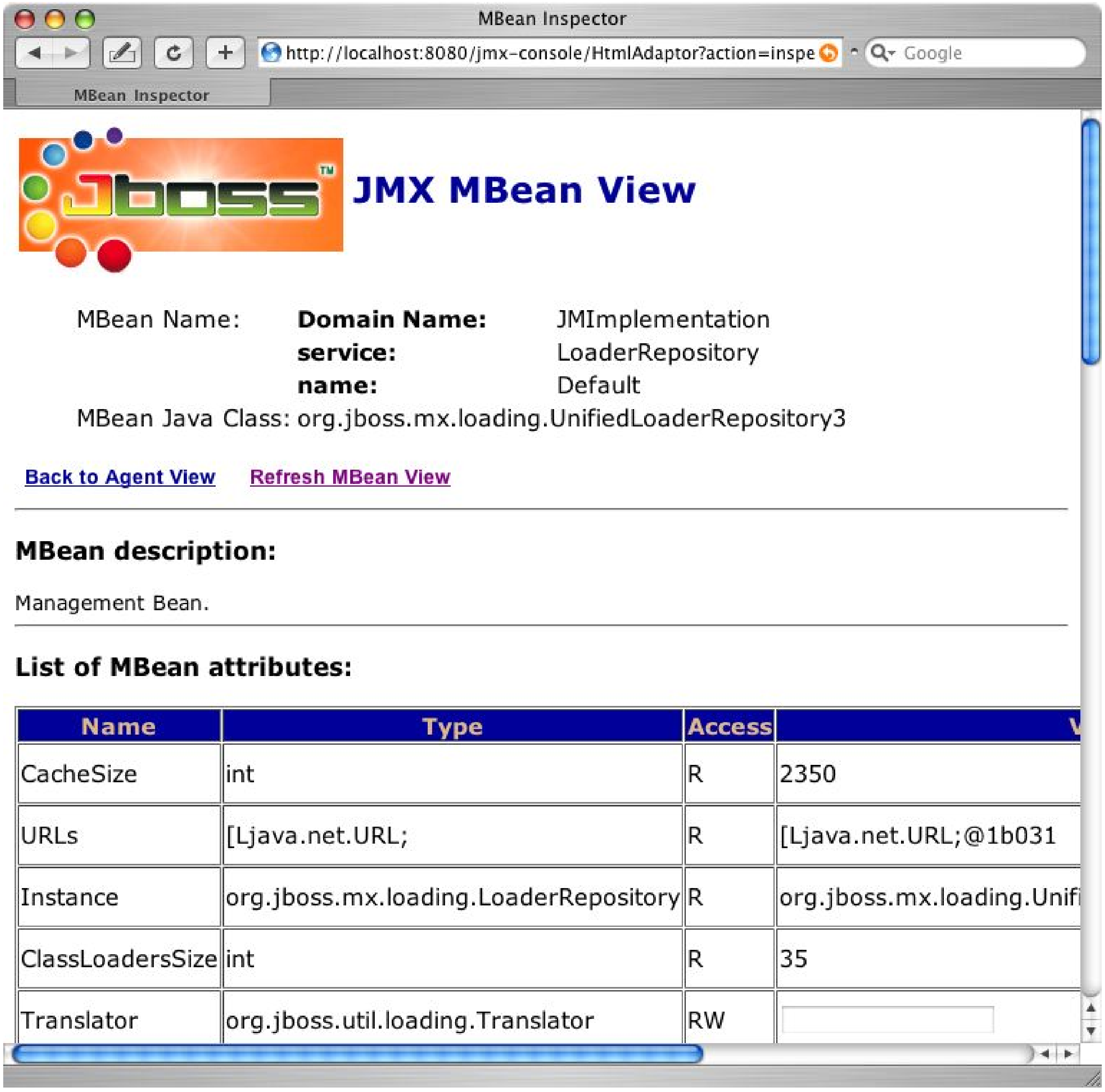
The central component is the org.jboss.mx.loading.UnifiedClassLoader3 (UCL) class loader. This is an extension of the standard java.net.URLClassLoader that overrides the standard parent delegation model to use a shared repository of classes and resources. This shared repository is the `org.jboss.mx.loading.UnifiedLoaderRepository3`. Every UCL is associated with a single `UnifiedLoaderRepository3`, and a `UnifiedLoaderRepository3` typically has many UCLs. A UCL may have multiple URLs associated with it for class and resource loading. Deployers use the top-level deployment's UCL as a shared class loader and all deployment archives are assigned to this class loader. We will talk about the JBoss deployers and their interaction with the class loading system in more detail latter in Section 1.4.2.

When a UCL is asked to load a class, it first looks to the repository cache it is associated with to see if the class has already been loaded. Only if the class does not exist in the repository will it be loaded into the repository by the UCL. By default, there is a single `UnifiedLoaderRepository3` shared across all UCL instances. This means the UCLs form a single flat class loader namespace. The complete sequence of steps that occur when a `UnfiedClassLoader3.loadClass(String, boolean)` method is called is:

1. Check the `UnifiedLoaderRepository3` classes cache associated with the `UnifiedClassLoader3`. If the class is found in the cache it is returned.
2. Else, ask the `UnfiedClassLoader3` if it can load the class. This is essentially a call to the superclass `URLClassLoader.loadClass(String, boolean)` method to see if the class is among the URLs associated with the class loader, or visible to the parent class loader. If the class is found it is placed into the repository classes cache and returned.
3. Else, the repository is queried for all UCLs that are capable of providing the class based on the repository package name to UCL map. When a UCL is added to a repository an association between the package names available in the URLs associated with the UCL is made, and a mapping from package names to the UCLs with classes in the package is updated. This allows for a quick determination of which UCLs are capable of loading the class. The UCLs are then queried for the requested class in the order in which the UCLs were added to the repository. If a UCL is found that can load the class it is returned, else a `java.lang.ClassNotFoundException` is thrown.

1.2.2.4.1. Viewing Classes in the Loader Repository

Another useful source of information on classes is the UnifiedLoaderRepository itself. This is an MBean that contains operations to display class and package information. The default repository is located under a standard JMX name of `JMImplementation:name=Default,service=LoaderRepository`, and its MBean can be accessed via the JMX console by following its link from the front page. The JMX console view of this MBean is shown in Figure 1.4.



MBean Name: **Domain Name:** JMImplementation
service: LoaderRepository
name: Default
MBean Java Class: org.jboss.mx.loading.UnifiedLoaderRepository3

MBean description:

Management Bean.

List of MBean attributes:

Name	Type	Access	V
CacheSize	int	R	2350
URLs	[Ljava.net.URL;	R	[Ljava.net.URL;@1b031
Instance	org.jboss.mx.loading.LoaderRepository	R	org.jboss.mx.loading.Unifi
ClassLoadersSize	int	R	35
Translator	org.jboss.util.loading.Translator	RW	

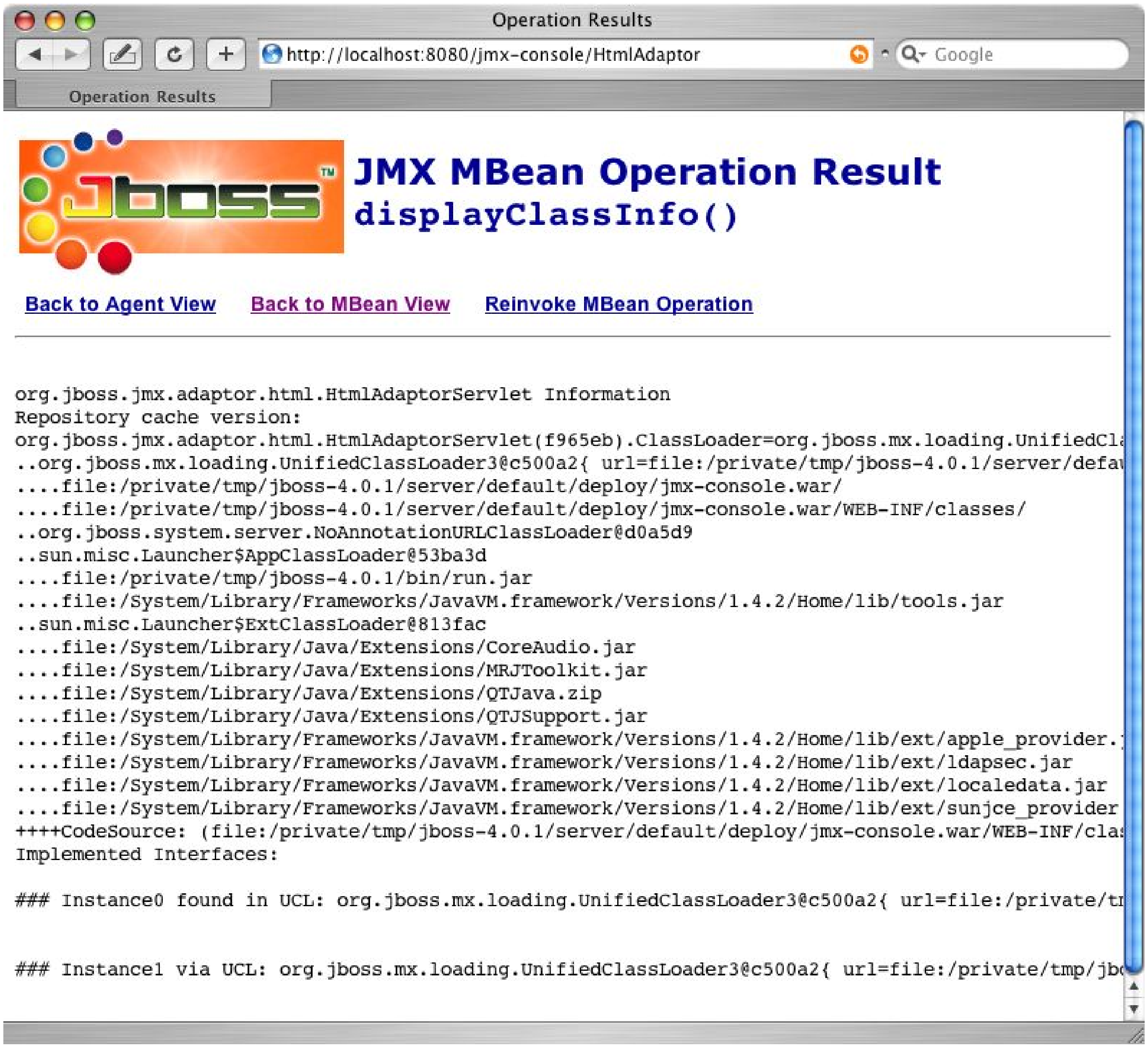
Figure 1.4. The default class LoaderRepository MBean view in the JMX console

Two useful operations you will find here are `getPackageClassLoaders(String)` and `displayClassInfo(String)`. The `getPackageClassLoaders` operation returns a set of class loaders that have been indexed to contain classes or resources for the given package name. The package name must have a trailing period. If you type in the package name `org.jboss.ejb.`, the following information is displayed:

```
[org.jboss.mx.loading.UnifiedClassLoader3@e26ae7{
  url=file:/private/tmp/jboss-4.0.1/server/default/tmp/deploy/tmp11895jboss-service.xml,
  addedOrder=2}]
```

This is the string representation of the set. It shows one `UnifiedClassLoader3` instance with a primary URL pointing to the `jboss-service.xml` descriptor. This is the second class loader added to the repository (shown by `addedOrder=2`). It is the class loader that owns all of the JARs in the `lib` directory of the server configuration (e.g., `server/default/lib`).

The view the information for a given class, use the `displayClassInfo` operation, passing in the fully qualified name of the class to view. For example, if we use `org.jboss.jmx.adaptor.html.HtmlAdaptorServlet` which is from the package we just looked at, the following description is displayed:



```
org.jboss.jmx.adaptor.html.HtmlAdaptorServlet Information
Repository cache version:
org.jboss.jmx.adaptor.html.HtmlAdaptorServlet(f965eb).ClassLoader=org.jboss.mx.loading.UnifiedCla
..org.jboss.mx.loading.UnifiedClassLoader3@c500a2{ url=file:/private/tmp/jboss-4.0.1/server/defau
....file:/private/tmp/jboss-4.0.1/server/default/deploy/jmx-console.war/
....file:/private/tmp/jboss-4.0.1/server/default/deploy/jmx-console.war/WEB-INF/classes/
..org.jboss.system.server.NoAnnotationURLClassLoader@d0a5d9
..sun.misc.Launcher$AppClassLoader@53ba3d
....file:/private/tmp/jboss-4.0.1/bin/run.jar
....file:/System/Library/Frameworks/JavaVM.framework/Versions/1.4.2/Home/lib/tools.jar
..sun.misc.Launcher$ExtClassLoader@813fac
....file:/System/Library/Java/Extensions/CoreAudio.jar
....file:/System/Library/Java/Extensions/MRJToolkit.jar
....file:/System/Library/Java/Extensions/QTJava.zip
....file:/System/Library/Java/Extensions/QTJSupport.jar
....file:/System/Library/Frameworks/JavaVM.framework/Versions/1.4.2/Home/lib/ext/apple_provider.
....file:/System/Library/Frameworks/JavaVM.framework/Versions/1.4.2/Home/lib/ext/ldapsec.jar
....file:/System/Library/Frameworks/JavaVM.framework/Versions/1.4.2/Home/lib/ext/localedata.jar
....file:/System/Library/Frameworks/JavaVM.framework/Versions/1.4.2/Home/lib/ext/sunjce_provider
++++CodeSource: (file:/private/tmp/jboss-4.0.1/server/default/deploy/jmx-console.war/WEB-INF/cla
Implemented Interfaces:

### Instance0 found in UCL: org.jboss.mx.loading.UnifiedClassLoader3@c500a2{ url=file:/private/t


### Instance1 via UCL: org.jboss.mx.loading.UnifiedClassLoader3@c500a2{ url=file:/private/tmp/jb
```

The information is a dump of the information for the Class instance in the loader repository if one has been loaded, followed by the class loaders that are seen to have the class file available. If a class is seen to have more than one class loader associated with it, then there is the potential for class loading related errors.

1.2.2.4.2. Scoping Classes

If you need to deploy multiple versions of an application you need to use deployment based scoping. With deployment based scoping, each deployment creates its own class loader repository in the form of a `HeirarchicalLoaderRepository3` that looks first to the `UnifiedClassLoader3` instances of the deployment units included in the EAR before delegating to the default `UnifiedLoaderRepository3`. To enable an EAR specific loader repository, you need to create a `META-INF/jboss-app.xml` descriptor as shown in Example 1.9.

Example 1.9. An example jboss-app.xml descriptor for enabled scoped class loading at the EAR level.

```
<jboss-app>
    <loader-repository>some.dot.com:loader=webtest.ear</loader-repository>
</jboss-app>
```

The value of the `loader-repository` element is the JMX object name to assign to the repository created for the EAR. This must be unique and valid JMX ObjectName, but the actual name is not important.

1.2.2.4.3. The Complete Class Loading Model

The previous discussion of the core class loading components introduced the custom `UnifiedClassLoader3` and `UnifiedLoaderRepository3` classes that form a shared class loading space. The complete class loading picture must also include the parent class loader used by `UnifiedClassLoader3s` as well as class loaders introduced for scoping and other specialty class loading purposes. Figure 1.5 shows an outline of the class hierarchy that would exist for an EAR deployment containing EJBs and WARs.

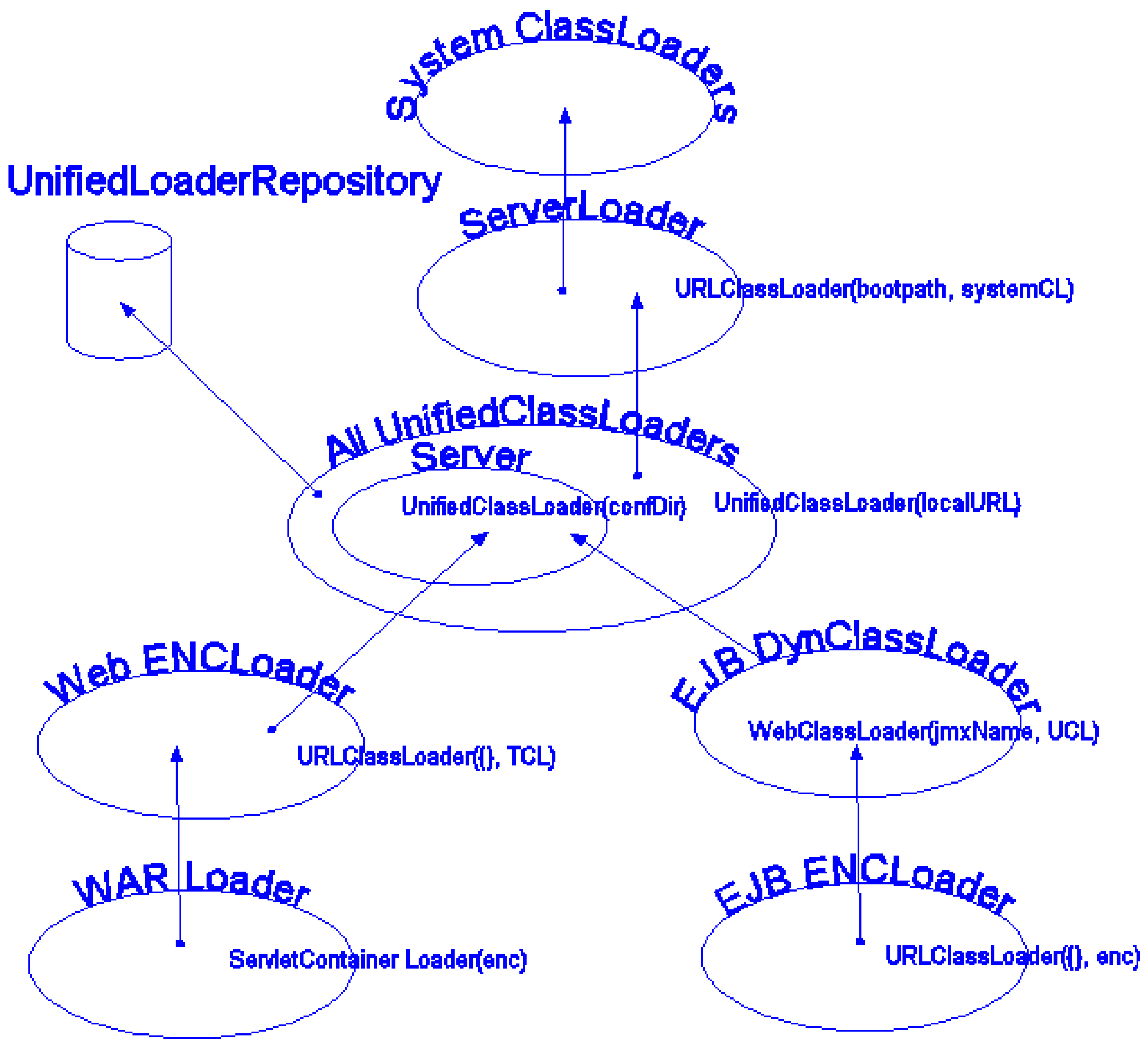


Figure 1.5. A complete class loader view

The following points apply to this figure:

- **System ClassLoaders**: The System ClassLoaders node refers to either the thread context class loader (TCL) of the VM main thread or of the thread of the application that is loading the JBoss server if it is embedded.
- **ServerLoader**: The ServerLoader node refers to the a `URLClassLoader` that delegates to the System ClassLoaders and contains the following boot URLs:
  - All URLs referenced via the `jboss.boot.library.list` system property. These are path specifications relative to the `libraryURL` defined by the `jboss.lib.url` property. If there is no `jboss.lib.url` property spe-

cified, it defaults to `jboss.home.url + /lib/`. If there is no `jboss.boot.library` property specified, it defaults to `jaxp.jar`, `log4j-boot.jar`, `jboss-common.jar`, and `jboss-system.jar`.

  - The JAXP JAR which is either `crimson.jar` or `xerces.jar` depending on the `-j` option to the `Main` entry point. The default is `crimson.jar`.
  - The JBoss JMX jar and GNU regex jar, `jboss-jmx.jar` and `gnu-regexp.jar`.
  - Oswego concurrency classes JAR, `concurrent.jar`
  - Any JARs specified as libraries via `-L` command line options
  - Any other JARs or directories specified via `-C` command line options

- **Server**: The Server node represent a collection of UCLs created by the `org.jboss.system.server.Server` interface implementation. The default implementation creates UCLs for the `patchDir` entries as well as the server `conf` directory. The last UCL created is set as the JBoss main thread context class loader. This will be combined into a single UCL now that multiple URLs per UCL are supported.
- **All UnifiedClassLoader3s**: The *All UnifiedClassLoader3* node represents the UCLs created by deployers. This covers EARs, jars, WARs, SARs and directories seen by the deployment scanner as well as JARs referenced by their manifests and any nested deployment units they may contain. This is a flat namespace and there should not be multiple instances of a class in different deployment JARs. If there are, only the first loaded will be used and the results may not be as expected. There is a mechanism for scoping visibility based on EAR deployment units that we discussed in Section 1.2.2.4.2. Use this mechanism if you need to deploy multiple versions of a class in a given JBoss server.
- **EJB DynClassLoader**: The EJB `DynClassLoader` node is a subclass of `URLClassLoader` that is used to provide RMI dynamic class loading via the simple HTTP WebService. It specifies an empty `URL[]` and delegates to the TCL as its parent class loader. If the WebService is configured to allow system level classes to be loaded, all classes in the `UnifiedLoaderRepository3` as well as the system classpath are available via HTTP.
- **EJB ENCLoader**: The *EJB ENCLoader* node is a `URLClassLoader` that exists only to provide a unique context for an EJB deployment's `java:comp` JNDI context. It specifies an empty `URL[]` and delegates to the EJB `DynClassLoader` as its parent class loader.
- **Web ENCLoader**: The Web `ENCLoader` node is a URLClassLoader that exists only to provide a unique context for a web deployment's `java:comp` JNDI context. It specifies an empty `URL[]` and delegates to the TCL as its parent class loader.
- **WAR Loader**: The *WAR Loader* is a servlet container specific classloader that delegates to the Web ENCLoader as its parent class loader. The default behavior is to load from its parent class loader and then the WAR `WEB-INF classes` and `lib` directories. If the servlet 2.3 class loading model is enabled it will first load from the its `WEB-INF` directories and then the parent class loader.

In its current form there are some advantages and disadvantages to the JBoss class loading architecture. Advantages include:

- Classes do not need to be replicated across deployment units in order to have access to them.

- Many future possibilities including novel partitioning of the repositories into domains, dependency and conflict detection, etc.

Disadvantages include:

- Existing deployments may need to be repackaged to avoid duplicate classes. Duplication of classes in a loader repository can lead to class cast exceptions and linkage errors depending on how the classes are loaded.
- Deployments that depend on different versions of a given class need to be isolated in separate EARs and a unique `HeirarchicalLoaderRepository3` defined using a `jboss-app.xml` descriptor.

1.2.3. JBoss XMBeans

XMBeans are the JBoss JMX implementation version of the JMX model MBean. XMBeans have the richness of the dynamic MBean metadata without the tedious programming required by a direct implementation of the `DynamicMBean` interface. The JBoss model MBean implementation allows one to specify the management interface of a component through a XML descriptor, hence the X in XMBean. In addition to providing a simple mechanism for describing the metadata required for a dynamic MBean, XMBeans also allow for the specification of attribute persistence, caching behavior, and even advanced customizations like the MBean implementation interceptors. The high level elements of the `jboss_xmbean_1_2.dtd` for the XMBean descriptor is given in Figure 1.6.

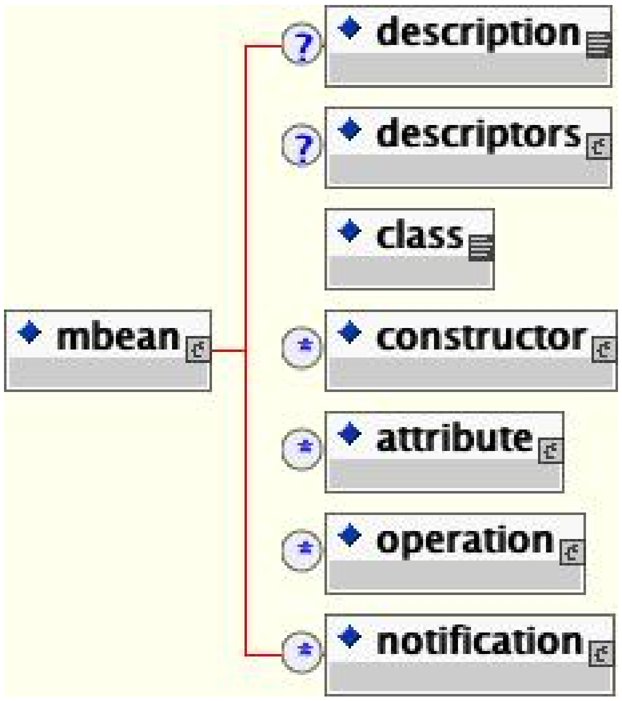


Figure 1.6. The JBoss 1.0 XMBean DTD Overview (jboss_xmbean_1_2.dtd)

The `mbean` element is the root element of the document containing the required elements for describing the management interface of one MBean (constructors, attributes, operations and notifications). It also includes an optional description element, which can be used to describe the purpose of the MBean, as well as an optional descriptors element which allows for persistence policy specification, attribute caching, etc.

1.2.3.1. Descriptors

The descriptors element contains all the descriptors for a containing element, as subelements. The descriptors suggested in the JMX specification as well as those used by JBoss have predefined elements and attributes, whereas custom descriptors have a generic descriptor element with name and value attributes as show in Figure 1.7.

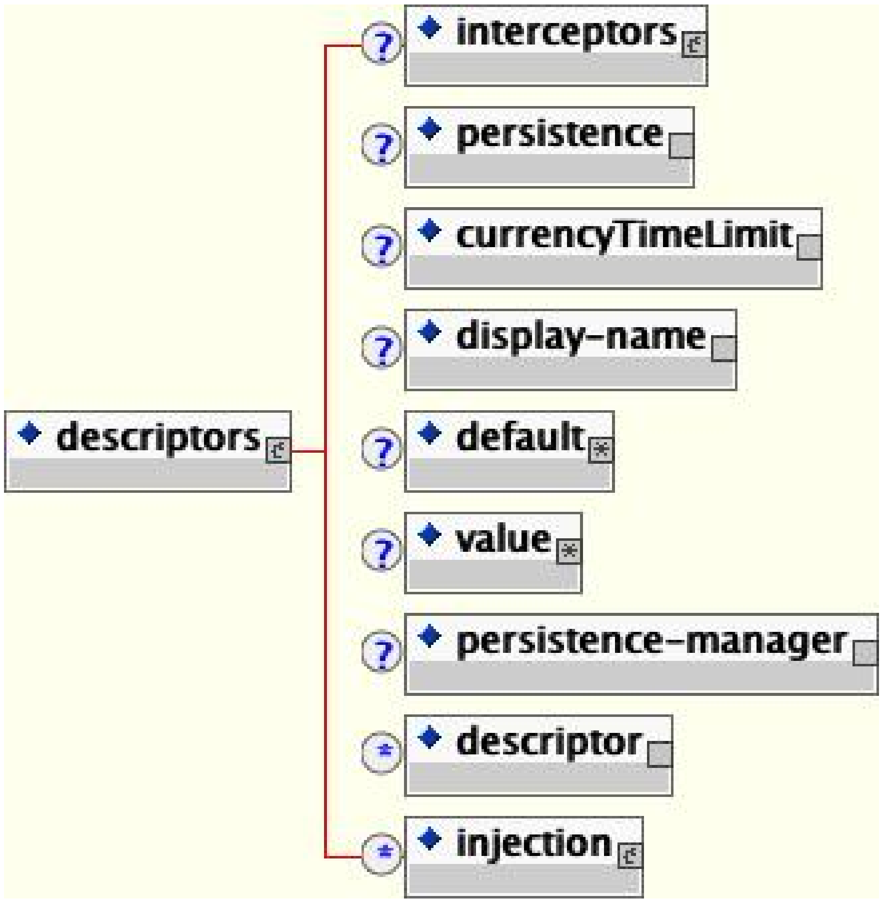


Figure 1.7. The descriptors element content model

The key descriptors child elements include:

- **interceptors**: The `interceptors` element specifies a customized stack of interceptors that will be used in place of the default stack. Currently this is only used when specified at the MBean level, but it could define a custom attribute or operation level interceptor stack in the future. The content of the interceptors element specifies a custom interceptor stack. If no interceptors element is specified the standard `ModelMBean` interceptors will be used. The standard interceptors are:

  - org.jboss.mx.interceptor.PersistenceInterceptor
  - org.jboss.mx.interceptor.MBeanAttributeInterceptor
  - org.jboss.mx.interceptor.ObjectReferenceInterceptor

  When specifying a custom interceptor stack you would typically include the standard interceptors along with your own unless you are replacing the corresponding standard interceptor.

Each interceptor element content value specifies the fully qualified class name of the interceptor implementation. The class must implement the `org.jboss.mx.interceptor.Interceptor` interface. The interceptor class must also have either a no-arg constructor, or a constructor that accepts a `javax.management.MBeanInfo`.

The interceptor elements may have any number of attributes that correspond to JavaBean style properties on the interceptor class implementation. For each `interceptor` element attribute specified, the interceptor class is queried for a matching setter method. The attribute value is converted to the true type of the interceptor class property using the `java.beans.PropertyEditor` associated with the type. It is an error to specify an attribute for which there is no setter or `PropertyEditor`.

- **persistence**: The `persistence` element allows the specification of the `persistPolicy`, `persistPeriod`, `persistLocation`, and `persistName` persistence attributes suggested by the JMX specification. The persistence element attributes are:

  - **persistPolicy**: The `persistPolicy` attribute defines when attributes should be persisted and its value must be one of

    - **Never**: attribute values are transient values that are never persisted
    - **OnUpdate**: attribute values are persisted whenever they are updated
    - **OnTimer**: attribute values are persisted based on the time given by the `persistPeriod`.
    - **NoMoreOftenThan**: attribute values are persisted when updated but no more often than the `persistPeriod`.

  - **persistPeriod**: The `persistPeriod` attribute gives the update frequency in milliseconds if the `perisitPolicy` attribute is `NoMoreOftenThan` or `OnTimer`.
  - **persistLocation**: The `persistLocation` attribute specifies the location of the persistence store. Its form depends on the JMX persistence implementation. Currently this should refer to a directory into which the attributes will be serialized if using the default JBoss persistence manager.
  - **persistName**: The `persistName` attribute can be used in conjunction with the `persistLocation` attribute to further qualify the persistent store location. For a directory `persistLocation` the `persistName` specifies the file to which the attributes are stored within the directory.

- **currencyTimeLimit**: The `currencyTimeLimit` element specifies the time in seconds that a cached value of an attribute remains valid. Its value attribute gives the time in seconds. A value of 0 indicates that an attribute value should always be retrieved from the MBean and never cached. A value of -1 indicates that a cache value is always valid.
- **display-name**: The `display-name` element specifies the human friendly name of an item.
- **default**: The `default` element specifies a default value to use when a field has not been set. Note that this value is not written to the MBean on startup as is the case with the `jboss-service.xml` attribute element content value. Rather, the default value is used only if there is no attribute accessor defined, and there is no value element defined.

- **value**: The `value` element specifies a management attribute's current value. Unlike the `default` element, the `value` element is written through to the MBean on startup provided there is a setter method available.
- **persistence-manager**: The `persistence-manager` element gives the name of a class to use as the persistence manager. The `value` attribute specifies the class name that supplies the `org.jboss.mx.persistence.PersistenceManager` interface implementation. The only implementation currently supplied by JBoss is the `org.jboss.mx.persistence.ObjectStreamPersistenceManager` which serializes the `ModelMBeanInfo` content to a file using Java serialization.
- **descriptor**: The `descriptor` element specifies an arbitrary descriptor not known to JBoss. Its `name` attribute specifies the type of the descriptor and its `value` attribute specifies the descriptor value. The `descriptor` element allows for the attachment of arbitrary management metadata.
- **injection**: The `injection` element describes an injection point for receiving information from the microkernel. Each injection point specifies the type and the set method to use to inject the information into the resource. The `injection` element supports type attributes:
  - **id**: The `id` attribute specifies the injection point type. The current injection point types are:
    - **MBeanServerType**: An *MBeanServerType* injection point receives a reference to the *MBeanServer* that the XMBean is registered with.
    - **MBeanInfoType**: An *MBeanInfoType* injection point receives a reference to the XMBean *ModelMBeanInfo* metadata.
    - **ObjectNameType**: The *ObjectName* injection point receives the *ObjectName* that the XMBean is registered under.
- **setMethod**: The *setMethod* attribute gives the name of the method used to set the injection value on the resource. The set method should accept values of the type corresponding to the injection point type.

Note that any of the constructor, attribute, operation or notification elements may have a `descriptors` element to specify the specification defined descriptors as well as arbitrary extension descriptor settings.

1.2.3.2. The Management Class

The `class` element specifies the fully qualified name of the managed object whose management interface is described by the XMBean descriptor.

1.2.3.3. The Constructors

The `constructor` element(s) specifies the constructors available for creating an instance of the managed object. The constructor element and its content model are shown in Figure 1.8.

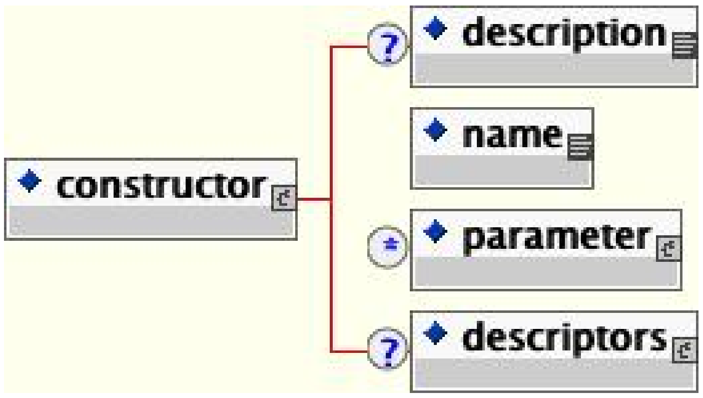


Figure 1.8. The XMBean constructor element and its content model

The key child elements are:

- **description**: A description of the constructor.
- **name**: The name of the constructor, which must be the same as the implementation class.
- **parameter**: The parameter element describes a constructor parameter. The parameter element has the following attributes:
  - **description**: An optional description of the parameter.
  - **name**: The required variable name of the parameter.
  - **type**: The required fully qualified class name of the parameter type.
- **descriptors**: Any descriptors to associate with the constructor metadata.

1.2.3.4. The Attributes

The `attribute` element(s) specifies the management attributes exposed by the MBean. The attribute element and its content model are shown in Figure 1.9.

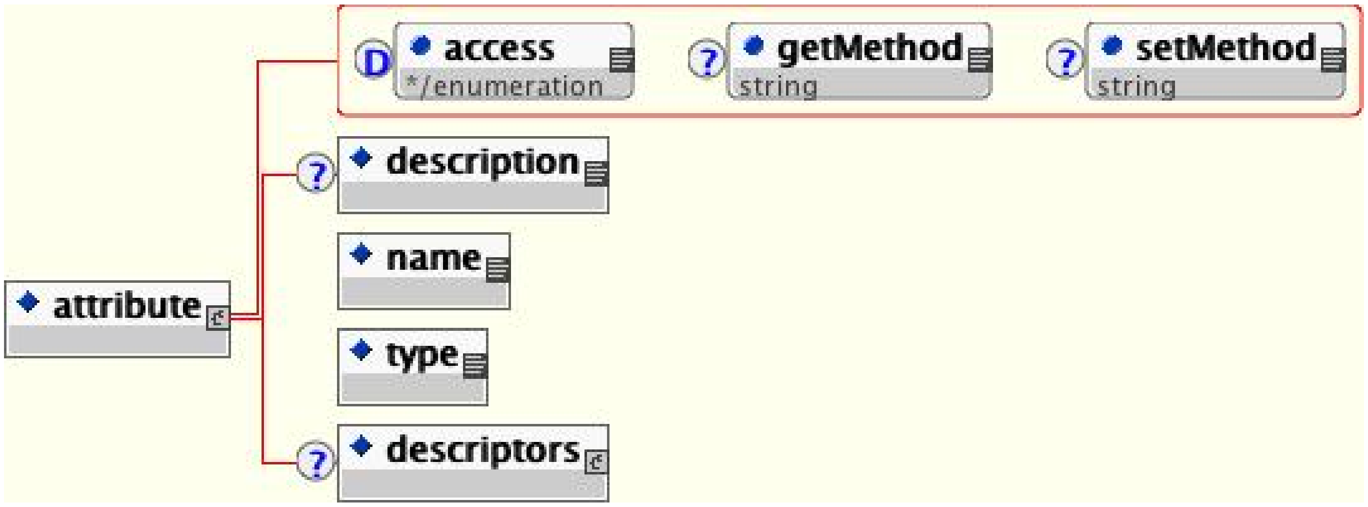


Figure 1.9. The XMBean attribute element and its content model

The `attribute` element supported attributes include:

- **access**: The optional `access` attribute defines the read/write access modes of an attribute. It must be one of:
  - **read-only**: The attribute may only be read.
  - **write-only**: The attribute may only be written.
  - **read-write**: The attribute is both readable and writable. This is the implied default.
- **getMethod**: The `getMethod` attribute defines the name of the method which reads the named attribute. This must be specified if the managed attribute should be obtained from the MBean instance.
- **setMethod**: The `setMethod` attribute defines the name of the method which writes the named attribute. This must be specified if the managed attribute should be obtained from the MBean instance.

The key child elements of the attribute element include:

- **description**: A description of the attribute.
- **name**: The name of the attribute as would be used in the `MBeanServer.getAttribute()` operation.
- **type**: The fully qualified class name of the attribute type.
- **descriptors**: Any additional descriptors that affect the attribute persistence, caching, default value, etc.

1.2.3.5. The Operations

The management operations exposed by the XMBean are specified via one or more operation elements. The operation element and its content model are shown in Figure 1.10.

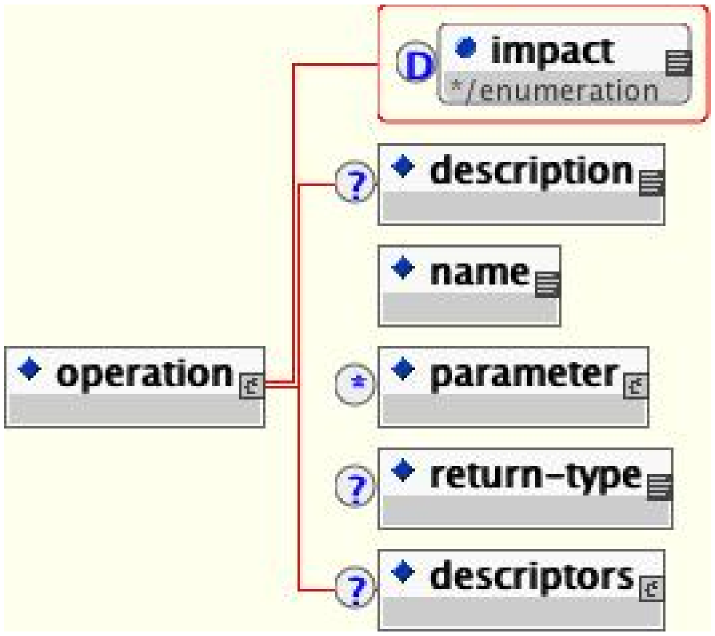


Figure 1.10. The XMBean operation element and its content model

The impact attribute defines the impact of executing the operation and must be one of:

- **ACTION**: The operation changes the state of the MBean component (write operation)
- **INFO**: The operation should not alter the state of the MBean component (read operation).
- **ACTION_INFO**: The operation behaves like a read/write operation.

The child elements are:

- **description**: This element specifies a human readable description of the operation.
- **name**: This element contains the operation's name
- **parameter**: This element describes the operation's signature.
- **return-type**: This element contains a fully qualified class name of the return type from this operation. If not specified, it defaults to void.
- **descriptors**: Any descriptors to associate with the operation metadata.

1.2.3.6. Notifications

The `notification` element(s) describes the management notifications that may be emitted by the XMBean. The notification element and its content model is shown in Figure 1.11.

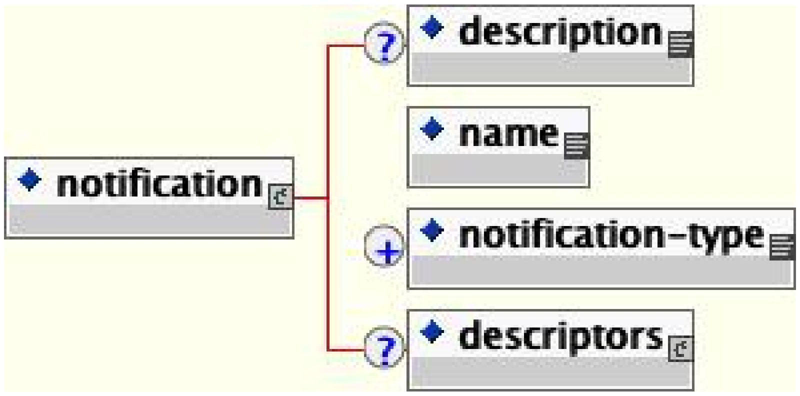


Figure 1.11. The XMBean notification element and content model

The child elements are:

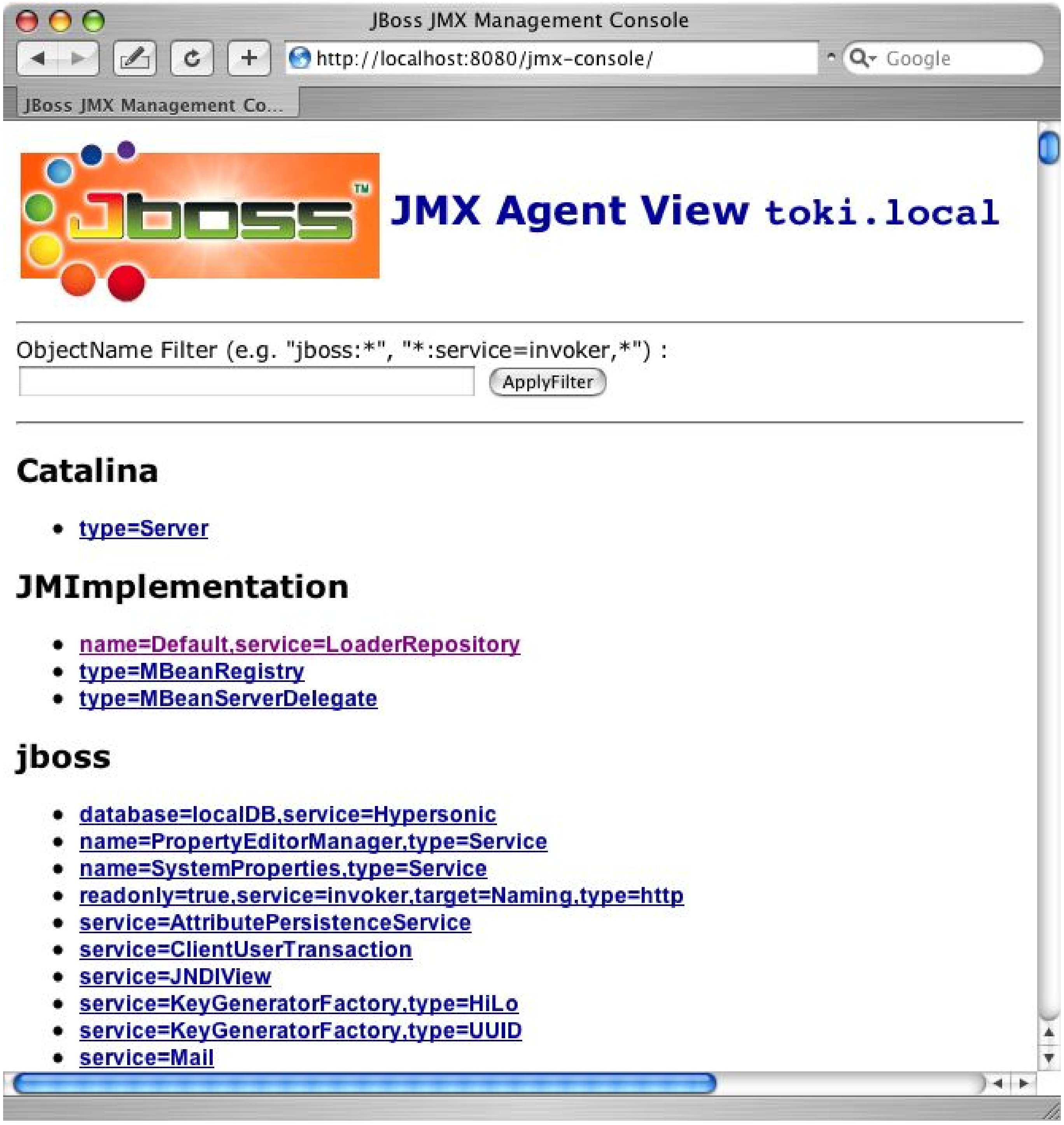
- **description**: This element gives a human readable description of the notification.
- **name**: This element contains the fully qualified name of the notification class.
- **notification-type**: This element contains the dot-separated notification type string.
- **descriptors**: Any descriptors to associate with the notification metadata.

1.3. Connecting to the JMX Server

JBoss includes adaptors that allow access to the JMX MBeanServer from outside of the JBoss server VM. The current adaptors include HTML, an RMI interface, and an EJB.

1.3.1. Inspecting the Server - the JMX Console Web Application

JBoss comes with its own implementation of a JMX HTML adaptor that allows one to view the server's MBeans using a standard web browser. The default URL for the console web application is http://localhost:8080/jmx-console/. If you browse this location you will see something similar to that presented in Figure 1.12.


JBoss JMX Management Console
http://localhost:8080/jmx-console/
Google
JBoss JMX Management Co...

JMX Agent View toki.local

ObjectName Filter (e.g. "jboss:*", "*:service=invoker,*") :

ApplyFilter

Catalina

- type=Server

JMImplementation

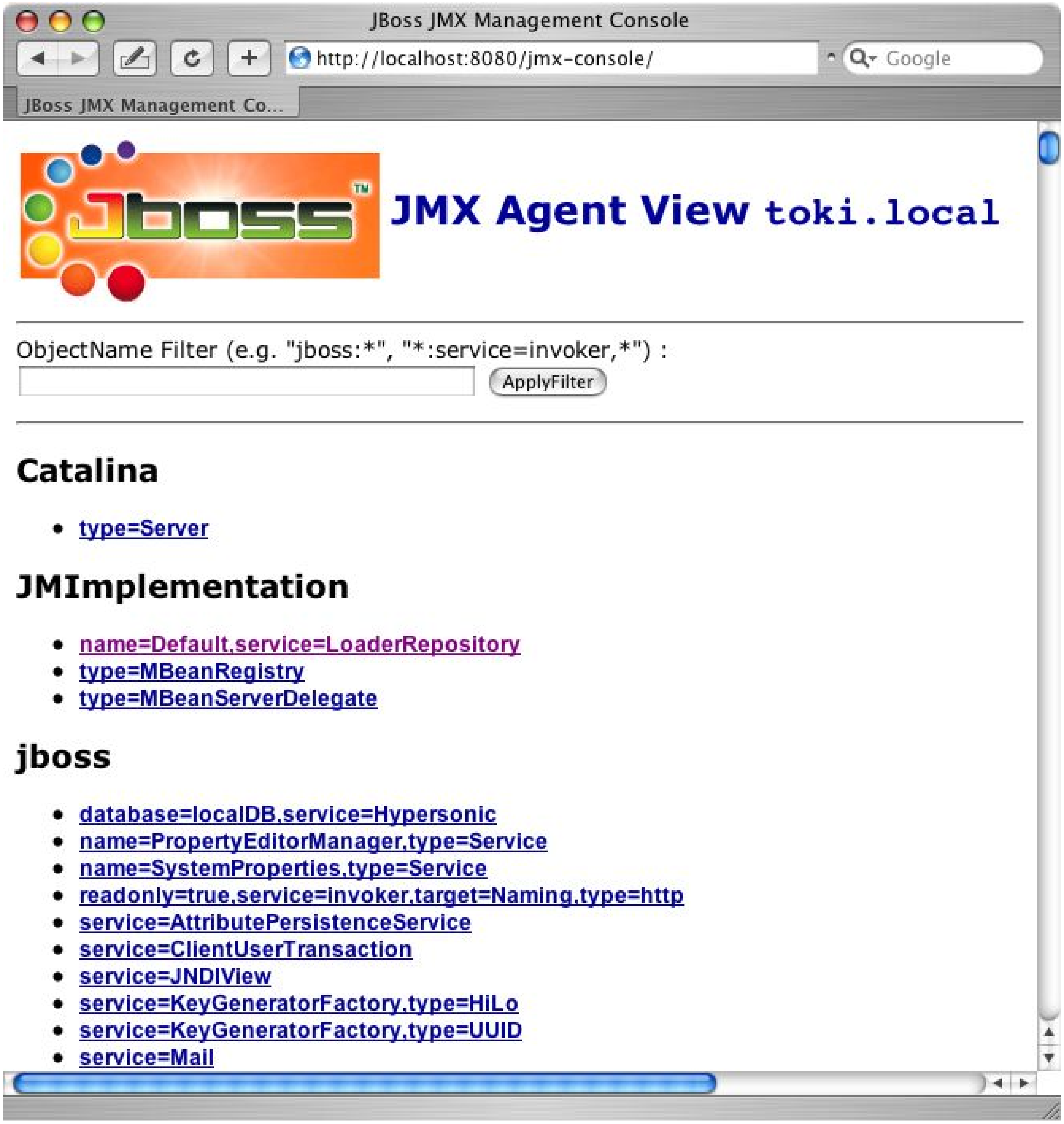
- name=Default,service=LoaderRepository
- type=MBeanRegistry
- type=MBeanServerDelegate

jboss

- database=localDB,service=Hypersonic
- name=PropertyEditorManager,type=Service
- name=SystemProperties,type=Service
- readonly=true,service=invoker,target=Naming,type=http
- service=AttributePersistenceService
- service=ClientUserTransaction
- service=JNDIView
- service=KeyGeneratorFactory,type=HiLo
- service=KeyGeneratorFactory,type=UUID
- service=Mail

Figure 1.12. The JBoss JMX console web application agent view

The top view is called the agent view and it provides a listing of all MBeans registered with the `MBeanServer` sorted by the domain portion of the MBean's `ObjectName`. Under each domain are the MBeans under that domain. When you select one of the MBeans you will be taken to the MBean view. This allows one to view and edit an MBean's attributes as well as invoke operations. As an example, Figure 1.13 shows the MBean view for the `jboss.system:type=Server` MBean.


JBoss JMX Management Console
http://localhost:8080/jmx-console/
Google
JBoss JMX Management Co...
ApplyFilter

JMX Agent View toki.local

ObjectName Filter (e.g. "jboss:*", "*:service=invoker,*") :

Catalina

- type=Server

JMImplementation

- name=Default,service=LoaderRepository
- type=MBeanRegistry
- type=MBeanServerDelegate

jboss

- database=localDB,service=Hypersonic
- name=PropertyEditorManager,type=Service
- name=SystemProperties,type=Service
- readonly=true,service=invoker,target=Naming,type=http
- service=AttributePersistenceService
- service=ClientUserTransaction
- service=JNDIView
- service=KeyGeneratorFactory,type=HiLo
- service=KeyGeneratorFactory,type=UUID
- service=Mail

Figure 1.13. The MBean view for the "jboss.system:type=Server" MBean

The source code for the JMX console web application is located in the `varia` module under the `src/main/org/jboss/jmx` directory. Its web pages are located under `varia/src/resources/jmx`. The application is a simple MVC servlet with JSP views that utilize the MBeanServer.

1.3.1.1. Securing the JMX Console

Since the JMX console web application is just a standard servlet, it may be secured using standard J2EE role based security. The `jmx-console.war` that is deployed as an unpacked WAR that includes template settings for quickly enabling simple username and password based access restrictions. If you look at the `jmx-console.war` in the `server/default/deploy` directory you will find the `web.xml` and `jboss-web.xml` descriptors in the `WEB-INF` directory. The `jmx-console-roles.properties` and `jmx-console-users.properties` files are located in the `server/default/conf/props` directory.

By uncommenting the security sections of the `web.xml` and `jboss-web.xml` descriptors as shown in Example 1.10, you enable HTTP basic authentication that restricts access to the JMX Console application to the user `admin` with password `admin`. The username and password are determined by the `admin=admin` line in the `jmx-console-users.properties` file.

Example 1.10. The jmx-console.war web.xml descriptors with the security elements uncommented.

```
<?xml version="1.0"?>
<!DOCTYPE web-app PUBLIC
          "-//Sun Microsystems, Inc.//DTD Web Application 2.3//EN"
          "http://java.sun.com/dtd/web-app_2_3.dtd">
<web-app>
    <!-- ... -->

    <!-- A security constraint that restricts access to the HTML JMX console
         to users with the role JBossAdmin. Edit the roles to what you want and
         uncomment the WEB-INF/jboss-web.xml/security-domain element to enable
         secured access to the HTML JMX console.
    -->
    <security-constraint>
        <web-resource-collection>
            <web-resource-name>HtmlAdaptor</web-resource-name>
            <description> An example security config that only allows users with
                the role JBossAdmin to access the HTML JMX console web
                application </description>
            <url-pattern>/*</url-pattern>
            <http-method>GET</http-method>
            <http-method>POST</http-method>
        </web-resource-collection>
        <auth-constraint>
            <role-name>JBossAdmin</role-name>
        </auth-constraint>
    </security-constraint>
    <login-config>
        <auth-method>BASIC</auth-method>
        <realm-name>JBoss JMX Console</realm-name>
    </login-config>
    <security-role>
        <role-name>JBossAdmin</role-name>
    </security-role>
</web-app>
```

Example 1.11. The jmx-console.war jboss-web.xml descriptors with the security elements uncommented.

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE jboss-web
    PUBLIC "-//JBoss//DTD Web Application 2.3//EN"
    "http://www.jboss.org/j2ee/dtd/jboss-web_3_0.dtd">
<jboss-web>
```

```
    <!--
        Uncomment the security-domain to enable security. You will
        need to edit the htmladaptor login configuration to setup the
        login modules used to authentication users.
    -->
    <security-domain>java:/jaas/jmx-console</security-domain>
</jboss-web>
```

Make these changes and then when you try to access the JMX Console URL. You will see a dialog similar to that shown in Figure 1.14.

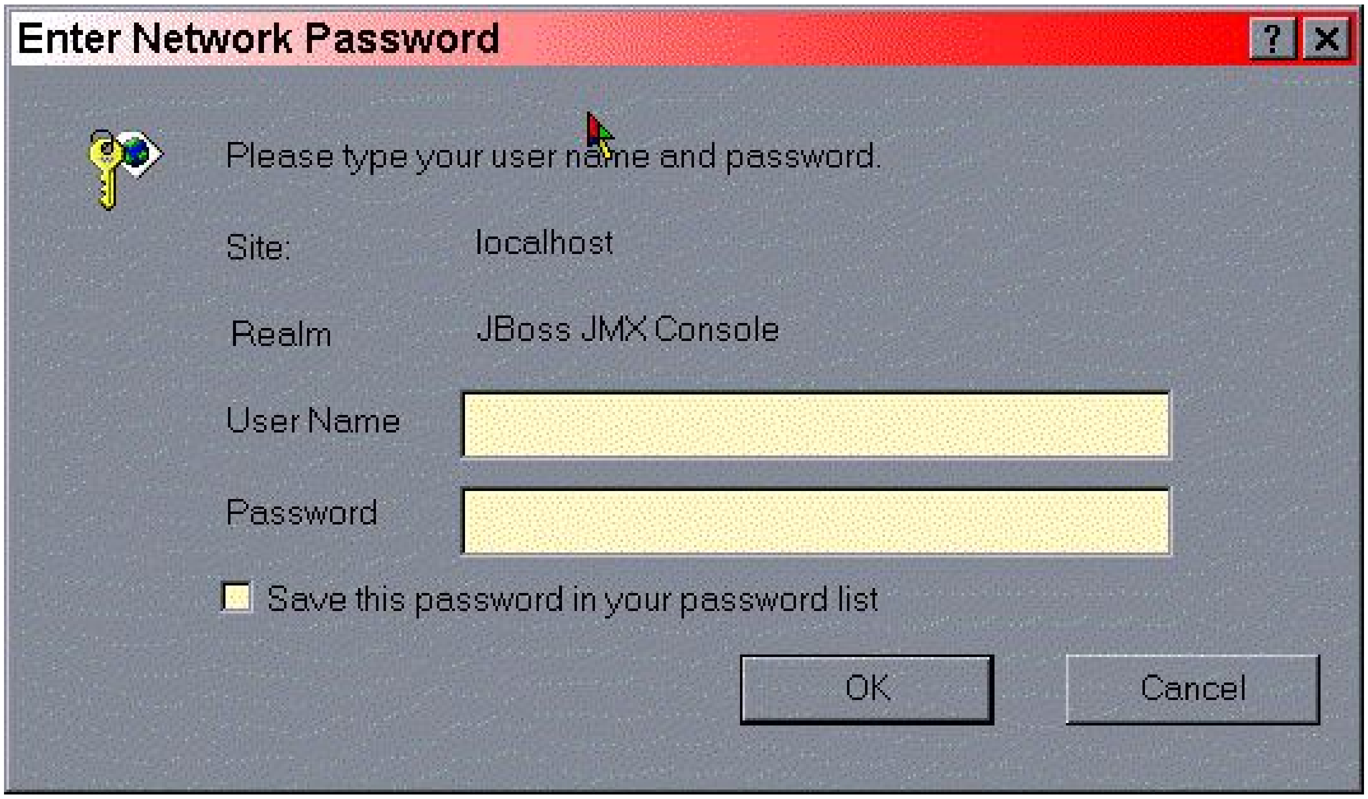


Figure 1.14. The JMX Console basic HTTP login dialog.

You probably to use the properties files for securing access to the JMX console application. To see how to properly configure the security settings of web applications see Chapter 7.

1.3.2. Connecting to JMX Using RMI

JBoss supplies an RMI interface for connecting to the JMX MBeanServer. This interface is `org.jboss.jmx.adaptor.rmi.RMIAdaptor`. The `RMIAdaptor` interface is bound into JNDI in the default location of `jmx/invoker/RMIAdaptor` as well as `jmx/rmi/RMIAdaptor` for backwards compatibility with older clients.

Example 1.12 shows a client that makes use of the `RMIAdaptor` interface to query the `MBeanInfo` for the `JNDIView` MBean. It also invokes the MBean's `list(boolean)` method and displays the result.

Example 1.12. A JMX client that uses the RMIAdaptor

```
public class JMXBrowser
{
    /**
     * @param args the command line arguments
     */
    public static void main(String[] args) throws Exception
    {
        InitialContext ic = new InitialContext();
        RMIAdaptor server = (RMIAdaptor) ic.lookup("jmx/invoker/RMIAdaptor");

        // Get the MBeanInfo for the JNDIView MBean
        ObjectName name = new ObjectName("jboss:service=JNDIView");
        MBeanInfo  info = server.getMBeanInfo(name);
        System.out.println("JNDIView Class: " + info.getClassName());

        MBeanOperationInfo[] opInfo = info.getOperations();
        System.out.println("JNDIView Operations: ");
        for(int o = 0; o < opInfo.length; o ++) {
            MBeanOperationInfo op = opInfo[o];

            String returnType = op.getReturnType();
            String opName     = op.getName();
            System.out.print(" + " + returnType + " " + opName + "(");

            MBeanParameterInfo[] params = op.getSignature();
            for(int p = 0; p < params.length; p++)  {
                MBeanParameterInfo paramInfo = params[p];

                String pname = paramInfo.getName();
                String type  = paramInfo.getType();

                if (pname.equals(type)) {
                    System.out.print(type);
                } else {
                    System.out.print(type + " " + name);
                }

                if (p < params.length-1) {
                    System.out.print(',');
                }
            }
            System.out.println(")");
        }

        // Invoke the list(boolean) op
        String[] sig    = {"boolean"};
        Object[] opArgs = {Boolean.TRUE};
        Object   result = server.invoke(name, "list", opArgs, sig);

        System.out.println("JNDIView.list(true) output:\n"+result);
    }
}
```

To test the client access using the `RMIAdaptor`, run the following:

```
[examples]$ ant -Dchap=jmx -Dex=4 run-example
...

run-example4:
     [java] JNDIView Class: org.jboss.mx.modelmbean.XMBean
     [java] JNDIView Operations:
     [java]  + java.lang.String list(boolean jboss:service=JNDIView)
     [java]  + java.lang.String listXML()
     [java]  + void create()
     [java]  + void start()
     [java]  + void stop()
     [java]  + void destroy()
     [java]  + void jbossInternalLifecycle(java.lang.String jboss:service=JNDIView)
     [java]  + java.lang.String getName()
     [java]  + int getState()
     [java]  + java.lang.String getStateString()
     [java] JNDIView.list(true) output:
     [java] <h1>java: Namespace</h1>
     [java] <pre>
     [java]   +- XAConnectionFactory (class: org.jboss.mq.SpyXAConnectionFactory)
     [java]   +- DefaultDS (class: javax.sql.DataSource)
     [java]   +- SecurityProxyFactory (class: org.jboss.security.SubjectSecurityProxyFactory)
     [java]   +- DefaultJMSProvider (class: org.jboss.jms.jndi.JNDIProviderAdapter)
     [java]   +- comp (class: javax.naming.Context)
     [java]   +- JmsXA (class: org.jboss.resource.adapter.jms.JmsConnectionFactoryImpl)
     [java]   +- ConnectionFactory (class: org.jboss.mq.SpyConnectionFactory)
     [java]   +- jaas (class: javax.naming.Context)
     [java]   |   +- JmsXARealm (class: org.jboss.security.plugins.SecurityDomainContext)
     [java]   |   +- jbossmq (class: org.jboss.security.plugins.SecurityDomainContext)
     [java]   |   +- HsqlDbRealm (class: org.jboss.security.plugins.SecurityDomainContext)
     [java]   +- timedCacheFactory (class: javax.naming.Context)
     [java] Failed to lookup: timedCacheFactory, errmsg=null
     [java]   +- TransactionPropagationContextExporter (class: org.jboss.tm.TransactionPropag
ationContextFactory)
     [java]   +- StdJMSPool (class: org.jboss.jms.asf.StdServerSessionPoolFactory)
     [java]   +- Mail (class: javax.mail.Session)
     [java]   +- TransactionPropagationContextImporter (class: org.jboss.tm.TransactionPropag
ationContextImporter)
     [java]   +- TransactionManager (class: org.jboss.tm.TxManager)
     [java] </pre>
     [java] <h1>Global JNDI Namespace</h1>
     [java] <pre>
     [java]   +- XAConnectionFactory (class: org.jboss.mq.SpyXAConnectionFactory)
     [java]   +- UIL2ConnectionFactory[link -> ConnectionFactory] (class: javax.naming.Lin
kRef)
     [java]   +- UserTransactionSessionFactory (proxy: $Proxy11 implements interface org.jbos
s.tm.usertx.interfaces.UserTransactionSessionFactory)
     [java]   +- HTTPConnectionFactory (class: org.jboss.mq.SpyConnectionFactory)
     [java]   +- console (class: org.jnp.interfaces.NamingContext)
     [java]   |   +- PluginManager (proxy: $Proxy36 implements interface org.jboss.console.ma
nager.PluginManagerMBean)
     [java]   +- UIL2XAConnectionFactory[link -> XAConnectionFactory] (class: javax.naming
.LinkRef)
     [java]   +- UUIDKeyGeneratorFactory (class: org.jboss.ejb.plugins.keygenerator.uuid.UUID
KeyGeneratorFactory)
     [java]   +- HTTPXAConnectionFactory (class: org.jboss.mq.SpyXAConnectionFactory)
     [java]   +- topic (class: org.jnp.interfaces.NamingContext)
     [java]   |   +- testDurableTopic (class: org.jboss.mq.SpyTopic)
     [java]   |   +- testTopic (class: org.jboss.mq.SpyTopic)
     [java]   |   +- securedTopic (class: org.jboss.mq.SpyTopic)
     [java]   +- queue (class: org.jnp.interfaces.NamingContext)
     [java]   |   +- A (class: org.jboss.mq.SpyQueue)
     [java]   |   +- testQueue (class: org.jboss.mq.SpyQueue)
     [java]   |   +- ex (class: org.jboss.mq.SpyQueue)
     [java]   |   +- DLQ (class: org.jboss.mq.SpyQueue)
     [java]   |   +- D (class: org.jboss.mq.SpyQueue)
     [java]   |   +- C (class: org.jboss.mq.SpyQueue)
     [java]   |   +- B (class: org.jboss.mq.SpyQueue)
     [java]   +- ConnectionFactory (class: org.jboss.mq.SpyConnectionFactory)
     [java]   +- UserTransaction (class: org.jboss.tm.usertx.client.ClientUserTransaction)
     [java]   +- jmx (class: org.jnp.interfaces.NamingContext)
     [java]   |   +- invoker (class: org.jnp.interfaces.NamingContext)
     [java]   |   |   +- RMIAdaptor (proxy: $Proxy35 implements interface org.jboss.jmx.adapt
or.rmi.RMIAdaptor,interface org.jboss.jmx.adaptor.rmi.RMIAdaptorExt)
     [java]   |   +- rmi (class: org.jnp.interfaces.NamingContext)
     [java]   |   |   +- RMIAdaptor[link -> jmx/invoker/RMIAdaptor] (class: javax.naming.L
inkRef)
     [java]   +- HiLoKeyGeneratorFactory (class: org.jboss.ejb.plugins.keygenerator.hilo.HiLo
KeyGeneratorFactory)
     [java]   +- UILXAConnectionFactory[link -> XAConnectionFactory] (class: javax.naming.
LinkRef)
     [java]   +- UILConnectionFactory[link -> ConnectionFactory] (class: javax.naming.Link
Ref)
     [java] </pre>
```

1.3.3. Command Line Access to JMX

JBoss provides a simple command line tool that allows for interaction with a remote JMX server instance. This tool is called twiddle (for twiddling bits via JMX) and is located in the `bin` directory of the distribution. Twiddle is a command execution tool, not a general command shell. It is run using either the `twiddle.sh` or `twiddle.bat` scripts, and passing in a `-h`(`--help`) argument provides the basic syntax, and `--help-commands` shows what you can do with the tool:

```
[bin]$ ./twiddle.sh -h
A JMX client to 'twiddle' with a remote JBoss server.

usage: twiddle.sh [options] <command> [command_arguments]

options:
    -h, --help                Show this help message
        --help-commands       Show a list of commands
    -H=<command>              Show command specific help
    -c=command.properties     Specify the command.properties file to use
    -D<name>[=<value>]        Set a system property
    --                        Stop processing options
    -s, --server=<url>        The JNDI URL of the remote server
    -a, --adapter=<name>      The JNDI name of the RMI adapter to use
    -q, --quiet               Be somewhat more quiet
```

1.3.3.1. Connecting twiddle to a Remote Server

By default the twiddle command will connect to the localhost at port 1099 to lookup the default `jmx/rmi/RMIAdaptor` binding of the `RMIAdaptor` service as the connector for communicating with the JMX server. To connect to a different server/port combination you can use the `-s` (`--server`) option:

```
[bin]$ ./twiddle.sh -s toki serverinfo -d jboss
[bin]$ ./twiddle.sh -s toki:1099 serverinfo -d jboss
```

To connect using a different RMIAdaptor binding use the `-a` (--`adapter`) option:

```
[bin]$ ./twiddle.sh -s toki -a jmx/rmi/RMIAdaptor serverinfo -d jboss
```

1.3.3.2. Sample twiddle Command Usage

To access basic information about a server, use the `serverinfo` command. This currently supports:

```
[bin]$ ./twiddle.sh -H serverinfo
Get information about the MBean server

usage: serverinfo [options]
```

```
options:
    -d, --domain    Get the default domain
    -c, --count     Get the MBean count
    -l, --list      List the MBeans
    --              Stop processing options
[bin]$ ./twiddle.sh --server=toki serverinfo --count
460
[bin]$ ./twiddle.sh --server=toki serverinfo --domain
jboss
```

To query the server for the name of MBeans matching a pattern, use the `query` command. This currently supports:

```
[bin]$ ./twiddle.sh -H query
Query the server for a list of matching MBeans

usage: query [options] <query>
options:
    -c, --count    Display the matching MBean count
    --             Stop processing options
Examples:
 query all mbeans: query '*:*'
 query all mbeans in the jboss.j2ee domain: query 'jboss.j2ee:*'
[bin]$ ./twiddle.sh -s toki query 'jboss:service=invoker,*'
jboss:readonly=true,service=invoker,target=Naming,type=http
jboss:service=invoker,type=jrmp
jboss:service=invoker,type=local
jboss:service=invoker,type=pooled
jboss:service=invoker,type=http
jboss:service=invoker,target=Naming,type=http
```

To get the attributes of an MBean, use the get command:

```
[bin]$ ./twiddle.sh -H get
Get the values of one or more MBean attributes

usage: get [options] <name> [<attr>+]
  If no attribute names are given all readable attributes are retrieved
options:
    --noprefix    Do not display attribute name prefixes
    --            Stop processing options
[bin]$ ./twiddle.sh get jboss:service=invoker,type=jrmp RMIObjectPort StateString
RMIObjectPort=4444
StateString=Started
[bin]$ ./twiddle.sh get jboss:service=invoker,type=jrmp
ServerAddress=0.0.0.0
RMIClientSocketFactoryBean=null
StateString=Started
State=3
RMIServerSocketFactoryBean=org.jboss.net.sockets.DefaultSocketFactory@ad093076
EnableClassCaching=false
SecurityDomain=null
RMIServerSocketFactory=null
Backlog=200
RMIObjectPort=4444
Name=JRMPInvoker
RMIClientSocketFactory=null
```

To query the MBeanInfo for an MBean, use the info command:

```
[bin]$ ./twiddle.sh -H info
Get the metadata for an MBean
```

```
usage: info <mbean-name>
  Use '*' to query for all attributes
[bin]$ Description: Management Bean.
+++ Attributes:
 Name: ServerAddress
 Type: java.lang.String
 Access: rw
 Name: RMIClientSocketFactoryBean
 Type: java.rmi.server.RMIClientSocketFactory
 Access: rw
 Name: StateString
 Type: java.lang.String
 Access: r-
 Name: State
 Type: int
 Access: r-
 Name: RMIServerSocketFactoryBean
 Type: java.rmi.server.RMIServerSocketFactory
 Access: rw
 Name: EnableClassCaching
 Type: boolean
 Access: rw
 Name: SecurityDomain
 Type: java.lang.String
 Access: rw
 Name: RMIServerSocketFactory
 Type: java.lang.String
 Access: rw
 Name: Backlog
 Type: int
 Access: rw
 Name: RMIObjectPort
 Type: int
 Access: rw
 Name: Name
 Type: java.lang.String
 Access: r-
 Name: RMIClientSocketFactory
 Type: java.lang.String
 Access: rw
+++ Operations:
 void start()
 void jbossInternalLifecycle(java.lang.String java.lang.String)
 void create()
 void stop()
 void destroy()
```

To invoke an operation on an MBean, use the invoker command:

```
[bin]$ ./twiddle.sh -H invoke
Invoke an operation on an MBean

usage: invoke [options] <query> <operation> (<arg>)*

options:
    -q, --query-type[=<type>]    Treat object name as a query
    --                           Stop processing options

query type:
    f[irst]    Only invoke on the first matching name [default]
    a[ll]      Invoke on all matching names
[bin]$ ./twiddle.sh invoke jboss:service=JNDIView list true
<h1>java: Namespace</h1>
<pre>
  +- XAConnectionFactory (class: org.jboss.mq.SpyXAConnectionFactory)
  +- DefaultDS (class: javax.sql.DataSource)
  +- SecurityProxyFactory (class: org.jboss.security.SubjectSecurityProxyFactory)
  +- DefaultJMSProvider (class: org.jboss.jms.jndi.JNDIProviderAdapter)
  +- comp (class: javax.naming.Context)
  +- JmsXA (class: org.jboss.resource.adapter.jms.JmsConnectionFactoryImpl)
  +- ConnectionFactory (class: org.jboss.mq.SpyConnectionFactory)
  +- jaas (class: javax.naming.Context)
  |   +- JmsXARealm (class: org.jboss.security.plugins.SecurityDomainContext)
  |   +- jbossmq (class: org.jboss.security.plugins.SecurityDomainContext)
  |   +- HsqlDbRealm (class: org.jboss.security.plugins.SecurityDomainContext)
  +- timedCacheFactory (class: javax.naming.Context)
Failed to lookup: timedCacheFactory, errmsg=null
  +- TransactionPropagationContextExporter (class: org.jboss.tm.TransactionPropagationContext
Factory)
  +- StdJMSPool (class: org.jboss.jms.asf.StdServerSessionPoolFactory)
  +- Mail (class: javax.mail.Session)
  +- TransactionPropagationContextImporter (class: org.jboss.tm.TransactionPropagationContext
Importer)
  +- TransactionManager (class: org.jboss.tm.TxManager)
</pre>
<h1>Global JNDI Namespace</h1>
<pre>
  +- XAConnectionFactory (class: org.jboss.mq.SpyXAConnectionFactory)
  +- UIL2ConnectionFactory[link -> ConnectionFactory] (class: javax.naming.LinkRef)
  +- UserTransactionSessionFactory (proxy: $Proxy11 implements interface org.jboss.tm.usertx.
interfaces.UserTransactionSessionFactory)
  +- HTTPConnectionFactory (class: org.jboss.mq.SpyConnectionFactory)
  +- console (class: org.jnp.interfaces.NamingContext)
  |   +- PluginManager (proxy: $Proxy36 implements interface org.jboss.console.manager.Plugin
ManagerMBean)
  +- UIL2XAConnectionFactory[link -> XAConnectionFactory] (class: javax.naming.LinkRef)
  +- UUIDKeyGeneratorFactory (class: org.jboss.ejb.plugins.keygenerator.uuid.UUIDKeyGenerator
Factory)
  +- HTTPXAConnectionFactory (class: org.jboss.mq.SpyXAConnectionFactory)
  +- topic (class: org.jnp.interfaces.NamingContext)
  |   +- testDurableTopic (class: org.jboss.mq.SpyTopic)
  |   +- testTopic (class: org.jboss.mq.SpyTopic)
  |   +- securedTopic (class: org.jboss.mq.SpyTopic)
  +- queue (class: org.jnp.interfaces.NamingContext)
  |   +- A (class: org.jboss.mq.SpyQueue)
  |   +- testQueue (class: org.jboss.mq.SpyQueue)
  |   +- ex (class: org.jboss.mq.SpyQueue)
  |   +- DLQ (class: org.jboss.mq.SpyQueue)
  |   +- D (class: org.jboss.mq.SpyQueue)
  |   +- C (class: org.jboss.mq.SpyQueue)
  |   +- B (class: org.jboss.mq.SpyQueue)
  +- ConnectionFactory (class: org.jboss.mq.SpyConnectionFactory)
  +- UserTransaction (class: org.jboss.tm.usertx.client.ClientUserTransaction)
  +- jmx (class: org.jnp.interfaces.NamingContext)
  |   +- invoker (class: org.jnp.interfaces.NamingContext)
  |   |   +- RMIAdaptor (proxy: $Proxy35 implements interface org.jboss.jmx.adaptor.rmi.RMIAd
aptor,interface org.jboss.jmx.adaptor.rmi.RMIAdaptorExt)
  |   +- rmi (class: org.jnp.interfaces.NamingContext)
  |   |   +- RMIAdaptor[link -> jmx/invoker/RMIAdaptor] (class: javax.naming.LinkRef)
  +- HiLoKeyGeneratorFactory (class: org.jboss.ejb.plugins.keygenerator.hilo.HiLoKeyGenerator
Factory)
  +- UILXAConnectionFactory[link -> XAConnectionFactory] (class: javax.naming.LinkRef)
  +- UILConnectionFactory[link -> ConnectionFactory] (class: javax.naming.LinkRef)
</pre>
```

1.3.4. Connecting to JMX Using Any Protocol

With the detached invokers and a somewhat generalized proxy factory capability, you can really talk to the JMX server using the `InvokerAdaptorService` and a proxy factory service to expose an `RMIAdaptor` or similar interface over your protocol of choice. We will introduce the detached invoker notion along with proxy factories in Section 1.6. See Section 1.6.1 for an example of an invoker service that allows one to access the MBean server using to the `RMIAdaptor` interface over any protocol for which a proxy factory service exists.

1.4. Using JMX as a Microkernel

When JBoss starts up, one of the first steps performed is to create an MBean server instance (`javax.management.MBeanServer`). The JMX MBean server in the JBoss architecture plays the role of a microkernel. All other manageable MBean components are plugged into JBoss by registering with the MBean server. The kernel in that sense is only an framework, and not a source of actual functionality. The functionality is provided by MBeans, and in fact all major JBoss components are manageable MBeans interconnected through the MBean server.

1.4.1. The Startup Process

In this section we will describe the JBoss server startup process. A summary of the steps that occur during the JBoss server startup sequence is:

1. The run start script initiates the boot sequence using the `org.jboss.Main.main(String[])` method entry point.

2. The `Main.main` method creates a thread group named `jboss` and then starts a thread belonging to this thread group. This thread invokes the Main.boot method.

3. The `Main.boot` method processes the `Main.main` arguments and then creates an `org.jboss.system.server.ServerLoader` using the system properties along with any additional properties specified as arguments.

4. The XML parser libraries, `jboss-jmx.jar`, `concurrent.jar` and extra libraries and classpaths given as arguments are registered with the `ServerLoader` .

5. The JBoss server instance is created using the `ServerLoader.load(ClassLoader)` method with the current thread context class loader passed in as the `ClassLoader` argument. The returned server instance is an implementation of the `org.jboss.system.server.Server` interface. The creation of the server instance entails:

   - Creating a `java.net.URLClassLoader` with the URLs of the jars and directories registered with the `ServerLoader` . This `URLClassLoader` uses the `ClassLoader` passed in as its parent and it is pushed as the thread context class loader.

   - The class name of the implementation of the `Server` interface to use is determined by the `jboss.server.type` property. This defaults to `org.jboss.system.server.ServerImpl`.

   - The `Server` implementation class is loaded using the `URLClassLoader` created in step 6 and instantiated using its no-arg constructor. The thread context class loader present on entry into the `ServerLoader.load` method is restored and the server instance is returned.

6. The server instance is initialized with the properties passed to the `ServerLoader` constructor using the `Server.init(Properties)` method.

7. The server instance is then started using the `Server.start()` method. The default implementation performs the following steps:

   - Set the thread context class loader to the class loader used to load the `ServerImpl` class.
   - Create an `MBeanServer` under the `jboss` domain using the `MBeanServerFactory.createMBeanServer(String)` method.
   - Register the `ServerImpl` and `ServerConfigImpl` MBeans with the MBean server.
   - Initialize the unified class loader repository to contain all JARs in the optional patch directory as well as the server configuration file conf directory, for example, `server/default/conf`. For each JAR and directory an `org.jboss.mx.loading.UnifiedClassLoader` is created and registered with the unified repository. One of these `UnifiedClassLoader` is then set as the thread context class loader. This effectively makes all `UnifiedClassLoaders` available through the thread context class loader.
   - The `org.jboss.system.ServiceController` MBean is created. The `ServiceController` manages the JBoss MBean services life cycle. We will discuss the JBoss MBean services notion in detail in Section 1.4.2.
   - The `org.jboss.deployment.MainDeployer` is created and started. The `MainDeployer` manages deployment dependencies and directing deployments to the correct deployer.
   - The `org.jboss.deployment.JARDeployer` is created and started. The `JARDeployer` handles the deployment of JARs that are simple library JARs.
   - The `org.jboss.deployment.SARDeployer` is created and started. The SARDeployer handles the deployment of JBoss MBean services.
   - The `MainDeployer` is invoked to deploy the services defined in the `conf/jboss-service.xml` of the current server file set.
   - Restore the thread context class loader.

The JBoss server starts out as nothing more than a container for the JMX MBean server, and then loads its personality based on the services defined in the `jboss-service.xml` MBean configuration file from the named configuration set passed to the server on the command line. Because MBeans define the functionality of a JBoss server instance, it is important to understand how the core JBoss MBeans are written, and how you should integrate your existing services into JBoss using MBeans. This is the topic of the next section.

1.4.2. JBoss MBean Services

As we have seen, JBoss relies on JMX to load in the MBean services that make up a given server instance's personality. All of the bundled functionality provided with the standard JBoss distribution is based on MBeans. The best way to add services to the JBoss server is to write your own JMX MBeans.

There are two classes of MBeans: those that are independent of JBoss services, and those that are dependent on

JBoss services. MBeans that are independent of JBoss services are the trivial case. They can be written per the JMX specification and added to a JBoss server by adding an mbean tag to the `deploy/user-service.xml` file. Writing an MBean that relies on a JBoss service such as naming requires you to follow the JBoss service pattern. The JBoss MBean service pattern consists of a set of life cycle operations that provide state change notifications. The notifications inform an MBean service when it can create, start, stop, and destroy itself. The management of the MBean service life cycle is the responsibility of three JBoss MBeans: `SARDeployer`, `ServiceConfigurator` and `ServiceController`.

1.4.2.1. The SARDeployer MBean

JBoss manages the deployment of its MBean services via a custom MBean that loads an XML variation of the standard JMX MLet configuration file. This custom MBean is implemented in the `org.jboss.deployment.SARDeployer` class. The `SARDeployer` MBean is loaded when JBoss starts up as part of the bootstrap process. The SAR acronym stands for *service archive*.

The `SARDeployer` handles services archives. A service archive can be either a jar that ends with a `.sar` suffix and contains a `META-INF/jboss-service.xml` descriptor, or a standalone XML descriptor with a naming pattern that matches `*-service.xml`. The DTD for the service descriptor is `jboss-service_4.0.dtd` and is shown in Figure 1.15.

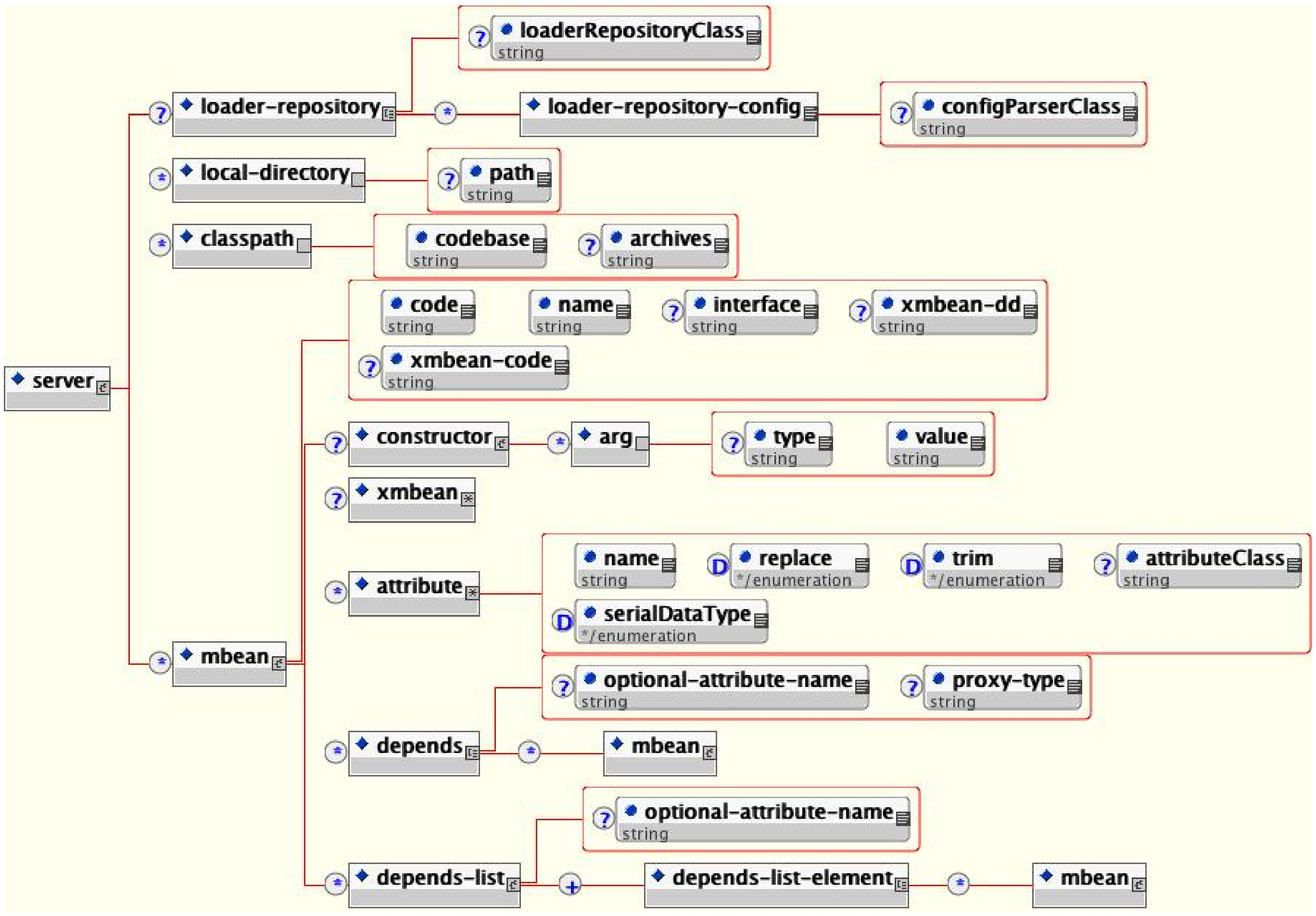


Figure 1.15. The DTD for the MBean service descriptor parsed by the SARDeployer

The elements of the DTD are:

- **loader-repository**: This element specifies the name of the `UnifiedLoaderRepository` MBean to use for the SAR to provide SAR level scoping of classes deployed in the sar. It is a unique JMX `ObjectName` string. It may also specify an arbitrary configuration by including a `loader-repository-config` element. The optional `loaderRepositoryClass` attribute specifies the fully qualified name of the loader repository implementation class. It defaults to `org.jboss.mx.loading.HeirachicalLoaderRepository3`.

  - **loader-repository-config**: This optional element specifies an arbitrary configuration that may be used to configure the `loadRepositoryClass`. The optional `configParserClass` attribute gives the fully qualified name of the `org.jboss.mx.loading.LoaderRepositoryFactory.LoaderRepositoryConfigParser` implementation to use to parse the `loader-repository-config` content.

- **local-directory**: This element specifies a path within the deployment archive that should be copied to the `server/<config>/db` directory for use by the MBean. The path attribute is the name of an entry within the deployment archive.

- **classpath**: This element specifies one or more external JARs that should be deployed with the MBean(s). The optional archives attribute specifies a comma separated list of the JAR names to load, or the `*` wild card to signify that all jars should be loaded. The wild card only works with file URLs, and http URLs if the web server supports the WEBDAV protocol. The codebase attribute specifies the URL from which the JARs specified in the archive attribute should be loaded. If the codebase is a path rather than a URL string, the full URL is built by treating the codebase value as a path relative to the JBoss distribution `server/<config>` directory. The order of JARs specified in the archives as well as the ordering across multiple classpath element is used as the classpath ordering of the JARs. Therefore, if you have patches or inconsistent versions of classes that require a certain ordering, use this feature to ensure the correct ordering.

- **mbean**: This element specifies an MBean service. The required code attribute gives the fully qualified name of the MBean implementation class. The required name attribute gives the JMX `ObjectName` of the MBean. The optional `xmbean-dd` attribute specifies the path to the XMBean resource if this MBean service uses the JBoss XMBean descriptor to define a Model MBean management interface.

  - **constructor**: The `constructor` element defines a non-default constructor to use when instantiating the MBean The `arg` element specify the constructor arguments in the order of the constructor signature. Each `arg` has a `type` and `value` attribute.

  - **attribute**: Each attribute element specifies a name/value pair of the attribute of the MBean. The name of the attribute is given by the name attribute, and the attribute element body gives the value. The body may be a text representation of the value, or an arbitrary element and child elements if the type of the MBean attribute is `org.w3c.dom.Element`. For text values, the text is converted to the attribute type using the JavaBean `java.beans.PropertyEditor` mechanism.

  - **server/mbean/depends** and **server/mbean/depends-list**: these elements specify a dependency from the MBean using the element to the MBean(s) named by the `depends` or `depends-list` elements. Section 1.4.2.4. Note that the dependency value can be another mbean element which defines a nested mbean.

MBean attribute values don't need to be hardcoded literal strings. Service files may contain references to system properties using the `${name}` notation, where `name` is the name of a Java system property. The value of this system property, as would be returned from the call `System.getProperty("name")`. Multiple properties can be specified separated by commas like `${name1,name2,name3}`. If there is no system property named `name1`, `name2` will be tried and then `name3`. This allows multiple levels of substitution to be used. Finally, a default value can be added using a colon separator. The substitution `${name:default value}` would substitute the the text "`default value`" if the system property `name` didn't exist. If none of the listed properties exist and no default value is given, no substitution will occur.

When the `SARDeployer` is asked to deploy a service performs several steps. Figure 1.16 is a sequence diagram that shows the init through start phases of a service.

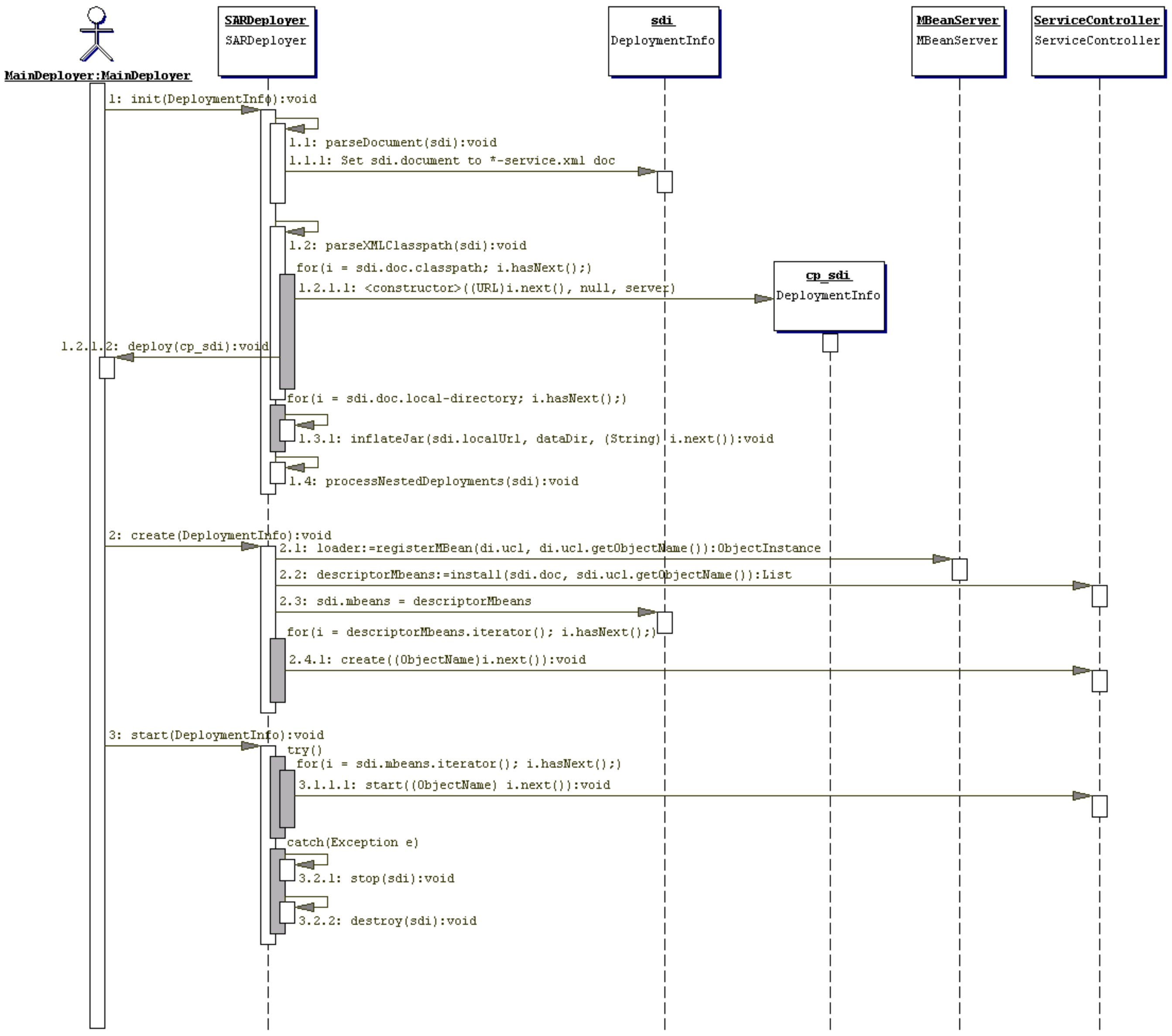

MainDeployer:MainDeployer
SARDeployer
SARDeployer
sdi
DeploymentInfo
MBeanServer
MBeanServer
ServiceController
ServiceController
1: init(DeploymentInfo):void
1.1: parseDocument(sdi):void
1.1.1: Set sdi.document to *-service.xml doc
1.2: parseXMLClasspath(sdi):void
for(i = sdi.doc.classpath; i.hasNext();)
1.2.1.1: <constructor>((URL)i.next(), null, server)
cp_sdi
DeploymentInfo
1.2.1.2: deploy(cp_sdi):void
for(i = sdi.doc.local-directory; i.hasNext();)
1.3.1: inflateJar(sdi.localUrl, dataDir, (String) i.next()):void
1.4: processNestedDeployments(sdi):void
2: create(DeploymentInfo):void
2.1: loader:=registerMBean(di.ucl, di.ucl.getObjectName()):ObjectInstance
2.2: descriptorMbeans:=install(sdi.doc, sdi.ucl.getObjectName()):List
2.3: sdi.mbeans = descriptorMbeans
for(i = descriptorMbeans.iterator(); i.hasNext();)
2.4.1: create((ObjectName)i.next()):void
3: start(DeploymentInfo):void
try()
for(i = sdi.mbeans.iterator(); i.hasNext();)
3.1.1.1: start((ObjectName) i.next()):void
catch(Exception e)
3.2.1: stop(sdi):void
3.2.2: destroy(sdi):void

Figure 1.16. A sequence diagram highlighting the main activities performed by the SARDeployer to start a JBoss MBean service

In Figure 1.16 the following is illustrated:

- Methods prefixed with 1.1 correspond to the load and parse of the XML service descriptor.

- Methods prefixed with 1.2 correspond to processing each classpath element in the service descriptor to create an independent deployment that makes the jar or directory available through a `UnifiedClassLoader` registered with the unified loader repository.
- Methods prefixed with 1.3 correspond to processing each `local-directory` element in the service descriptor. This does a copy of the SAR elements specified in the path attribute to the `server/<config>/db` directory.
- Method 1.4. Process each deployable unit nested in the service a child deployment is created and added to the service deployment info subdeployment list.
- Method 2.1. The `UnifiedClassLoader` of the SAR deployment unit is registered with the MBean Server so that is can be used for loading of the SAR MBeans.
- Method 2.2. For each MBean element in the descriptor, create an instance and initialize its attributes with the values given in the service descriptor. This is done by calling the `ServiceController.install` method.
- Method 2.4.1. For each MBean instance created, obtain its JMX `ObjectName` and ask the ServiceController to handle the create step of the service life cycle. The `ServiceController` handles the dependencies of the MBean service. Only if the service's dependencies are satisfied is the service create method invoked.
- Methods prefixed with 3.1 correspond to the start of each MBean service defined in the service descriptor. For each MBean instance created, obtain its JMX ObjectName and ask the `ServiceController` to handle the start step of the service life cycle. The `ServiceController` handles the dependencies of the MBean service. Only if the service's dependencies are satisfied is the service start method invoked.

1.4.2.2. The Service Life Cycle Interface

The JMX specification does not define any type of life cycle or dependency management for MBeans. The JBoss ServiceController MBean introduces this notion. A JBoss MBean is an extension of the JMX MBean in that an MBean is expected to decouple creation from the life cycle of its service duties. This is necessary to implement any type of dependency management. For example, if you are writing an MBean that needs a JNDI naming service to be able to function, your MBean needs to be told when its dependencies are satisfied. This ranges from difficult to impossible to do if the only life cycle event is the MBean constructor. Therefore, JBoss introduces a service life cycle interface that describes the events a service can use to manage its behavior. The following listing shows the `org.jboss.system.Service` interface:

```
package org.jboss.system;
public interface Service
{
    public void create() throws Exception;
    public void start() throws Exception;
    public void stop();
    public void destroy();
}
```

The `ServiceController` MBean invokes the methods of the `Service` interface at the appropriate times of the service life cycle. We'll discuss the methods in more detail in the `ServiceController` section.

1.4.2.3. The ServiceController MBean

JBoss manages dependencies between MBeans via the `org.jboss.system.ServiceController` custom MBean. The SARDeployer delegates to the ServiceController when initializing, creating, starting, stopping and destroying

MBean services. Figure 1.17 shows a sequence diagram that highlights interaction between the `SARDeployer` and `ServiceController`.

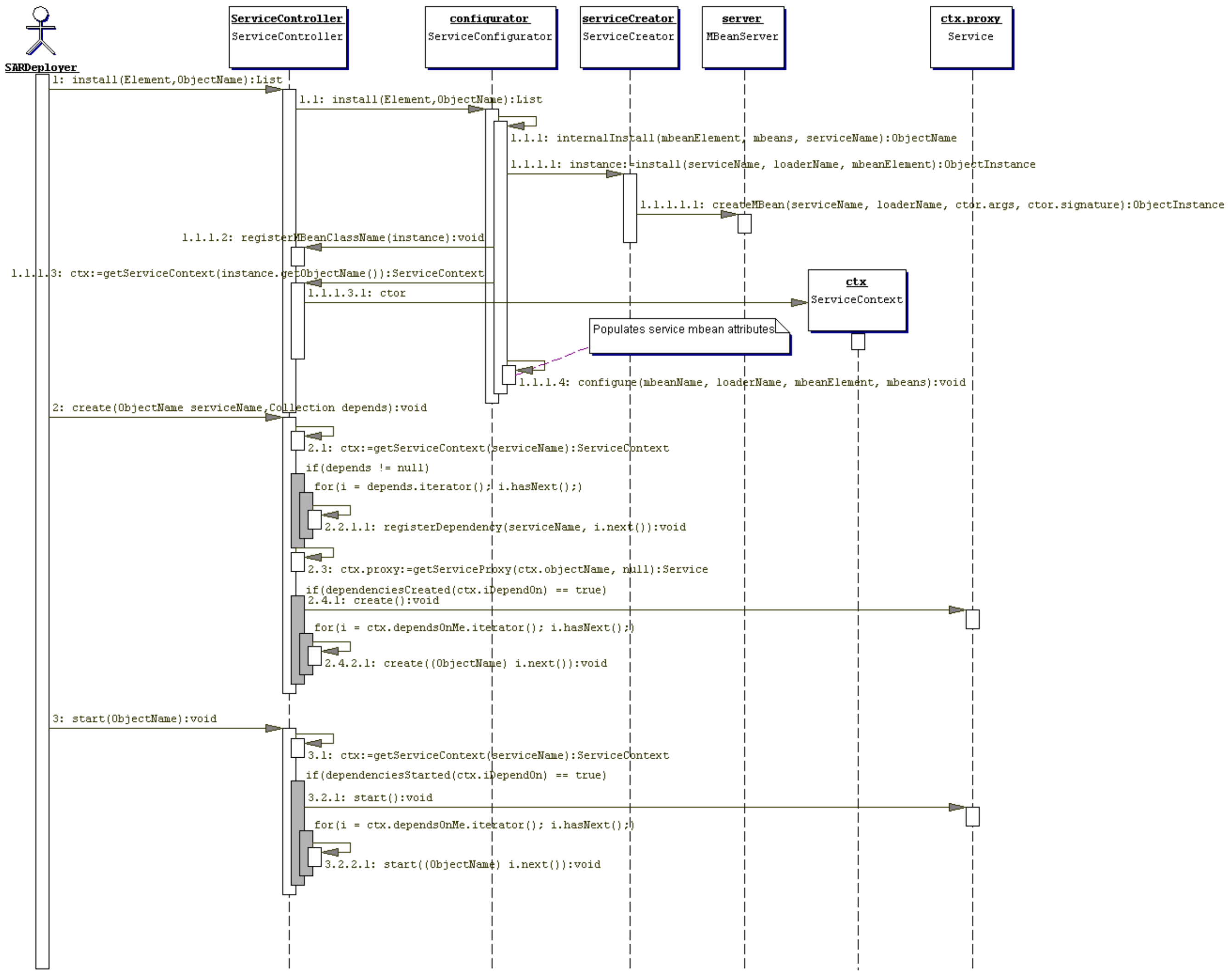

SARDeployer
ServiceController
ServiceController
configurator
ServiceConfigurator
serviceCreator
ServiceCreator
server
MBeanServer
ctx.proxy
Service
1: install(Element,ObjectName):List
1.1: install(Element,ObjectName):List
1.1.1: internalInstall(mbeanElement, mbeans, serviceName):ObjectName
1.1.1.1: instance:=install(serviceName, loaderName, mbeanElement):ObjectInstance
1.1.1.1.1: createMBean(serviceName, loaderName, ctor.args, ctor.signature):ObjectInstance
1.1.1.2: registerMBeanClassName(instance):void
1.1.1.3: ctx:=getServiceContext(instance.getObjectName()):ServiceContext
1.1.1.3.1: ctor
ctx
ServiceContext
Populates service mbean attributes
1.1.1.4: configure(mbeanName, loaderName, mbeanElement, mbeans):void
2: create(ObjectName serviceName,Collection depends):void
2.1: ctx:=getServiceContext(serviceName):ServiceContext
if(depends != null)
for(i = depends.iterator(); i.hasNext();)
2.2.1.1: registerDependency(serviceName, i.next()):void
2.3: ctx.proxy:=getServiceProxy(ctx.objectName, null):Service
if(dependenciesCreated(ctx.iDependOn) == true)
2.4.1: create():void
for(i = ctx.dependsOnMe.iterator(); i.hasNext();)
2.4.2.1: create((ObjectName) i.next()):void
3: start(ObjectName):void
3.1: ctx:=getServiceContext(serviceName):ServiceContext
if(dependenciesStarted(ctx.iDependOn) == true)
3.2.1: start():void
for(i = ctx.dependsOnMe.iterator(); i.hasNext();)
3.2.2.1: start((ObjectName) i.next()):void

Figure 1.17. The interaction between the SARDeployer and ServiceController to start a service

The `ServiceController` MBean has four key methods for the management of the service life cycle: `create`, `start`, `stop` and `destroy`.

1.4.2.3.1. The create(ObjectName) method

The `create(ObjectName)` method is called whenever an event occurs that affects the named services state. This could be triggered by an explicit invocation by the `SARDeployer`, a notification of a new class, or another service reaching its created state.

When a service's `create` method is called, all services on which the service depends have also had their create method invoked. This gives an MBean an opportunity to check that required MBeans or resources exist. A service cannot utilize other MBean services at this point, as most JBoss MBean services do not become fully functional until they have been started via their `start` method. Because of this, service implementations often do not implement `create` in favor of just the `start` method because that is the first point at which the service can be fully functional.

1.4.2.3.2. The start(ObjectName) method

The `start(ObjectName)` method is called whenever an event occurs that affects the named services state. This could be triggered by an explicit invocation by the `SARDeployer`, a notification of a new class, or another service reaching its started state.

When a service's `start` method is called, all services on which the service depends have also had their `start` method invoked. Receipt of a `start` method invocation signals a service to become fully operational since all services upon which the service depends have been created and started.

1.4.2.3.3. The stop(ObjectName) method

The `stop(ObjectName)` method is called whenever an event occurs that affects the named services state. This could be triggered by an explicit invocation by the `SARDeployer`, notification of a class removal, or a service on which other services depend reaching its stopped state.

1.4.2.3.4. The destroy(ObjectName) method

The `destroy(ObjectName)` method is called whenever an event occurs that affects the named services state. This could be triggered by an explicit invocation by the `SARDeployer`, notification of a class removal, or a service on which other services depend reaching its destroyed state.

Service implementations often do not implement `destroy` in favor of simply implementing the `stop` method, or neither `stop` nor `destroy` if the service has no state or resources that need cleanup.

1.4.2.4. Specifying Service Dependencies

To specify that an MBean service depends on other MBean services you need to declare the dependencies in the mbean element of the service descriptor. This is done using the `depends` and `depends-list` elements. One difference between the two elements relates to the `optional-attribute-name` attribute usage. If you track the `ObjectNames` of dependencies using single valued attributes you should use the depends element. If you track the `ObjectNames` of dependencies using `java.util.List` compatible attributes you would use the `depends-list` element. If you only want to specify a dependency and don't care to have the associated service `ObjectName` bound to an attribute of your MBean then use whatever element is easiest. The following listing shows example service descriptor fragments that illustrate the usage of the dependency related elements.

```
<mbean code="org.jboss.mq.server.jmx.Topic"
       name="jms.topic:service=Topic,name=testTopic">
    <!-- Declare a dependency on the "jboss.mq:service=DestinationManager" and
         bind this name to the DestinationManager attribute -->
    <depends optional-attribute-name="DestinationManager">
        jboss.mq:service=DestinationManager
    </depends>

    <!-- Declare a dependency on the "jboss.mq:service=SecurityManager" and
         bind this name to the SecurityManager attribute -->
    <depends optional-attribute-name="SecurityManager">
        jboss.mq:service=SecurityManager
    </depends>

    <!-- ... -->

    <!-- Declare a dependency on the
         "jboss.mq:service=CacheManager" without
         any binding of the name to an attribute-->
    <depends>jboss.mq:service=CacheManager</depends>
</mbean>

<mbean code="org.jboss.mq.server.jmx.TopicMgr"
       name="jboss.mq.destination:service=TopicMgr">
    <!-- Declare a dependency on the given topic destination mbeans and
         bind these names to the Topics attribute -->
    <depends-list optional-attribute-name="Topics">
        <depends-list-element>jms.topic:service=Topic,name=A</depends-list-element>
        <depends-list-element>jms.topic:service=Topic,name=B</depends-list-element>
        <depends-list-element>jms.topic:service=Topic,name=C</depends-list-element>
    </depends-list>
</mbean>
```

Another difference between the `depends` and `depends-list` elements is that the value of the depends element may be a complete MBean service configuration rather than just the `ObjectName` of the service. Example 1.13 shows an example from the `hsqldb-service.xml` descriptor. In this listing the `org.jboss.resource.connectionmanager.RARDeployment` service configuration is defined using a nested `mbean` element as the `depends` element value. This indicates that the `org.jboss.resource.connectionmanager.LocalTxConnectionManager` MBean depends on this service. The `jboss.jca:service=LocalTxDS,name=hsqldbDS ObjectName` will be bound to the `ManagedConnectionFactory-Name` attribute of the `LocalTxConnectionManager` class.

Example 1.13. An example of using the depends element to specify the complete configuration of a depended on service.

```
<mbean code="org.jboss.resource.connectionmanager.LocalTxConnectionManager"
       name="jboss.jca:service=LocalTxCM,name=hsqldbDS">
    <depends optional-attribute-name="ManagedConnectionFactoryName">
        <!--embedded mbean-->
        <mbean code="org.jboss.resource.connectionmanager.RARDeployment"
               name="jboss.jca:service=LocalTxDS,name=hsqldbDS">
            <attribute name="JndiName">DefaultDS</attribute>
            <attribute name="ManagedConnectionFactoryProperties">
                <properties>
                    <config-property name="ConnectionURL"
                                     type="java.lang.String">
                        jdbc:hsqldb:hsql://localhost:1476
                    </config-property>
                    <config-property name="DriverClass" type="java.lang.String">
                        org.hsqldb.jdbcDriver
                    </config-property>
                    <config-property name="UserName" type="java.lang.String">
                        sa
                    </config-property>
                    <config-property name="Password" type="java.lang.String"/>
                </properties>
            </attribute>
            <!-- ... -->
        </mbean>
    </depends>
    <!-- ... -->
</mbean>
```

1.4.2.5. Identifying Unsatisfied Dependencies

The `ServiceController` MBean supports two operations that can help determine which MBeans are not running due to unsatisfied dependencies. The first operation is `listIncompletelyDeployed`. This returns a `java.util.List` of `org.jboss.system.ServiceContext` objects for the MBean services that are not in the `RUNNING` state.

The second operation is `listWaitingMBeans`. This operation returns a `java.util.List` of the JMX `ObjectNames` of MBean services that cannot be deployed because the class specified by the code attribute is not available.

1.4.2.6. Hot Deployment of Components, the URLDeploymentScanner

The `URLDeploymentScanner` MBean service provides the JBoss hot deployment capability. This service watches one or more URLs for deployable archives and deploys the archives as they appear or change. It also undeploys previously deployed applications if the archive from which the application was deployed is removed. The configurable attributes include:

- **URLs**: A comma separated list of URL strings for the locations that should be watched for changes. Strings that do not correspond to valid URLs are treated as file paths. Relative file paths are resolved against the server home URL, for example, `JBOSS_DIST/server/default` for the default config file set. If a URL represents a file then the file is deployed and watched for subsequent updates or removal. If a URL ends in `/` to represent a directory, then the contents of the directory are treated as a collection of deployables and scanned for content that are to be watched for updates or removal. The requirement that a URL end in a `/` to identify a directory follows the RFC2518 convention and allows discrimination between collections and directories that are simply unpacked archives.

  The default value for the URLs attribute is `deploy/` which means that any SARs, EARs, JARs, WARs, RARs, etc. dropped into the `server/<name>/deploy` directory will be automatically deployed and watched for updates.

  Example URLs include:

  - **deploy/** scans `${jboss.server.url}/deploy/`, which is local or remote depending on the URL used to boot the server
  - **${jboss.server.home.dir}/deploy/** scans *${jboss.server.home.dir)/deploy*, which is always local
  - **file:/var/opt/myapp.ear** deploys `myapp.ear` from a local location
  - **file:/var/opt/apps/** scans the specified directory
  - **http://www.test.com/netboot/myapp.ear** deploys `myapp.ear` from a remote location
  - **http://www.test.com/netboot/apps/** scans the specified remote location using WebDAV. This will only work if the remote http server supports the WebDAV PROPFIND command.

- **ScanPeriod**: The time in milliseconds between runs of the scanner thread. The default is 5000 (5 seconds).

- **URLComparator**: The class name of a `java.util.Comparator` implementation used to specify a deployment ordering for deployments found in a scanned directory. The implementation must be able to compare two `java.net.URL` objects passed to its compare method. The default setting is the `org.jboss.deployment.DeploymentSorter` class which orders based on the deployment URL suffix. The ordering of suffixes is: `deployer`, `deployer.xml`, `sar`, `rar`, `ds.xml`, `service.xml`, `har`, `jar`, `war`, `wsr`, `ear`, `zip`, `bsh`, `last`.

  An alternate implementation is the `org.jboss.deployment.scanner.PrefixDeploymentSorter` class. This orders the URLs based on numeric prefixes. The prefix digits are converted to an int (ignoring leading zeroes), smaller prefixes are ordered ahead of larger numbers. Deployments that do not start with any digits will be deployed after all numbered deployments. Deployments with the same prefix value are further sorted by the `DeploymentSorter` logic.

- **Filter**: The class name of a `java.io.FileFilter` implementation that is used to filter the contents of scanned directories. Any file not accepted by this filter will not be deployed. The default is `org.jboss.deployment.scanner.DeploymentFilter` which is an implementation that rejects the following patterns:

  `"#*"`, `"%*"`, `",*"`, `".*"`, `"_$*"`, `"*#"`, `"*$"`, `"*%"`, `"*.BAK"`, `"*.old"`, `"*.orig"`, `"*.rej"`, `"*.bak"`, `"*.sh"`, `"*,v"`, `"*~"`, `".make.state"`, `".nse_depinfo"`, `"CVS"`, `"CVS.admin"`, `"RCS"`, `"RCSLOG"`, `"SCCS"`, `"TAGS"`, `"core"`, `"tags"`

- **RecursiveSearch**: This property indicates whether or not deploy subdirectories are seen to be holding deployable content. If this is false, deploy subdirectories that do not contain a dot (`.`) in their name are seen to be unpackaged JARs with nested subdeployments. If true, then deploy subdirectories are just groupings of deployable content. The difference between the two views shows is related to the depth first deployment model JBoss supports. The false setting which treats directories as unpackaged JARs with nested content triggers the deployment of the nested content as soon as the JAR directory is deployed. The true setting simply ignores the directory and adds its content to the list of deployable packages and calculates the order based on the previous filter logic. The default is true.

- **Deployer**: The JMX `ObjectName` string of the MBean that implements the `org.jboss.deployment.Deployer` interface operations. The default setting is to use the `MainDeployer` created by the bootstrap startup process.

1.4.3. Writing JBoss MBean Services

Writing a custom MBean service that integrates into the JBoss server requires the use of the `org.jboss.system.Service` interface pattern if the custom service is dependent on other services. When a custom MBean depends on other MBean services you cannot perform any service dependent initialization in any of the `javax.management.MBeanRegistration` interface methods since JMX has no dependency notion. Instead, you must manage dependency state using the `Service` interface `create` and/or `start` methods. You can do this using any one of the following approaches:

- Add any of the `Service` methods that you want called on your MBean to your MBean interface. This allows your MBean implementation to avoid dependencies on JBoss specific interfaces.

- Have your MBean interface extend the `org.jboss.system.Service` interface.

- Have your MBean interface extend the `org.jboss.system.ServiceMBean` interface. This is a subinterface of `org.jboss.system.Service` that adds `getName()`, `getState()`, `getStateString()` methods.

Which approach you choose depends on whether or not you want your code to be coupled to JBoss specific code. If you don't, then you would use the first approach. If you don't care about dependencies on JBoss classes, the simplest approach is to have your MBean interface extend from `org.jboss.system.ServiceMBean` and your MBean implementation class extend from the abstract `org.jboss.system.ServiceMBeanSupport` class. This class implements the `org.jboss.system.ServiceMBean` interface. `ServiceMBeanSupport` provides implementations of the `create`, `start`, `stop`, and `destroy` methods that integrate logging and JBoss service state management tracking. Each method delegates any subclass specific work to `createService`, `startService`, `stopService`, and `des-`

troyService methods respectively. When subclassing ServiceMBeanSupport, you would override one or more of the createService, startService, stopService, and destroyService methods as required

1.4.3.1. A Standard MBean Example

This section develops a simple MBean that binds a HashMap into the JBoss JNDI namespace at a location determined by its JndiName attribute to demonstrate what is required to create a custom MBean. Because the MBean uses JNDI, it depends on the JBoss naming service MBean and must use the JBoss MBean service pattern to be notified when the naming service is available.

Version one of the classes, shown in Example 1.14, is based on the service interface method pattern. This version of the interface declares the start and stop methods needed to start up correctly without using any JBoss-specific classes.

Example 1.14. JNDIMapMBean interface and implementation based on the service interface method pattern

```
package org.jboss.book.jmx.ex1;

// The JNDIMap MBean interface
import javax.naming.NamingException;

public interface JNDIMapMBean
{
    public String getJndiName();
    public void setJndiName(String jndiName) throws NamingException;
    public void start() throws Exception;
    public void stop() throws Exception;
}
```

```
package org.jboss.book.jmx.ex1;

// The JNDIMap MBean implementation
import java.util.HashMap;
import javax.naming.InitialContext;
import javax.naming.Name;
import javax.naming.NamingException;
import org.jboss.naming.NonSerializableFactory;

public class JNDIMap implements JNDIMapMBean
{
    private String jndiName;
    private HashMap contextMap = new HashMap();
    private boolean started;

    public String getJndiName()
    {
        return jndiName;
    }
    public void setJndiName(String jndiName) throws NamingException
    {
        String oldName = this.jndiName;
        this.jndiName = jndiName;
        if (started) {
            unbind(oldName);
            try {
                rebind();
            } catch(Exception e) {
                NamingException ne = new NamingException("Failedto update jndiName");
                ne.setRootCause(e);
                throw ne;
            }
        }
    }

    public void start() throws Exception
    {
        started = true;
        rebind();
    }

    public void stop()
    {
        started = false;
        unbind(jndiName);
    }

    private void rebind() throws NamingException
    {
        InitialContext rootCtx = new InitialContext();
        Name fullName = rootCtx.getNameParser("").parse(jndiName);
        System.out.println("fullName="+fullName);
        NonSerializableFactory.rebind(fullName, contextMap, true);
    }

    private void unbind(String jndiName)
    {
        try {
            InitialContext rootCtx = new InitialContext();
            rootCtx.unbind(jndiName);
            NonSerializableFactory.unbind(jndiName);
        } catch(NamingException e) {
            e.printStackTrace();
        }
    }
}
```

Version two of the classes, shown in Example 1.14, use the JBoss `ServiceMBean` interface and `ServiceMBeanSupport` class. In this version, the implementation class extends the `ServiceMBeanSupport` class and overrides the `startService` and `stopService` methods. `JNDIMapMBean` also implements the abstract `getName` method to return a descriptive name for the MBean. The `JNDIMapMBean` interface extends the `org.jboss.system.ServiceMBean` interface and only declares the setter and getter methods for the `JndiName` attribute because it inherits the service life cycle methods from `ServiceMBean`. This is the third approach mentioned at the start of the Section 1.4.2.

Example 1.15. JNDIMap MBean interface and implementation based on the ServiceMBean interface and ServiceMBeanSupport class

```
package org.jboss.book.jmx.ex2;

// The JNDIMap MBean interface
import javax.naming.NamingException;

public interface JNDIMapMBean extends org.jboss.system.ServiceMBean
{
    public String getJndiName();
    public void setJndiName(String jndiName) throws NamingException;
}
```

```
package org.jboss.book.jmx.ex2;
// The JNDIMap MBean implementation
```

```
import java.util.HashMap;
import javax.naming.InitialContext;
import javax.naming.Name;
import javax.naming.NamingException;
import org.jboss.naming.NonSerializableFactory;

public class JNDIMap extends org.jboss.system.ServiceMBeanSupport
    implements JNDIMapMBean
{
    private String jndiName;
    private HashMap contextMap = new HashMap();

    public String getJndiName()
    {
        return jndiName;
    }

    public void setJndiName(String jndiName)
        throws NamingException
    {
        String oldName = this.jndiName;
        this.jndiName = jndiName;
        if (super.getState() == STARTED) {
            unbind(oldName);
            try {
                rebind();
            } catch(Exception e) {
                NamingException ne = new NamingException("Failed to update jndiName");
                ne.setRootCause(e);
                throw ne;
            }
        }
    }

    public void startService() throws Exception
    {
        rebind();
    }

    public void stopService()
    {
        unbind(jndiName);
    }

    private void rebind() throws NamingException
    {
        InitialContext rootCtx = new InitialContext();
        Name fullName = rootCtx.getNameParser("").parse(jndiName);
        log.info("fullName="+fullName);
        NonSerializableFactory.rebind(fullName, contextMap, true);
    }

    private void unbind(String jndiName)
    {
        try {
            InitialContext rootCtx = new InitialContext();
            rootCtx.unbind(jndiName);
            NonSerializableFactory.unbind(jndiName);
        } catch(NamingException e) {
            log.error("Failed to unbind map", e);
        }
    }
}
```

The source code for these MBeans along with the service descriptors is located in the `examples/src/main/org/jboss/book/jmx/{ex1,ex2}` directories.

The jboss-service.xml descriptor for the first version is shown below.

```
<!-- The SAR META-INF/jboss-service.xml descriptor -->
<server>
    <mbean code="org.jboss.book.jmx.ex1.JNDIMap"
           name="chap2.ex1:service=JNDIMap">
        <attribute name="JndiName">inmemory/maps/MapTest</attribute>
        <depends>jboss:service=Naming</depends>
    </mbean>
</server>
```

The JNDIMap MBean binds a `HashMap` object under the `inmemory/maps/MapTest` JNDI name and the client code fragment demonstrates retrieving the HashMap object from the `inmemory/maps/MapTest` location. The corresponding client code is shown below.

```
// Sample lookup code
InitialContext ctx = new InitialContext();
HashMap map = (HashMap) ctx.lookup("inmemory/maps/MapTest");
```

1.4.3.2. XMBean Examples

In this section we will develop a variation of the `JNDIMap` MBean introduced in the preceding section that exposes its management metadata using the JBoss XMBean framework. Our core managed component will be exactly the same core code from the `JNDIMap` class, but it will not implement any specific management related interface. We will illustrate the following capabilities not possible with a standard MBean:

- The ability to add rich descriptions to attribute and operations
- The ability to expose notification information
- The ability to add persistence of attributes
- The ability to add custom interceptors for security and remote access through a typed interface

1.4.3.2.1. Version 1, The Annotated JNDIMap XMBean

Let's start with a simple XMBean variation of the standard MBean version of the JNDIMap that adds the descriptive information about the attributes and operations and their arguments. The following listing shows the `jboss-service.xml` descriptor and the `jndimap-xmbean1.xml` XMBean descriptor. The source can be found in the `src/main/org/jboss/book/jmx/xmbean` directory of the book examples.

```
<?xml version='1.0' encoding='UTF-8' ?>
<!DOCTYPE server PUBLIC
                     "-//JBoss//DTD MBean Service 3.2//EN"
                     "http://www.jboss.org/j2ee/dtd/jboss-service_3_2.dtd">
<server>
    <mbean code="org.jboss.book.jmx.xmbean.JNDIMap"
           name="chap2.xmbean:service=JNDIMap"
           xmbean-dd="META-INF/jndimap-xmbean.xml">
        <attribute name="JndiName">inmemory/maps/MapTest</attribute>
        <depends>jboss:service=Naming</depends>
    </mbean>
```

```
</server>
```

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE mbean PUBLIC
          "-//JBoss//DTD JBOSS XMBEAN 1.0//EN"
          "http://www.jboss.org/j2ee/dtd/jboss_xmbean_1_0.dtd">
<mbean>
    <description>The JNDIMap XMBean Example Version 1</description>
    <descriptors>
        <persistence persistPolicy="Never" persistPeriod="10"
            persistLocation="data/JNDIMap.data" persistName="JNDIMap"/>
        <currencyTimeLimit value="10"/>
        <state-action-on-update value="keep-running"/>
    </descriptors>
    <class>org.jboss.test.jmx.xmbean.JNDIMap</class>
    <constructor>
        <description>The default constructor</description>
        <name>JNDIMap</name>
    </constructor>
    <!-- Attributes -->
    <attribute access="read-write" getMethod="getJndiName" setMethod="setJndiName">
        <description>
            The location in JNDI where the Map we manage will be bound
        </description>
        <name>JndiName</name>
        <type>java.lang.String</type>
        <descriptors>
            <default value="inmemory/maps/MapTest"/>
        </descriptors>
    </attribute>
    <attribute access="read-write" getMethod="getInitialValues"
               setMethod="setInitialValues">
        <description>The array of initial values that will be placed into the
            map associated with the service. The array is a collection of
            key,value pairs with elements[0,2,4,...2n] being the keys and
            elements [1,3,5,...,2n+1] the associated values. The
            "[Ljava.lang.String;" type signature is the VM representation of the
            java.lang.String[] type. </description>
        <name>InitialValues</name>
        <type>[Ljava.lang.String;</type>
        <descriptors>
            <default value="key0,value0"/>
        </descriptors>
    </attribute>
    <!-- Operations -->
    <operation>
        <description>The start lifecycle operation</description>
        <name>start</name>
    </operation>
    <operation>
        <description>The stop lifecycle operation</description>
        <name>stop</name>
    </operation>
    <operation impact="ACTION">
        <description>Put a value into the map</description>
        <name>put</name>
        <parameter>
            <description>The key the value will be store under</description>
            <name>key</name>
            <type>java.lang.Object</type>
        </parameter>
        <parameter>
            <description>The value to place into the map</description>
            <name>value</name>
            <type>java.lang.Object</type>
        </parameter>
    </operation>
    <operation impact="INFO">
        <description>Get a value from the map</description>
        <name>get</name>
        <parameter>
            <description>The key to lookup in the map</description>
            <name>get</name>
            <type>java.lang.Object</type>
        </parameter>
        <return-type>java.lang.Object</return-type>
    </operation>
    <!-- Notifications -->
    <notification>
        <description>The notification sent whenever a value is get into the map
            managed by the service</description>
        <name>javax.management.Notification</name>
        <notification-type>org.jboss.book.jmx.xmbean.JNDIMap.get</notification-type>
    </notification>
    <notification>
        <description>The notification sent whenever a value is put into the map
            managed by the service</description>
        <name>javax.management.Notification</name>
        <notification-type>org.jboss.book.jmx.xmbean.JNDIMap.put</notification-type>
    </notification>
</mbean>
```

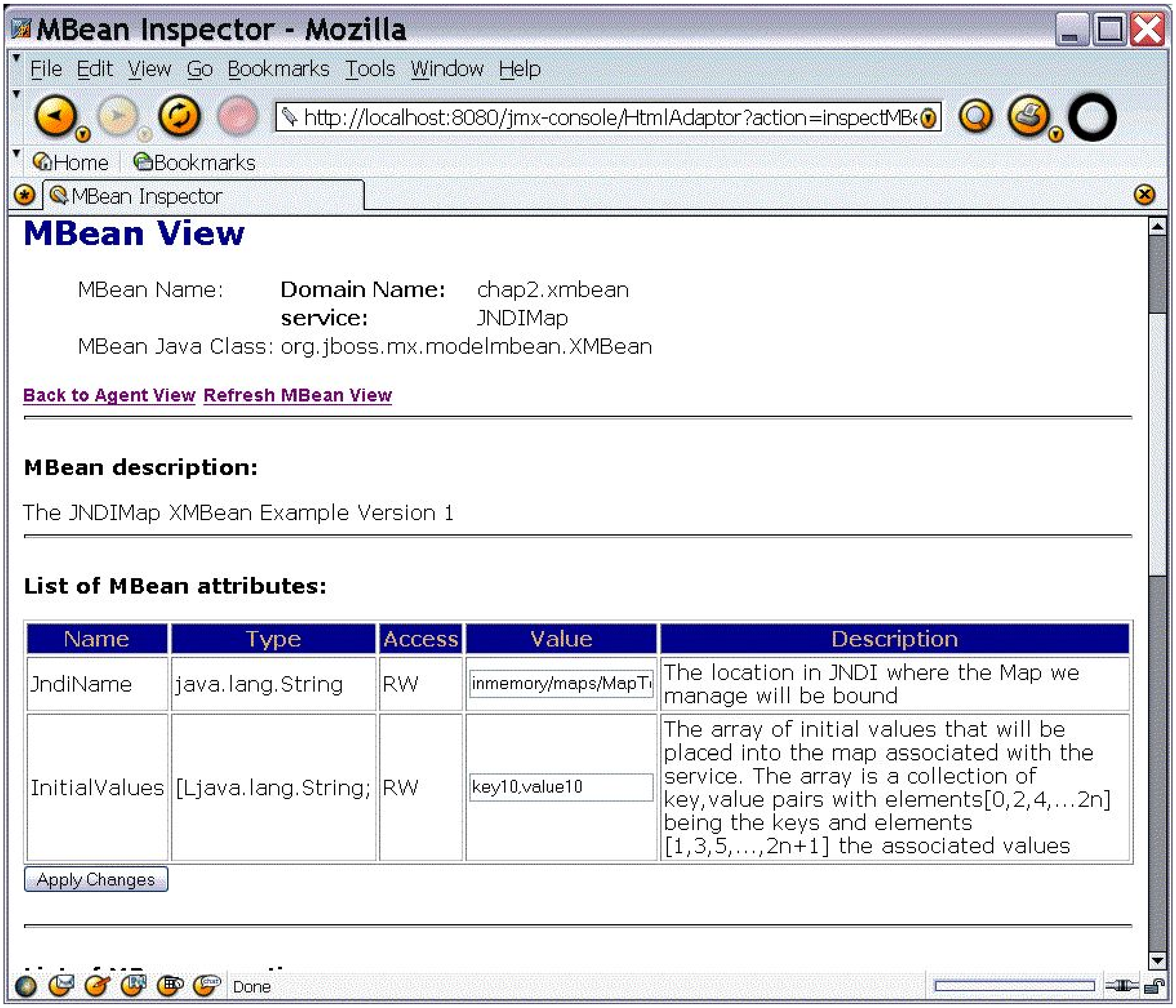
You can build, deploy and test the XMBean as follows:

```
[examples]$ ant -Dchap=jmx -Dex=xmbean1 run-example
...
run-examplexmbean1:
     [java] JNDIMap Class: org.jboss.mx.modelmbean.XMBean
     [java] JNDIMap Operations:
     [java]  + void start()
     [java]  + void stop()
     [java]  + void put(java.lang.Object chap2.xmbean:service=JNDIMap,java.lang.Object
                        chap2.xmbean:service=JNDIMap)
     [java]  + java.lang.Object get(java.lang.Object chap2.xmbean:service=JNDIMap)
     [java] name=chap2.xmbean:service=JNDIMap
     [java] listener=org.jboss.book.jmx.xmbean.TestXMBean1$Listener@f38cf0
     [java] key=key0, value=value0
     [java] handleNotification, event: javax.management.Notification[source=chap2.xmbean:
            service=JNDIMap][type=org.jboss.book.jmx.xmbean.JNDIMap.put][message=]
     [java] JNDIMap.put(key1, value1) successful
     [java] handleNotification, event: javax.management.Notification[source=chap2.xmbean:
            service=JNDIMap][type=org.jboss.book.jmx.xmbean.JNDIMap.get][message=]
     [java] JNDIMap.get(key0): null
     [java] handleNotification, event: javax.management.Notification[source=chap2.xmbean:
            service=JNDIMap][type=org.jboss.book.jmx.xmbean.JNDIMap.get][message=]
     [java] JNDIMap.get(key1): value1
     [java] handleNotification, event: javax.management.Notification[source=chap2.xmbean:
            service=JNDIMap][type=org.jboss.book.jmx.xmbean.JNDIMap.put][message=]
     [java] handleNotification, event: javax.management.AttributeChangeNotification[source
            =chap2.xmbean:service=JNDIMap][type=jmx.attribute.change][message=InitialValues
            changed from javax.management.Attribute@82a72a to
            javax.management.Attribute@acdb96]
```

The functionality is largely the same as the Standard MBean with the notable exception of the JMX notifications. A Standard MBean has no way of declaring that it will emit notifications. An XMBean may declare the notifications it emits using notification elements as is shown in the version 1 descriptor. We see the notifications from the get and put operations on the test client console output. Note that there is also an `jmx.attribute.change notifica-`

tion emitted when the `InitialValues` attribute was changed. This is because the `ModelMBean` interface extends the `ModelMBeanNotificationBroadcaster` which supports `AttributeChangeNotificationListeners`.

The other major difference between the Standard and XMBean versions of JNDIMap is the descriptive metadata. Look at the `chap2.xmbean:service=JNDIMap` in the JMX Console, and you will see the attributes section as shown in Figure 1.18.


MBean Inspector - Mozilla
File Edit View Go Bookmarks Tools Window Help
http://localhost:8080/jmx-console/HtmlAdaptor?action=inspectMBe
Home
Bookmarks
MBean Inspector
Back to Agent View
Refresh MBean View
Apply Changes
Done

MBean View

MBean Name: Domain Name: chap2.xmbean
service: JNDIMap
MBean Java Class: org.jboss.mx.modelmbean.XMBean

MBean description:

The JNDIMap XMBean Example Version 1

List of MBean attributes:

Name	Type	Access	Value	Description
JndiName	java.lang.String	RW	inmemory/maps/MapT	The location in JNDI where the Map we manage will be bound
InitialValues	[Ljava.lang.String;	RW	key10,value10	The array of initial values that will be placed into the map associated with the service. The array is a collection of key,value pairs with elements[0,2,4,...2n] being the keys and elements [1,3,5,...,2n+1] the associated values

Figure 1.18. The Version 1 JNDIMapXMBean jmx-console view

Notice that the JMX Console now displays the full attribute description as specified in the XMBean descriptor rather than `MBean Attribute` text seen in standard MBean implementations. Scroll down to the operations and you will also see that these now also have nice descriptions of their function and parameters.

1.4.3.2.2. Version 2, Adding Persistence to the JNDIMap XMBean

In version 2 of the XMBean we add support for persistence of the XMBean attributes. The updated XMBean deployment descriptor is given below.

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE mbean PUBLIC
          "-//JBoss//DTD JBOSS XMBEAN 1.0//EN"
          "http://www.jboss.org/j2ee/dtd/jboss_xmbean_1_0.dtd">
<mbean>
    <description>The JNDIMap XMBean Example Version 2</description>
    <descriptors>
        <persistence persistPolicy="OnUpdate" persistPeriod="10"
            persistLocation="${jboss.server.data.dir}" persistName="JNDIMap.ser"/>
        <currencyTimeLimit value="10"/>
        <state-action-on-update value="keep-running"/>
        <persistence-manager value="org.jboss.mx.persistence.ObjectStreamPersistenceManager"/>
    </descriptors>   <class>org.jboss.test.jmx.xmbean.JNDIMap</class>
    <constructor>
        <description>The default constructor</description>
        <name>JNDIMap</name>
    </constructor>
    <!-- Attributes -->
    <attribute access="read-write" getMethod="getJndiName" setMethod="setJndiName">
        <description>
            The location in JNDI where the Map we manage will be bound
        </description>
        <name>JndiName</name>
        <type>java.lang.String</type>
        <descriptors>
            <default value="inmemory/maps/MapTest"/>
        </descriptors>
    </attribute>
    <attribute access="read-write" getMethod="getInitialValues"
               setMethod="setInitialValues">
        <description>The array of initial values that will be placed into the
            map associated with the service. The array is a collection of
            key,value pairs with elements[0,2,4,...2n] being the keys and
            elements [1,3,5,...,2n+1] the associated values</description>
        <name>InitialValues</name>
        <type>[Ljava.lang.String;</type>
        <descriptors>
            <default value="key0,value0"/>
        </descriptors>
    </attribute>
    <!-- Operations -->
    <operation>
        <description>The start lifecycle operation</description>
        <name>start</name>
    </operation>
    <operation>
        <description>The stop lifecycle operation</description>
        <name>stop</name>
    </operation>
    <operation impact="ACTION">
        <description>Put a value into the nap</description>
        <name>put</name>
        <parameter>
            <description>The key the value will be store under</description>
            <name>key</name>
            <type>java.lang.Object</type>
        </parameter>
        <parameter>
            <description>The value to place into the map</description>
            <name>value</name>
            <type>java.lang.Object</type>
        </parameter>
    </operation>
    <operation impact="INFO">
        <description>Get a value from the map</description>
        <name>get</name>
        <parameter>
            <description>The key to lookup in the map</description>
            <name>get</name>
            <type>java.lang.Object</type>
        </parameter>
        <return-type>java.lang.Object</return-type>
    </operation>
    <!-- Notifications -->
    <notification>
        <description>The notification sent whenever a value is get into the map
            managed by the service</description>
        <name>javax.management.Notification</name>
        <notification-type>org.jboss.book.jmx.xmbean.JNDIMap.get</notification-type>
    </notification>
    <notification>
        <description>The notification sent whenever a value is put into the map
            managed by the service</description>
        <name>javax.management.Notification</name>
        <notification-type>org.jboss.book.jmx.xmbean.JNDIMap.put</notification-type>
    </notification>
</mbean>
```

Build, deploy and test the version 2 XMBean as follows:

```
[examples]$ ant -Dchap=jmx -Dex=xmbean2 -Djboss.deploy.conf=rmi-adaptor run-example
...
run-examplexmbean2:
     [java] JNDIMap Class: org.jboss.mx.modelmbean.XMBean
     [java] JNDIMap Operations:
     [java]  + void start()
     [java]  + void stop()
     [java]  + void put(java.lang.Object chap2.xmbean:service=JNDIMap,java.lang.Object cha
p2.xmbean:service=JNDIMap)
     [java]  + java.lang.Object get(java.lang.Object chap2.xmbean:service=JNDIMap)
     [java]  + java.lang.String getJndiName()
     [java]  + void setJndiName(java.lang.String chap2.xmbean:service=JNDIMap)
     [java]  + [Ljava.lang.String; getInitialValues()
     [java]  + void setInitialValues([Ljava.lang.String; chap2.xmbean:service=JNDIMap)
     [java] handleNotification, event: null
     [java] key=key10, value=value10
     [java] handleNotification, event: javax.management.Notification[source=chap2.xmbean:s
ervice=JNDIMap,type=org.jboss.chap2.xmbean.JNDIMap.put,sequenceNumber=7,timeStamp=10986326
93716,message=null,userData=null]
     [java] JNDIMap.put(key1, value1) successful
     [java] handleNotification, event: javax.management.Notification[source=chap2.xmbean:s
ervice=JNDIMap,type=org.jboss.chap2.xmbean.JNDIMap.get,sequenceNumber=8,timeStamp=10986326
93857,message=null,userData=null]
     [java] JNDIMap.get(key0): null
     [java] handleNotification, event: javax.management.Notification[source=chap2.xmbean:s
ervice=JNDIMap,type=org.jboss.chap2.xmbean.JNDIMap.get,sequenceNumber=9,timeStamp=10986326
93896,message=null,userData=null]
     [java] JNDIMap.get(key1): value1
     [java] handleNotification, event: javax.management.Notification[source=chap2.xmbean:s
ervice=JNDIMap,type=org.jboss.chap2.xmbean.JNDIMap.put,sequenceNumber=10,timeStamp=1098632
693925,message=null,userData=null]
```

There is nothing manifestly different about this version of the XMBean at this point because we have done nothing to test that changes to attribute value are actually persisted. Perform this test by running example xmbean2a several times:

```
[examples] ant -Dchap=jmx -Dex=xmbean2a run-example
...
```

```
     [java] InitialValues.length=2
     [java] key=key10, value=value10
```

```
[examples] ant -Dchap=jmx -Dex=xmbean2a run-example
...
     [java] InitialValues.length=4
     [java] key=key10, value=value10
     [java] key=key2, value=value2
```

```
[examples] ant -Dchap=jmx -Dex=xmbean2a run-example
...
     [java] InitialValues.length=6
     [java] key=key10, value=value10
     [java] key=key2, value=value2
     [java] key=key3, value=value3
```

The `org.jboss.book.jmx.xmbean.TestXMBeanRestart` used in this example obtains the current `InitialValues` attribute setting, and then adds another key/value pair to it. The client code is shown below.

```
package org.jboss.book.jmx.xmbean;

import javax.management.Attribute;
import javax.management.ObjectName;
import javax.naming.InitialContext;

import org.jboss.jmx.adaptor.rmi.RMIAdaptor;

/**
 *  A client that demonstrates the persistence of the xmbean
 *  attributes. Every time it run it looks up the InitialValues
 *  attribute, prints it out and then adds a new key/value to the
 *  list.
 *
 *  @author Scott.Stark@jboss.org
 *  @version $Revision: 1.2 $
 */
public class TestXMBeanRestart
{
    /**
     * @param args the command line arguments
     */
    public static void main(String[] args) throws Exception
    {
        InitialContext ic = new InitialContext();
        RMIAdaptor server = (RMIAdaptor) ic.lookup("jmx/rmi/RMIAdaptor");

        // Get the InitialValues attribute
        ObjectName name = new ObjectName("chap2.xmbean:service=JNDIMap");
        String[] initialValues = (String[])
            server.getAttribute(name, "InitialValues");
        System.out.println("InitialValues.length="+initialValues.length);
        int length = initialValues.length;
        for (int n = 0; n < length; n += 2) {
            String key = initialValues[n];
            String value = initialValues[n+1];

            System.out.println("key="+key+", value="+value);
        }
        // Add a new key/value pair
        String[] newInitialValues = new String[length+2];
        System.arraycopy(initialValues, 0, newInitialValues,
                        0, length);
        newInitialValues[length] = "key"+(length/2+1);
        newInitialValues[length+1] = "value"+(length/2+1);

        Attribute ivalues = new
            Attribute("InitialValues", newInitialValues);
        server.setAttribute(name, ivalues);
    }
}
```

At this point you may even shutdown the JBoss server, restart it and then rerun the initial example to see if the changes are persisted across server restarts:

```
[examples]$ ant -Dchap=jmx -Dex=xmbean2 run-example
...

run-examplexmbean2:
     [java] JNDIMap Class: org.jboss.mx.modelmbean.XMBean
     [java] JNDIMap Operations:
     [java]  + void start()
     [java]  + void stop()
     [java]  + void put(java.lang.Object chap2.xmbean:service=JNDIMap,java.lang.Object cha
p2.xmbean:service=JNDIMap)
     [java]  + java.lang.Object get(java.lang.Object chap2.xmbean:service=JNDIMap)
     [java]  + java.lang.String getJndiName()
     [java]  + void setJndiName(java.lang.String chap2.xmbean:service=JNDIMap)
     [java]  + [Ljava.lang.String; getInitialValues()
     [java]  + void setInitialValues([Ljava.lang.String; chap2.xmbean:service=JNDIMap)
     [java] handleNotification, event: null
     [java] key=key10, value=value10
     [java] key=key2, value=value2
     [java] key=key3, value=value3
     [java] key=key4, value=value4
     [java] handleNotification, event: javax.management.Notification[source=chap2.xmbean:s
ervice=JNDIMap,type=org.jboss.book.jmx.xmbean.JNDIMap.put,sequenceNumber=3,timeStamp=10986
33664712,message=null,userData=null]
     [java] JNDIMap.put(key1, value1) successful
     [java] handleNotification, event: javax.management.Notification[source=chap2.xmbean:s
ervice=JNDIMap,type=org.jboss.book.jmx.xmbean.JNDIMap.get,sequenceNumber=4,timeStamp=10986
33664821,message=null,userData=null]
     [java] JNDIMap.get(key0): null
     [java] handleNotification, event: javax.management.Notification[source=chap2.xmbean:s
ervice=JNDIMap,type=org.jboss.book.jmx.xmbean.JNDIMap.get,sequenceNumber=5,timeStamp=10986
33664860,message=null,userData=null]
     [java] JNDIMap.get(key1): value1
     [java] handleNotification, event: javax.management.Notification[source=chap2.xmbean:s
ervice=JNDIMap,type=org.jboss.book.jmx.xmbean.JNDIMap.put,sequenceNumber=6,timeStamp=10986
33664877,message=null,userData=null]
     [java] handleNotification, event: javax.management.Notification[source=chap2.xmbean:s
ervice=JNDIMap,type=org.jboss.book.jmx.xmbean.JNDIMap.put,sequenceNumber=7,timeStamp=10986
33664895,message=null,userData=null]
     [java] handleNotification, event: javax.management.Notification[source=chap2.xmbean:s
ervice=JNDIMap,type=org.jboss.book.jmx.xmbean.JNDIMap.put,sequenceNumber=8,timeStamp=10986
33664899,message=null,userData=null]
     [java] handleNotification, event: javax.management.Notification[source=chap2.xmbean:s
ervice=JNDIMap,type=org.jboss.book.jmx.xmbean.JNDIMap.put,sequenceNumber=9,timeStamp=10986
33665614,message=null,userData=null]
```

You see that the last `InitialValues` attribute setting is in fact visible.

1.4.4. Deployment Ordering and Dependencies

We have seen how to manage dependencies using the service descriptor `depends` and `depends-list` tags. The deployment ordering supported by the deployment scanners provides a coarse-grained dependency management in that there is an order to deployments. If dependencies are consistent with the deployment packages then this is a simpler mechanism than having to enumerate the explicit MBean-MBean dependencies. By writing your own filters you can change the coarse grained ordering performed by the deployment scanner.

When a component archive is deployed, its nested deployment units are processed in a depth first ordering. Structuring of components into an archive hierarchy is yet another way to manage deployment ordering.You will need to explicitly state your MBean dependencies if your packaging structure does not happen to resolve the dependencies. Let's consider an example component deployment that consists of an MBean that uses an EJB. Here is the structure of the example EAR.

```
output/jmx/jmx-ex3.ear
+- META-INF/MANIFEST.MF
+- META-INF/jboss-app.xml
+- jmx-ex3.jar (archive) [EJB jar]
| +- META-INF/MANIFEST.MF
| +- META-INF/ejb-jar.xml
| +- org/jboss/book/jmx/ex3/EchoBean.class
| +- org/jboss/book/jmx/ex3/EchoLocal.class
| +- org/jboss/book/jmx/ex3/EchoLocalHome.class
+- jmx-ex3.sar (archive) [MBean sar]
| +- META-INF/MANIFEST.MF
| +- META-INF/jboss-service.xml
| +- org/jboss/book/jmx/ex3/EjbMBeanAdaptor.class
+- META-INF/application.xml
```

The EAR contains a `jmx-ex3.jar` and `jmx-ex3.sar`. The `jmx-ex3.jar` is the EJB archive and the `jmx-ex3.sar` is the MBean service archive. We have implemented the service as a Dynamic MBean to provide an illustration of their use.

```
package org.jboss.book.jmx.ex3;

import java.lang.reflect.Method;
import javax.ejb.CreateException;
import javax.management.Attribute;
import javax.management.AttributeList;
import javax.management.AttributeNotFoundException;
import javax.management.DynamicMBean;
import javax.management.InvalidAttributeValueException;
import javax.management.JMRuntimeException;
import javax.management.MBeanAttributeInfo;
import javax.management.MBeanConstructorInfo;
import javax.management.MBeanInfo;
import javax.management.MBeanNotificationInfo;
import javax.management.MBeanOperationInfo;
import javax.management.MBeanException;
import javax.management.MBeanServer;
import javax.management.ObjectName;
import javax.management.ReflectionException;
import javax.naming.InitialContext;
import javax.naming.NamingException;

import org.jboss.system.ServiceMBeanSupport;

/**
 *  An example of a DynamicMBean that exposes select attributes and
 *  operations of an EJB as an MBean.
 *  @author Scott.Stark@jboss.org
 *  @version $Revision: 1.2 $
 */
public class EjbMBeanAdaptor extends ServiceMBeanSupport
    implements DynamicMBean
{
    private String helloPrefix;
    private String ejbJndiName;
    private EchoLocalHome home;

    /** These are the mbean attributes we expose
     */
    private MBeanAttributeInfo[] attributes = {
        new MBeanAttributeInfo("HelloPrefix", "java.lang.String",
                               "The prefix message to append to the session echo reply",
                               true, // isReadable
                               true, // isWritable
                               false), // isIs
        new MBeanAttributeInfo("EjbJndiName", "java.lang.String",
                               "The JNDI name of the session bean local home",
                               true, // isReadable
                               true, // isWritable
                               false) // isIs
    };

    /**
     * These are the mbean operations we expose
     */
    private MBeanOperationInfo[] operations;

    /**
     * We override this method to setup our echo operation info. It
     * could also be done in a ctor.
     */
    public ObjectName preRegister(MBeanServer server,
                                  ObjectName name)
        throws Exception
    {
        log.info("preRegister notification seen");

        operations = new MBeanOperationInfo[5];

        Class thisClass = getClass();
        Class[] parameterTypes = {String.class};
        Method echoMethod =
            thisClass.getMethod("echo", parameterTypes);
        String desc = "The echo op invokes the session bean echo method and"
            + " returns its value prefixed with the helloPrefix attribute value";
        operations[0] = new MBeanOperationInfo(desc, echoMethod);

        // Add the Service interface operations from our super class
        parameterTypes = new Class[0];
        Method createMethod =
            thisClass.getMethod("create", parameterTypes);
        operations[1] = new MBeanOperationInfo("The
                JBoss Service.create", createMethod);
        Method startMethod =
            thisClass.getMethod("start", parameterTypes);
        operations[2] = new MBeanOperationInfo("The
                JBoss Service.start", startMethod);
        Method stopMethod =
            thisClass.getMethod("stop", parameterTypes);
        operations[3] = new MBeanOperationInfo("The
                JBoss Service.stop", startMethod);
        Method destroyMethod =
            thisClass.getMethod("destroy", parameterTypes);
        operations[4] = new MBeanOperationInfo("The
                JBoss Service.destroy", startMethod);
        return name;
    }


    // --- Begin ServiceMBeanSupport overides
    protected void createService() throws Exception
    {
        log.info("Notified of create state");
    }

    protected void startService() throws Exception
    {
        log.info("Notified of start state");
        InitialContext ctx = new InitialContext();
        home = (EchoLocalHome) ctx.lookup(ejbJndiName);
    }

    protected void stopService()
    {
        log.info("Notified of stop state");
    }

    // --- End ServiceMBeanSupport overides

    public String getHelloPrefix()
    {
        return helloPrefix;
    }
    public void setHelloPrefix(String helloPrefix)
    {
        this.helloPrefix = helloPrefix;
    }

    public String getEjbJndiName()
    {
        return ejbJndiName;
    }
    public void setEjbJndiName(String ejbJndiName)
    {
        this.ejbJndiName = ejbJndiName;
    }

    public String echo(String arg)
        throws CreateException, NamingException
    {
        log.debug("Lookup EchoLocalHome@"+ejbJndiName);
        EchoLocal bean = home.create();
        String echo = helloPrefix + bean.echo(arg);
        return echo;
    }

    // --- Begin DynamicMBean interface methods
    /**
     *  Returns the management interface that describes this dynamic
     *  resource.  It is the responsibility of the implementation to
     *  make sure the description is accurate.
     *
     * @return the management interface descriptor.
     */
    public MBeanInfo getMBeanInfo()
    {
        String classname = getClass().getName();
        String description = "This is an MBean that uses a session bean in the"
            + " implementation of its echo operation.";
        MBeanInfo[] constructors = null;
        MBeanNotificationInfo[] notifications = null;
        MBeanInfo mbeanInfo = new MBeanInfo(classname,
                                            description, attributes,
                                            constructors, operations,
                                            notifications);
        // Log when this is called so we know when in the
        lifecycle this is used
            Throwable trace = new Throwable("getMBeanInfo trace");
        log.info("Don't panic, just a stack
                trace", trace);
        return mbeanInfo;
    }

    /**
     *  Returns the value of the attribute with the name matching the
     *  passed string.
     *
     * @param attribute the name of the attribute.
     * @return the value of the attribute.
     * @exception AttributeNotFoundException when there is no such
     * attribute.
     * @exception MBeanException wraps any error thrown by the
     * resource when
     * getting the attribute.
     * @exception ReflectionException wraps any error invoking the
     * resource.
     */
    public Object getAttribute(String attribute)
        throws AttributeNotFoundException,
               MBeanException,
               ReflectionException
    {
        Object value = null;
        if (attribute.equals("HelloPrefix")) {
            value = getHelloPrefix();
        } else if(attribute.equals("EjbJndiName")) {
            value = getEjbJndiName();
        } else {
            throw new AttributeNotFoundException("Unknown
                attribute("+attribute+") requested");
        }
        return value;
    }

    /**
     * Returns the values of the attributes with names matching the
     * passed string array.
     *
     * @param attributes the names of the attribute.
     * @return an {@link AttributeList AttributeList} of name
     * and value pairs.
     */
    public AttributeList getAttributes(String[] attributes)
    {
        AttributeList values = new AttributeList();
        for (int a = 0; a < attributes.length; a++) {
            String name = attributes[a];
            try {
                Object value = getAttribute(name);
                Attribute attr = new Attribute(name, value);
                values.add(attr);
            } catch(Exception e) {
                log.error("Failed to find attribute: "+name, e);
            }
        }
        return values;
    }
    /**
     *  Sets the value of an attribute. The attribute and new value
     *  are passed in the name value pair {@link Attribute
     *  Attribute}.
     *
     * @see javax.management.Attribute
     *
     * @param attribute the name and new value of the attribute.
     * @exception AttributeNotFoundException when there is no such
     * attribute.
     * @exception InvalidAttributeValueException when the new value
     * cannot be converted to the type of the attribute.
     * @exception MBeanException wraps any error thrown by the
     * resource when setting the new value.
     * @exception ReflectionException wraps any error invoking the
     * resource.
     */
    public void setAttribute(Attribute attribute)
        throws AttributeNotFoundException,
               InvalidAttributeValueException,
               MBeanException,
               ReflectionException
    {
        String name = attribute.getName();
        if (name.equals("HelloPrefix")) {
            String value = attribute.getValue().toString();
            setHelloPrefix(value);
        } else if(name.equals("EjbJndiName")) {
            String value = attribute.getValue().toString();
            setEjbJndiName(value);
        } else {
            throw new AttributeNotFoundException("Unknown attribute("+name+") requested");
        }
    }

    /**
     * Sets the values of the attributes passed as an
     * {@link AttributeList AttributeList} of name and new
     * value pairs.
     *
     * @param attributes the name an new value pairs.
     * @return an {@link AttributeList AttributeList} of name and
     * value pairs that were actually set.
     */
    public AttributeList setAttributes(AttributeList attributes)
    {
        AttributeList setAttributes = new AttributeList();
        for(int a = 0; a < attributes.size(); a++) {
            Attribute attr = (Attribute) attributes.get(a);
            try {
                setAttribute(attr);
                setAttributes.add(attr);
            } catch(Exception ignore) {
            }
        }
        return setAttributes;
    }

    /**
     *  Invokes a resource operation.
     *
     *  @param actionName the name of the operation to perform.
     *  @param params the parameters to pass to the operation.
     *  @param signature the signartures of the parameters.
     *  @return the result of the operation.
     *  @exception MBeanException wraps any error thrown by the
     *  resource when performing the operation.
     *  @exception ReflectionException wraps any error invoking the
     *  resource.
     */
    public Object invoke(String actionName, Object[] params,
                         String[] signature)
        throws MBeanException,
               ReflectionException
    {
        Object rtnValue = null;
        log.debug("Begin invoke, actionName="+actionName);
        try {
            if (actionName.equals("echo")) {
                String arg = (String) params[0];
                rtnValue = echo(arg);
                log.debug("Result: "+rtnValue);
            } else if (actionName.equals("create")) {
                super.create();
            } else if (actionName.equals("start")) {
                super.start();
            } else if (actionName.equals("stop")) {
                super.stop();
            } else if (actionName.equals("destroy")) {
                super.destroy();
            } else {
                throw new JMRuntimeException("Invalid state,
                don't know about op="+actionName);
            }
        } catch(Exception e) {
            throw new ReflectionException(e, "echo failed");
        }


        log.debug("End invoke, actionName="+actionName);
        return rtnValue;
    }

    // --- End DynamicMBean interface methods

}
```

Believe it or not, this is a very trivial MBean. The vast majority of the code is there to provide the MBean metadata and handle the callbacks from the MBean Server. This is required because a Dynamic MBean is free to expose whatever management interface it wants. A Dynamic MBean can in fact change its management interface at runtime simply by returning different metadata from the `getMBeanInfo` method. Of course, some clients may not be happy with such a dynamic object, but the MBean Server will do nothing to prevent a Dynamic MBean from changing its interface.

There are two points to this example. First, demonstrate how an MBean can depend on an EJB for some of its functionality and second, how to create MBeans with dynamic management interfaces. If we were to write a standard MBean with a static interface for this example it would look like the following.

```
public interface EjbMBeanAdaptorMBean
{
    public String getHelloPrefix();
    public void setHelloPrefix(String prefix);
    public String getEjbJndiName();
    public void setEjbJndiName(String jndiName);
    public String echo(String arg) throws CreateException, NamingException;
    public void create() throws Exception;
    public void start() throws Exception;
    public void stop();
    public void destroy();
}
```

Moving to lines 67-83, this is where the MBean operation metadata is constructed. The `echo(String)`, `create()`, `start()`, `stop()` and `destroy()` operations are defined by obtaining the corresponding java.lang.reflect.Method object and adding a description. Let's go through the code and discuss where this interface implementation exists and how the MBean uses the EJB. Beginning with lines 40-51, the two `MBeanAttributeInfo` instances created define the attributes of the MBean. These attributes correspond to the `getHelloPrefix`/`setHelloPrefix` and `getEjbJndiName`/`setEjbJndiName` of the static interface. One thing to note in terms of why one might want to use a Dynamic MBean is that you have the ability to associate descriptive text with the attribute metadata. This is not something you can do with a static interface.

Lines 88-103 correspond to the JBoss service life cycle callbacks. Since we are subclassing the `ServiceMBeanSupport` utility class, we override the `createService`, `startService`, and `stopService` template callbacks rather than the `create`, `start`, and `stop` methods of the service interface. Note that we cannot attempt to lookup the `EchoLocalHome` interface of the EJB we make use of until the `startService` method. Any attempt to access the home interface in an earlier life cycle method would result in the name not being found in JNDI because the EJB container had not gotten to the point of binding the home interfaces. Because of this dependency we will need to specify that the MBean service depends on the EchoLocal EJB container to ensure that the service is not started before the EJB container is started. We will see this dependency specification when we look at the service descriptor.

Lines 105-121 are the `HelloPrefix` and `EjbJndiName` attribute accessors implementations. These are invoked in response to `getAttribute`/`setAttribute` invocations made through the MBean Server.

Lines 123-130 correspond to the `echo(String)` operation implementation. This method invokes the `EchoLocal.echo(String)` EJB method. The local bean interface is created using the `EchoLocalHome` that was obtained in the `startService` method.

The remainder of the class makes up the Dynamic MBean interface implementation. Lines 133-152 correspond to the MBean metadata accessor callback. This method returns a description of the MBean management interface in the form of the `javax.management.MBeanInfo` object. This is made up of a `description`, the `MBeanAttributeInfo` and `MBeanOperationInfo` metadata created earlier, as well as constructor and notification information. This MBean does not need any special constructors or notifications so this information is null.

Lines 154-258 handle the attribute access requests. This is rather tedious and error prone code so a toolkit or infrastructure that helps generate these methods should be used. A Model MBean framework based on XML called XBeans is currently being investigated in JBoss. Other than this, no other Dynamic MBean frameworks currently exist.

Lines 260-310 correspond to the operation invocation dispatch entry point. Here the request operation action name is checked against those the MBean handles and the appropriate method is invoked.

The `jboss-service.xml` descriptor for the MBean is given below. The dependency on the EJB container MBean is highlighted in bold. The format of the EJB container MBean ObjectName is: `"jboss.j2ee:service=EJB,jndiName=" + <home-jndi-name>` where the <home-jndi-name> is the EJB home interface JNDI name.

```
<server>
    <mbean code="org.jboss.book.jmx.ex3.EjbMBeanAdaptor"
           name="jboss.book:service=EjbMBeanAdaptor">
        <attribute name="HelloPrefix">AdaptorPrefix</attribute>
        <attribute name="EjbJndiName">local/chap2.EchoBean</attribute>
        <depends>jboss.j2ee:service=EJB,jndiName=local/chap2.EchoBean</depends>
    </mbean>
</server>
```

Deploy the example ear by running:

```
[examples]$ ant -Dchap=jmx -Dex=3 run-example
```

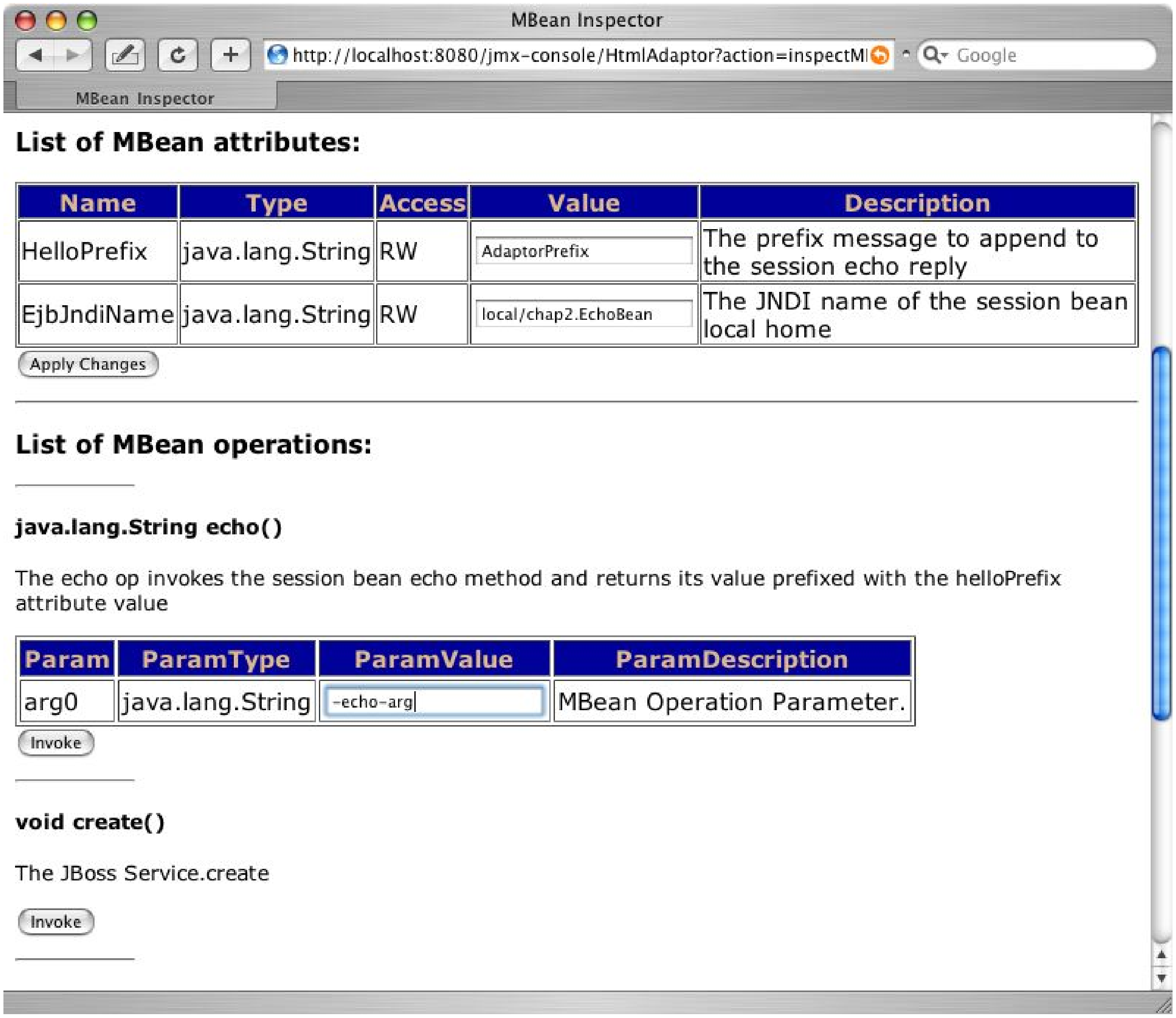
On the server console there will be messages similar to the following:

```
14:57:12,906 INFO  [EARDeployer] Init J2EE application: file:/private/tmp/jboss-4.0.1/server/
default/deploy/chap2-ex3.ear
14:57:13,044 INFO  [EjbMBeanAdaptor] Don't panic, just a stack trace
java.lang.Throwable: getMBeanInfo trace
  at org.jboss.book.jmx.ex3.EjbMBeanAdaptor.getMBeanInfo(EjbMBeanAdaptor.java:153)
...
14:57:13,088 INFO  [EjbMBeanAdaptor] preRegister notification seen
14:57:13,093 INFO  [EjbMBeanAdaptor] Don't panic, just a stack trace
java.lang.Throwable: getMBeanInfo trace
  at org.jboss.book.jmx.ex3.EjbMBeanAdaptor.getMBeanInfo(EjbMBeanAdaptor.java:153)
...
14:57:13,117 INFO  [EjbMBeanAdaptor] Don't panic, just a stack trace
java.lang.Throwable: getMBeanInfo trace
  at org.jboss.book.jmx.ex3.EjbMBeanAdaptor.getMBeanInfo(EjbMBeanAdaptor.java:153)
...
14:57:13,140 WARN  [EjbMBeanAdaptor] Unexcepted error accessing MBeanInfo for null
java.lang.NullPointerException
  at org.jboss.system.ServiceMBeanSupport.postRegister(ServiceMBeanSupport.java:418)
...
14:57:13,203 INFO  [EjbMBeanAdaptor] Don't panic, just a stack trace
java.lang.Throwable: getMBeanInfo trace
  at org.jboss.book.jmx.ex3.EjbMBeanAdaptor.getMBeanInfo(EjbMBeanAdaptor.java:153)
...
14:57:13,232 INFO  [EjbMBeanAdaptor] Don't panic, just a stack trace
java.lang.Throwable: getMBeanInfo trace
  at org.jboss.book.jmx.ex3.EjbMBeanAdaptor.getMBeanInfo(EjbMBeanAdaptor.java:153)
...
14:57:13,420 INFO  [EjbModule] Deploying Chap2EchoInfoBean
14:57:13,443 INFO  [EjbModule] Deploying chap2.EchoBean
14:57:13,488 INFO  [EjbMBeanAdaptor] Don't panic, just a stack trace
java.lang.Throwable: getMBeanInfo trace
  at org.jboss.book.jmx.ex3.EjbMBeanAdaptor.getMBeanInfo(EjbMBeanAdaptor.java:153)
...
14:57:13,542 INFO  [EjbMBeanAdaptor] Don't panic, just a stack trace
java.lang.Throwable: getMBeanInfo trace
  at org.jboss.book.jmx.ex3.EjbMBeanAdaptor.getMBeanInfo(EjbMBeanAdaptor.java:153)
...
14:57:13,558 INFO  [EjbMBeanAdaptor] Begin invoke, actionName=create
14:57:13,560 INFO  [EjbMBeanAdaptor] Notified of create state
14:57:13,562 INFO  [EjbMBeanAdaptor] End invoke, actionName=create
14:57:13,604 INFO  [EjbMBeanAdaptor] Don't panic, just a stack trace
java.lang.Throwable: getMBeanInfo trace
  at org.jboss.book.jmx.ex3.EjbMBeanAdaptor.getMBeanInfo(EjbMBeanAdaptor.java:153)
...
14:57:13,621 INFO  [EjbMBeanAdaptor] Don't panic, just a stack trace
java.lang.Throwable: getMBeanInfo trace
  at org.jboss.book.jmx.ex3.EjbMBeanAdaptor.getMBeanInfo(EjbMBeanAdaptor.java:153)
14:57:13,641 INFO  [EjbMBeanAdaptor] Begin invoke, actionName=getState
14:57:13,942 INFO  [EjbMBeanAdaptor] Begin invoke, actionName=start
14:57:13,944 INFO  [EjbMBeanAdaptor] Notified of start state
14:57:13,951 INFO  [EjbMBeanAdaptor] Testing Echo
14:57:13,983 INFO  [EchoBean] echo, info=echo info, arg=, arg=startService
14:57:13,986 INFO  [EjbMBeanAdaptor] echo(startService) = startService
```

```
14:57:13,988 INFO  [EjbMBeanAdaptor] End invoke, actionName=start
14:57:13,991 INFO  [EJBDeployer] Deployed: file:/tmp/jboss-4.0.5.GA/server/default/tmp/deploy
/tmp60550jmx-ex3.ear-contents/jmx-ex3.jar
14:57:14,075 INFO  [EARDeployer] Started J2EE application: ...
```

The stack traces are not exceptions. They are traces coming from the `EjbMBeanAdaptor` code to demonstrate that clients ask for the MBean interface when they want to discover the MBean's capabilities. Notice that the EJB container (lines with [EjbModule]) is started before the example MBean (lines with [EjbMBeanAdaptor]).

Now, let's invoke the echo method using the JMX console web application. Go to the JMX Console (http://localhost:8080/jmx-console) and find the *service=EjbMBeanAdaptor* in the *jboss.book* domain. Click on the link and scroll down to the *echo* operation section. The view should be like that shown in Figure 1.19.


MBean Inspector
http://localhost:8080/jmx-console/HtmlAdaptor?action=inspectMI
Google
MBean Inspector

List of MBean attributes:

Name	Type	Access	Value	Description
HelloPrefix	java.lang.String	RW	AdaptorPrefix	The prefix message to append to the session echo reply
EjbJndiName	java.lang.String	RW	local/chap2.EchoBean	The JNDI name of the session bean local home

List of MBean operations:

java.lang.String echo()

The echo op invokes the session bean echo method and returns its value prefixed with the helloPrefix attribute value

Param	ParamType	ParamValue	ParamDescription
arg0	java.lang.String	-echo-arg	MBean Operation Parameter.

void create()

The JBoss Service.create

Figure 1.19. The EjbMBeanAdaptor MBean operations JMX console view

As shown, we have already entered an argument string of `-echo-arg` into the ParamValue text field. Press the Invoke button and a result string of `AdaptorPrefix-echo-arg` is displayed on the results page. The server console will show several stack traces from the various metadata queries issues by the JMX console and the MBean invoke method debugging lines:

```
10:51:48,671 INFO [EjbMBeanAdaptor] Begin invoke, actionName=echo
10:51:48,671 INFO [EjbMBeanAdaptor] Lookup EchoLocalHome@local/chap2.EchoBean
10:51:48,687 INFO [EchoBean] echo, info=echo info, arg=, arg=-echo-arg
10:51:48,687 INFO [EjbMBeanAdaptor] Result: AdaptorPrefix-echo-arg
10:51:48,687 INFO [EjbMBeanAdaptor] End invoke, actionName=echo
```

1.5. JBoss Deployer Architecture

JBoss has an extensible deployment architecture that allows one to incorporate components into the bare JBoss JMX microkernel. The `MainDeployer` is the deployment entry point. Requests to deploy a component are sent to the `MainDeployer` and it determines if there is a subdeployer capable of handling the deployment, and if there is, it delegates the deployment to the subdeployer. We saw an example of this when we looked at how the `MainDeployer` used the `SARDeployer` to deploy MBean services. Among the deployers provided with JBoss are:

- **AbstractWebDeployer**: This subdeployer handles web application archives (WARs). It accepts deployment archives and directories whose name ends with a `war` suffix. WARs must have a `WEB-INF/web.xml` descriptor and may have a `WEB-INF/jboss-web.xml` descriptor.
- **EARDeployer**: This subdeployer handles enterprise application archives (EARs). It accepts deployment archives and directories whose name ends with an `ear` suffix. EARs must have a `META-INF/application.xml` descriptor and may have a `META-INF/jboss-app.xml` descriptor.
- **EJBDeployer**: This subdeployer handles enterprise bean jars. It accepts deployment archives and directories whose name ends with a `jar` suffix. EJB jars must have a `META-INF/ejb-jar.xml` descriptor and may have a `META-INF/jboss.xml` descriptor.
- **JARDeployer**: This subdeployer handles library JAR archives. The only restriction it places on an archive is that it cannot contain a `WEB-INF` directory.
- **RARDeployer**: This subdeployer handles JCA resource archives (RARs). It accepts deployment archives and directories whose name ends with a `rar` suffix. RARs must have a `META-INF/ra.xml` descriptor.
- **SARDeployer**: This subdeployer handles JBoss MBean service archives (SARs). It accepts deployment archives and directories whose name ends with a `sar` suffix, as well as standalone XML files that end with `service.xml`. SARs that are jars must have a `META-INF/jboss-service.xml` descriptor.
- **XSLSubDeployer**: This subdeployer deploys arbitrary XML files. JBoss uses the XSLSubDeployer to deploy `ds.xml` files and transform them into `service.xml` files for the `SARDeployer`. However, it is not limited to just this task.
- **HARDeployer**: This subdeployer deploys hibernate archives (HARs). It accepts deployment archives and directories whose name ends with a `har` suffix. HARs must have a `META-INF/hibernate-service.xml` descriptor.
- **AspectDeployer**: This subdeployer deploys AOP archives. It accepts deployment archives and directories whose name ends with an `aop` suffix as well as `aop.xml` files. AOP archives must have a `META-INF/jboss-aop.xml` descriptor.

- **ClientDeployer**: This subdeployer deploys J2EE application clients. It accepts deployment archives and directories whose name ends with a `jar` suffix. J2EE clients must have a `META-INF/application-client.xml` descriptor and may have a `META-INF/jboss-client.xml` descriptor.
- **BeanShellSubDeployer**: This subdeployer deploys bean shell scripts as MBeans. It accepts files whose name ends with a `bsh` suffix.

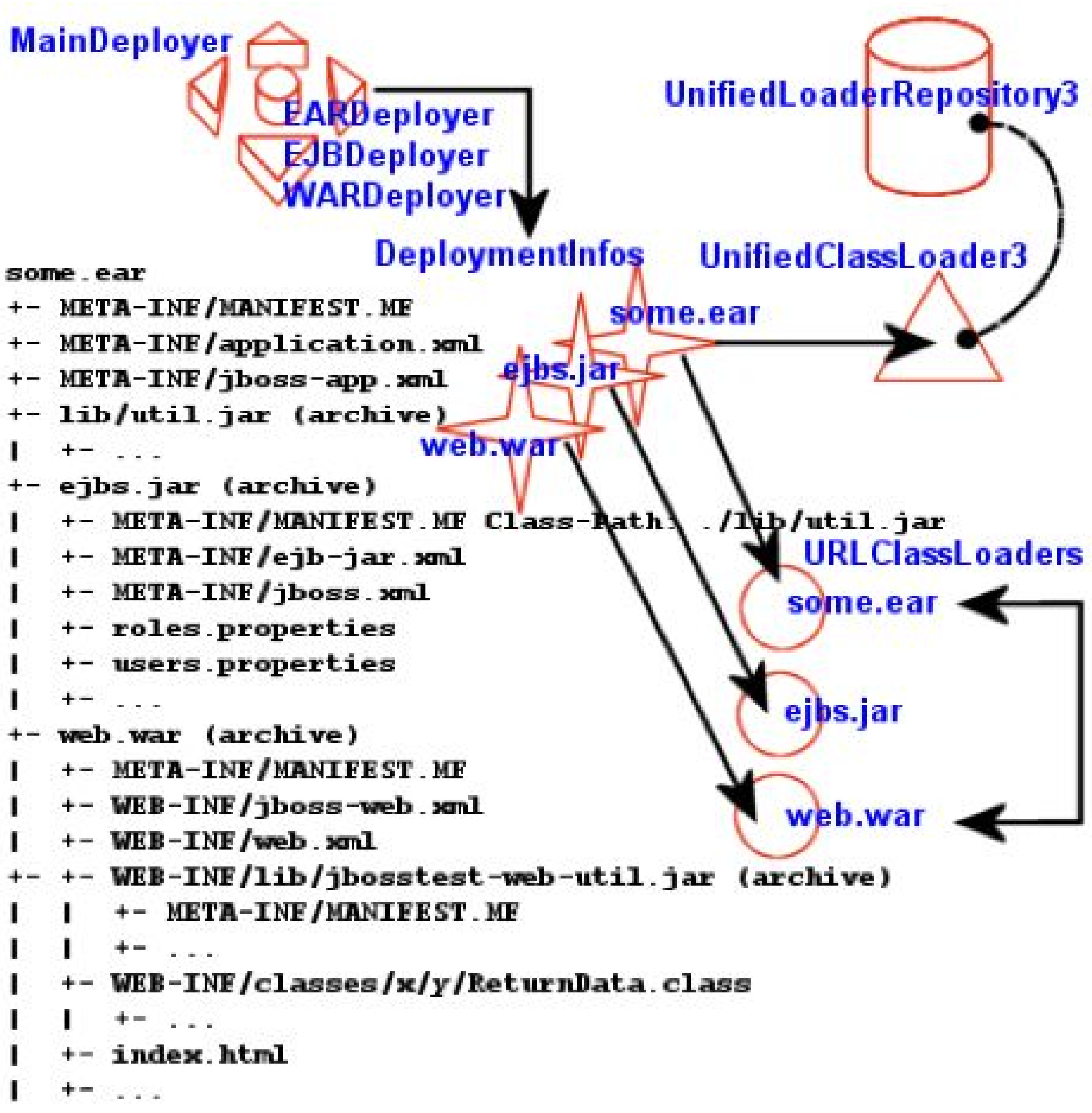
The MainDeployer, JARDeployer and SARDeployer are hard coded deployers in the JBoss server core. All other deployers are MBean services that register themselves as deployers with the MainDeployer using the `addDeployer(SubDeployer)` operation.

The `MainDeployer` communicates information about the component to be deployed the `SubDeployer` using a `DeploymentInfo` object. The `DeploymentInfo` object is a data structure that encapsulates the complete state of a deployable component.

When the `MainDeployer` receives a deployment request, it iterates through its registered subdeployers and invokes the `accepts(DeploymentInfo)` method on the subdeployer. The first subdeployer to return true is chosen. The MainDeployer will delegate the init, create, start, stop and destroy deployment life cycle operations to the subdeployer.

1.5.1. Deployers and ClassLoaders

Deployers are the mechanism by which components are brought into a JBoss server. Deployers are also the creators of the majority of UCL instances, and the primary creator is the MainDeployer. The MainDeployer creates the UCL for a deployment early on during its init method. The UCL is created by calling the DeploymentInfo.createClassLoaders() method. Only the topmost `DeploymentInfo` will actually create a UCL. All subdeployments will add their class paths to their parent `DeploymentInfo` UCL. Every deployment does have a standalone URLClassLoader that uses the deployment URL as its path. This is used to localize the loading of resources such as deployment descriptors. Figure 1.20 provides an illustration of the interaction between Deployers, DeploymentInfos and class loaders.



```
some.ear
+- META-INF/MANIFEST.MF
+- META-INF/application.xml
+- META-INF/jboss-app.xml
+- lib/util.jar (archive)
|   +- ...
+- ejbs.jar (archive)
|   +- META-INF/MANIFEST.MF Class-Path: ./lib/util.jar
|   +- META-INF/ejb-jar.xml
|   +- META-INF/jboss.xml
|   +- roles.properties
|   +- users.properties
|   +- ...
+- web.war (archive)
|   +- META-INF/MANIFEST.MF
|   +- WEB-INF/jboss-web.xml
|   +- WEB-INF/web.xml
+- +- WEB-INF/lib/jbosstest-web-util.jar (archive)
|   |   +- META-INF/MANIFEST.MF
|   |   +- ...
|   +- WEB-INF/classes/x/y/ReturnData.class
|   |   +- ...
|   +- index.html
|   +- ...
```

Figure 1.20. An illustration of the class loaders involved with an EAR deployment

The figure illustrates an EAR deployment with EJB and WAR subdeployments. The EJB deployment references the `lib/util.jar` utility jar via its manifest. The WAR includes classes in its `WEB-INF/classes` directory as well as the `WEB-INF/lib/jbosstest-web-util.jar`. Each deployment has a `DeploymentInfo` instance that has a `URL-ClassLoader` pointing to the deployment archive. The `DeploymentInfo` associated with `some.ear` is the only one to have a UCL created. The `ejbs.jar` and `web.war` `DeploymentInfos` add their deployment archive to the `some.ear` UCL classpath, and share this UCL as their deployment UCL. The `EJBDeployer` also adds any manifest jars to the EAR UCL.

The `WARDeployer` behaves differently than other deployers in that it only adds its WAR archive to the `Deploy-mentInfo` UCL classpath. The loading of classes from the WAR `WEB-INF/classes` and `WEB-INF/lib` locations is handled by the servlet container class loader. The servlet container class loaders delegate to the WAR `Deploy-`

mentInfo UCL as their parent class loader, but the server container class loader is not part of the JBoss class loader repository. Therefore, classes inside of a WAR are not visible to other components. Classes that need to be shared between web application components and other components such as EJBs, and MBeans need to be loaded into the shared class loader repository either by including the classes into a SAR or EJB deployment, or by referencing a jar containing the shared classes through a manifest `Class-Path` entry. In the case of a SAR, the SAR classpath element in the service deployment serves the same purpose as a JAR manifest `Class-Path`.

1.6. Remote Access to Services, Detached Invokers

In addition to the MBean services notion that allows for the ability to integrate arbitrary functionality, JBoss also has a detached invoker concept that allows MBean services to expose functional interfaces via arbitrary protocols for remote access by clients. The notion of a detached invoker is that remoting and the protocol by which a service is accessed is a functional aspect or service independent of the component. Thus, one can make a naming service available for use via RMI/JRMP, RMI/HTTP, RMI/SOAP, or any arbitrary custom transport.

Let's begin our discussion of the detached invoker architecture with an overview of the components involved. The main components in the detached invoker architecture are shown in Figure 1.21.

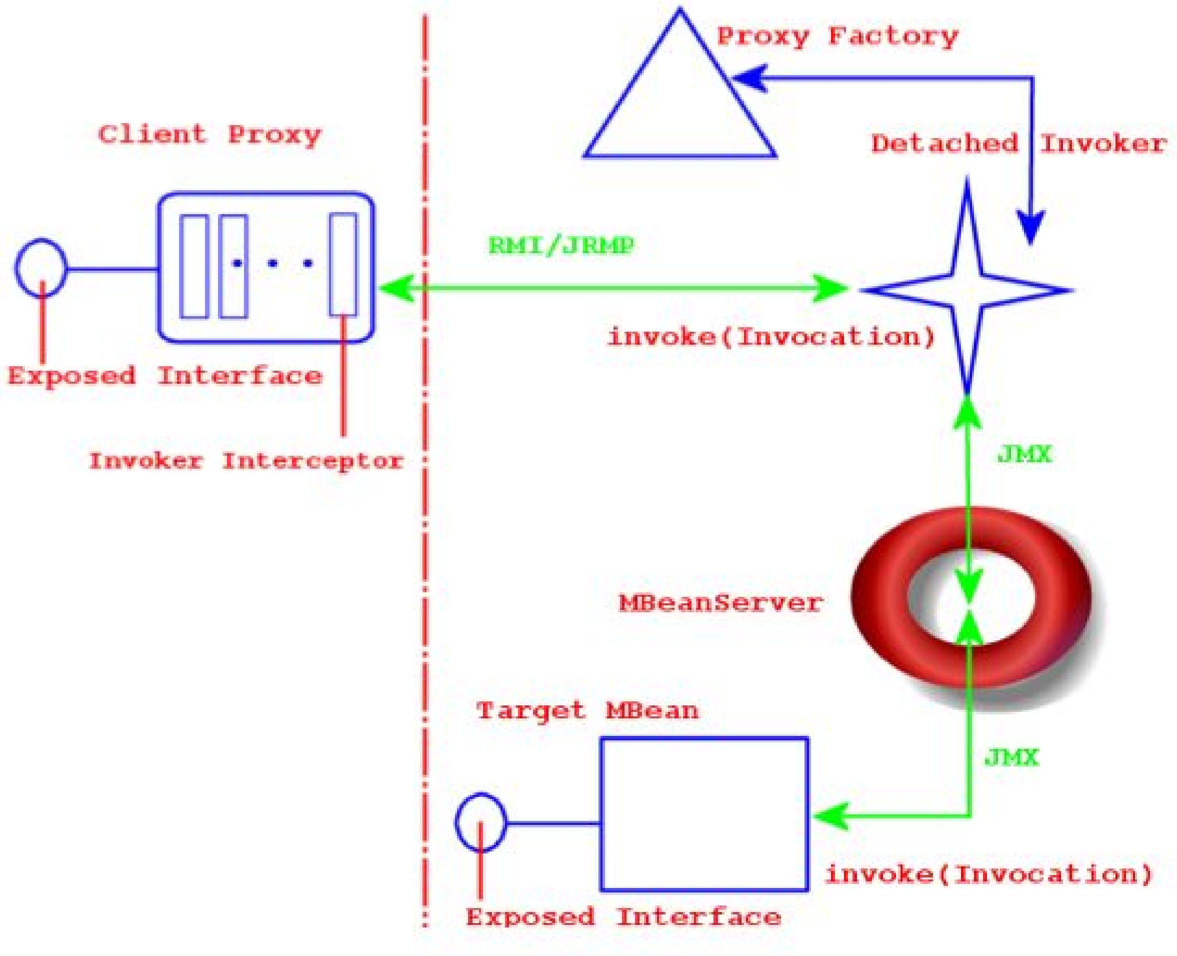


Figure 1.21. The main components in the detached invoker architecture

On the client side, there exists a client proxy which exposes the interface(s) of the MBean service. This is the same smart, compile-less dynamic proxy that we use for EJB home and remote interfaces. The only difference between the proxy for an arbitrary service and the EJB is the set of interfaces exposed as well as the client side interceptors found inside the proxy. The client interceptors are represented by the rectangles found inside of the client proxy. An interceptor is an assembly line type of pattern that allows for transformation of a method invocation and/or return values. A client obtains a proxy through some lookup mechanism, typically JNDI. Although RMI is indicated in Figure 1.21, the only real requirement on the exposed interface and its types is that they are serializable between the client server over JNDI as well as the transport layer.

The choice of the transport layer is determined by the last interceptor in the client proxy, which is referred to as the *Invoker Interceptor* in Figure 1.21. The invoker interceptor contains a reference to the transport specific stub of the server side *Detached Invoker* MBean service. The invoker interceptor also handles the optimization of calls that occur within the same VM as the target MBean. When the invoker interceptor detects that this is the case the call is passed to a call-by-reference invoker that simply passes the invocation along to the target MBean.

The detached invoker service is responsible for making a generic invoke operation available via the transport the detached invoker handles. The `Invoker` interface illustrates the generic invoke operation.

```
package org.jboss.invocation;

import java.rmi.Remote;
import org.jboss.proxy.Interceptor;
import org.jboss.util.id.GUID;


public interface Invoker
    extends Remote
{
    GUID ID = new GUID();

    String getServerHostName() throws Exception;

    Object invoke(Invocation invocation) throws Exception;
}
```

The Invoker interface extends `Remote` to be compatible with RMI, but this does not mean that an invoker must expose an RMI service stub. The detached invoker service simply acts as a transport gateway that accepts invocations represented as the `org.jboss.invocation.Invocation` object over its specific transport, unmarshalls the invocation, forwards the invocation onto the destination MBean service, represented by the *Target MBean* in Figure 1.21, and marshalls the return value or exception resulting from the forwarded call back to the client.

The `Invocation` object is just a representation of a method invocation context. This includes the target MBean name, the method, the method arguments, a context of information associated with the proxy by the proxy factory, and an arbitrary map of data associated with the invocation by the client proxy interceptors.

The configuration of the client proxy is done by the server side proxy factory MBean service, indicated by the *Proxy Factory* component in Figure 1.21. The proxy factory performs the following tasks:

- Create a dynamic proxy that implements the interface the target MBean wishes to expose.
- Associate the client proxy interceptors with the dynamic proxy handler.
- Associate the invocation context with the dynamic proxy. This includes the target MBean, detached invoker

stub and the proxy JNDI name.

- Make the proxy available to clients by binding the proxy into JNDI.

The last component in Figure 1.21 is the *Target MBean* service that wishes to expose an interface for invocations to remote clients. The steps required for an MBean service to be accessible through a given interface are:

- Define a JMX operation matching the signature: `public Object invoke(org.jboss.invocation.Invocation) throws Exception`
- Create a `HashMap<Long, Method>` mapping from the exposed interface `java.lang.reflect.Methods` to the long hash representation using the `org.jboss.invocation.MarshalledInvocation.calculateHash` method.
- Implement the `invoke(Invocation)` JMX operation and use the interface method hash mapping to transform from the long hash representation of the invoked method to the `java.lang.reflect.Method` of the exposed interface. Reflection is used to perform the actual invocation on the object associated with the MBean service that actually implements the exposed interface.

1.6.1. A Detached Invoker Example, the MBeanServer Invoker Adaptor Service

In the section on connecting to the JMX server we mentioned that there was a service that allows one to access the `javax.management.MBeanServer` via any protocol using an invoker service. In this section we present the `org.jboss.jmx.connector.invoker.InvokerAdaptorService` and its configuration for access via RMI/JRMP as an example of the steps required to provide remote access to an MBean service.

The `InvokerAdaptorService` is a simple MBean service that only exists to fulfill the target MBean role in the detached invoker pattern.

Example 1.16. The InvokerAdaptorService MBean

```
package org.jboss.jmx.connector.invoker;
public interface InvokerAdaptorServiceMBean
    extends org.jboss.system.ServiceMBean
{
    Class getExportedInterface();
    void setExportedInterface(Class exportedInterface);

    Object invoke(org.jboss.invocation.Invocation invocation)
        throws Exception;
}

package org.jboss.jmx.connector.invoker;

import java.lang.reflect.InvocationTargetException;
import java.lang.reflect.Method;
import java.lang.reflect.UndeclaredThrowableException;
import java.util.Collections;
import java.util.HashMap;
import java.util.Map;

import javax.management.MBeanServer;
import javax.management.ObjectName;

import org.jboss.invocation.Invocation;
import org.jboss.invocation.MarshalledInvocation;
import org.jboss.mx.server.ServerConstants;
import org.jboss.system.ServiceMBeanSupport;
import org.jboss.system.Registry;

public class InvokerAdaptorService
    extends ServiceMBeanSupport
    implements InvokerAdaptorServiceMBean, ServerConstants
{
    private static ObjectName mbeanRegistry;

    static {
        try {
            mbeanRegistry = new ObjectName(MBEAN_REGISTRY);
        } catch (Exception e) {
            throw new RuntimeException(e.toString());
        }
    }

    private Map marshalledInvocationMapping = new HashMap();
    private Class exportedInterface;

    public Class getExportedInterface()
    {
        return exportedInterface;
    }

    public void setExportedInterface(Class exportedInterface)
    {
        this.exportedInterface = exportedInterface;
    }

    protected void startService()
        throws Exception
    {
        // Build the interface method map
        Method[] methods = exportedInterface.getMethods();
        HashMap tmpMap = new HashMap(methods.length);
        for (int m = 0; m < methods.length; m ++) {
            Method method = methods[m];
            Long hash = new Long(MarshalledInvocation.calculateHash(method));
            tmpMap.put(hash, method);
        }

        marshalledInvocationMapping = Collections.unmodifiableMap(tmpMap);
        // Place our ObjectName hash into the Registry so invokers can
        // resolve it
        Registry.bind(new Integer(serviceName.hashCode()), serviceName);
    }

    protected void stopService()
        throws Exception
    {
        Registry.unbind(new Integer(serviceName.hashCode()));
    }


    public Object invoke(Invocation invocation)
        throws Exception
    {
        // Make sure we have the correct classloader before unmarshalling
        Thread thread = Thread.currentThread();
        ClassLoader oldCL = thread.getContextClassLoader();

        // Get the MBean this operation applies to
        ClassLoader newCL = null;
        ObjectName objectName = (ObjectName)
            invocation.getValue("JMX_OBJECT_NAME");
        if (objectName != null) {
            // Obtain the ClassLoader associated with the MBean deployment
            newCL = (ClassLoader)
                server.invoke(mbeanRegistry, "getValue",
                              new Object[] { objectName, CLASSLOADER },
                              new String[] { ObjectName.class.getName(),
                                             "java.lang.String" });
        }

        if (newCL != null && newCL != oldCL) {
            thread.setContextClassLoader(newCL);
        }

        try {
            // Set the method hash to Method mapping
            if (invocation instanceof MarshalledInvocation) {
                MarshalledInvocation mi = (MarshalledInvocation) invocation;
                mi.setMethodMap(marshalledInvocationMapping);
            }

            // Invoke the MBeanServer method via reflection
            Method method = invocation.getMethod();
            Object[] args = invocation.getArguments();
            Object value = null;
            try {
                String name = method.getName();
                Class[] sig = method.getParameterTypes();
                Method mbeanServerMethod =
                    MBeanServer.class.getMethod(name, sig);
                value = mbeanServerMethod.invoke(server, args);
            } catch(InvocationTargetException e) {
                Throwable t = e.getTargetException();
                if (t instanceof Exception) {
                    throw (Exception) t;
                } else {
                    throw new UndeclaredThrowableException(t, method.toString());
                }
            }

            return value;
        } finally {
            if (newCL != null && newCL != oldCL) {
                thread.setContextClassLoader(oldCL);
            }
        }
    }
}
```

Let's go through the key details of this service. The `InvokerAdaptorServiceMBean` Standard MBean interface of the `InvokerAdaptorService` has a single `ExportedInterface` attribute and a single `invoke(Invocation)` operation. The `ExportedInterface` attribute allows customization of the type of interface the service exposes to clients. This has to be compatible with the `MBeanServer` class in terms of method name and signature. The `invoke(Invocation)` operation is the required entry point that target MBean services must expose to participate in the detached invoker pattern. This operation is invoked by the detached invoker services that have been configured to provide access to the `InvokerAdaptorService`.

Lines 54-64 of the InvokerAdaptorService build the HashMap<Long, Method> of the ExportedInterface Class using the `org.jboss.invocation.MarshalledInvocation.calculateHash(Method)` utility method. Because java.lang.reflect.Method instances are not serializable, a MarshalledInvocation version of the non-serializable Invocation class is used to marshall the invocation between the client and server. The MarshalledInvocation replaces the Method instances with their corresponding hash representation. On the server side, the MarshalledInvocation must be told what the hash to Method mapping is.

Line 64 creates a mapping between the InvokerAdaptorService service name and its hash code representation. This is used by detached invokers to determine what the target MBean ObjectName of an Invocation is. When the target MBean name is store in the Invocation, its store as its hashCode because ObjectNames are relatively expensive objects to create. The org.jboss.system.Registry is a global map like construct that invokers use to store the hash code to ObjectName mappings in.

Lines 77-93 obtain the name of the MBean on which the MBeanServer operation is being performed and lookup the class loader associated with the MBean's SAR deployment. This information is available via the org.jboss.mx.server.registry.BasicMBeanRegistry, a JBoss JMX implementation specific class. It is generally necessary for an MBean to establish the correct class loading context because the detached invoker protocol layer may not have access to the class loaders needed to unmarshall the types associated with an invocation.

Lines 101-105 install the ExposedInterface class method hash to method mapping if the invocation argument is of type MarshalledInvocation. The method mapping calculated previously at lines 54-62 is used here.

Lines 107-114 perform a second mapping from the ExposedInterface Method to the matching method of the MBeanServer class. The InvokerServiceAdaptor decouples the ExposedInterface from the MBeanServer class in that it allows an arbitrary interface. This is needed on one hand because the standard java.lang.reflect.Proxy class can only proxy interfaces. It also allows one to only expose a subset of the MBeanServer methods and add transport specific exceptions like java.rmi.RemoteException to the ExposedInterface method signatures.

Line 115 dispatches the MBeanServer method invocation to the MBeanServer instance to which the InvokerAdaptorService was deployed. The server instance variable is inherited from the ServiceMBeanSupport superclass.

Lines 117-124 handle any exceptions coming from the reflective invocation including the unwrapping of any declared exception thrown by the invocation.

Line 126 is the return of the successful MBeanServer method invocation result.

Note that the InvokerAdaptorService MBean does not deal directly with any transport specific details. There is the calculation of the method hash to Method mapping, but this is a transport independent detail.

Now let's take a look at how the InvokerAdaptorService may be used to expose the same org.jboss.jmx.adaptor.rmi.RMIAdaptor interface via RMI/JRMP as seen in Connecting to JMX Using RMI. We will start by presenting the proxy factory and InvokerAdaptorService configurations found in the default setup in the jmx-invoker-adaptor-service.sar deployment. Example 1.17 shows the jboss-service.xml descriptor for this deployment.

Example 1.17. The default jmx-invoker-adaptor-server.sar jboss-service.xml deployment descriptor

```
<server>
    <!-- The JRMP invoker proxy configuration for the InvokerAdaptorService -->
    <mbean code="org.jboss.invocation.jrmp.server.JRMPProxyFactory"
           name="jboss.jmx:type=adaptor,name=Invoker,protocol=jrmp,service=proxyFactory">
        <!-- Use the standard JRMPInvoker from conf/jboss-service.xml -->
        <attribute name="InvokerName">jboss:service=invoker,type=jrmp</attribute>
        <!-- The target MBean is the InvokerAdaptorService configured below -->
        <attribute name="TargetName">jboss.jmx:type=adaptor,name=Invoker</attribute>
        <!-- Where to bind the RMIAdaptor proxy -->
        <attribute name="JndiName">jmx/invoker/RMIAdaptor</attribute>
        <!-- The RMI compabitle MBeanServer interface -->
        <attribute name="ExportedInterface">org.jboss.jmx.adaptor.rmi.RMIAdaptor</attribute>
        <attribute name="ClientInterceptors">
            <iterceptors>
                <interceptor>org.jboss.proxy.ClientMethodInterceptor</interceptor>
                <interceptor>
                    org.jboss.jmx.connector.invoker.client.InvokerAdaptorClientInterceptor
                </interceptor>
                <interceptor>org.jboss.invocation.InvokerInterceptor</interceptor>
            </iterceptors>
        </attribute>
        <depends>jboss:service=invoker,type=jrmp</depends>
    </mbean>
    <!-- This is the service that handles the RMIAdaptor invocations by routing
         them to the MBeanServer the service is deployed under. -->
    <mbean code="org.jboss.jmx.connector.invoker.InvokerAdaptorService"
           name="jboss.jmx:type=adaptor,name=Invoker">
        <attribute name="ExportedInterface">org.jboss.jmx.adaptor.rmi.RMIAdaptor</attribute>
    </mbean>
</server>
```

The first MBean, `org.jboss.invocation.jrmp.server.JRMPProxyFactory`, is the proxy factory MBean service that creates proxies for the RMI/JRMP protocol. The configuration of this service as shown in Example 1.17 states that the JRMPInvoker will be used as the detached invoker, the `InvokerAdaptorService` is the target mbean to which requests will be forwarded, that the proxy will expose the `RMIAdaptor` interface, the proxy will be bound into JNDI under the name `jmx/invoker/RMIAdaptor`, and the proxy will contain 3 interceptors: `ClientMethodInterceptor`, `InvokerAdaptorClientInterceptor`, `InvokerInterceptor`. The configuration of the `InvokerAdaptorService` simply sets the RMIAdaptor interface that the service is exposing.

The last piece of the configuration for exposing the `InvokerAdaptorService` via RMI/JRMP is the detached invoker. The detached invoker we will use is the standard RMI/JRMP invoker used by the EJB containers for home and remote invocations, and this is the `org.jboss.invocation.jrmp.server.JRMPInvoker` MBean service configured in the `conf/jboss-service.xml` descriptor. That we can use the same service instance emphasizes the detached nature of the invokers. The JRMPInvoker simply acts as the RMI/JRMP endpoint for all RMI/JRMP proxies regardless of the interface(s) the proxies expose or the service the proxies utilize.

1.6.2. Detached Invoker Reference

1.6.2.1. The JRMPInvoker - RMI/JRMP Transport

The `org.jboss.invocation.jrmp.server.JRMPInvoker` class is an MBean service that provides the RMI/JRMP implementation of the Invoker interface. The JRMPInvoker exports itself as an RMI server so that when it is used as the Invoker in a remote client, the JRMPInvoker stub is sent to the client instead and invocations use the RMI/JRMP protocol.

The JRMPInvoker MBean supports a number of attribute to configure the RMI/JRMP transport layer. Its configurable attributes are:

- **RMIObjectPort**: sets the RMI server socket listening port number. This is the port RMI clients will connect to when communicating through the proxy interface. The default setting in the `jboss-service.xml` descriptor is

4444, and if not specified, the attribute defaults to 0 to indicate an anonymous port should be used.

- **RMIClientSocketFactory**: specifies a fully qualified class name for the `java.rmi.server.RMIClientSocketFactory` interface to use during export of the proxy interface.
- **RMIServerSocketFactory**: specifies a fully qualified class name for the `java.rmi.server.RMIServerSocketFactory` interface to use during export of the proxy interface.
- **ServerAddress**: specifies the interface address that will be used for the RMI server socket listening port. This can be either a DNS hostname or a dot-decimal Internet address. Since the `RMIServerSocketFactory` does not support a method that accepts an InetAddress object, this value is passed to the `RMIServerSocketFactory` implementation class using reflection. A check for the existence of a `public void setBindAddress(java.net.InetAddress addr)` method is made, and if one exists the `RMIServerSocketAddr` value is passed to the `RMIServerSocketFactory` implementation. If the `RMIServerSocketFactory` implementation does not support such a method, the `ServerAddress` value will be ignored.
- **SecurityDomain**: specifies the JNDI name of an `org.jboss.security.SecurityDomain` interface implementation to associate with the `RMIServerSocketFactory` implementation. The value will be passed to the `RMIServerSocketFactory` using reflection to locate a method with a signature of `public void setSecurityDomain(org.jboss.security.SecurityDomain d)`. If no such method exists the `SecurityDomain` value will be ignored.

1.6.2.2. The PooledInvoker - RMI/Socket Transport

The `org.jboss.invocation.pooled.server.PooledInvoker` is an MBean service that provides RMI over a custom socket transport implementation of the Invoker interface. The `PooledInvoker` exports itself as an RMI server so that when it is used as the `Invoker` in a remote client, the `PooledInvoker` stub is sent to the client instead and invocations use the custom socket protocol.

The `PooledInvoker` MBean supports a number of attribute to configure the socket transport layer. Its configurable attributes are:

- **NumAcceptThreads**: The number of threads that exist for accepting client connections. The default is 1.
- **MaxPoolSize**: The number of server threads for processing client. The default is 300.
- **SocketTimeout**: The socket timeout value passed to the `Socket.setSoTimeout()` method. The default is 60000.
- **ServerBindPort**: The port used for the server socket. A value of 0 indicates that an anonymous port should be chosen.
- **ClientConnectAddress**: The address that the client passes to the `Socket(addr, port)` constructor. This defaults to the server `InetAddress.getLocalHost()` value.
- **ClientConnectPort**: The port that the client passes to the `Socket(addr, port)` constructor. The default is the port of the server listening socket.
- **ClientMaxPoolSize**: The client side maximum number of threads. The default is 300.

- **Backlog**: The backlog associated with the server accept socket. The default is 200.
- **EnableTcpNoDelay**: A boolean flag indicating if client sockets will enable the `TcpNoDelay` flag on the socket. The default is false.
- **ServerBindAddress**: The address on which the server binds its listening socket. The default is an empty value which indicates the server should be bound on all interfaces.
- **TransactionManagerService**: The JMX ObjectName of the JTA transaction manager service.

1.6.2.3. The IIOPInvoker - RMI/IIOP Transport

The `org.jboss.invocation.iiop.IIOPInvoker` class is an MBean service that provides the RMI/IIOP implementation of the `Invoker` interface. The `IIOPInvoker` routes IIOP requests to CORBA servants. This is used by the `org.jboss.proxy.ejb.IORFactory` proxy factory to create RMI/IIOP proxies. However, rather than creating Java proxies (as the JRMP proxy factory does), this factory creates CORBA IORs. An `IORFactory` is associated to a given enterprise bean. It registers with the IIOP invoker two CORBA servants: `anEjbHomeCorbaServant` for the bean's `EJBHome` and an `EjbObjectCorbaServant` for the bean's `EJBObjects`.

The IIOPInvoker MBean has no configurable properties, since all properties are configured from the `conf/jacorb.properties` property file used by the JacORB CORBA service.

1.6.2.4. The JRMPProxyFactory Service - Building Dynamic JRMP Proxies

The `org.jboss.invocation.jrmp.server.JRMPProxyFactory` MBean service is a proxy factory that can expose any interface with RMI compatible semantics for access to remote clients using JRMP as the transport.

The JRMPProxyFactory supports the following attributes:

- **InvokerName**: The server side JRMPInvoker MBean service JMX ObjectName string that will handle the RMI/JRMP transport.
- **TargetName**: The server side MBean that exposes the `invoke(Invocation)` JMX operation for the exported interface. This is used as the destination service for any invocations done through the proxy.
- **JndiName**: The JNDI name under which the proxy will be bound.
- **ExportedInterface**: The fully qualified class name of the interface that the proxy implements. This is the typed view of the proxy that the client uses for invocations.
- **ClientInterceptors**: An XML fragment of interceptors/interceptor elements with each interceptor element body specifying the fully qualified class name of an `org.jboss.proxy.Interceptor` implementation to include in the proxy interceptor stack. The ordering of the interceptors/interceptor elements defines the order of the interceptors.

1.6.2.5. The HttpInvoker - RMI/HTTP Transport

The `org.jboss.invocation.http.server.HttpInvoker` MBean service provides support for making invocations into the JMX bus over HTTP. Unlike the `JRMPInvoker`, the `HttpInvoker` is not an implementation of `Invoker`, but it does implement the Invoker.invoke method. The HttpInvoker is accessed indirectly by issuing an HTTP POST against the `org.jboss.invocation.http.servlet.InvokerServlet`. The `HttpInvoker` exports a client side proxy in the form of the `org.jboss.invocation.http.interfaces.HttpInvokerProxy` class, which is an implementation of `Invoker`, and is serializable. The `HttpInvoker` is a drop in replacement for the `JRMPInvoker` as the target of the `bean-invoker` and `home-invoker` EJB configuration elements. The `HttpInvoker` and `InvokerServlet` are deployed in the `http-invoker.sar` discussed in the JNDI chapter in the section entitled Accessing JNDI over HTTP

The HttpInvoker supports the following attributes:

- **InvokerURL**: This is either the http URL to the `InvokerServlet` mapping, or the name of a system property that will be resolved inside the client VM to obtain the http URL to the `InvokerServlet`.
- **InvokerURLPrefix**: If there is no `invokerURL` set, then one will be constructed via the concatenation of `invokerURLPrefix` + the local host + `invokerURLSuffix`. The default prefix is `http://`.
- **InvokerURLSuffix**: If there is no `invokerURL` set, then one will be constructed via the concatenation of `invokerURLPrefix` + the local host + `invokerURLSuffix`. The default suffix is `:8080/invoker/JMXInvokerServlet`.
- **UseHostName**: A boolean flag if the `InetAddress.getHostName()` or `getHostAddress()` method should be used as the host component of `invokerURLPrefix` + host + `invokerURLSuffix`. If true `getHostName()` is used, otherwise `getHostAddress()` is used.

1.6.2.6. The HA JRMPInvoker - Clustered RMI/JRMP Transport

The `org.jboss.proxy.generic.ProxyFactoryHA` service is an extension of the `ProxyFactoryHA` that is a cluster aware factory. The `ProxyFactoryHA` fully supports all of the attributes of the `JRMPProxyFactory`. This means that customized bindings of the port, interface and socket transport are available to clustered RMI/JRMP as well. In addition, the following cluster specific attributes are supported:

- **PartitionObjectName**: The JMX `ObjectName` of the cluster service to which the proxy is to be associated with.
- **LoadBalancePolicy**: The class name of the `org.jboss.ha.framework.interfaces.LoadBalancePolicy` interface implementation to associate with the proxy.

1.6.2.7. The HA HttpInvoker - Clustered RMI/HTTP Transport

The RMI/HTTP layer allows for software load balancing of the invocations in a clustered environment. The HA capable extension of the HTTP invoker borrows much of its functionality from the HA-RMI/JRMP clustering. To enable HA-RMI/HTTP you need to configure the invokers for the EJB container. This is done through either a `jboss.xml` descriptor, or the `standardjboss.xml` descriptor.

1.6.2.8. HttpProxyFactory - Building Dynamic HTTP Proxies

The `org.jboss.invocation.http.server.HttpProxyFactory` MBean service is a proxy factory that can expose any interface with RMI compatible semantics for access to remote clients using HTTP as the transport.

The HttpProxyFactory supports the following attributes:

- **InvokerName**: The server side MBean that exposes the invoke operation for the exported interface. The name is embedded into the `HttpInvokerProxy` context as the target to which the invocation should be forwarded by the `HttpInvoker`.

- **JndiName**: The JNDI name under which the `HttpInvokerProxy` will be bound. This is the name clients lookup to obtain the dynamic proxy that exposes the service interfaces and marshalls invocations over HTTP. This may be specified as an empty value to indicate that the proxy should not be bound into JNDI.
- **InvokerURL**: This is either the http URL to the `InvokerServlet` mapping, or the name of a system property that will be resolved inside the client VM to obtain the http URL to the `InvokerServlet`.
- **InvokerURLPrefix**: If there is no `invokerURL` set, then one will be constructed via the concatenation of `invokerURLPrefix` + the local host + `invokerURLSuffix`. The default prefix is `http://`.
- **InvokerURLSuffix**: If there is no `invokerURL` set, then one will be constructed via the concatenation of `invokerURLPrefix` + the local host + `invokerURLSuffix`. The default suffix is `:8080/invoker/JMXInvokerServlet`.
- **UseHostName**: A boolean flag indicating if the `InetAddress.getHostName()` or `getHostAddress()` method should be used as the host component of `invokerURLPrefix` + host + `invokerURLSuffix`. If true `getHostName()` is used, otherwise `getHostAddress()` is used.
- **ExportedInterface**: The name of the RMI compatible interface that the `HttpInvokerProxy` implements.

1.6.2.9. Steps to Expose Any RMI Interface via HTTP

Using the `HttpProxyFactory` MBean and JMX, you can expose any interface for access using HTTP as the transport. The interface to expose does not have to be an RMI interface, but it does have to be compatible with RMI in that all method parameters and return values are serializable. There is also no support for converting RMI interfaces used as method parameters or return values into their stubs.

The three steps to making your object invocable via HTTP are:

- Create a mapping of longs to the RMI interface methods using the `MarshalledInvocation.calculateHash` method. Here for example, is the procedure for an RMI `SRPRemoteServerInterface` interface:

```
import java.lang.reflect.Method;
import java.util.HashMap;
import org.jboss.invocation.MarshalledInvocation;

HashMap marshalledInvocationMapping = new HashMap();

// Build the Naming interface method map
Method[] methods = SRPRemoteServerInterface.class.getMethods();
for(int m = 0; m < methods.length; m ++) {
    Method method = methods[m];
    Long hash = new Long(MarshalledInvocation.calculateHash(method));
    marshalledInvocationMapping.put(hash, method);
}
```

- Either create or extend an existing MBean to support an invoke operation. Its signature is `Object invoke(Invocation invocation) throws Exception`, and the steps it performs are as shown here for the `SRPRemoteServerInterface` interface. Note that this uses the `marshalledInvocationMapping` from step 1 to map from the `Long` method hashes in the `MarshalledInvocation` to the `Method` for the interface.

```
import org.jboss.invocation.Invocation;
import org.jboss.invocation.MarshalledInvocation;

public Object invoke(Invocation invocation)
    throws Exception
{
    SRPRemoteServerInterface theServer = <the_actual_rmi_server_object>;
    // Set the method hash to Method mapping
    if (invocation instanceof MarshalledInvocation) {
        MarshalledInvocation mi = (MarshalledInvocation) invocation;
        mi.setMethodMap(marshalledInvocationMapping);
    }

    // Invoke the Naming method via reflection
    Method method = invocation.getMethod();
    Object[] args = invocation.getArguments();
    Object value = null;
    try {
        value = method.invoke(theServer, args);
    } catch(InvocationTargetException e) {
        Throwable t = e.getTargetException();
        if (t instanceof Exception) {
            throw (Exception) e;
        } else {
            throw new UndeclaredThrowableException(t, method.toString());
        }
    }

    return value;
}
```

- Create a configuration of the `HttpProxyFactory` MBean to make the RMI/HTTP proxy available through JNDI. For example:

```
<!-- Expose the SRP service interface via HTTP -->
<mbean code="org.jboss.invocation.http.server.HttpProxyFactory"
       name="jboss.security.tests:service=SRP/HTTP">
    <attribute name="InvokerURL">http://localhost:8080/invoker/JMXInvokerServlet</attribute>
    <attribute name="InvokerName">jboss.security.tests:service=SRPService</attribute>
    <attribute name="ExportedInterface">
        org.jboss.security.srp.SRPRemoteServerInterface
    </attribute>
    <attribute name="JndiName">srp-test-http/SRPServerInterface</attribute>
</mbean>
```

Any client may now lookup the RMI interface from JNDI using the name specified in the `HttpProxyFactory` (e.g., `srp-test-http/SRPServerInterface`) and use the obtain proxy in exactly the same manner as the RMI/JRMP version.

2

Naming on JBoss

The JNDI Naming Service

The naming service plays a key role in enterprise Java applications, providing the core infrastructure that is used to locate objects or services in an application server. It is also the mechanism that clients external to the application server use to locate services inside the application server. Application code, whether it is internal or external to the JBoss instance, need only know that it needs to talk to the a message queue named `queue/IncomingOrders` and would not need to worry about any of the details of how the queue is configured. In a clustered environment, naming services are even more valuable. A client of a service would desire to look up the `ProductCatalog` session bean from the cluster without worrying which machine the service is residing. Whether it is a big clustered service, a local resource or just a simple application component that is needed, the JNDI naming service provides the glue that lets code find the objects in the system by name.

2.1. An Overview of JNDI

JNDI is a standard Java API that is bundled with JDK1.3 and higher. JNDI provides a common interface to a variety of existing naming services: DNS, LDAP, Active Directory, RMI registry, COS registry, NIS, and file systems. The JNDI API is divided logically into a client API that is used to access naming services, and a service provider interface (SPI) that allows the user to create JNDI implementations for naming services.

The SPI layer is an abstraction that naming service providers must implement to enable the core JNDI classes to expose the naming service using the common JNDI client interface. An implementation of JNDI for a naming service is referred to as a JNDI provider. JBoss naming is an example JNDI implementation, based on the SPI classes. Note that the JNDI SPI is not needed by J2EE component developers.

For a thorough introduction and tutorial on JNDI, which covers both the client and service provider APIs, see the Sun tutorial at http://java.sun.com/products/jndi/tutorial/.

The main JNDI API package is the `javax.naming` package. It contains five interfaces, 10 classes, and several exceptions. There is one key class, `InitialContext`, and two key interfaces, `Context` and `Name`

2.1.1. Names

The notion of a name is of fundamental importance in JNDI. The naming system determines the syntax that the name must follow. The syntax of the naming system allows the user to parse string representations of names into its components. A name is used with a naming system to locate objects. In the simplest sense, a naming system is just a collection of objects with unique names. To locate an object in a naming system you provide a name to the naming system, and the naming system returns the object store under the name.

As an example, consider the Unix file system's naming convention. Each file is named from its path relative to the root of the file system, with each component in the path separated by the forward slash character ("/"). The file's path is ordered from left to right. The pathname/usr/jboss/readme.txt, for example, names a file readme.txt in the directory jboss, under the directory usr, located in the root of the file system. JBoss naming uses a UNIX-style namespace as its naming convention.

The javax.naming.Name interface represents a generic name as an ordered sequence of components. It can be a composite name (one that spans multiple namespaces), or a compound name (one that is used within a single hierarchical naming system). The components of a name are numbered. The indexes of a name with N components range from 0 up to, but not including, N. The most significant component is at index 0. An empty name has no components.

A composite name is a sequence of component names that span multiple namespaces. An example of a composite name would be the hostname and file combination commonly used with UNIX commands like scp. For example, the following command copies localfile.txt to the file remotefile.txt in the tmp directory on host ahost.someorg.org:

```
scp localfile.txt ahost.someorg.org:/tmp/remotefile.txt
```

A compound name is derived from a hierarchical namespace. Each component in a compound name is an atomic name, meaning a string that cannot be parsed into smaller components. A file pathname in the UNIX file system is an example of a compound name. ahost.someorg.org:/tmp/remotefile.txt is a composite name that spans the DNS and UNIX file system namespaces. The components of the composite name are ahost.someorg.org and /tmp/remotefile.txt. A component is a string name from the namespace of a naming system. If the component comes from a hierarchical namespace, that component can be further parsed into its atomic parts by using the javax.naming.CompoundName class. The JNDI API provides the javax.naming.CompositeName class as the implementation of the Name interface for composite names.

2.1.2. Contexts

The javax.naming.Context interface is the primary interface for interacting with a naming service. The Context interface represents a set of name-to-object bindings. Every context has an associated naming convention that determines how the context parses string names into javax.naming.Name instances. To create a name to object binding you invoke the bind method of a Context and specify a name and an object as arguments. The object can later be retrieved using its name using the Context lookup method. A Context will typically provide operations for binding a name to an object, unbinding a name, and obtaining a listing of all name-to-object bindings. The object you bind into a Context can itself be of type Context . The Context object that is bound is referred to as a subcontext of the Context on which the bind method was invoked.

As an example, consider a file directory with a pathname /usr, which is a context in the UNIX file system. A file directory named relative to another file directory is a subcontext (commonly referred to as a subdirectory). A file directory with a pathname /usr/jboss names a jboss context that is a subcontext of usr. In another example, a DNS domain, such as org, is a context. A DNS domain named relative to another DNS domain is another example of a subcontext. In the DNS domain jboss.org, the DNS domain jboss is a subcontext of org because DNS names are parsed right to left.

2.1.2.1. Obtaining a Context using InitialContext

All naming service operations are performed on some implementation of the Context interface. Therefore, you need a way to obtain a Context for the naming service you are interested in using. The `javax.naming.IntialContext` class implements the `Context` interface, and provides the starting point for interacting with a naming service.

When you create an `InitialContext`, it is initialized with properties from the environment. JNDI determines each property's value by merging the values from the following two sources, in order.

- The first occurrence of the property from the constructor's environment parameter and (for appropriate properties) the applet parameters and system properties.
- All `jndi.properties` resource files found on the classpath.

For each property found in both of these two sources, the property's value is determined as follows. If the property is one of the standard JNDI properties that specify a list of JNDI factories, all of the values are concatenated into a single colon-separated list. For other properties, only the first value found is used. The preferred method of specifying the JNDI environment properties is through a `jndi.properties` file, which allows your code to externalize the JNDI provider specific information so that changing JNDI providers will not require changes to your code or recompilation.

The `Context` implementation used internally by the `InitialContext` class is determined at runtime. The default policy uses the environment property `java.naming.factory.initial`, which contains the class name of the `javax.naming.spi.InitialContextFactory` implementation. You obtain the name of the `InitialContextFactory` class from the naming service provider you are using.

Example 2.1 gives a sample `jndi.properties` file a client application would use to connect to a JBossNS service running on the local host at port 1099. The client application would need to have the `jndi.properties` file available on the application classpath. These are the properties that the JBossNS JNDI implementation requires. Other JNDI providers will have different properties and values.

Example 2.1. A sample jndi.properties file

```
### JBossNS properties
java.naming.factory.initial=org.jnp.interfaces.NamingContextFactory
java.naming.provider.url=jnp://localhost:1099
java.naming.factory.url.pkgs=org.jboss.naming:org.jnp.interfaces
```

2.2. The JBossNS Architecture

The JBossNS architecture is a Java socket/RMI based implementation of the `javax.naming.Context` interface. It is a client/server implementation that can be accessed remotely. The implementation is optimized so that access from within the same VM in which the JBossNS server is running does not involve sockets. Same VM access occurs through an object reference available as a global singleton. Figure 2.1 illustrates some of the key classes in the JBossNS implementation and their relationships.

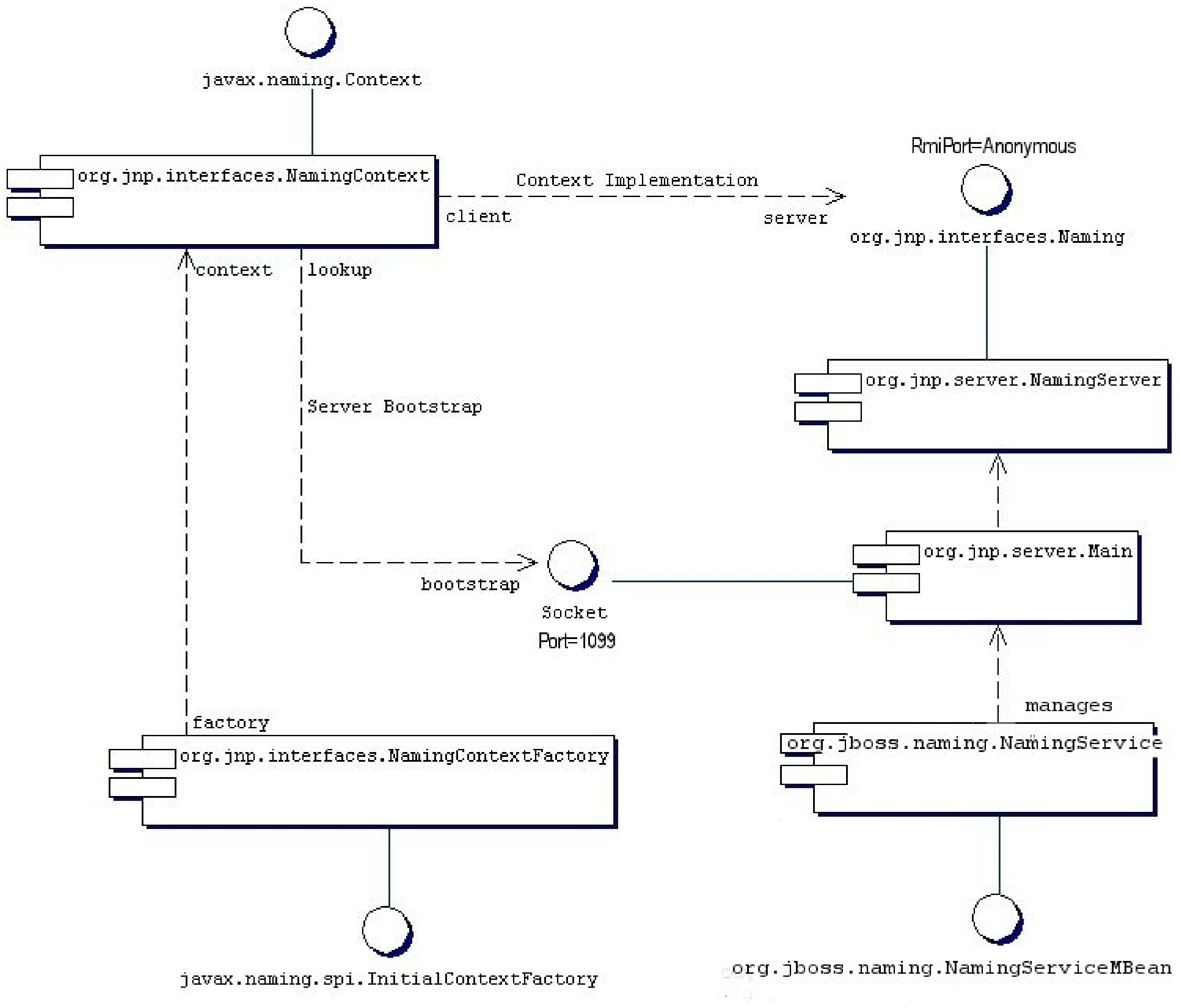

javax.naming.Context
org.jnp.interfaces.NamingContext
Context Implementation
client
server
RmiPort=Anonymous
org.jnp.interfaces.Naming
context
lookup
Server Bootstrap
org.jnp.server.NamingServer
org.jnp.server.Main
bootstrap
Socket
Port=1099
factory
manages
org.jnp.interfaces.NamingContextFactory
org.jboss.naming.NamingService
javax.naming.spi.InitialContextFactory
org.jboss.naming.NamingServiceMBean

Figure 2.1. Key components in the JBossNS architecture.

We will start with the `NamingService` MBean. The `NamingService` MBean provides the JNDI naming service. This is a key service used pervasively by the J2EE technology components. The configurable attributes for the `NamingService` are as follows.

- **Port**: The jnp protocol listening port for the `NamingService`. If not specified default is 1099, the same as the RMI registry default port.
- **RmiPort**: The RMI port on which the RMI Naming implementation will be exported. If not specified the default is 0 which means use any available port.
- **BindAddress**: The specific address the `NamingService` listens on. This can be used on a multi-homed host for a `java.net.ServerSocket` that will only accept connect requests on one of its addresses.
- **RmiBindAddress**: The specific address the RMI server portion of the `NamingService` listens on. This can be

used on a multi-homed host for a `java.net.ServerSocket` that will only accept connect requests on one of its addresses. If this is not specified and the `BindAddress` is, the `RmiBindAddress` defaults to the `BindAddress` value.

- **Backlog**: The maximum queue length for incoming connection indications (a request to connect) is set to the `backlog` parameter. If a connection indication arrives when the queue is full, the connection is refused.
- **ClientSocketFactory**: An optional custom `java.rmi.server.RMIClientSocketFactory` implementation class name. If not specified the default `RMIClientSocketFactory` is used.
- **ServerSocketFactory**: An optional custom `java.rmi.server.RMIServerSocketFactory` implementation class name. If not specified the default `RMIServerSocketFactory` is used.
- **JNPServerSocketFactory**: An optional custom `javax.net.ServerSocketFactory` implementation class name. This is the factory for the `ServerSocket` used to bootstrap the download of the JBossNS `Naming` interface. If not specified the `javax.net.ServerSocketFactory.getDefault()` method value is used.

The `NamingService` also creates the `java:comp` context such that access to this context is isolated based on the context class loader of the thread that accesses the `java:comp` context. This provides the application component private ENC that is required by the J2EE specs. This segregation is accomplished by binding a `javax.naming.Reference` to a context that uses the `org.jboss.naming.ENCFactory` as its `javax.naming.ObjectFactory`. When a client performs a lookup of `java:comp`, or any subcontext, the `ENCFactory` checks the thread context `ClassLoader`, and performs a lookup into a map using the `ClassLoader` as the key.

If a context instance does not exist for the class loader instance, one is created and associated with that class loader in the `ENCFactory` map. Thus, correct isolation of an application component's ENC relies on each component receiving a unique `ClassLoader` that is associated with the component threads of execution.

The `NamingService` delegates its functionality to an `org.jnp.server.Main` MBean. The reason for the duplicate MBeans is because JBossNS started out as a stand-alone JNDI implementation, and can still be run as such. The `NamingService` MBean embeds the `Main` instance into the JBoss server so that usage of JNDI with the same VM as the JBoss server does not incur any socket overhead. The configurable attributes of the NamingService are really the configurable attributes of the JBossNS `Main` MBean. The setting of any attributes on the `NamingService` MBean simply set the corresponding attributes on the `Main` MBean the `NamingService` contains. When the `NamingService` is started, it starts the contained `Main` MBean to activate the JNDI naming service.

In addition, the `NamingService` exposes the `Naming` interface operations through a JMX detyped invoke operation. This allows the naming service to be accessed via JMX adaptors for arbitrary protocols. We will look at an example of how HTTP can be used to access the naming service using the invoke operation later in this chapter.

The details of threads and the thread context class loader won't be explored here, but the JNDI tutorial provides a concise discussion that is applicable. See http://java.sun.com/products/jndi/tutorial/beyond/misc/classloader.html for the details.

When the `Main` MBean is started, it performs the following tasks:

- Instantiates an `org.jnp.naming.NamingService` instance and sets this as the local VM server instance. This is used by any `org.jnp.interfaces.NamingContext` instances that are created within the JBoss server VM to avoid RMI calls over TCP/IP.

- Exports the `NamingServer` instance's `org.jnp.naming.interfaces.Naming` RMI interface using the configured `RmiPort`, `ClientSocketFactory`, `ServerSocketFactory`attributes.
- Creates a socket that listens on the interface given by the `BindAddress` and `Port` attributes.
- Spawns a thread to accept connections on the socket.

2.3. The Naming InitialContext Factories

The JBoss JNDI provider currently supports several different `InitialContext` factory implementations.

2.3.1. The standard naming context factory

The most commonly used factory is the `org.jnp.interfaces.NamingContextFactory` implementation. Its properties include:

- **java.naming.factory.initial**: The name of the environment property for specifying the initial context factory to use. The value of the property should be the fully qualified class name of the factory class that will create an initial context. If it is not specified, a `javax.naming.NoInitialContextException` will be thrown when an `InitialContext` object is created.
- **java.naming.provider.url**: The name of the environment property for specifying the location of the JBoss JNDI service provider the client will use. The `NamingContextFactory` class uses this information to know which JBossNS server to connect to. The value of the property should be a URL string. For JBossNS the URL format is `jnp://host:port/[jndi_path]`. The `jnp:` portion of the URL is the protocol and refers to the socket/RMI based protocol used by JBoss. The `jndi_path` portion of the URL is an optional JNDI name relative to the root context, for example, `apps` or `apps/tmp`. Everything but the host component is optional. The following examples are equivalent because the default port value is 1099.
  - `jnp://www.jboss.org:1099/`
  - `www.jboss.org:1099`
  - `www.jboss.org`
- **java.naming.factory.url.pkgs**: The name of the environment property for specifying the list of package prefixes to use when loading in URL context factories. The value of the property should be a colon-separated list of package prefixes for the class name of the factory class that will create a URL context factory. For the JBoss JNDI provider this must be `org.jboss.naming:org.jnp.interfaces`. This property is essential for locating the `jnp:` and `java:` URL context factories of the JBoss JNDI provider.
- **jnp.socketFactory**: The fully qualified class name of the `javax.net.SocketFactory` implementation to use to create the bootstrap socket. The default value is `org.jnp.interfaces.TimedSocketFactory`. The `TimedSocketFactory` is a simple `SocketFactory` implementation that supports the specification of a connection and read timeout. These two properties are specified by:
- **jnp.timeout**: The connection timeout in milliseconds. The default value is 0 which means the connection will block until the VM TCP/IP layer times out.
- **jnp.sotimeout**: The connected socket read timeout in milliseconds. The default value is 0 which means reads

will block. This is the value passed to the `Socket.setSoTimeout` on the newly connected socket.

When a client creates an `InitialContext` with these JBossNS properties available, the `org.jnp.interfaces.NamingContextFactory` object is used to create the `Context` instance that will be used in subsequent operations. The `NamingContextFactory` is the JBossNS implementation of the `javax.naming.spi.InitialContextFactory` interface. When the `NamingContextFactory` class is asked to create a `Context`, it creates an `org.jnp.interfaces.NamingContext` instance with the `InitialContext` environment and name of the context in the global JNDI namespace. It is the `NamingContext` instance that actually performs the task of connecting to the JBossNS server, and implements the `Context` interface. The `Context.PROVIDER_URL` information from the environment indicates from which server to obtain a `NamingServer` RMI reference.

The association of the `NamingContext` instance to a `NamingServer` instance is done in a lazy fashion on the first `Context` operation that is performed. When a `Context` operation is performed and the `NamingContext` has no `NamingServer` associated with it, it looks to see if its environment properties define a `Context.PROVIDER_URL`. A `Context.PROVIDER_URL` defines the host and port of the JBossNS server the `Context` is to use. If there is a provider URL, the `NamingContext` first checks to see if a `Naming` instance keyed by the host and port pair has already been created by checking a `NamingContext` class static map. It simply uses the existing `Naming` instance if one for the host port pair has already been obtained. If no `Naming` instance has been created for the given host and port, the `NamingContext` connects to the host and port using a `java.net.Socket`, and retrieves a `Naming` RMI stub from the server by reading a `java.rmi.MarshalledObject` from the socket and invoking its get method. The newly obtained Naming instance is cached in the `NamingContext` server map under the host and port pair. If no provider URL was specified in the JNDI environment associated with the context, the `NamingContext` simply uses the in VM Naming instance set by the `Main` MBean.

The `NamingContext` implementation of the `Context` interface delegates all operations to the `Naming` instance associated with the `NamingContext`. The `NamingServer` class that implements the `Naming` interface uses a `java.util.Hashtable` as the `Context` store. There is one unique `NamingServer` instance for each distinct JNDI Name for a given JBossNS server. There are zero or more transient `NamingContext` instances active at any given moment that refers to a `NamingServer` instance. The purpose of the `NamingContext` is to act as a `Context` to the `Naming` interface adaptor that manages translation of the JNDI names passed to the `NamingContext` . Because a JNDI name can be relative or a URL, it needs to be converted into an absolute name in the context of the JBossNS server to which it refers. This translation is a key function of the `NamingContext`.

2.3.2. The org.jboss.naming.NamingContextFactory

This version of the `InitialContextFactory` implementation is a simple extension of the jnp version which differs from the jnp version in that it stores the last configuration passed to its `InitialContextFactory.getInitialContext(Hashtable env)` method in a public thread local variable. This is used by EJB handles and other JNDI sensitive objects like the `UserTransaction` factory to keep track of the JNDI context that was in effect when they were created. If you want this environment to be bound to the object even after its serialized across vm boundaries, then you should the `org.jboss.naming.NamingContextFactory`. If you want the environment that is defined in the current VM `jndi.properties` or system properties, then you should use the `org.jnp.interfaces.NamingContextFactory` version.

2.3.3. Naming Discovery in Clustered Environments

When running in a clustered JBoss environment, you can choose not to specify a `Context.PROVIDER_URL` value and let the client query the network for available naming services. This only works with JBoss servers running with the `all` configuration, or an equivalent configuration that has `org.jboss.ha.framework.server.ClusterPartition` and `org.jboss.ha.jndi.HANamingService` services deployed. The discovery process consists of sending a multicast request packet to the discovery address/port and waiting for any node to respond. The response is a HA-RMI version of the `Naming` interface. The following `InitialContext` proerties affect the discovery configuration:

- **jnp.partitionName**: The cluster partition name discovery should be restricted to. If you are running in an environment with multiple clusters, you may want to restrict the naming discovery to a particular cluster. There is no default value, meaning that any cluster response will be accepted.
- **jnp.discoveryGroup**: The multicast IP/address to which the discovery query is sent. The default is 230.0.0.4.
- **jnp.discoveryPort**: The port to which the discovery query is sent. The default is 1102.
- **jnp.discoveryTimeout**: The time in milliseconds to wait for a discovery query response. The default value is 5000 (5 seconds).
- **jnp.disableDiscovery**: A flag indicating if the discovery process should be avoided. Discovery occurs when either no `Context.PROVIDER_URL` is specified, or no valid naming service could be located among the URLs specified. If the `jnp.disableDiscovery` flag is true, then discovery will not be attempted.

2.3.4. The HTTP InitialContext Factory Implementation

The JNDI naming service can be accessed over HTTP. From a JNDI client's perspective this is a transparent change as they continue to use the JNDI `Context` interface. Operations through the `Context` interface are translated into HTTP posts to a servlet that passes the request to the NamingService using its JMX invoke operation. Advantages of using HTTP as the access protocol include better access through firewalls and proxies setup to allow HTTP, as well as the ability to secure access to the JNDI service using standard servlet role based security.

To access JNDI over HTTP you use the `org.jboss.naming.HttpNamingContextFactory` as the factory implementation. The complete set of support `InitialContext` environment properties for this factory are:

- **java.naming.factory.initial**: The name of the environment property for specifying the initial context factory, which must be `org.jboss.naming.HttpNamingContextFactory`.
- **java.naming.provider.url** (or `Context.PROVIDER_URL`): This must be set to the HTTP URL of the JNDI factory. The full HTTP URL would be the public URL of the JBoss servlet container plus `/invoker/JNDIFactory`. Examples include:

  - `http://www.jboss.org:8080/invoker/JNDIFactory`
  - `http://www.jboss.org/invoker/JNDIFactory`
  - `https://www.jboss.org/invoker/JNDIFactory`

  The first example accesses the servlet using the port 8080. The second uses the standard HTTP port 80, and the third uses an SSL encrypted connection to the standard HTTPS port 443.
- **java.naming.factory.url.pkgs**: For all JBoss JNDI provider this must be `org.jboss.naming:org.jnp.interfaces`. This property is essential for locating the `jnp:` and `java:` URL context factories of the JBoss JNDI provider.

The JNDI `Context` implementation returned by the `HttpNamingContextFactory` is a proxy that delegates invocations made on it to a bridge servlet which forwards the invocation to the `NamingService` through the JMX bus and marshalls the reply back over HTTP. The proxy needs to know what the URL of the bridge servlet is in order to operate. This value may have been bound on the server side if the JBoss web server has a well known public interface. If the JBoss web server is sitting behind one or more firewalls or proxies, the proxy cannot know what URL is required. In this case, the proxy will be associated with a system property value that must be set in the client VM. For more information on the operation of JNDI over HTTP see Section 2.4.1.

2.3.5. The Login InitialContext Factory Implementation

JAAS is the preferred method for authenticating a remote client to JBoss. However, for simplicity and to ease the migration from other application server environment that do not use JAAS, JBoss alows you the security credentials to be passed through the `InitialContext`. JAAS is still used under the covers, but there is no manifest use of the JAAS interfaces in the client application.

The factory class that provides this capability is the `org.jboss.security.jndi.LoginInitialContextFactory`. The complete set of support `InitialContext` environment properties for this factory are:

- **java.naming.factory.initial**: The name of the environment property for specifying the initial context factory, which must be `org.jboss.security.jndi.LoginInitialContextFactory`.
- **java.naming.provider.url**: This must be set to a `NamingContextFactory` provider URL. The `LoginIntialContext` is really just a wrapper around the `NamingContextFactory` that adds a JAAS login to the existing `NamingContextFactory` behavior.
- **java.naming.factory.url.pkgs**: For all JBoss JNDI provider this must be `org.jboss.naming:org.jnp.interfaces`. This property is essential for locating the `jnp:` and `java:` URL context factories of the JBoss JNDI provider.
- **java.naming.security.principal** (or `Context.SECURITY_PRINCIPAL`): The principal to authenticate. This may be either a `java.security.Principal` implementation or a string representing the name of a principal.
- **java.naming.security.credentials** (or `Context.SECURITY_CREDENTIALS`), The credentials that should be used to authenticate the principal, e.g., password, session key, etc.
- **java.naming.security.protocol**: (`Context.SECURITY_PROTOCOL`) This gives the name of the JAAS login module to use for the authentication of the principal and credentials.

2.3.6. The ORBInitialContextFactory

When using Sun's CosNaming it is necessary to use a different naming context factory from the default. CosNaming looks for the ORB in JNDI instead of using the the ORB configured in `deploy/iiop-service.xml?`. It is necessary to set the global context factory to `org.jboss.iiop.naming.ORBInitialContextFactory`, which sets the ORB to JBoss's ORB. This is done in the `conf/jndi.propeties` file:

```
# DO NOT EDIT THIS FILE UNLESS YOU KNOW WHAT YOU ARE DOING
#
java.naming.factory.initial=org.jboss.iiop.naming.ORBInitialContextFactory
java.naming.factory.url.pkgs=org.jboss.naming:org.jnp.interfaces
```

It is also necessary to use `ORBInitialContextFactory` when using CosNaming in an application client.

2.4. JNDI over HTTP

In addition to the legacy RMI/JRMP with a socket bootstrap protocol, JBoss provides support for accessing its JNDI naming service over HTTP.

2.4.1. Accessing JNDI over HTTP

This capability is provided by `http-invoker.sar`. The structure of the `http-invoker.sar` is:

```
http-invoker.sar
+- META-INF/jboss-service.xml
+- invoker.war
| +- WEB-INF/jboss-web.xml
| +- WEB-INF/classes/org/jboss/invocation/http/servlet/InvokerServlet.class
| +- WEB-INF/classes/org/jboss/invocation/http/servlet/NamingFactoryServlet.class
| +- WEB-INF/classes/org/jboss/invocation/http/servlet/ReadOnlyAccessFilter.class
| +- WEB-INF/classes/roles.properties
| +- WEB-INF/classes/users.properties
| +- WEB-INF/web.xml
| +- META-INF/MANIFEST.MF
+- META-INF/MANIFEST.MF
```

The `jboss-service.xml` descriptor defines the `HttpInvoker` and `HttpInvokerHA` MBeans. These services handle the routing of methods invocations that are sent via HTTP to the appropriate target MBean on the JMX bus.

The `http-invoker.war` web application contains servlets that handle the details of the HTTP transport. The `NamingFactoryServlet` handles creation requests for the JBoss JNDI naming service `javax.naming.Context` implementation. The `InvokerServlet` handles invocations made by RMI/HTTP clients. The `ReadOnlyAccessFilter` allows one to secure the JNDI naming service while making a single JNDI context available for read-only access by unauthenticated clients.

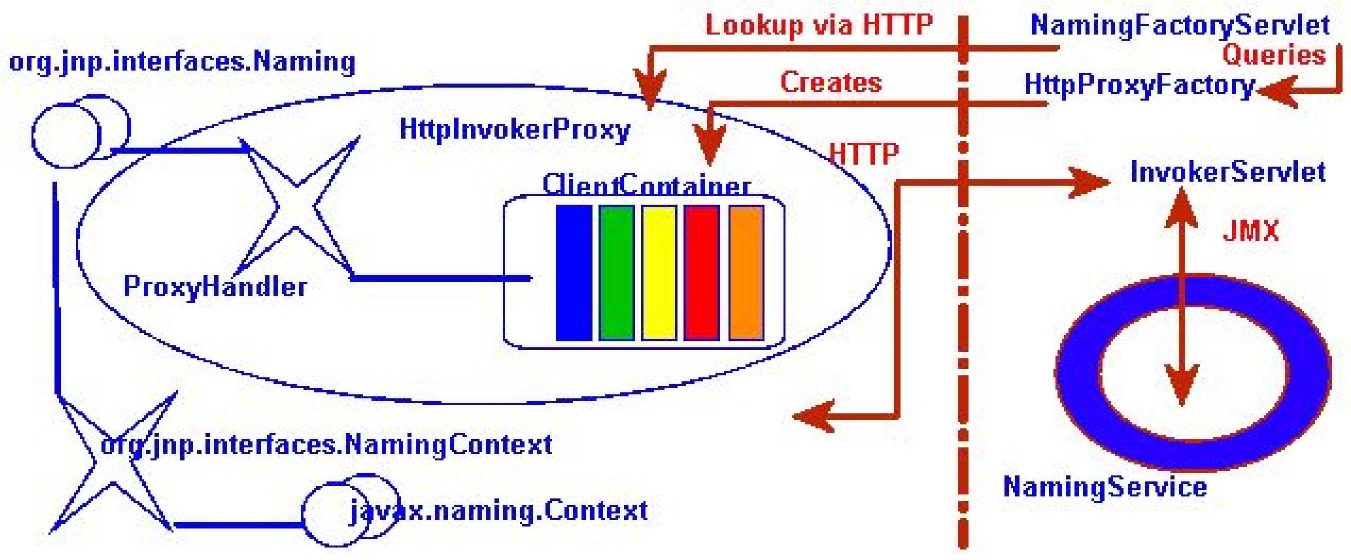


Figure 2.2. The HTTP invoker proxy/server structure for a JNDI Context

Before looking at the configurations let's look at the operation of the `http-invoker` services. Figure 2.2 shows a logical view of the structure of a JBoss JNDI proxy and its relationship to the JBoss server side components of the `http-invoker`. The proxy is obtained from the `NamingFactoryServlet` using an `InitialContext` with the `Context.INITIAL_CONTEXT_FACTORY` property set to `org.jboss.naming.HttpNamingContextFactory`, and the `Context.PROVIDER_URL` property set to the HTTP URL of the `NamingFactoryServlet`. The resulting proxy is embedded in an `org.jnp.interfaces.NamingContext` instance that provides the `Context` interface implementation.

The proxy is an instance of `org.jboss.invocation.http.interfaces.HttpInvokerProxy`, and implements the `org.jnp.interfaces.Naming` interface. Internally the `HttpInvokerProxy` contains an invoker that marshalls the `Naming` interface method invocations to the `InvokerServlet` via HTTP posts. The `InvokerServlet` translates these posts into JMX invocations to the `NamingService`, and returns the invocation response back to the proxy in the HTTP post reponse.

There are several configuration values that need to be set to tie all of these components together and Figure 2.3 illustrates the relationship between configuration files and the corresponding components.

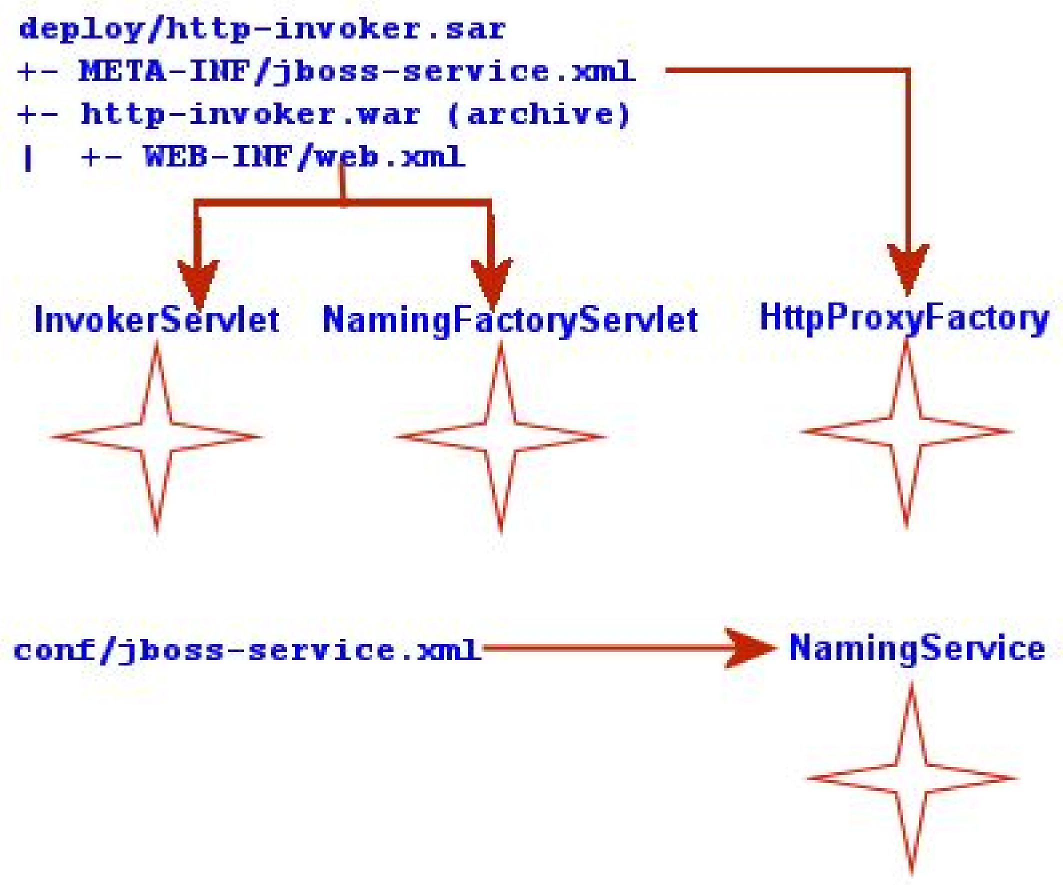


Figure 2.3. The relationship between configuration files and JNDI/HTTP component

The `http-invoker.sar/META-INF/jboss-service.xml` descriptor defines the `HttpProxyFactory` that creates the `HttpInvokerProxy` for the `NamingService`. The attributes that need to be configured for the `HttpProxyFactory` include:

- **InvokerName**: The JMX `ObjectName` of the `NamingService` defined in the `conf/jboss-service.xml` descriptor. The standard setting used in the JBoss distributions is `jboss:service=Naming`.
- **InvokerURL** or **InvokerURLPrefix** + InvokerURLSuffix + **UseHostName**. You can specify the full HTTP URL to the `InvokerServlet` using the `InvokerURL` attribute, or you can specify the hostname independent parts of the URL and have the `HttpProxyFactory` fill them in. An example `InvokerURL` value would be `http://jbosshost1.dot.com:8080/invoker/JMXInvokerServlet`. This can be broken down into:
    - **InvokerURLPrefix**: the URL prefix prior to the hostname. Typically this will be `http://` or `https://` if SSL is to be used.
    - **InvokerURLSuffix**: the URL suffix after the hostname. This will include the port number of the web server as well as the deployed path to the `InvokerServlet` . For the example `InvokerURL` value the `InvokerURLSuffix` would be `:8080/invoker/JMXInvokerServlet` without the quotes. The port number is determined by the web container service settings. The path to the `InvokerServlet` is specified in the `http-invoker.sar/invoker.war/WEB-INF/web.xml` descriptor.
    - **UseHostName**: a flag indicating if the hostname should be used in place of the host IP address when building the hostname portion of the full `InvokerURL`. If true, `InetAddress.getLocalHost().getHostName` method will be used. Otherwise, the `InetAddress.getLocalHost().getHostAddress()` method is used.
- **ExportedInterface**: The `org.jnp.interfaces.Naming` interface the proxy will expose to clients. The actual client of this proxy is the JBoss JNDI implementation `NamingContext` class, which JNDI client obtain from `InitialContext` lookups when using the JBoss JNDI provider.
- **JndiName**: The name in JNDI under which the proxy is bound. This needs to be set to a blank/empty string to indicate the interface should not be bound into JNDI. We can't use the JNDI to bootstrap itself. This is the role of the `NamingFactoryServlet`.

The `http-invoker.sar/invoker.war/WEB-INF/web.xml` descriptor defines the mappings of the `NamingFactoryServlet` and `InvokerServlet` along with their initialzation parameters. The configuration of the `NamingFactoryServlet` relevant to JNDI/HTTP is the `JNDIFactory` entry which defines:

- A `namingProxyMBean` initialization parameter that maps to the `HttpProxyFactory` MBean name. This is used by the `NamingFactoryServlet` to obtain the `Naming` proxy which it will return in response to HTTP posts. For the default `http-invoker.sar/META-INF/jboss-service.xml` settings the name `jboss:service=invoker,type=http,target=Naming`.
- A proxy initialzation parameter that defines the name of the `namingProxyMBean` attribute to query for the Naming proxy value. This defaults to an attribute name of `Proxy`.
- The servlet mapping for the `JNDIFactory` configuration. The default setting for the unsecured mapping is `/JNDIFactory/*`. This is relative to the context root of the `http-invoker.sar/invoker.war`, which by default is the WAR name minus the `.war` suffix.

The configuration of the `InvokerServlet` relevant to JNDI/HTTP is the `JMXInvokerServlet` which defines:

- The servlet mapping of the `InvokerServlet`. The default setting for the unsecured mapping is `/JMXInvokerServlet/*`. This is relative to the context root of the `http-invoker.sar/invoker.war`, which by default is the WAR name minus the `.war` suffix.

2.4.2. Accessing JNDI over HTTPS

To be able to access JNDI over HTTP/SSL you need to enable an SSL connector on the web container. The details of this are covered in the Integrating Servlet Containers for Tomcat. We will demonstrate the use of HTTPS with a simple example client that uses an HTTPS URL as the JNDI provider URL. We will provide an SSL connector configuration for the example, so unless you are interested in the details of the SSL connector setup, the example is self contained.

We also provide a configuration of the `HttpProxyFactory` setup to use an HTTPS URL. The following example shows the section of the `http-invoker.sar` `jboss-service.xml` descriptor that the example installs to provide this configuration. All that has changed relative to the standard HTTP configuration are the `InvokerURLPrefix` and `InvokerURLSuffix` attributes, which setup an HTTPS URL using the 8443 port.

```
<!-- Expose the Naming service interface via HTTPS -->
<mbean code="org.jboss.invocation.http.server.HttpProxyFactory"
       name="jboss:service=invoker,type=https,target=Naming">
    <!-- The Naming service we are proxying -->
    <attribute name="InvokerName">jboss:service=Naming</attribute>
    <!-- Compose the invoker URL from the cluster node address -->
    <attribute name="InvokerURLPrefix">https://</attribute>
    <attribute name="InvokerURLSuffix">:8443/invoker/JMXInvokerServlet </attribute>
    <attribute name="UseHostName">true</attribute>
    <attribute name="ExportedInterface">org.jnp.interfaces.Naming </attribute>
    <attribute name="JndiName"/>
    <attribute name="ClientInterceptors">
        <interceptors>
            <interceptor>org.jboss.proxy.ClientMethodInterceptor </interceptor>
            <interceptor>org.jboss.proxy.SecurityInterceptor</interceptor>
            <interceptor>org.jboss.naming.interceptors.ExceptionInterceptor </interceptor>
            <interceptor>org.jboss.invocation.InvokerInterceptor </interceptor>
        </interceptors>
    </attribute>
</mbean>
```

At a minimum, a JNDI client using HTTPS requires setting up a HTTPS URL protocol handler. We will be using the Java Secure Socket Extension (JSSE) for HTTPS. The JSSE documentation does a good job of describing what is necessary to use HTTPS, and the following steps were needed to configure the example client shown in Example 2.2:

- A protocol handler for HTTPS URLs must be made available to Java. The JSSE release includes an HTTPS handler in the `com.sun.net.ssl.internal.www.protocol` package. To enable the use of HTTPS URLs you include this package in the standard URL protocol handler search property, `java.protocol.handler.pkgs`. We set the `java.protocol.handler.pkgs` property in the Ant script.

- The JSSE security provider must be installed in order for SSL to work. This can be done either by installing the JSSE jars as an extension package, or programatically. We use the programatic approach in the example since this is less intrusive. Line 18 of the `ExClient` code demonstrates how this is done.

- The JNDI provider URL must use HTTPS as the protocol. Lines 24-25 of the `ExClient` code specify an HTTP/SSL connection to the localhost on port 8443. The hostname and port are defined by the web container SSL connector.

- The validation of the HTTPS URL hostname against the server certificate must be disabled. By default, the JSSE HTTPS protocol handler employs a strict validation of the hostname portion of the HTTPS URL against the common name of the server certificate. This is the same check done by web browsers when you connect to secured web site. We are using a self-signed server certificate that uses a common name of "`Chapter 8 SSL Example`" rather than a particular hostname, and this is likely to be common in development environments or intranets. The JBoss `HttpInvokerProxy` will override the default hostname checking if a `org.jboss.security.ignoreHttpsHost` system property exists and has a value of true. We set the `org.jboss.security.ignoreHttpsHost` property to true in the Ant script.

Example 2.2. A JNDI client that uses HTTPS as the transport

```
package org.jboss.chap3.ex1;

import java.security.Security;
import java.util.Properties;
import javax.naming.Context;
import javax.naming.InitialContext;

public class ExClient
{
    public static void main(String args[]) throws Exception
    {
        Properties env = new Properties();
        env.setProperty(Context.INITIAL_CONTEXT_FACTORY,
                        "org.jboss.naming.HttpNamingContextFactory");
        env.setProperty(Context.PROVIDER_URL,
                        "https://localhost:8443/invoker/JNDIFactorySSL");

        Context ctx = new InitialContext(env);
        System.out.println("Created InitialContext, env=" + env);

        Object data = ctx.lookup("jmx/invoker/RMIAdaptor");
        System.out.println("lookup(jmx/invoker/RMIAdaptor): " + data);
    }
}
```

To test the client, first build the chapter 3 example to create the `chap3` configuration fileset.

```
[examples]$ ant -Dchap=naming config
```

Next, start the JBoss server using the `naming` configuration fileset:

```
[bin]$ sh run.sh -c naming
```

And finally, run the `ExClient` using:

```
[examples]$ ant -Dchap=naming -Dex=1 run-example
...
run-example1:
     [java] Created InitialContext, env={java.naming.provider.url=https://localhost:8443/invo
ker/JNDIFactorySSL, java.naming.factory.initial=org.jboss.naming.HttpNamingContextFactory}
     [java] lookup(jmx/invoker/RMIAdaptor): org.jboss.invocation.jrmp.interfaces.JRMPInvokerP
roxy@cac3fa
```

2.4.3. Securing Access to JNDI over HTTP

One benefit to accessing JNDI over HTTP is that it is easy to secure access to the JNDI `InitialContext` factory as well as the naming operations using standard web declarative security. This is possible because the server side handling of the JNDI/HTTP transport is implemented with two servlets. These servlets are included in the `http-invoker.sar/invoker.war` directory found in the `default` and `all` configuration deploy directories as shown previously. To enable secured access to JNDI you need to edit the `invoker.war/WEB-INF/web.xml` descriptor and remove all unsecured servlet mappings. For example, the `web.xml` descriptor shown in Example 2.3 only allows access to the `invoker.war` servlets if the user has been authenticated and has a role of `HttpInvoker`.

Example 2.3. An example web.xml descriptor for secured access to the JNDI servlets

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE web-app PUBLIC
          "-//Sun Microsystems, Inc.//DTD Web Application 2.3//EN"
          "http://java.sun.com/dtd/web-app_2_3.dtd">
<web-app>
    <!-- ### Servlets -->
    <servlet>
        <servlet-name>JMXInvokerServlet</servlet-name>
        <servlet-class>
            org.jboss.invocation.http.servlet.InvokerServlet
        </servlet-class>
        <load-on-startup>1</load-on-startup>
    </servlet>   <servlet>
        <servlet-name>JNDIFactory</servlet-name>
        <servlet-class>
            org.jboss.invocation.http.servlet.NamingFactoryServlet
        </servlet-class>
        <init-param>
            <param-name>namingProxyMBean</param-name>
            <param-value>jboss:service=invoker,type=http,target=Naming</param-value>
        </init-param>
        <init-param>
            <param-name>proxyAttribute</param-name>
            <param-value>Proxy</param-value>
        </init-param>
        <load-on-startup>2</load-on-startup>
    </servlet>
    <!-- ### Servlet Mappings -->
    <servlet-mapping>
        <servlet-name>JNDIFactory</servlet-name>
        <url-pattern>/restricted/JNDIFactory/*</url-pattern>
    </servlet-mapping>
    <servlet-mapping>
        <servlet-name>JMXInvokerServlet</servlet-name>
        <url-pattern>/restricted/JMXInvokerServlet/*</url-pattern>
    </servlet-mapping>   <security-constraint>
        <web-resource-collection>
            <web-resource-name>HttpInvokers</web-resource-name>
            <description>An example security config that only allows users with
                the role HttpInvoker to access the HTTP invoker servlets </description>
            <url-pattern>/restricted/*</url-pattern>
            <http-method>GET</http-method>
            <http-method>POST</http-method>
        </web-resource-collection>
        <auth-constraint>
            <role-name>HttpInvoker</role-name>
        </auth-constraint>
    </security-constraint>
    <login-config>
```

```
        <auth-method>BASIC</auth-method>
        <realm-name>JBoss HTTP Invoker</realm-name>
    </login-config>   <security-role>
        <role-name>HttpInvoker</role-name>
    </security-role>
</web-app>
```

The `web.xml` descriptor only defines which sevlets are secured, and which roles are allowed to access the secured servlets. You must additionally define the security domain that will handle the authentication and authorization for the war. This is done through the `jboss-web.xml` descriptor, and an example that uses the `http-invoker` security domain is given below.

```
<jboss-web>
    <security-domain>java:/jaas/http-invoker</security-domain>
</jboss-web>
```

The `security-domain` element defines the name of the security domain that will be used for the JAAS login module configuration used for authentication and authorization. See Section 7.1.6 for additional details on the meaning and configuration of the security domain name.

2.4.4. Securing Access to JNDI with a Read-Only Unsecured Context

Another feature available for the JNDI/HTTP naming service is the ability to define a context that can be accessed by unauthenticated users in read-only mode. This can be important for services used by the authentication layer. For example, the `SRPLoginModule` needs to lookup the SRP server interface used to perform authentication. We'll now walk through how read-only JNDI works in JBoss.

First, the `ReadOnlyJNDIFactory` is declared in `invoker.sar/WEB-INF/web.xml`. It will be mapped to `/invoker/ReadOnlyJNDIFactory`.

```
<servlet>
    <servlet-name>ReadOnlyJNDIFactory</servlet-name>
    <description>A servlet that exposes the JBoss JNDI Naming service stub
          through http, but only for a single read-only context. The return content
          is serialized MarshalledValue containg the org.jnp.interfaces.Naming
          stub.
    </description>
    <servlet-class>org.jboss.invocation.http.servlet.NamingFactoryServlet</servlet-class>
    <init-param>
        <param-name>namingProxyMBean</param-name>
        <param-value>jboss:service=invoker,type=http,target=Naming,readonly=true</param-value>
    </init-param>
    <init-param>
        <param-name>proxyAttribute</param-name>
        <param-value>Proxy</param-value>
    </init-param>
    <load-on-startup>2</load-on-startup>
</servlet>

<!-- ... -->

<servlet-mapping>
    <servlet-name>ReadOnlyJNDIFactory</servlet-name>
    <url-pattern>/ReadOnlyJNDIFactory/*</url-pattern>
</servlet-mapping>
```

The factory only provides a JNDI stub which needs to be connected to an invoker. Here the invoker is `jboss:service=invoker,type=http,target=Naming,readonly=true`. This invoker is declared in the `http-invoker.sar/META-INF/jboss-service.xml` file.

```
<mbean code="org.jboss.invocation.http.server.HttpProxyFactory"
   name="jboss:service=invoker,type=http,target=Naming,readonly=true">
   <attribute name="InvokerName">jboss:service=Naming</attribute>
   <attribute name="InvokerURLPrefix">http://</attribute>
   <attribute name="InvokerURLSuffix">:8080/invoker/readonly/JMXInvokerServlet</attribute>
   <attribute name="UseHostName">true</attribute>
   <attribute name="ExportedInterface">org.jnp.interfaces.Naming</attribute>
   <attribute name="JndiName"></attribute>
   <attribute name="ClientInterceptors">
       <interceptors>
          <interceptor>org.jboss.proxy.ClientMethodInterceptor</interceptor>
          <interceptor>org.jboss.proxy.SecurityInterceptor</interceptor>
          <interceptor>org.jboss.naming.interceptors.ExceptionInterceptor</interceptor>
          <interceptor>org.jboss.invocation.InvokerInterceptor</interceptor>
       </interceptors>
   </attribute>
</mbean>
```

The proxy on the client side needs to talk back to a specific invoker servlet on the server side. The configuration here has the actual invocations going to `/invoker/readonly/JMXInvokerServlet`. This is actually the standard `JMXInvokerServlet` with a read-only filter attached.

```
<filter>
    <filter-name>ReadOnlyAccessFilter</filter-name>
    <filter-class>org.jboss.invocation.http.servlet.ReadOnlyAccessFilter</filter-class>
    <init-param>
        <param-name>readOnlyContext</param-name>
        <param-value>readonly</param-value>
        <description>The top level JNDI context the filter will enforce
            read-only access on. If specified only Context.lookup operations
            will be allowed on this context. Another other operations or
            lookups on any other context will fail. Do not associate this
            filter with the JMXInvokerServlets if you want unrestricted
            access. </description>
    </init-param>
    <init-param>
        <param-name>invokerName</param-name>
        <param-value>jboss:service=Naming</param-value>
        <description>The JMX ObjectName of the naming service mbean </description>
    </init-param>
</filter>

<filter-mapping>
    <filter-name>ReadOnlyAccessFilter</filter-name>
    <url-pattern>/readonly/*</url-pattern>
</filter-mapping>

<!-- ... -->
<!-- A mapping for the JMXInvokerServlet that only allows invocations
        of lookups under a read-only context. This is enforced by the
        ReadOnlyAccessFilter
        -->
<servlet-mapping>
    <servlet-name>JMXInvokerServlet</servlet-name>
    <url-pattern>/readonly/JMXInvokerServlet/*</url-pattern>
</servlet-mapping>
```

The `readOnlyContext` parameter is set to `readonly` which means that when you access JBoss through the

ReadOnlyJNDIFactory, you will only be able to access data in the readonly context. Here is a code fragment that illustrates the usage:

```
Properties env = new Properties();
env.setProperty(Context.INITIAL_CONTEXT_FACTORY,
                "org.jboss.naming.HttpNamingContextFactory");
env.setProperty(Context.PROVIDER_URL,
                "http://localhost:8080/invoker/ReadOnlyJNDIFactory");

Context ctx2 = new InitialContext(env);
Object data = ctx2.lookup("readonly/data");
```

Attempts to look up any objects outside of the readonly context will fail. Note that JBoss doesn't ship with any data in the readonly context, so the readonly context won't be bound usable unless you create it.

2.5. Additional Naming MBeans

In addition to the NamingService MBean that configures an embedded JBossNS server within JBoss, there are several additional MBean services related to naming that ship with JBoss. They are JndiBindingServiceMgr, NamingAlias, ExternalContext, and JNDIView.

2.5.1. JNDI Binding Manager

The JNDI binding manager service allows you to quickly bind objects into JNDI for use by application code. The MBean class for the binding service is org.jboss.naming.JNDIBindingServiceMgr. It has a single attribute, BindingsConfig, which accepts an XML document that conforms to the jndi-binding-service_1_0.xsd schema. The content of the BindingsConfig attribute is unmarshalled using the JBossXB framework. The following is an MBean definition that shows the most basic form usage of the JNDI binding manager service.

```
<mbean code="org.jboss.naming.JNDIBindingServiceMgr"
       name="jboss.tests:name=example1">
    <attribute name="BindingsConfig" serialDataType="jbxb">
        <jndi:bindings xmlns:xs="http://www.w3.org/2001/XMLSchema-instance"
                       xmlns:jndi="urn:jboss:jndi-binding-service"
                       xs:schemaLocation="urn:jboss:jndi-binding-service resource:jndi-binding-service_1_
            <jndi:binding name="bindexample/message">
                <jndi:value trim="true">
                    Hello, JNDI!
                </jndi:value>
            </jndi:binding>
        </jndi:bindings>
    </attribute>
</mbean>
```

This binds the text string "Hello, JNDI!" under the JNDI name bindexample/message. An application would look up the value just as it would for any other JNDI value. The trim attribute specifies that leading and trailing whitespace should be ignored. The use of the attribute here is purely for illustrative purposes as the default value is true.

```
InitialContext ctx  = new InitialContext();
String         text = (String) ctx.lookup("bindexample/message");
```

String values themselves are not that interesting. If a JavaBeans property editor is available, the desired class name can be specified using the type attribute

```
<jndi:binding name="urls/jboss-home">
    <jndi:value type="java.net.URL">http://www.jboss.org</jndi:value>
</jndi:binding>
```

The `editor` attribute can be used to specify a particular property editor to use.

```
<jndi:binding name="hosts/localhost">
    <jndi:value editor="org.jboss.util.propertyeditor.InetAddressEditor">
        127.0.0.1
    </jndi:value>
</jndi:binding>
```

For more complicated structures, any JBossXB-ready schema may be used. The following example shows how a `java.util.Properties` object would be mapped.

```
<jndi:binding name="maps/testProps">
    <java:properties xmlns:java="urn:jboss:java-properties"
                     xmlns:xs="http://www.w3.org/2001/XMLSchema-instance"
                     xs:schemaLocation="urn:jboss:java-properties resource:java-properties_1_0.xsd">
        <java:property>
            <java:key>key1</java:key>
            <java:value>value1</java:value>
        </java:property>
        <java:property>
            <java:key>key2</java:key>
            <java:value>value2</java:value>
        </java:property>
    </java:properties>
</jndi:binding>
```

For more information on JBossXB, see the JBossXB wiki page [http://wiki.jboss.org/wiki/Wiki.jsp?page=JBossXB].

2.5.2. The org.jboss.naming.NamingAlias MBean

The `NamingAlias` MBean is a simple utility service that allows you to create an alias in the form of a JNDI `javax.naming.LinkRef` from one JNDI name to another. This is similar to a symbolic link in the UNIX file system. To an alias you add a configuration of the `NamingAlias` MBean to the `jboss-service.xml` configuration file. The configurable attributes of the `NamingAlias` service are as follows:

- **FromName**: The location where the `LinkRef` is bound under JNDI.
- **ToName**: The to name of the alias. This is the target name to which the `LinkRef` refers. The name is a URL, or a name to be resolved relative to the `InitialContext`, or if the first character of the name is a dot (`.`), the name is relative to the context in which the link is bound.

The following example provides a mapping of the JNDI name `QueueConnectionFactory` to the name `ConnectionFactory`.

```
<mbean code="org.jboss.naming.NamingAlias"
       name="jboss.mq:service=NamingAlias,fromName=QueueConnectionFactory">
    <attribute name="ToName">ConnectionFactory</attribute>
    <attribute name="FromName">QueueConnectionFactory</attribute>
</mbean>
```

2.5.3. org.jboss.naming.ExternalContext MBean

The `ExternalContext` MBean allows you to federate external JNDI contexts into the JBoss server JNDI namespace. The term external refers to any naming service external to the JBossNS naming service running inside of the JBoss server VM. You can incorporate LDAP servers, file systems, DNS servers, and so on, even if the JNDI provider root context is not serializable. The federation can be made available to remote clients if the naming service supports remote access.

To incorporate an external JNDI naming service, you have to add a configuration of the `ExternalContext` MBean service to the `jboss-service.xml` configuration file. The configurable attributes of the `ExternalContext` service are as follows:

- **JndiName**: The JNDI name under which the external context is to be bound.
- **RemoteAccess**: A boolean flag indicating if the external `InitialContext` should be bound using a `Serializable` form that allows a remote client to create the external `InitialContext` . When a remote client looks up the external context via the JBoss JNDI `InitialContext`, they effectively create an instance of the external `InitialContext` using the same env properties passed to the `ExternalContext` MBean. This will only work if the client can do a `new InitialContext(env)` remotely. This requires that the `Context.PROVIDER_URL` value of env is resolvable in the remote VM that is accessing the context. This should work for the LDAP example. For the file system example this most likely won't work unless the file system path refers to a common network path. If this property is not given it defaults to false.
- **CacheContext**: The `cacheContext` flag. When set to true, the external `Context` is only created when the MBean is started and then stored as an in memory object until the MBean is stopped. If cacheContext is set to false, the external `Context` is created on each lookup using the MBean properties and InitialContext class. When the uncached `Context` is looked up by a client, the client should invoke `close()` on the Context to prevent resource leaks.
- **InitialContext**: The fully qualified class name of the `InitialContext` implementation to use. Must be one of: `javax.naming.InitialContext`, `javax.naming.directory.InitialDirContext` or `javax.naming.ldap.InitialLdapContext`. In the case of the `InitialLdapContext` a null `Controls` array is used. The default is `javax.naming.InitialContex`.
- **Properties**: The `Properties` attribute contains the JNDI properties for the external `InitialContext`. The input should be the text equivalent to what would go into a `jndi.properties` file.
- **PropertiesURL**: This set the `jndi.properties` information for the external `InitialContext` from an extern properties file. This is either a URL, string or a classpath resource name. Examples are as follows:
  - file:///config/myldap.properties
  - http://config.mycompany.com/myldap.properties
  - /conf/myldap.properties
  - myldap.properties

The MBean definition below shows a binding to an external LDAP context into the JBoss JNDI namespace under the name `external/ldap/jboss`.

```
<!-- Bind a remote LDAP server -->
<mbean code="org.jboss.naming.ExternalContext"
       name="jboss.jndi:service=ExternalContext,jndiName=external/ldap/jboss">
```

```
    <attribute name="JndiName">external/ldap/jboss</attribute>
    <attribute name="Properties">
        java.naming.factory.initial=com.sun.jndi.ldap.LdapCtxFactory
        java.naming.provider.url=ldap://ldaphost.jboss.org:389/o=jboss.org
        java.naming.security.principal=cn=Directory Manager
        java.naming.security.authentication=simple
        java.naming.security.credentials=secret
    </attribute>
    <attribute name="InitialContext"> javax.naming.ldap.InitialLdapContext </attribute>
    <attribute name="RemoteAccess">true</attribute>
</mbean>
```

With this configuration, you can access the external LDAP context located at `ldap://ldaphost.jboss.org:389/o=jboss.org` from within the JBoss VM using the following code fragment:

```
InitialContext iniCtx = new InitialContext();
LdapContext ldapCtx = iniCtx.lookup("external/ldap/jboss");
```

Using the same code fragment outside of the JBoss server VM will work in this case because the `RemoteAccess` property was set to true. If it were set to false, it would not work because the remote client would receive a `Reference` object with an `ObjectFactory` that would not be able to recreate the external `IntialContext`

```
<!-- Bind the /usr/local file system directory  -->
<mbean code="org.jboss.naming.ExternalContext"
       name="jboss.jndi:service=ExternalContext,jndiName=external/fs/usr/local">
    <attribute name="JndiName">external/fs/usr/local</attribute>
    <attribute name="Properties">
        java.naming.factory.initial=com.sun.jndi.fscontext.RefFSContextFactory
        java.naming.provider.url=file:///usr/local
    </attribute>
    <attribute name="InitialContext">javax.naming.IntialContext</attribute>
</mbean>
```

This configuration describes binding a local file system directory `/usr/local` into the JBoss JNDI namespace under the name `external/fs/usr/local`.

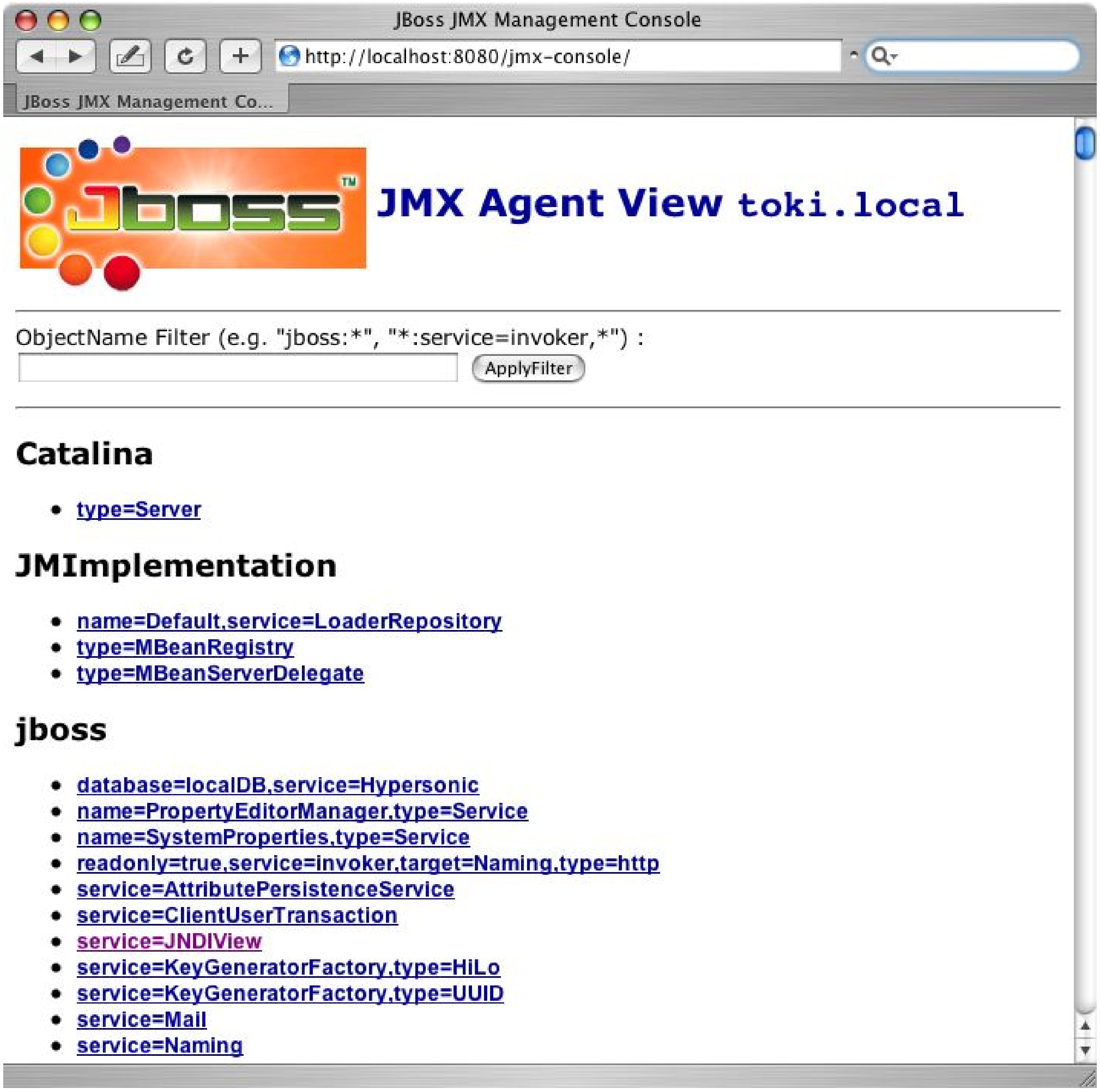
With this configuration, you can access the external file system context located at `file:///usr/local` from within the JBoss VM using the following code fragment:

```
InitialContext iniCtx = new InitialContext();
                Context ldapCtx = iniCtx.lookup("external/fs/usr/local");
```

Note that the use the Sun JNDI service providers, which must be downloaded from http://java.sun.com/products/jndi/serviceproviders.html. The provider JARs should be placed in the server configuration `lib` directory.

2.5.4. The org.jboss.naming.JNDIView MBean

The JNDIView MBean allows the user to view the JNDI namespace tree as it exists in the JBoss server using the JMX agent view interface. To view the JBoss JNDI namespace using the JNDIView MBean, you connect to the JMX Agent View using the http interface. The default settings put this at `http://localhost:8080/jmx-console/`. On this page you will see a section that lists the registered MBeans sortyed by domain. It should look something like that shown in Figure 2.4.


JBoss JMX Management Console
http://localhost:8080/jmx-console/
JBoss JMX Management Co...
ApplyFilter

JMX Agent View toki.local

ObjectName Filter (e.g. "jboss:*", "*:service=invoker,*") :

Catalina

- type=Server

JMImplementation

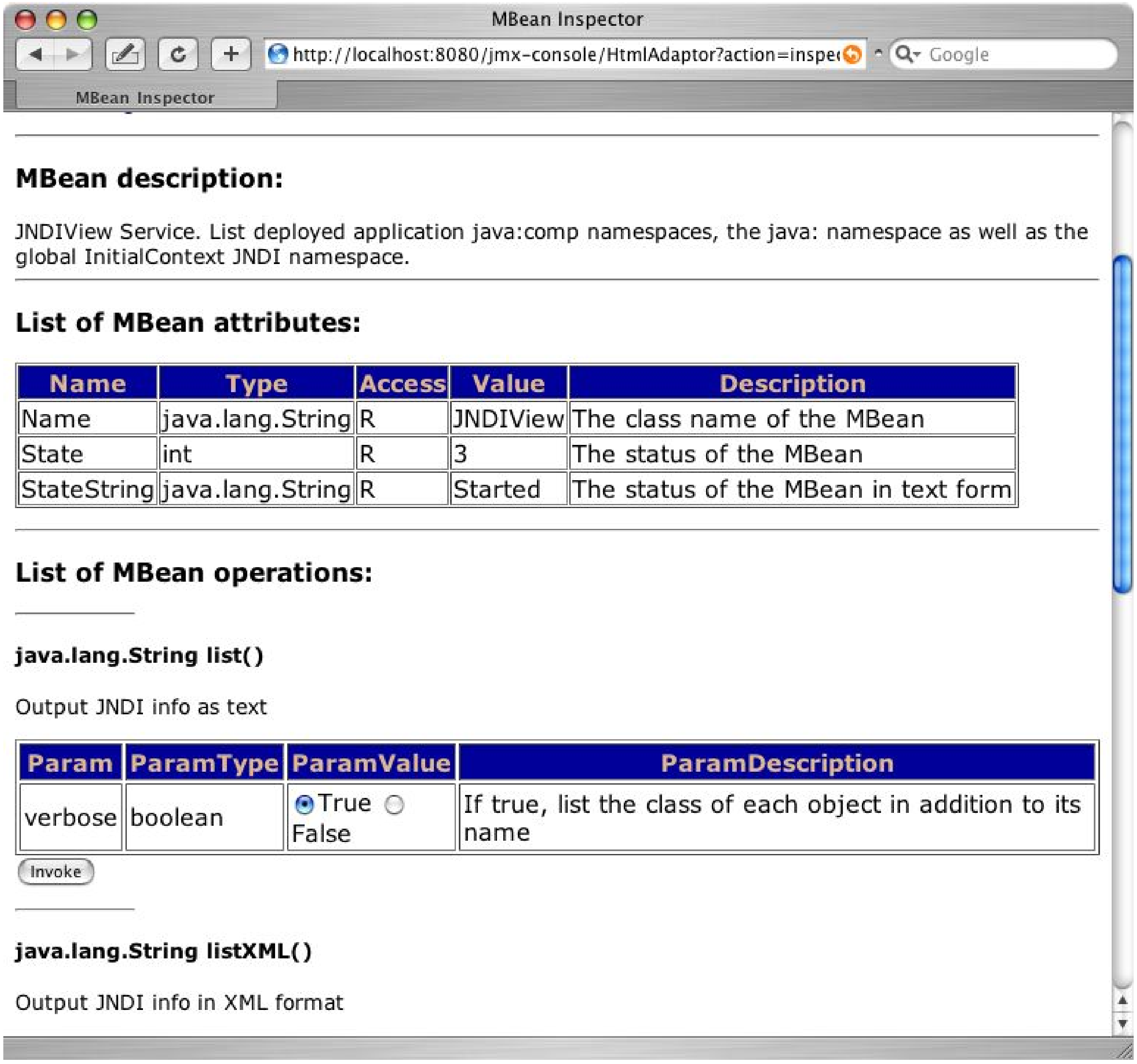
- name=Default,service=LoaderRepository
- type=MBeanRegistry
- type=MBeanServerDelegate

jboss

- database=localDB,service=Hypersonic
- name=PropertyEditorManager,type=Service
- name=SystemProperties,type=Service
- readonly=true,service=invoker,target=Naming,type=http
- service=AttributePersistenceService
- service=ClientUserTransaction
- service=JNDIView
- service=KeyGeneratorFactory,type=HiLo
- service=KeyGeneratorFactory,type=UUID
- service=Mail
- service=Naming

Figure 2.4. The JMX Console view of the configured JBoss MBeans

Selecting the JNDIView link takes you to the JNDIView MBean view, which will have a list of the JNDIView MBean operations. This view should look similar to that shown in Figure 2.5.



MBean description:

JNDIView Service. List deployed application java:comp namespaces, the java: namespace as well as the global InitialContext JNDI namespace.

List of MBean attributes:

Name	Type	Access	Value	Description
Name	java.lang.String	R	JNDIView	The class name of the MBean
State	int	R	3	The status of the MBean
StateString	java.lang.String	R	Started	The status of the MBean in text form

List of MBean operations:

java.lang.String list()

Output JNDI info as text

Param	ParamType	ParamValue	ParamDescription
verbose	boolean	[✓ True] False	If true, list the class of each object in addition to its name

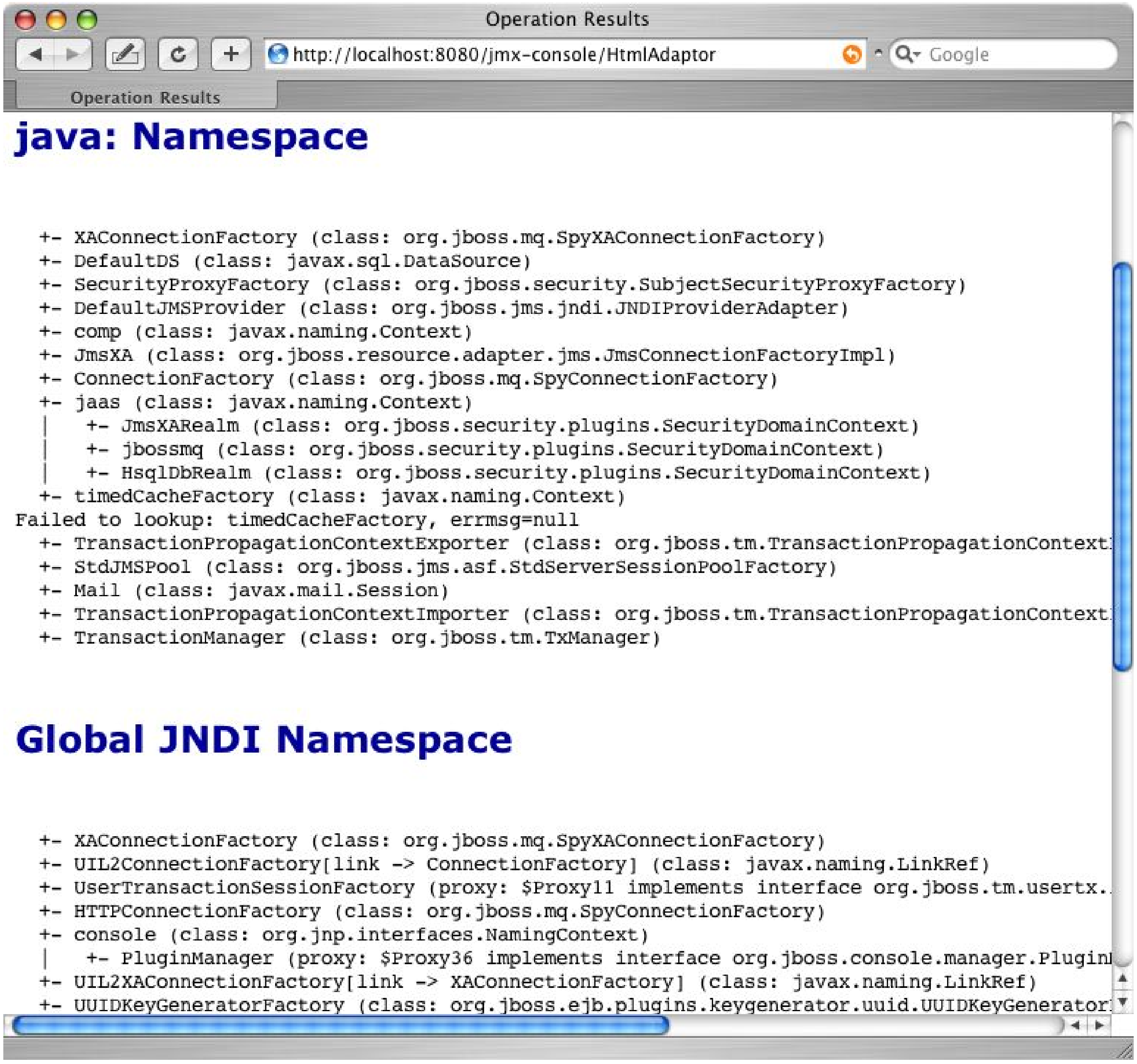
Invoke

java.lang.String listXML()

Output JNDI info in XML format

Figure 2.5. The JMX Console view of the JNDIView MBean

The list operation dumps out the JBoss server JNDI namespace as an HTML page using a simple text view. As an example, invoking the list operation produces the view shown in Figure 2.6.



java: Namespace

```
  +- XAConnectionFactory (class: org.jboss.mq.SpyXAConnectionFactory)
  +- DefaultDS (class: javax.sql.DataSource)
  +- SecurityProxyFactory (class: org.jboss.security.SubjectSecurityProxyFactory)
  +- DefaultJMSProvider (class: org.jboss.jms.jndi.JNDIProviderAdapter)
  +- comp (class: javax.naming.Context)
  +- JmsXA (class: org.jboss.resource.adapter.jms.JmsConnectionFactoryImpl)
  +- ConnectionFactory (class: org.jboss.mq.SpyConnectionFactory)
  +- jaas (class: javax.naming.Context)
  |   +- JmsXARealm (class: org.jboss.security.plugins.SecurityDomainContext)
  |   +- jbossmq (class: org.jboss.security.plugins.SecurityDomainContext)
  |   +- HsqlDbRealm (class: org.jboss.security.plugins.SecurityDomainContext)
  +- timedCacheFactory (class: javax.naming.Context)
Failed to lookup: timedCacheFactory, errmsg=null
  +- TransactionPropagationContextExporter (class: org.jboss.tm.TransactionPropagationContext
  +- StdJMSPool (class: org.jboss.jms.asf.StdServerSessionPoolFactory)
  +- Mail (class: javax.mail.Session)
  +- TransactionPropagationContextImporter (class: org.jboss.tm.TransactionPropagationContext
  +- TransactionManager (class: org.jboss.tm.TxManager)
```

Global JNDI Namespace

```
  +- XAConnectionFactory (class: org.jboss.mq.SpyXAConnectionFactory)
  +- UIL2ConnectionFactory[link -> ConnectionFactory] (class: javax.naming.LinkRef)
  +- UserTransactionSessionFactory (proxy: $Proxy11 implements interface org.jboss.tm.usertx.
  +- HTTPConnectionFactory (class: org.jboss.mq.SpyConnectionFactory)
  +- console (class: org.jnp.interfaces.NamingContext)
  |   +- PluginManager (proxy: $Proxy36 implements interface org.jboss.console.manager.Plugin
  +- UIL2XAConnectionFactory[link -> XAConnectionFactory] (class: javax.naming.LinkRef)
  +- UUIDKeyGeneratorFactory (class: org.jboss.ejb.plugins.keygenerator.uuid.UUIDKeyGenerator
```

Figure 2.6. The JMX Console view of the JNDIView list operation output

2.6. J2EE and JNDI - The Application Component Environment

JNDI is a fundamental aspect of the J2EE specifications. One key usage is the isolation of J2EE component code from the environment in which the code is deployed. Use of the application component's environment allows the application component to be customized without the need to access or change the application component's source code. The application component environment is referred to as the ENC, the enterprise naming context. It is the responsibility of the application component container to make an ENC available to the container components in the form of JNDI Context. The ENC is utilized by the participants involved in the life cycle of a J2EE component in the following ways.

- Application component business logic should be coded to access information from its ENC. The component provider uses the standard deployment descriptor for the component to specify the required ENC entries. The entries are declarations of the information and resources the component requires at runtime.
- The container provides tools that allow a deployer of a component to map the ENC references made by the component developer to the deployment environment entity that satisfies the reference.
- The component deployer utilizes the container tools to ready a component for final deployment.
- The component container uses the deployment package information to build the complete component ENC at runtime

The complete specification regarding the use of JNDI in the J2EE platform can be found in section 5 of the J2EE 1.4 specification. The J2EE specification is available at http://java.sun.com/j2ee/download.html.

An application component instance locates the ENC using the JNDI API. An application component instance creates a `javax.naming.InitialContext` object by using the no argument constructor and then looks up the naming environment under the name `java:comp/env`. The application component's environment entries are stored directly in the ENC, or in its subcontexts. Example 2.4 illustrates the prototypical lines of code a component uses to access its ENC.

Example 2.4. ENC access sample code

```
// Obtain the application component's ENC
Context iniCtx = new InitialContext();
Context compEnv = (Context) iniCtx.lookup("java:comp/env");
```

An application component environment is a local environment that is accessible only by the component when the application server container thread of control is interacting with the application component. This means that an EJB `Bean1` cannot access the ENC elements of EJB `Bean2`, and vice versa. Similarly, Web application `Web1` cannot access the ENC elements of Web application `Web2` or `Bean1` or `Bean2` for that matter. Also, arbitrary client code, whether it is executing inside of the application server VM or externally cannot access a component's `java:comp` JNDI context. The purpose of the ENC is to provide an isolated, read-only namespace that the application component can rely on regardless of the type of environment in which the component is deployed. The ENC must be isolated from other components because each component defines its own ENC content. Components `A` and `B`, for example, may define the same name to refer to different objects. For example, EJB `Bean1` may define an environment entry `java:comp/env/red` to refer to the hexadecimal value for the RGB color for red, while Web application `Web1` may bind the same name to the deployment environment language locale representation of red.

There are three commonly used levels of naming scope in JBoss: names under `java:comp`, names under `java:`, and any other name. As discussed, the `java:comp` context and its subcontexts are only available to the application component associated with that particular context. Subcontexts and object bindings directly under `java:` are only visible within the JBoss server virtual machine and not to remote clients. Any other context or object binding is available to remote clients, provided the context or object supports serialization. You'll see how the isolation of these naming scopes is achieved in the Section 2.2.

An example of where the restricting a binding to the `java:` context is useful would be a `javax.sql.DataSource` connection factory that can only be used inside of the JBoss server where the associated database pool resides. On the other hand, an EJB home interface would be bound to a globally visible name that should accessible by remote client.

2.6.1. ENC Usage Conventions

JNDI is used as the API for externalizing a great deal of information from an application component. The JNDI name that the application component uses to access the information is declared in the standard `ejb-jar.xml` deployment descriptor for EJB components, and the standard `web.xml` deployment descriptor for Web components. Several different types of information may be stored in and retrieved from JNDI including:

- Environment entries as declared by the `env-entry` elements
- EJB references as declared by `ejb-ref` and `ejb-local-ref` elements.
- Resource manager connection factory references as declared by the `resource-ref` elements
- Resource environment references as declared by the `resource-env-ref` elements

Each type of deployment descriptor element has a JNDI usage convention with regard to the name of the JNDI context under which the information is bound. Also, in addition to the standard deploymentdescriptor element, there is a JBoss server specific deployment descriptor element that maps the JNDI name as used by the application component to the deployment environment JNDI name.

2.6.1.1. Environment Entries

Environment entries are the simplest form of information stored in a component ENC, and are similar to operating system environment variables like those found on UNIX or Windows. Environment entries are a name-to-value binding that allows a component to externalize a value and refer to the value using a name.

An environment entry is declared using an `env-entry` element in the standard deployment descriptors. The `env-entry` element contains the following child elements:

- An optional **description** element that provides a description of the entry
- An **env-entry-name** element giving the name of the entry relative to `java:comp/env`
- An **env-entry-type** element giving the Java type of the entry value that must be one of:
  - `java.lang.Byte`
  - `java.lang.Boolean`
  - `java.lang.Character`
  - `java.lang.Double`
  - `java.lang.Float`
  - `java.lang.Integer`
  - `java.lang.Long`
  - `java.lang.Short`
  - `java.lang.String`
- An **env-entry-value** element giving the value of entry as a string

An example of an `env-entry` fragment from an `ejb-jar.xml` deployment descriptor is given in Example 2.5. There is no JBoss specific deployment descriptor element because an `env-entry` is a complete name and value specification. Example 2.6 shows a sample code fragment for accessing the `maxExemptions` and `taxRate` `env-entry` values declared in the deployment descriptor.

Example 2.5. An example ejb-jar.xml env-entry fragment

```
<!-- ... -->
<session>
    <ejb-name>ASessionBean</ejb-name>
    <!-- ... -->
    <env-entry>
        <description>The maximum number of tax exemptions allowed </description>
        <env-entry-name>maxExemptions</env-entry-name>
        <env-entry-type>java.lang.Integer</env-entry-type>
        <env-entry-value>15</env-entry-value>
    </env-entry>
    <env-entry>
        <description>The tax rate </description>
        <env-entry-name>taxRate</env-entry-name>
        <env-entry-type>java.lang.Float</env-entry-type>
        <env-entry-value>0.23</env-entry-value>
    </env-entry>
</session>
<!-- ... -->
```

Example 2.6. ENC env-entry access code fragment

```
InitialContext iniCtx = new InitialContext();
Context envCtx = (Context) iniCtx.lookup("java:comp/env");
Integer maxExemptions = (Integer) envCtx.lookup("maxExemptions");
Float taxRate = (Float) envCtx.lookup("taxRate");
```

2.6.1.2. EJB References

It is common for EJBs and Web components to interact with other EJBs. Because the JNDI name under which an EJB home interface is bound is a deployment time decision, there needs to be a way for a component developer to declare a reference to an EJB that will be linked by the deployer. EJB references satisfy this requirement.

An EJB reference is a link in an application component naming environment that points to a deployed EJB home interface. The name used by the application component is a logical link that isolates the component from the actual name of the EJB home in the deployment environment. The J2EE specification recommends that all references to enterprise beans be organized in the `java:comp/env/ejb` context of the application component's environment.

An EJB reference is declared using an `ejb-ref` element in the deployment descriptor. Each `ejb-ref` element describes the interface requirements that the referencing application component has for the referenced enterprise bean. The `ejb-ref` element contains the following child elements:

- An optional **description** element that provides the purpose of the reference.
- An **ejb-ref-name** element that specifies the name of the reference relative to the `java:comp/env` context. To place the reference under the recommended `java:comp/env/ejb` context, use an `ejb/link-name` form for the

`ejb-ref-name` value.

- An **ejb-ref-type** element that specifies the type of the EJB. This must be either `Entity` or `Session`.
- A **home** element that gives the fully qualified class name of the EJB home interface.
- A **remote** element that gives the fully qualified class name of the EJB remote interface.
- An optional **ejb-link** element that links the reference to another enterprise bean in the same EJB JAR or in the same J2EE application unit. The `ejb-link` value is the `ejb-name` of the referenced bean. If there are multiple enterprise beans with the same `ejb-name`, the value uses the path name specifying the location of the `ejb-jar` file that contains the referenced component. The path name is relative to the referencing `ejb-jar` file. The Application Assembler appends the `ejb-name` of the referenced bean to the path name separated by `#`. This allows multiple beans with the same name to be uniquely identified.

An EJB reference is scoped to the application component whose declaration contains the `ejb-ref` element. This means that the EJB reference is not accessible from other application components at runtime, and that other application components may define `ejb-ref` elements with the same `ejb-ref-name` without causing a name conflict. Example 2.7 provides an `ejb-jar.xml` fragment that illustrates the use of the `ejb-ref` element. A code sample that illustrates accessing the `ShoppingCartHome` reference declared in Example 2.7 is given in Example 2.8.

Example 2.7. An example ejb-jar.xml ejb-ref descriptor fragment

```
<!-- ... -->
<session>
    <ejb-name>ShoppingCartBean</ejb-name>
    <!-- ...-->
</session>

<session>
    <ejb-name>ProductBeanUser</ejb-name>
    <!--...-->
    <ejb-ref>
        <description>This is a reference to the store products entity </description>
        <ejb-ref-name>ejb/ProductHome</ejb-ref-name>
        <ejb-ref-type>Entity</ejb-ref-type>
        <home>org.jboss.store.ejb.ProductHome</home>
        <remote> org.jboss.store.ejb.Product</remote>
    </ejb-ref>

</session>

<session>
    <ejb-ref>
        <ejb-name>ShoppingCartUser</ejb-name>
        <!--...-->
        <ejb-ref-name>ejb/ShoppingCartHome</ejb-ref-name>
        <ejb-ref-type>Session</ejb-ref-type>
        <home>org.jboss.store.ejb.ShoppingCartHome</home>
        <remote> org.jboss.store.ejb.ShoppingCart</remote>
        <ejb-link>ShoppingCartBean</ejb-link>
    </ejb-ref>
</session>

<entity>
    <description>The Product entity bean </description>
    <ejb-name>ProductBean</ejb-name>
    <!--...-->
```

```
</entity>

<!--...-->
```

Example 2.8. ENC ejb-ref access code fragment

```
InitialContext iniCtx = new InitialContext();
Context ejbCtx = (Context) iniCtx.lookup("java:comp/env/ejb");
ShoppingCartHome home = (ShoppingCartHome) ejbCtx.lookup("ShoppingCartHome");
```

2.6.1.3. EJB References with `jboss.xml` and `jboss-web.xml`

The JBoss specific `jboss.xml` EJB deployment descriptor affects EJB references in two ways. First, the `jndi-name` child element of the `session` and `entity` elements allows the user to specify the deployment JNDI name for the EJB home interface. In the absence of a `jboss.xml` specification of the `jndi-name` for an EJB, the home interface is bound under the `ejb-jar.xml` `ejb-name` value. For example, the session EJB with the `ejb-name` of `ShoppingCart-Bean` in Example 2.7 would have its home interface bound under the JNDI name `ShoppingCartBean` in the absence of a `jboss.xml` `jndi-name` specification.

The second use of the `jboss.xml` descriptor with respect to `ejb-refs` is the setting of the destination to which a component's ENC `ejb-ref` refers. The `ejb-link` element cannot be used to refer to EJBs in another enterprise application. If your `ejb-ref` needs to access an external EJB, you can specify the JNDI name of the deployed EJB home using the `jboss.xml` `ejb-ref/jndi-name` element.

The `jboss-web.xml` descriptor is used only to set the destination to which a Web application ENC `ejb-ref` refers. The content model for the JBoss `ejb-ref` is as follows:

- An **ejb-ref-name** element that corresponds to the **ejb-ref-name** element in the **ejb-jar.xml** or **web.xml** standard descriptor
- A `jndi-name` element that specifies the JNDI name of the EJB home interface in the deployment environment

Example 2.9 provides an example `jboss.xml` descriptor fragment that illustrates the following usage points:

- The `ProductBeanUser` `ejb-ref` link destination is set to the deployment name of `jboss/store/ProductHome`
- The deployment JNDI name of the `ProductBean` is set to `jboss/store/ProductHome`

Example 2.9. An example jboss.xml ejb-ref fragment

```
<!-- ... -->
<session>
    <ejb-name>ProductBeanUser</ejb-name>
    <ejb-ref>
        <ejb-ref-name>ejb/ProductHome</ejb-ref-name>
        <jndi-name>jboss/store/ProductHome</jndi-name>
    </ejb-ref>
</session>
```

```
<entity>
    <ejb-name>ProductBean</ejb-name>
    <jndi-name>jboss/store/ProductHome</jndi-name>
     <!-- ... -->
</entity>
<!-- ... -->
```

2.6.1.4. EJB Local References

EJB 2.0 added local interfaces that do not use RMI call by value semantics. These interfaces use a call by reference semantic and therefore do not incur any RMI serialization overhead. An EJB local reference is a link in an application component naming environment that points to a deployed EJB local home interface. The name used by the application component is a logical link that isolates the component from the actual name of the EJB local home in the deployment environment. The J2EE specification recommends that all references to enterprise beans be organized in the `java:comp/env/ejb` context of the application component's environment.

An EJB local reference is declared using an `ejb-local-ref` element in the deployment descriptor. Each `ejb-local-ref` element describes the interface requirements that the referencing application component has for the referenced enterprise bean. The `ejb-local-ref` element contains the following child elements:

- An optional **description** element that provides the purpose of the reference.
- An **ejb-ref-name** element that specifies the name of the reference relative to the `java:comp/env` context. To place the reference under the recommended `java:comp/env/ejb` context, use an `ejb/link-name` form for the `ejb-ref-name` value.
- An **ejb-ref-type** element that specifies the type of the EJB. This must be either `Entity` or `Session`.
- A **local-home** element that gives the fully qualified class name of the EJB local home interface.
- A **local** element that gives the fully qualified class name of the EJB local interface.
- An **ejb-link** element that links the reference to another enterprise bean in the `ejb-jar` file or in the same J2EE application unit. The `ejb-link` value is the `ejb-name` of the referenced bean. If there are multiple enterprise beans with the same `ejb-name`, the value uses the path name specifying the location of the `ejb-jar` file that contains the referenced component. The path name is relative to the referencing `ejb-jar` file. The Application Assembler appends the `ejb-name` of the referenced bean to the path name separated by `#`. This allows multiple beans with the same name to be uniquely identified. An `ejb-link` element must be specified in JBoss to match the local reference to the corresponding EJB.

An EJB local reference is scoped to the application component whose declaration contains the `ejb-local-ref` element. This means that the EJB local reference is not accessible from other application components at runtime, and that other application components may define `ejb-local-ref` elements with the same `ejb-ref-name` without causing a name conflict. Example 2.10 provides an `ejb-jar.xml` fragment that illustrates the use of the `ejb-local-ref` element. A code sample that illustrates accessing the `ProbeLocalHome` reference declared in Example 2.10 is given in Example 2.11.

Example 2.10. An example ejb-jar.xml ejb-local-ref descriptor fragment

```
    <!-- ... -->
    <session>
        <ejb-name>Probe</ejb-name>
        <home>org.jboss.test.perf.interfaces.ProbeHome</home>
        <remote>org.jboss.test.perf.interfaces.Probe</remote>
        <local-home>org.jboss.test.perf.interfaces.ProbeLocalHome</local-home>
        <local>org.jboss.test.perf.interfaces.ProbeLocal</local>
        <ejb-class>org.jboss.test.perf.ejb.ProbeBean</ejb-class>
        <session-type>Stateless</session-type>
        <transaction-type>Bean</transaction-type>
    </session>
    <session>
        <ejb-name>PerfTestSession</ejb-name>
        <home>org.jboss.test.perf.interfaces.PerfTestSessionHome</home>
        <remote>org.jboss.test.perf.interfaces.PerfTestSession</remote>
        <ejb-class>org.jboss.test.perf.ejb.PerfTestSessionBean</ejb-class>
        <session-type>Stateless</session-type>
        <transaction-type>Container</transaction-type>
        <ejb-ref>
            <ejb-ref-name>ejb/ProbeHome</ejb-ref-name>
            <ejb-ref-type>Session</ejb-ref-type>
            <home>org.jboss.test.perf.interfaces.SessionHome</home>
            <remote>org.jboss.test.perf.interfaces.Session</remote>
            <ejb-link>Probe</ejb-link>
        </ejb-ref>
        <ejb-local-ref>
            <ejb-ref-name>ejb/ProbeLocalHome</ejb-ref-name>
            <ejb-ref-type>Session</ejb-ref-type>
            <local-home>org.jboss.test.perf.interfaces.ProbeLocalHome</local-home>
            <local>org.jboss.test.perf.interfaces.ProbeLocal</local>
            <ejb-link>Probe</ejb-link>
        </ejb-local-ref>
    </session>
    <!-- ... -->
```

Example 2.11. ENC ejb-local-ref access code fragment

```
InitialContext iniCtx = new InitialContext();
Context ejbCtx = (Context) iniCtx.lookup("java:comp/env/ejb");
ProbeLocalHome home = (ProbeLocalHome) ejbCtx.lookup("ProbeLocalHome");
```

2.6.1.5. Resource Manager Connection Factory References

Resource manager connection factory references allow application component code to refer to resource factories using logical names called resource manager connection factory references. Resource manager connection factory references are defined by the `resource-ref` elements in the standard deployment descriptors. The `Deployer` binds the resource manager connection factory references to the actual resource manager connection factories that exist in the target operational environment using the `jboss.xml` and `jboss-web.xml` descriptors.

Each `resource-ref` element describes a single resource manager connection factory reference. The `resource-ref` element consists of the following child elements:

- An optional **description** element that provides the purpose of the reference.
- A **res-ref-name** element that specifies the name of the reference relative to the `java:comp/env` context. The re-

source type based naming convention for which subcontext to place the `res-ref-name` into is discussed in the next paragraph.

- A **res-type** element that specifies the fully qualified class name of the resource manager connection factory.
- A **res-auth** element that indicates whether the application component code performs resource signon programmatically, or whether the container signs on to the resource based on the principal mapping information supplied by the Deployer. It must be one of `Application` or `Container`.
- An optional **res-sharing-scope** element. This currently is not supported by JBoss.

The J2EE specification recommends that all resource manager connection factory references be organized in the subcontexts of the application component's environment, using a different subcontext for each resource manager type. The recommended resource manager type to subcontext name is as follows:

- JDBC `DataSource` references should be declared in the `java:comp/env/jdbc` subcontext.
- JMS connection factories should be declared in the `java:comp/env/jms` subcontext.
- JavaMail connection factories should be declared in the `java:comp/env/mail` subcontext.
- URL connection factories should be declared in the `java:comp/env/url` subcontext.

Example 2.12 shows an example `web.xml` descriptor fragment that illustrates the `resource-ref` element usage. Example 2.13 provides a code fragment that an application component would use to access the `DefaultMail` resource declared by the `resource-ref`.

Example 2.12. A web.xml resource-ref descriptor fragment

```
<web>
    <!-- ... -->
    <servlet>
        <servlet-name>AServlet</servlet-name>
        <!-- ... -->
    </servlet>
    <!-- ... -->
    <!-- JDBC DataSources (java:comp/env/jdbc) -->
    <resource-ref>
        <description>The default DS</description>
        <res-ref-name>jdbc/DefaultDS</res-ref-name>
        <res-type>javax.sql.DataSource</res-type>
        <res-auth>Container</res-auth>
    </resource-ref>
    <!-- JavaMail Connection Factories (java:comp/env/mail) -->
    <resource-ref>
        <description>Default Mail</description>
        <res-ref-name>mail/DefaultMail</res-ref-name>
        <res-type>javax.mail.Session</res-type>
        <res-auth>Container</res-auth>
    </resource-ref>
    <!-- JMS Connection Factories (java:comp/env/jms) -->
    <resource-ref>
        <description>Default QueueFactory</description>
        <res-ref-name>jms/QueueFactory</res-ref-name>
        <res-type>javax.jms.QueueConnectionFactory</res-type>
        <res-auth>Container</res-auth>
    </resource-ref>
<web>
```

Example 2.13. ENC resource-ref access sample code fragment

```
Context initCtx = new InitialContext();
javax.mail.Session s = (javax.mail.Session)
initCtx.lookup("java:comp/env/mail/DefaultMail");
```

2.6.1.6. Resource Manager Connection Factory References with jboss.xml and jboss-web.xml

The purpose of the JBoss `jboss.xml` EJB deployment descriptor and `jboss-web.xml` Web application deployment descriptor is to provide the link from the logical name defined by the `res-ref-name` element to the JNDI name of the resource factory as deployed in JBoss. This is accomplished by providing a `resource-ref` element in the `jboss.xml` or `jboss-web.xml` descriptor. The JBoss `resource-ref` element consists of the following child elements:

- A **res-ref-name** element that must match the `res-ref-name` of a corresponding `resource-ref` element from the `ejb-jar.xml` or `web.xml` standard descriptors
- An optional **res-type** element that specifies the fully qualified class name of the resource manager connection factory
- A **jndi-name** element that specifies the JNDI name of the resource factory as deployed in JBoss
- A **res-url** element that specifies the URL string in the case of a `resource-ref` of type `java.net.URL`

Example 2.14 provides a sample `jboss-web.xml` descriptor fragment that shows sample mappings of the `resource-ref` elements given in Example 2.12.

Example 2.14. A sample jboss-web.xml resource-ref descriptor fragment

```
<jboss-web>
    <!-- ... -->
    <resource-ref>
        <res-ref-name>jdbc/DefaultDS</res-ref-name>
        <res-type>javax.sql.DataSource</res-type>
        <jndi-name>java:/DefaultDS</jndi-name>
    </resource-ref>
    <resource-ref>
        <res-ref-name>mail/DefaultMail</res-ref-name>
        <res-type>javax.mail.Session</res-type>
        <jndi-name>java:/Mail</jndi-name>
    </resource-ref>
    <resource-ref>
        <res-ref-name>jms/QueueFactory</res-ref-name>
        <res-type>javax.jms.QueueConnectionFactory</res-type>
        <jndi-name>QueueConnectionFactory</jndi-name>
    </resource-ref>
    <!-- ... -->
</jboss-web>
```

2.6.1.7. Resource Environment References

Resource environment references are elements that refer to administered objects that are associated with a resource (for example, JMS destinations) using logical names. Resource environment references are defined by the `resource-env-ref` elements in the standard deployment descriptors. The `Deployer` binds the resource environment references to the actual administered objects location in the target operational environment using the `jboss.xml` and `jboss-web.xml` descriptors.

Each `resource-env-ref` element describes the requirements that the referencing application component has for the referenced administered object. The `resource-env-ref` element consists of the following child elements:

- An optional **description** element that provides the purpose of the reference.
- A **resource-env-ref-name** element that specifies the name of the reference relative to the `java:comp/env` context. Convention places the name in a subcontext that corresponds to the associated resource factory type. For example, a JMS queue reference named `MyQueue` should have a `resource-env-ref-name` of `jms/MyQueue`.
- A **resource-env-ref-type** element that specifies the fully qualified class name of the referenced object. For example, in the case of a JMS queue, the value would be `javax.jms.Queue`.

Example 2.15 provides an example `resource-ref-env` element declaration by a session bean. Example 2.16 gives a code fragment that illustrates how to look up the `StockInfo` queue declared by the `resource-env-ref`.

Example 2.15. An example ejb-jar.xml resource-env-ref fragment

```
<session>
    <ejb-name>MyBean</ejb-name>
    <!-- ... -->
    <resource-env-ref>
        <description>This is a reference to a JMS queue used in the
            processing of Stock info
        </description>
        <resource-env-ref-name>jms/StockInfo</resource-env-ref-name>
        <resource-env-ref-type>javax.jms.Queue</resource-env-ref-type>
    </resource-env-ref>
    <!-- ... -->
</session>
```

Example 2.16. ENC resource-env-ref access code fragment

```
InitialContext iniCtx = new InitialContext();
javax.jms.Queue q = (javax.jms.Queue)
envCtx.lookup("java:comp/env/jms/StockInfo");
```

2.6.1.8. Resource Environment References and jboss.xml, jboss-web.xml

The purpose of the JBoss `jboss.xml` EJB deployment descriptor and `jboss-web.xml` Web application deployment descriptor is to provide the link from the logical name defined by the `resource-env-ref-name` element to the JNDI name of the administered object deployed in JBoss. This is accomplished by providing a `resource-env-ref` element in the `jboss.xml` or `jboss-web.xml` descriptor. The JBoss `resource-env-ref` element consists of the following child elements:

- A `resource-env-ref-name` element that must match the `resource-env-ref-name` of a corresponding `resource-env-ref` element from the `ejb-jar.xml` or `web.xml` standard descriptors
- A `jndi-name` element that specifies the JNDI name of the resource as deployed in JBoss

Example 2.17 provides a sample `jboss.xml` descriptor fragment that shows a sample mapping for the `StockInfo` `resource-env-ref`.

Example 2.17. A sample jboss.xml resource-env-ref descriptor fragment

```
<session>
    <ejb-name>MyBean</ejb-name>
    <!-- ... -->
    <resource-env-ref>
        <resource-env-ref-name>jms/StockInfo</resource-env-ref-name>
        <jndi-name>queue/StockInfoQueue</jndi-name>
    </resource-env-ref>
    <!-- ... -->
</session>
```

3

Transactions on JBoss

The JTA Transaction Service

This chapter discusses transaction management in JBoss and the JBossTX architecture. The JBossTX architecture allows for any Java Transaction API (JTA) transaction manager implementation to be used. JBossTX includes a fast in-VM implementation of a JTA compatible transaction manager that is used as the default transaction manager. We will first provide an overview of the key transaction concepts and notions in the JTA to provide sufficient background for the JBossTX architecture discussion. We will then discuss the interfaces that make up the JBossTX architecture and conclude with a discussion of the MBeans available for integration of alternate transaction managers.

3.1. Transaction/JTA Overview

For the purpose of this discussion, we can define a transaction as a unit of work containing one or more operations involving one or more shared resources having ACID properties. ACID is an acronym for atomicity, consistency, isolation and durability, the four important properties of transactions. The meanings of these terms is:

- **Atomicity**: A transaction must be atomic. This means that either all the work done in the transaction must be performed, or none of it must be performed. Doing part of a transaction is not allowed.
- **Consistency**: When a transaction is completed, the system must be in a stable and consistent condition.
- **Isolation**: Different transactions must be isolated from each other. This means that the partial work done in one transaction is not visible to other transactions until the transaction is committed, and that each process in a multi-user system can be programmed as if it was the only process accessing the system.
- **Durability**: The changes made during a transaction are made persistent when it is committed. When a transaction is committed, its changes will not be lost, even if the server crashes afterwards.

To illustrate these concepts, consider a simple banking account application. The banking application has a database with a number of accounts. The sum of the amounts of all accounts must always be 0. An amount of money M is moved from account A to account B by subtracting M from account A and adding M to account B. This operation must be done in a transaction, and all four ACID properties are important.

The atomicity property means that both the withdrawal and deposit is performed as an indivisible unit. If, for some reason, both cannot be done nothing will be done.

The consistency property means that after the transaction, the sum of the amounts of all accounts must still be 0.

The isolation property is important when more than one bank clerk uses the system at the same time. A withdrawal or deposit could be implemented as a three-step process: First the amount of the account is read from the database;

then something is subtracted from or added to the amount read from the database; and at last the new amount is written to the database. Without transaction isolation several bad things could happen. For example, if two processes read the amount of account A at the same time, and each independently added or subtracted something before writing the new amount to the database, the first change would be incorrectly overwritten by the last.

The durability property is also important. If a money transfer transaction is committed, the bank must trust that some subsequent failure cannot undo the money transfer.

3.1.1. Pessimistic and optimistic locking

Transactional isolation is usually implemented by locking whatever is accessed in a transaction. There are two different approaches to transactional locking: Pessimistic locking and optimistic locking.

The disadvantage of pessimistic locking is that a resource is locked from the time it is first accessed in a transaction until the transaction is finished, making it inaccessible to other transactions during that time. If most transactions simply look at the resource and never change it, an exclusive lock may be overkill as it may cause lock contention, and optimistic locking may be a better approach. With pessimistic locking, locks are applied in a fail-safe way. In the banking application example, an account is locked as soon as it is accessed in a transaction. Attempts to use the account in other transactions while it is locked will either result in the other process being delayed until the account lock is released, or that the process transaction will be rolled back. The lock exists until the transaction has either been committed or rolled back.

With optimistic locking, a resource is not actually locked when it is first is accessed by a transaction. Instead, the state of the resource at the time when it would have been locked with the pessimistic locking approach is saved. Other transactions are able to concurrently access to the resource and the possibility of conflicting changes is possible. At commit time, when the resource is about to be updated in persistent storage, the state of the resource is read from storage again and compared to the state that was saved when the resource was first accessed in the transaction. If the two states differ, a conflicting update was made, and the transaction will be rolled back.

In the banking application example, the amount of an account is saved when the account is first accessed in a transaction. If the transaction changes the account amount, the amount is read from the store again just before the amount is about to be updated. If the amount has changed since the transaction began, the transaction will fail itself, otherwise the new amount is written to persistent storage.

3.1.2. The components of a distributed transaction

There are a number of participants in a distributed transaction. These include:

- **Transaction Manager**: This component is distributed across the transactional system. It manages and coordinates the work involved in the transaction. The transaction manager is exposed by the `javax.transaction.TransactionManager` interface in JTA.
- **Transaction Context**: A transaction context identifies a particular transaction. In JTA the corresponding interface is `javax.transaction.Transaction`.
- **Transactional Client**: A transactional client can invoke operations on one or more transactional objects in a single transaction. The transactional client that started the transaction is called the transaction originator. A transaction client is either an explicit or implicit user of JTA interfaces and has no interface representation in

the JTA.

- **Transactional Object**: A transactional object is an object whose behavior is affected by operations performed on it within a transactional context. A transactional object can also be a transactional client. Most Enterprise Java Beans are transactional objects.
- **Recoverable Resource**: A recoverable resource is a transactional object whose state is saved to stable storage if the transaction is committed, and whose state can be reset to what it was at the beginning of the transaction if the transaction is rolled back. At commit time, the transaction manager uses the two-phase XA protocol when communicating with the recoverable resource to ensure transactional integrity when more than one recoverable resource is involved in the transaction being committed. Transactional databases and message brokers like JBossMQ are examples of recoverable resources. A recoverable resource is represented using the `javax.transaction.xa.XAResource` interface in JTA.

3.1.3. The two-phase XA protocol

When a transaction is about to be committed, it is the responsibility of the transaction manager to ensure that either all of it is committed, or that all of is rolled back. If only a single recoverable resource is involved in the transaction, the task of the transaction manager is simple: It just has to tell the resource to commit the changes to stable storage.

When more than one recoverable resource is involved in the transaction, management of the commit gets more complicated. Simply asking each of the recoverable resources to commit changes to stable storage is not enough to maintain the atomic property of the transaction. The reason for this is that if one recoverable resource has committed and another fails to commit, part of the transaction would be committed and the other part rolled back.

To get around this problem, the two-phase XA protocol is used. The XA protocol involves an extra prepare phase before the actual commit phase. Before asking any of the recoverable resources to commit the changes, the transaction manager asks all the recoverable resources to prepare to commit. When a recoverable resource indicates it is prepared to commit the transaction, it has ensured that it can commit the transaction. The resource is still able to rollback the transaction if necessary as well.

So the first phase consists of the transaction manager asking all the recoverable resources to prepare to commit. If any of the recoverable resources fails to prepare, the transaction will be rolled back. But if all recoverable resources indicate they were able to prepare to commit, the second phase of the XA protocol begins. This consists of the transaction manager asking all the recoverable resources to commit the transaction. Because all the recoverable resources have indicated they are prepared, this step cannot fail.

3.1.4. Heuristic exceptions

In a distributed environment communications failures can happen. If communication between the transaction manager and a recoverable resource is not possible for an extended period of time, the recoverable resource may decide to unilaterally commit or rollback changes done in the context of a transaction. Such a decision is called a heuristic decision. It is one of the worst errors that may happen in a transaction system, as it can lead to parts of the transaction being committed while other parts are rolled back, thus violating the atomicity property of transaction and possibly leading to data integrity corruption.

Because of the dangers of heuristic exceptions, a recoverable resource that makes a heuristic decision is required to maintain all information about the decision in stable storage until the transaction manager tells it to forget about the heuristic decision. The actual data about the heuristic decision that is saved in stable storage depends on the type of recoverable resource and is not standardized. The idea is that a system manager can look at the data, and possibly edit the resource to correct any data integrity problems.

There are several different kinds of heuristic exceptions defined by the JTA. The `javax.transaction.HeuristicCommitException` is thrown when a recoverable resource is asked to rollback to report that a heuristic decision was made and that all relevant updates have been committed. On the opposite end is the `javax.transaction.HeuristicRollbackException`, which is thrown by a recoverable resource when it is asked to commit to indicate that a heuristic decision was made and that all relevant updates have been rolled back.

The `javax.transaction.HeuristicMixedException` is the worst heuristic exception. It is thrown to indicate that parts of the transaction were committed, while other parts were rolled back. The transaction manager throws this exception when some recoverable resources did a heuristic commit, while other recoverable resources did a heuristic rollback.

3.1.5. Transaction IDs and branches

In JTA, the identity of transactions is encapsulated in objects implementing the `javax.transaction.xa.Xid` interface. The transaction ID is an aggregate of three parts:

- The format identifier indicates the transaction family and tells how the other two parts should be interpreted.
- The global transaction id identified the global transaction within the transaction family.
- The branch qualifier denotes a particular branch of the global transaction.

Transaction branches are used to identify different parts of the same global transaction. Whenever the transaction manager involves a new recoverable resource in a transaction it creates a new transaction branch.

3.2. JBoss Transaction Internals

The JBoss application server is written to be independent of the actual transaction manager used. JBoss uses the JTA `javax.transaction.TransactionManager` interface as its view of the server transaction manager. Thus, JBoss may use any transaction manager which implements the JTA `TransactionManager` interface. Whenever a transaction manager is used it is obtained from the well-known JNDI location, `java:/TransactionManager`. This is the globally available access point for the server transaction manager.

If transaction contexts are to be propagated with RMI/JRMP calls, the transaction manager must also implement two simple interfaces for the import and export of transaction propagation contexts (TPCs). The interfaces are `TransactionPropagationContextImporter`, and `TransactionPropagationContextFactory`, both in the `org.jboss.tm` package.

Being independent of the actual transaction manager used also means that JBoss does not specify the format of type of the transaction propagation contexts used. In JBoss, a TPC is of type `Object`, and the only requirement is that the TPC must implementation the `java.io.Serializable` interface.

When using the RMI/JRMP protocol for remote calls, the TPC is carried as a field in the `org.jboss.ejb.plugins.jrmp.client.RemoteMethodInvocation` class that is used to forward remote method invocation requests.

3.2.1. Adapting a Transaction Manager to JBoss

A transaction manager has to implement the Java Transaction API to be easily integrated with JBoss. As almost everything in JBoss, the transaction manager is managed as an MBean. Like all JBoss services, it should implement `org.jboss.system.ServiceMBean` to ensure proper life-cycle management.

The primary requirement of the transaction manager service on startup is that it binds its implementation of the three required interfaces into JNDI. These interfaces and their JNDI locations are:

- The `javax.transaction.TransactionManager` interface is used by the application server to manage transactions on behalf of the transactional objects that use container managed transactions. It must be bound under the JNDI name `java:/TransactionManager`.
- The `TransactionPropagationContextFactory` interface is called by JBoss whenever a transaction propagation context is needed for transporting a transaction with a remote method call. It must be bound under the JNDI name `java:/TransactionPropagationContextImporter`.
- The `TransactionPropagationContextImporter` interface is called by JBoss whenever a transaction propagation context from an incoming remote method invocation has to be converted to a transaction that can be used within the receiving JBoss server VM.

Establishing these JNDI bindings is all the transaction manager service needs to do to install its implementation as the JBoss server transaction manager.

3.2.2. The Default Transaction Manager

JBoss is by default configured to use the fast in-VM transaction manager. This transaction manager is very fast, but does have two limitations.

- It does not do transactional logging, and is thus incapable of automated recovery after a server crash.
- While it does support propagating transaction contexts with remote calls, it does not support propagating transaction contexts to other virtual machines, so all transactional work must be done in the same virtual machine as the JBoss server.

The corresponding default transaction manager MBean service is the `org.jboss.tm.TransactionManagerService` MBean. It has two configurable attributes:

- **TransactionTimeout**: The default transaction timeout in seconds. The default value is 300 seconds (5 minutes).
- **InterruptThreads**: Indicates whether or not the transaction manager should interrupt threads when the transaction times out. The default value is false.
- **GlobalIdsEnabled**: Indicates whether or not the transaction manager should use global transaction ids. This

should be set to true for transaction demarcation over IIOP The default value is true.

- **XidFactory**: The JMX `ObjectName` of the MBean service that provides the `org.jboss.tm.XidFactoryMBean` implementation. The `XidFactoryMBean` interface is used to create `javax.transaction.xa.Xid` instances. This is a workaround for XA JDBC drivers that only work with their own Xid implementation. Examples of such drivers are the older Oracle XA drivers. The default factory is `jboss:service=XidFactory`.

3.2.2.1. org.jboss.tm.XidFactory

The `XidFactory` MBean is a factory for `javax.transaction.xa.Xid` instances in the form of `org.jboss.tm.XidImpl`. The `XidFactory` allows for customization of the `XidImpl` that it constructs through the following attributes:

- **BaseGlobalId**: This is used for building globally unique transaction identifiers. This must be set individually if multiple JBoss instances are running on the same machine. The default value is the host name of the JBoss server, followed by a slash.
- **GlobalIdNumber**: A long value used as initial transaction id. The default is 0.
- **Pad**: The pad value determines whether the byte[] returned by the Xid `getGlobalTransactionId` and `get-BranchQualifier` methods should be equal to maximum 64 byte length or a variable value <= 64. Some resource managers (Oracle, for example) require ids that are max length in size.

3.2.3. UserTransaction Support

The JTA `javax.transaction.UserTransaction` interface allows applications to explicitly control transactions. For enterprise session beans that manage transaction themselves (BMT), a `UserTransaction` can be obtained by calling the `getUserTransaction` method on the bean context object, `javax.ejb.SessionContext`.

The `ClientUserTransactionService` MBean publishes a `UserTransaction` implementation under the JNDI name `UserTransaction`. When the `UserTransaction` is obtained with a JNDI lookup from a external client, a very simple `UserTransaction` suitable for thin clients is returned. This `UserTransaction` implementation only controls the transactions on the server the `UserTransaction` object was obtained from. Local transactional work done in the client is not done within the transactions started by this `UserTransaction` object.

When a `UserTransaction` object is obtained by looking up JNDI name `UserTransaction` in the same virtual machine as JBoss, a simple interface to the JTA `TransactionManager` is returned. This is suitable for web components running in web containers embedded in JBoss. When components are deployed in an embedded web server, the deployer will make a JNDI link from the standard `java:comp/UserTransaction` ENC name to the global `UserTransaction` binding so that the web components can lookup the `UserTranaction` instance under JNDI name as specified by the J2EE.

Note: For BMT beans, do not obtain the `UserTransaction` interface using a JNDI lookup. Doing this violates the EJB specification, and the returned `UserTransaction` object does not have the hooks the EJB container needs to make important checks.

4

EJBs on JBoss

The EJB Container Configuration and Architecture

The JBoss EJB container architecture employs a modular plug-in approach. All key aspects of the EJB container may be replaced by custom versions of a plug-in and/or an interceptor by a developer. This approach allows for fine tuned customization of the EJB container behavior to optimally suite your needs. Most of the EJB container behavior is configurable through the EJB JAR `META-INF/jboss.xml` descriptor and the default server-wide equivalent `standardjboss.xml` descriptor. We will look at various configuration capabilities throughout this chapter as we explore the container architecture.

4.1. The EJB Client Side View

We will begin our tour of the EJB container by looking at the client view of an EJB through the home and remote proxies. It is the responsibility of the container provider to generate the `javax.ejb.EJBHome` and `javax.ejb.EJBObject` for an EJB implementation. A client never references an EJB bean instance directly, but rather references the `EJBHome` which implements the bean home interface, and the `EJBObject` which implements the bean remote interface. Figure 4.1 shows the composition of an EJB home proxy and its relation to the EJB deployment.

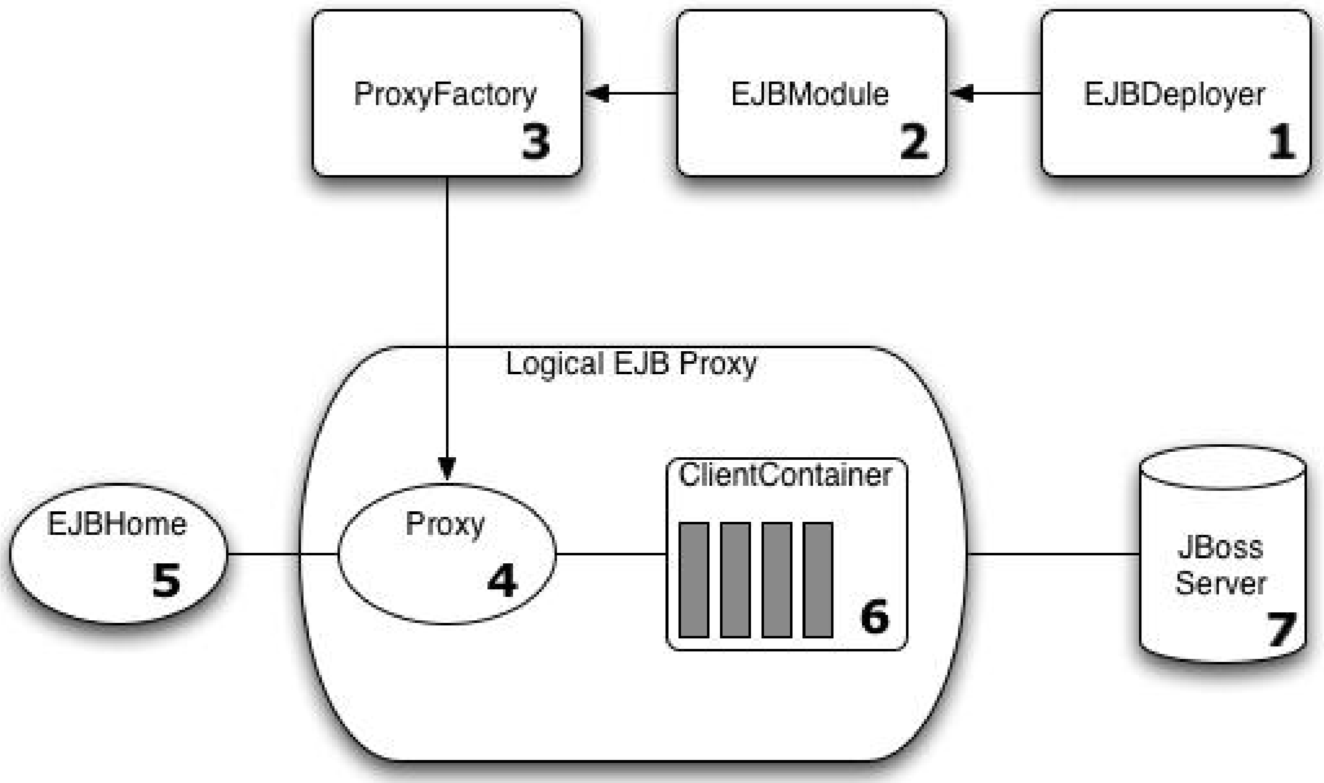


Figure 4.1. The composition of an EJBHome proxy in JBoss.

The numbered items in the figure are:

1. The EJBDeployer (`org.jboss.ejb.EJBDeployer`) is invoked to deploy an EJB JAR. An `EJBModule` (`org.jboss.ejb.EJBModule`) is created to encapsulate the deployment metadata.

2. The create phase of the `EJBModule` life cycle creates an `EJBProxyFactory` (`org.jboss.ejb.EJBProxyFactory`) that manages the creation of EJB home and remote interface proxies based on the `EJBModule invoker-proxy-bindings` metadata. There can be multiple proxy factories associated with an EJB and we will look at how this is defined shortly.

3. The `ProxyFactory` constructs the logical proxies and binds the homes into JNDI. A logical proxy is composed of a dynamic `Proxy` (`java.lang.reflect.Proxy`), the home interfaces of the EJB that the proxy exposes, the `ProxyHandler` (`java.lang.reflect.InvocationHandler`) implementation in the form of the `ClientContainer` (`org.jboss.proxy.ClientContainer`), and the client side interceptors.

4. The proxy created by the `EJBProxyFactory` is a standard dynamic proxy. It is a serializable object that proxies the EJB home and remote interfaces as defined in the `EJBModule` metadata. The proxy translates requests made through the strongly typed EJB interfaces into a detyped invocation using the `ClientContainer` handler associated with the proxy. It is the dynamic proxy instance that is bound into JNDI as the EJB home interface that clients lookup. When a client does a lookup of an EJB home, the home proxy is transported into the client VM along with the `ClientContainer` and its interceptors. The use of dynamic proxies avoids the EJB specific compilation step required by many other EJB containers.

5. The EJB home interface is declared in the ejb-jar.xml descriptor and available from the EJBModule metadata. A key property of dynamic proxies is that they are seen to implement the interfaces they expose. This is true in the sense of Java's strong type system. A proxy can be cast to any of the home interfaces and reflection on the proxy provides the full details of the interfaces it proxies.

6. The proxy delegates calls made through any of its interfaces to the `ClientContainer` handler. The single method required of the handler is: `public Object invoke(Object proxy, Method m, Object[] args) throws Throwable`. The `EJBProxyFactory` creates a `ClientContainer` and assigns this as the `ProxyHandler`. The `ClientContainer`'s state consists of an `InvocationContext` (`org.jboss.invocation.InvocationContext`) and a chain of interceptors (`org.jboss.proxy.Interceptor`). The `InvocationContext` contains:

   - the JMX `ObjectName` of the EJB container MBean the `Proxy` is associated with
   - the `javax.ejb.EJBMetaData` for the EJB
   - the JNDI name of the EJB home interface
   - the transport specific invoker (`org.jboss.invocation.Invoker`)

   The interceptor chain consists of the functional units that make up the EJB home or remote interface behavior. This is a configurable aspect of an EJB as we will see when we discuss the `jboss.xml` descriptor, and the interceptor makeup is contained in the `EJBModule` metadata. Interceptors (`org.jboss.proxy.Interceptor`) handle the different EJB types, security, transactions and transport. You can add your own interceptors as well.

7. The transport specific invoker associated with the proxy has an association to the server side detached invoker

that handles the transport details of the EJB method invocation. The detached invoker is a JBoss server side component.

The configuration of the client side interceptors is done using the `jboss.xml` `client-interceptors` element. When the `ClientContainer` invoke method is called it creates an untyped `Invocation` (`org.jboss.invocation.Invocation`) to encapsulate request. This is then passed through the interceptor chain. The last interceptor in the chain will be the transport handler that knows how to send the request to the server and obtain the reply, taking care of the transport specific details.

As an example of the client interceptor configuration usage, consider the default stateless session bean configuration found in the `server/default/standardjboss.xml` descriptor. Example 4.1 shows the `stateless-rmi-invoker` client interceptors configuration referenced by the Standard Stateless SessionBean.

Example 4.1. The client-interceptors from the Standard Stateless SessionBean configuration.

```
<invoker-proxy-binding>
    <name>stateless-rmi-invoker</name>
    <invoker-mbean>jboss:service=invoker,type=jrmp</invoker-mbean>
    <proxy-factory>org.jboss.proxy.ejb.ProxyFactory</proxy-factory>
        <proxy-factory-config>
        <client-interceptors>
            <home>
                <interceptor>org.jboss.proxy.ejb.HomeInterceptor</interceptor>
                <interceptor>org.jboss.proxy.SecurityInterceptor</interceptor>
                <interceptor>org.jboss.proxy.TransactionInterceptor</interceptor>
                <interceptor call-by-value="false">
                    org.jboss.invocation.InvokerInterceptor
                </interceptor>
                <interceptor call-by-value="true">
                    org.jboss.invocation.MarshallingInvokerInterceptor
                </interceptor>
            </home>
            <bean>
                <interceptor>org.jboss.proxy.ejb.StatelessSessionInterceptor</interceptor>
                <interceptor>org.jboss.proxy.SecurityInterceptor</interceptor>
                <interceptor>org.jboss.proxy.TransactionInterceptor</interceptor>
                <interceptor call-by-value="false">
                    org.jboss.invocation.InvokerInterceptor
                </interceptor>
                <interceptor call-by-value="true">
                    org.jboss.invocation.MarshallingInvokerInterceptor
                </interceptor>
            </bean>
        </client-interceptors>
    </proxy-factory-config>
</invoker-proxy-binding>
```

```
<container-configuration>
    <container-name>Standard Stateless SessionBean</container-name>
    <call-logging>false</call-logging>
    <invoker-proxy-binding-name>stateless-rmi-invoker</invoker-proxy-binding-name>
    <!-- ... -->
</container-configuration>
```

This is the client interceptor configuration for stateless session beans that is used in the absence of an EJB JAR `META-INF/jboss.xml` configuration that overrides these settings. The functionality provided by each client interceptor is:

- **org.jboss.proxy.ejb.HomeInterceptor**: handles the `getHomeHandle`, `getEJBMetaData`, and remove methods of the `EJBHome` interface locally in the client VM. Any other methods are propagated to the next interceptor.
- **org.jboss.proxy.ejb.StatelessSessionInterceptor**: handles the `toString`, `equals`, `hashCode`, `getHandle`, `getEJBHome` and `isIdentical` methods of the `EJBObject` interface locally in the client VM. Any other methods are propagated to the next interceptor.
- **org.jboss.proxy.SecurityInterceptor**: associates the current security context with the method invocation for use by other interceptors or the server.
- **org.jboss.proxy.TransactionInterceptor**: associates any active transaction with the invocation method invocation for use by other interceptors.
- **org.jboss.invocation.InvokerInterceptor**: encapsulates the dispatch of the method invocation to the transport specific invoker. It knows if the client is executing in the same VM as the server and will optimally route the invocation to a by reference invoker in this situation. When the client is external to the server VM, this interceptor delegates the invocation to the transport invoker associated with the invocation context. In the case of the Example 4.1 configuration, this would be the invoker stub associated with the `jboss:service=invoker,type=jrmp`, the `JRMPInvoker` service.

  org.jboss.invocation.MarshallingInvokerInterceptor: extends the `InvokerInterceptor` to not optimize in-VM invocations. This is used to force `call-by-value` semantics for method calls.

4.1.1. Specifying the EJB Proxy Configuration

To specify the EJB invocation transport and the client proxy interceptor stack, you need to define an `invoker-proxy-binding` in either the EJB JAR `META-INF/jboss.xml descriptor`, or the server `standardjboss.xml` descriptor. There are several default `invoker-proxy-bindings` defined in the `standardjboss.xml` descriptor for the various default EJB container configurations and the standard RMI/JRMP and RMI/IIOP transport protocols. The current default proxy configurations are:

- **entity-rmi-invoker**: a RMI/JRMP configuration for entity beans
- **clustered-entity-rmi-invoker**: a RMI/JRMP configuration for clustered entity beans
- **stateless-rmi-invoker**: a RMI/JRMP configuration for stateless session beans
- **clustered-stateless-rmi-invoker**: a RMI/JRMP configuration for clustered stateless session beans
- **stateful-rmi-invoker**: a RMI/JRMP configuration for clustered stateful session beans
- **clustered-stateful-rmi-invoker**: a RMI/JRMP configuration for clustered stateful session beans
- **message-driven-bean**: a JMS invoker for message driven beans
- **singleton-message-driven-bean**: a JMS invoker for singleton message driven beans
- **message-inflow-driven-bean**: a JMS invoker for message inflow driven beans

- **jms-message-inflow-driven-bean**: a JMS inflow invoker for standard message driven beans
- **iiop**: a RMI/IIOP for use with session and entity beans.

To introduce a new protocol binding, or customize the proxy factory, or the client side interceptor stack, requires defining a new `invoker-proxy-binding`. The full `invoker-proxy-binding` DTD fragment for the specification of the proxy configuration is given in Figure 4.2.

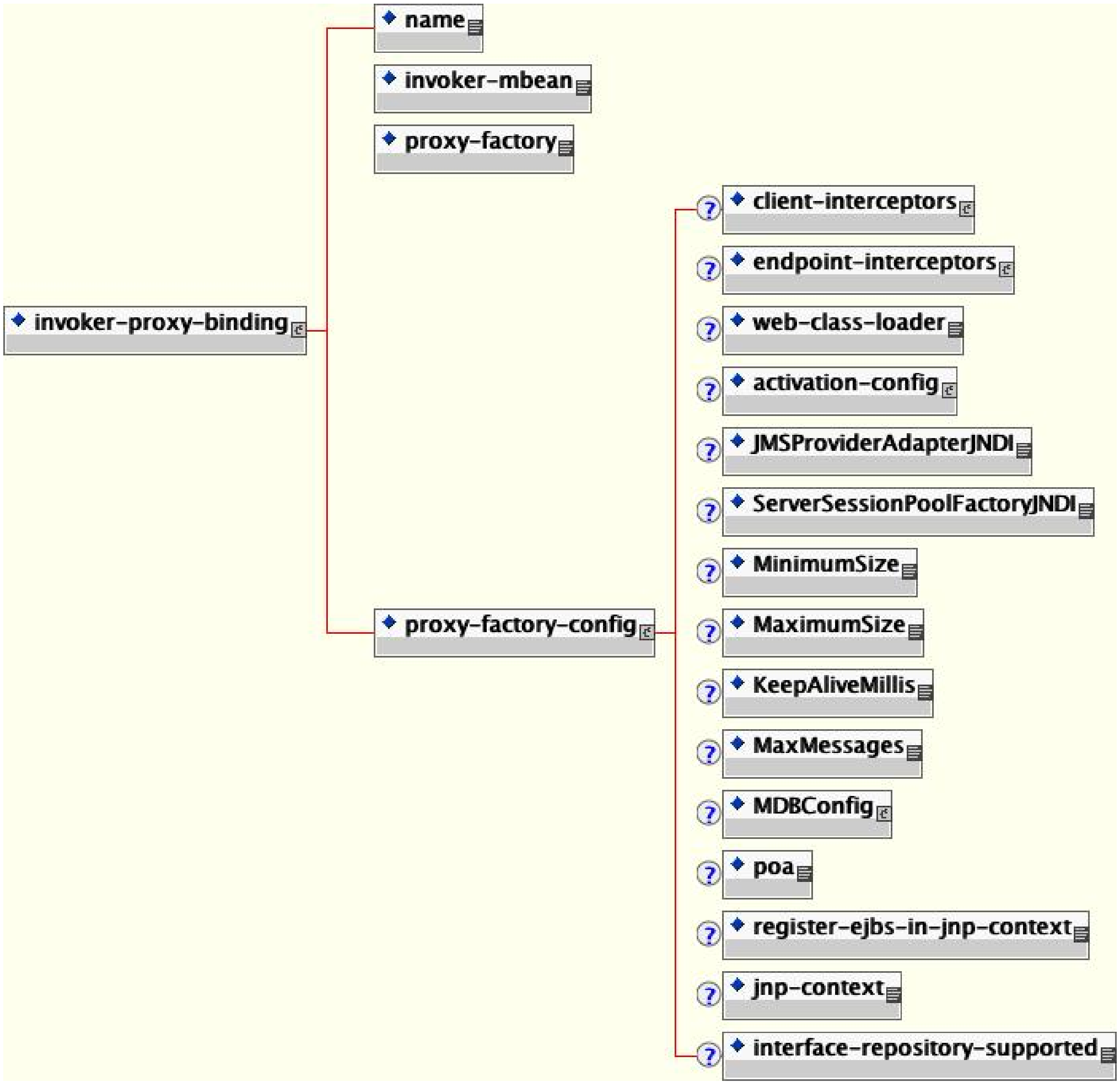


Figure 4.2. The invoker-proxy-binding schema

The `invoker-proxy-binding` child elements are:

- **name**: The `name` element gives a unique name for the `invoker-proxy-binding`. The name is used to reference the binding from the EJB container configuration when setting the default proxy binding as well as the EJB deployment level to specify addition proxy bindings. You will see how this is done when we look at the `jboss.xml` elements that control the server side EJB container configuration.

- **invoker-mbean**: The `invoker-mbean` element gives the JMX `ObjectName` string of the detached invoker MBean service the proxy invoker will be associated with.

- **proxy-factory**: The `proxy-factory` element specifies the fully qualified class name of the proxy factory, which must implement the `org.jboss.ejb.EJBProxyFactory` interface. The `EJBProxyFactory` handles the configuration of the proxy and the association of the protocol specific invoker and context. The current JBoss implementations of the `EJBProxyFactory` interface include:

  - **org.jboss.proxy.ejb.ProxyFactory**: The RMI/JRMP specific factory.

  - **org.jboss.proxy.ejb.ProxyFactoryHA**: The cluster RMI/JRMP specific factory.

  - **org.jboss.ejb.plugins.jms.JMSContainerInvoker**: The JMS specific factory.

  - **org.jboss.proxy.ejb.IORFactory**: The RMI/IIOP specific factory.

- **proxy-factory-config**: The `proxy-factory-config` element specifies additional information for the `proxy-factory` implementation. Unfortunately, its currently an unstructured collection of elements. Only a few of the elements apply to each type of proxy factory. The child elements break down into the three invocation protocols: RMI/RJMP, RMI/IIOP and JMS.

For the RMI/JRMP specific proxy factories, `org.jboss.proxy.ejb.ProxyFactory` and `org.jboss.proxy.ejb.ProxyFactoryHA` the following elements apply:

- **client-interceptors**: The `client-interceptors` define the home, remote and optionally the multi-valued proxy interceptor stacks.

- **web-class-loader**: The web class loader defines the instance of the `org.jboss.web.WebClassLoader` that should be associated with the proxy for dynamic class loading.

The following `proxy-factory-config` is for an entity bean accessed over RMI.

```
<proxy-factory-config>
    <client-interceptors>
        <home>
            <interceptor>org.jboss.proxy.ejb.HomeInterceptor</interceptor>
            <interceptor>org.jboss.proxy.SecurityInterceptor</interceptor>
            <interceptor>org.jboss.proxy.TransactionInterceptor</interceptor>
            <interceptor call-by-value="false">
                org.jboss.invocation.InvokerInterceptor
            </interceptor>
            <interceptor call-by-value="true">
                org.jboss.invocation.MarshallingInvokerInterceptor
            </interceptor>
        </home>
        <bean>
            <interceptor>org.jboss.proxy.ejb.EntityInterceptor</interceptor>
            <interceptor>org.jboss.proxy.SecurityInterceptor</interceptor>
            <interceptor>org.jboss.proxy.TransactionInterceptor</interceptor>
            <interceptor call-by-value="false">
                org.jboss.invocation.InvokerInterceptor
            </interceptor>
            <interceptor call-by-value="true">
                org.jboss.invocation.MarshallingInvokerInterceptor
            </interceptor>
        </bean>
        <list-entity>
            <interceptor>org.jboss.proxy.ejb.ListEntityInterceptor</interceptor>
            <interceptor>org.jboss.proxy.SecurityInterceptor</interceptor>
            <interceptor>org.jboss.proxy.TransactionInterceptor</interceptor>
            <interceptor call-by-value="false">
                org.jboss.invocation.InvokerInterceptor
            </interceptor>
            <interceptor call-by-value="true">
                org.jboss.invocation.MarshallingInvokerInterceptor
            </interceptor>
        </list-entity>
    </client-interceptors>
</proxy-factory-config>
```

For the RMI/IIOP specific proxy factory, `org.jboss.proxy.ejb.IORFactory`, the following elements apply:

- **web-class-loader**: The web class loader defines the instance of the `org.jboss.web.WebClassLoader` that should be associated with the proxy for dynamic class loading.
- **poa**: The portable object adapter usage. Valid values are `per-servant` and `shared`.
- **register-ejbs-in-jnp-context**: A flag indicating if the EJBs should be register in JNDI.
- **jnp-context**: The JNDI context in which to register EJBs.
- **interface-repository-supported**: This indicates whether or not a deployed EJB has its own CORBA interface repository.

The following shows a `proxy-factory-config` for EJBs accessed over IIOP.

```
<proxy-factory-config>
    <web-class-loader>org.jboss.iiop.WebCL</web-class-loader>
    <poa>per-servant</poa>
    <register-ejbs-in-jnp-context>true</register-ejbs-in-jnp-context>
    <jnp-context>iiop</jnp-context>
</proxy-factory-config>
```

For the JMS specific proxy factory, `org.jboss.ejb.plugins.jms.JMSContainerInvoker`, the following elements apply:

- **MinimumSize**: This specifies the minimum pool size for MDBs processing . This defaults to 1.
- **MaximumSize**: This specifies the upper limit to the number of concurrent MDBs that will be allowed for the JMS destination. This defaults to 15.
- **MaxMessages**: This specifies the `maxMessages` parameter value for the `createConnectionConsumer` method of `javax.jms.QueueConnection` and `javax.jms.TopicConnection` interfaces, as well as the `maxMessages` parameter value for the `createDurableConnectionConsumer` method of `javax.jms.TopicConnection`. It is the maximum number of messages that can be assigned to a server session at one time. This defaults to 1. This

value should not be modified from the default unless your JMS provider indicates this is supported.

- **KeepAliveMillis**: This specifies the keep alive time interval in milliseconds for sessions in the session pool. The default is 30000 (30 seconds).
- **MDBConfig**: Configuration for the MDB JMS connection behavior. Among the elements supported are:
  - **ReconnectIntervalSec**: The time to wait (in seconds) before trying to recover the connection to the JMS server.
  - **DeliveryActive**: Whether or not the MDB is active at startup. The default is true.
  - **DLQConfig**: Configuration for an MDB's dead letter queue, used when messages are redelivered too many times.
  - **JMSProviderAdapterJNDI**: The JNDI name of the JMS provider adapter in the `java:/` namespace. This is mandatory for an MDB and must implement `org.jboss.jms.jndi.JMSProviderAdapter`.
  - **ServerSessionPoolFactoryJNDI**: The JNDI name of the session pool in the `java:/` namespace of the JMS provider's session pool factory. This is mandatory for an MDB and must implement `org.jboss.jms.asf.ServerSessionPoolFactory`.

Example 4.2 gives a sample `proxy-factory-config` fragment taken from the `standardjboss.xml` descriptor.

Example 4.2. A sample JMSContainerInvoker proxy-factory-config

```
<proxy-factory-config>
    <JMSProviderAdapterJNDI>DefaultJMSProvider</JMSProviderAdapterJNDI>
    <ServerSessionPoolFactoryJNDI>StdJMSPool</ServerSessionPoolFactoryJNDI>
    <MinimumSize>1</MinimumSize>
    <MaximumSize>15</MaximumSize>
    <KeepAliveMillis>30000</KeepAliveMillis>
    <MaxMessages>1</MaxMessages>
    <MDBConfig>
        <ReconnectIntervalSec>10</ReconnectIntervalSec>
        <DLQConfig>
            <DestinationQueue>queue/DLQ</DestinationQueue>
            <MaxTimesRedelivered>10</MaxTimesRedelivered>
            <TimeToLive>0</TimeToLive>
        </DLQConfig>
    </MDBConfig>
</proxy-factory-config>
```

4.2. The EJB Server Side View

Every EJB invocation must end up at a JBoss server hosted EJB container. In this section we will look at how invocations are transported to the JBoss server VM and find their way to the EJB container via the JMX bus.

4.2.1. Detached Invokers - The Transport Middlemen

We looked at the detached invoker architecture in the context of exposing RMI compatible interfaces of MBean services earlier. Here we will look at how detached invokers are used to expose the EJB container home and bean interfaces to clients. The generic view of the invoker architecture is presented in Figure 4.3.

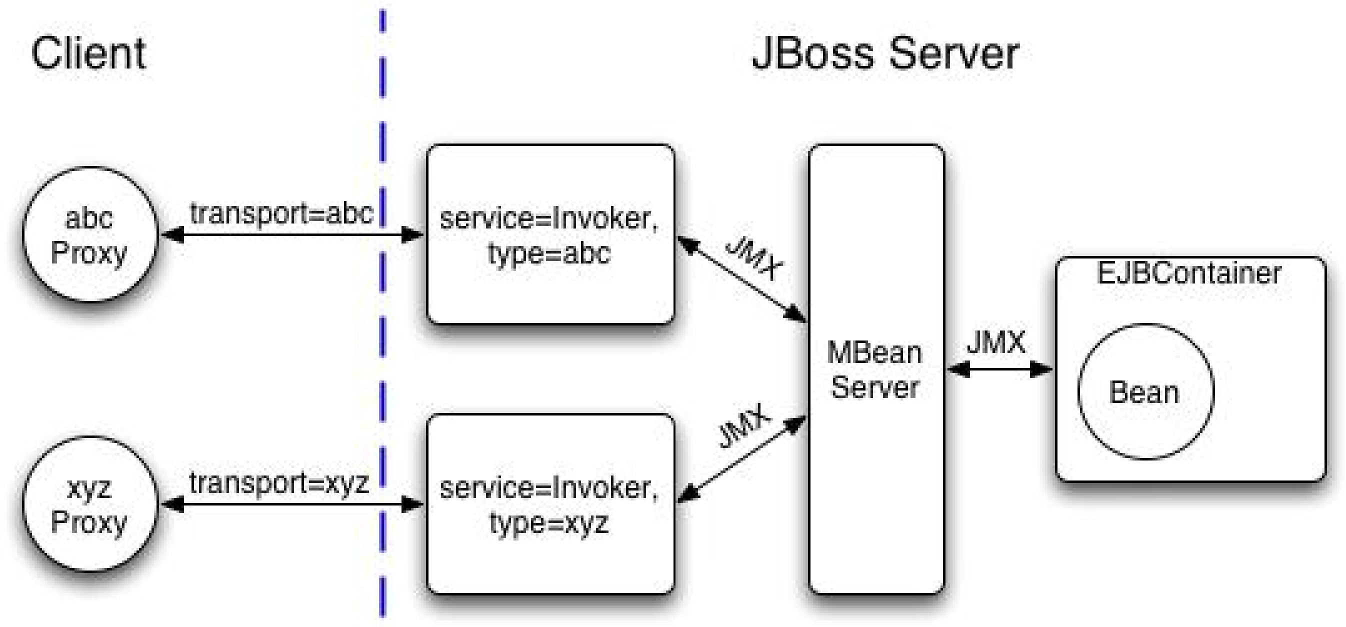


Figure 4.3. The transport invoker server side architecture

For each type of home proxy there is a binding to an invoker and its associated transport protocol. A container may have multiple invocation protocols active simultaneously. In the `jboss.xml` file, an `invoker-proxy-binding-name` maps to an `invoker-proxy-binding/name` element. At the `container-configuration` level this specifies the default invoker that will be used for EJBs deployed to the container. At the bean level, the `invoker-bindings` specify one or more invokers to use with the EJB container MBean.

When one specifies multiple invokers for a given EJB deployment, the home proxy must be given a unique JNDI binding location. This is specified by the `invoker/jndi-name` element value. Another issue when multiple invokers exist for an EJB is how to handle remote homes or interfaces obtained when the EJB calls other beans. Any such interfaces need to use the same invoker used to call the outer EJB in order for the resulting remote homes and interfaces to be compatible with the proxy the client has initiated the call through. The `invoker/ejb-ref` elements allow one to map from a protocol independent ENC `ejb-ref` to the home proxy binding for `ejb-ref` target EJB home that matches the referencing invoker type.

An example of using a custom `JRMPInvoker` MBean that enables compressed sockets for session beans can be found in the `org.jboss.test.jrmp` package of the testsuite. The following example illustrates the custom `JRMPInvoker` configuration and its mapping to a stateless session bean.

```
<server>
    <mbean code="org.jboss.invocation.jrmp.server.JRMPInvoker"
          name="jboss:service=invoker,type=jrmp,socketType=CompressionSocketFactory">
        <attribute name="RMIObjectPort">4445</attribute>
        <attribute name="RMIClientSocketFactory">
            org.jboss.test.jrmp.ejb.CompressionClientSocketFactory
        </attribute>
        <attribute name="RMIServerSocketFactory">
            org.jboss.test.jrmp.ejb.CompressionServerSocketFactory
        </attribute>
</mbean>
                </server>
```

Here the default `JRMPInvoker` has been customized to bind to port 4445 and to use custom socket factories that enable compression at the transport level.

```
<?xml version="1.0"?>
<!DOCTYPE jboss PUBLIC
          "-//JBoss//DTD JBOSS 3.2//EN"
          "http://www.jboss.org/j2ee/dtd/jboss_3_2.dtd">
<!-- The jboss.xml descriptor for the jrmp-comp.jar ejb unit -->
<jboss>
    <enterprise-beans>
        <session>
            <ejb-name>StatelessSession</ejb-name>
            <configuration-name>Standard Stateless SessionBean</configuration-name>
            <invoker-bindings>
                <invoker>
                    <invoker-proxy-binding-name>
                        stateless-compression-invoker
                    </invoker-proxy-binding-name>
                    <jndi-name>jrmp-compressed/StatelessSession</jndi-name>
                </invoker>
            </invoker-bindings>
        </session>
    </enterprise-beans>

    <invoker-proxy-bindings>
        <invoker-proxy-binding>
            <name>stateless-compression-invoker</name>
            <invoker-mbean>
                jboss:service=invoker,type=jrmp,socketType=CompressionSocketFactory
            </invoker-mbean>
            <proxy-factory>org.jboss.proxy.ejb.ProxyFactory</proxy-factory>
            <proxy-factory-config>
                <client-interceptors>
                    <home>
                        <interceptor>org.jboss.proxy.ejb.HomeInterceptor</interceptor>
                        <interceptor>org.jboss.proxy.SecurityInterceptor</interceptor>
                        <interceptor>org.jboss.proxy.TransactionInterceptor</interceptor>
                        <interceptor>org.jboss.invocation.InvokerInterceptor</interceptor>
                    </home>
                    <bean>
                        <interceptor>
                            org.jboss.proxy.ejb.StatelessSessionInterceptor
                        </interceptor>
                        <interceptor>org.jboss.proxy.SecurityInterceptor</interceptor>
                        <interceptor>org.jboss.proxy.TransactionInterceptor</interceptor>
                        <interceptor>org.jboss.invocation.InvokerInterceptor</interceptor>
                    </bean>
                </client-interceptors>
            </proxy-factory-config>
        </invoker-proxy-binding>
    </invoker-proxy-bindings>
</jboss>
```

The `StatelessSession` EJB `invoker-bindings` settings specify that the `stateless-compression-invoker` will be used with the home interface bound under the JNDI name `jrmp-compressed/StatelessSession`. The `stateless-compression-invoker` is linked to the custom JRMP invoker we just declared.

The following example, `org.jboss.test.hello` testsuite package, is an example of using the `HttpInvoker` to configure a stateless session bean to use the RMI/HTTP protocol.

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE jboss PUBLIC
          "-//JBoss//DTD JBOSS 3.2//EN"
          "http://www.jboss.org/j2ee/dtd/jboss_3_2.dtd">
<jboss>
    <enterprise-beans>
        <session>
            <ejb-name>HelloWorldViaHTTP</ejb-name>
            <jndi-name>helloworld/HelloHTTP</jndi-name>
            <invoker-bindings>
                <invoker>
                    <invoker-proxy-binding-name>
                        stateless-http-invoker
                    </invoker-proxy-binding-name>
                </invoker>
            </invoker-bindings>
        </session>
    </enterprise-beans>
    <invoker-proxy-bindings>
        <!-- A custom invoker for RMI/HTTP -->
        <invoker-proxy-binding>
            <name>stateless-http-invoker</name>
            <invoker-mbean>jboss:service=invoker,type=http</invoker-mbean>
            <proxy-factory>org.jboss.proxy.ejb.ProxyFactory</proxy-factory>
            <proxy-factory-config>
                <client-interceptors>
                    <home>
                        <interceptor>org.jboss.proxy.ejb.HomeInterceptor</interceptor>
                        <interceptor>org.jboss.proxy.SecurityInterceptor</interceptor>
                        <interceptor>org.jboss.proxy.TransactionInterceptor</interceptor>
                        <interceptor>org.jboss.invocation.InvokerInterceptor</interceptor>
                    </home>
                    <bean>
                        <interceptor>
                            org.jboss.proxy.ejb.StatelessSessionInterceptor
                        </interceptor>
                        <interceptor>org.jboss.proxy.SecurityInterceptor</interceptor>
                        <interceptor>org.jboss.proxy.TransactionInterceptor</interceptor>
                        <interceptor>org.jboss.invocation.InvokerInterceptor</interceptor>
                    </bean>
                </client-interceptors>
            </proxy-factory-config>
        </invoker-proxy-binding>
    </invoker-proxy-bindings>
</jboss>
```

Here a custom invoker-proxy-binding named `stateless-http-invoker` is defined. It uses the `HttpInvoker` MBean as the detached invoker. The `jboss:service=invoker,type=http` name is the default name of the `HttpInvoker` MBean as found in the `http-invoker.sar/META-INF/jboss-service.xml` descriptor, and its service descriptor fragment is show here:

```
<!-- The HTTP invoker service configuration -->
<mbean code="org.jboss.invocation.http.server.HttpInvoker"
       name="jboss:service=invoker,type=http">
    <!-- Use a URL of the form http://<hostname>:8080/invoker/EJBInvokerServlet
         where <hostname> is InetAddress.getHostname value on which the server
         is running. -->
    <attribute name="InvokerURLPrefix">http://</attribute>
    <attribute name="InvokerURLSuffix">:8080/invoker/EJBInvokerServlet</attribute>
    <attribute name="UseHostName">true</attribute>
</mbean>
```

The client proxy posts the EJB invocation content to the `EJBInvokerServlet` URL specified in the `HttpInvoker` service configuration.

4.2.2. The HA JRMPInvoker - Clustered RMI/JRMP Transport

The `org.jboss.invocation.jrmp.server.JRMPInvokerHA` service is an extension of the `JRMPInvoker` that is a cluster aware invoker. The `JRMPInvokerHA` fully supports all of the attributes of the `JRMPInvoker`. This means that customized bindings of the port, interface and socket transport are available to clustered RMI/JRMP as well. For additional information on the clustering architecture and the implementation of the HA RMI proxies see the JBoss Clustering docs.

4.2.3. The HA HttpInvoker - Clustered RMI/HTTP Transport

The RMI/HTTP layer allows for software load balancing of the invocations in a clustered environment. An HA capable extension of the HTTP invoker has been added that borrows much of its functionality from the HA-RMI/JRMP clustering.

To enable HA-RMI/HTTP you need to configure the invokers for the EJB container. This is done through either a `jboss.xml` descriptor, or the `standardjboss.xml` descriptor. Example 4.3 shows is an example of a stateless session configuration taken from the `org.jboss.test.hello` testsuite package.

Example 4.3. A jboss.xml stateless session configuration for HA-RMI/HTTP

```
<jboss>
    <enterprise-beans>
        <session>
            <ejb-name>HelloWorldViaClusteredHTTP</ejb-name>
            <jndi-name>helloworld/HelloHA-HTTP</jndi-name>
            <invoker-bindings>
                <invoker>
                    <invoker-proxy-binding-name>
                        stateless-httpHA-invoker
                    </invoker-proxy-binding-name>
                </invoker>
            </invoker-bindings>
            <clustered>true</clustered>
        </session>
    </enterprise-beans>
    <invoker-proxy-bindings>
        <invoker-proxy-binding>
            <name>stateless-httpHA-invoker</name>
            <invoker-mbean>jboss:service=invoker,type=httpHA</invoker-mbean>
            <proxy-factory>org.jboss.proxy.ejb.ProxyFactoryHA</proxy-factory>
            <proxy-factory-config>
                <client-interceptors>
                    <home>
                        <interceptor>org.jboss.proxy.ejb.HomeInterceptor</interceptor>
                        <interceptor>org.jboss.proxy.SecurityInterceptor</interceptor>
                        <interceptor>org.jboss.proxy.TransactionInterceptor</interceptor>
                        <interceptor>org.jboss.invocation.InvokerInterceptor</interceptor>
                    </home>
                    <bean>
                        <interceptor>
                            org.jboss.proxy.ejb.StatelessSessionInterceptor
                        </interceptor>
                        <interceptor>org.jboss.proxy.SecurityInterceptor</interceptor>
                        <interceptor>org.jboss.proxy.TransactionInterceptor</interceptor>
                        <interceptor>org.jboss.invocation.InvokerInterceptor</interceptor>
                    </bean>
                </client-interceptors>
            </proxy-factory-config>
        </invoker-proxy-binding>
    </invoker-proxy-bindings>
</jboss>
```

The `stateless-httpHA-invoker` invoker-proxy-binding references the `jboss:service=invoker,type=httpHA` invoker service. This service would be configured as shown below.

```
<mbean code="org.jboss.invocation.http.server.HttpInvokerHA"
       name="jboss:service=invoker,type=httpHA">
    <!-- Use a URL of the form
         http://<hostname>:8080/invoker/EJBInvokerHAServlet
         where <hostname> is InetAddress.getHostname value on which the server
         is running.
    -->
    <attribute name="InvokerURLPrefix">http://</attribute>
    <attribute name="InvokerURLSuffix">:8080/invoker/EJBInvokerHAServlet</attribute>
    <attribute name="UseHostName">true</attribute>
</mbean>
```

The URL used by the invoker proxy is the `EJBInvokerHAServlet` mapping as deployed on the cluster node. The `HttpInvokerHA` instances across the cluster form a collection of candidate http URLs that are made available to the client side proxy for failover and/or load balancing.

4.3. The EJB Container

An EJB container is the component that manages a particular class of EJB. In JBoss there is one instance of the `org.jboss.ejb.Container` created for each unique configuration of an EJB that is deployed. The actual object that is instantiated is a subclass of `Container` and the creation of the container instance is managed by the `EJBDeployer` MBean.

4.3.1. EJBDeployer MBean

The `org.jboss.ejb.EJBDeployer` MBean is responsible for the creation of EJB containers. Given an EJB JAR that is ready for deployment, the `EJBDeployer` will create and initialize the necessary EJB containers, one for each type of EJB. The configurable attributes of the `EJBDeployer` are:

- **VerifyDeployments**: a boolean flag indicating if the EJB verifier should be run. This validates that the EJBs in a deployment unit conform to the EJB 2.1 specification. Setting this to true is useful for ensuring your deployments are valid.
- **VerifierVerbose**: A boolean that controls the verboseness of any verification failures/warnings that result from the verification process.
- **StrictVerifier**: A boolean that enables/disables strict verification. When strict verification is enable an EJB will deploy only if verifier reports no errors.

- **CallByValue**: a boolean flag that indicates call by value semantics should be used by default.
- **ValidateDTDs**: a boolean flag that indicates if the `ejb-jar.xml` and `jboss.xml` descriptors should be validated against their declared DTDs. Setting this to true is useful for ensuring your deployment descriptors are valid.
- **MetricsEnabled**: a boolean flag that controls whether container interceptors marked with an `metricsEnabled=true` attribute should be included in the configuration. This allows one to define a container interceptor configuration that includes metrics type interceptors that can be toggled on and off.
- **WebServiceName**: The JMX ObjectName string of the web service MBean that provides support for the dynamic class loading of EJB classes.
- **TransactionManagerServiceName**: The JMX ObjectName string of the JTA transaction manager service. This must have an attribute named `TransactionManager` that returns that `javax.transaction.TransactionManager` instance.

The deployer contains two central methods: deploy and undeploy. The deploy method takes a URL, which either points to an EJB JAR, or to a directory whose structure is the same as a valid EJB JAR (which is convenient for development purposes). Once a deployment has been made, it can be undeployed by calling undeploy on the same URL. A call to deploy with an already deployed URL will cause an undeploy, followed by deployment of the URL. JBoss has support for full re-deployment of both implementation and interface classes, and will reload any changed classes. This will allow you to develop and update EJBs without ever stopping a running server.

During the deployment of the EJB JAR the `EJBDeployer` and its associated classes perform three main functions, verify the EJBs, create a container for each unique EJB, initialize the container with the deployment configuration information. We will talk about each function in the following sections.

4.3.1.1. Verifying EJB deployments

When the `VerifyDeployments` attribute of the `EJBDeployer` is true, the deployer performs a verification of EJBs in the deployment. The verification checks that an EJB meets EJB specification compliance. This entails validating that the EJB deployment unit contains the required home and remote, local home and local interfaces. It will also check that the objects appearing in these interfaces are of the proper types and that the required methods are present in the implementation class. This is a useful behavior that is enabled by default since there are a number of steps that an EJB developer and deployer must perform correctly to construct a proper EJB JAR, and it is easy to make a mistake. The verification stage attempts to catch any errors and fail the deployment with an error that indicates what needs to be corrected.

Probably the most problematic aspect of writing EJBs is the fact that there is a disconnection between the bean implementation and its remote and home interfaces, as well as its deployment descriptor configuration. It is easy to have these separate elements get out of synch. One tool that helps eliminate this problem is XDoclet. It allows you to use custom JavaDoc-like tags in the EJB bean implementation class to generate the related bean interfaces, deployment descriptors and related objects. See the XDoclet home page, http://sourceforge.net/projects/xdoclet for additional details.

4.3.1.2. Deploying EJBs Into Containers

The most important role performed by the `EJBDeployer` is the creation of an EJB container and the deployment of the EJB into the container. The deployment phase consists of iterating over EJBs in an EJB JAR, and extracting the bean classes and their metadata as described by the `ejb-jar.xml` and `jboss.xml` deployment descriptors. For each

EJB in the EJB JAR, the following steps are performed:

- Create subclass of `org.jboss.ejb.Container` depending on the type of the EJB: stateless, stateful, BMP entity, CMP entity, or message driven. The container is assigned a unique `ClassLoader` from which it can load local resources. The uniqueness of the `ClassLoader` is also used to isolate the standard `java:comp` JNDI namespace from other J2EE components.
- Set all container configurable attributes from a merge of the `jboss.xml` and `standardjboss.xml` descriptors.
- Create and add the container interceptors as configured for the container.
- Associate the container with an application object. This application object represents a J2EE enterprise application and may contain multiple EJBs and web contexts.

If all EJBs are successfully deployed, the application is started which in turn starts all containers and makes the EJBs available to clients. If any EJB fails to deploy, a deployment exception is thrown and the deployment module is failed.

4.3.1.3. Container configuration information

JBoss externalizes most if not all of the setup of the EJB containers using an XML file that conforms to the `jboss_4_0.dtd`. The section DTD that relates to container configuration information is shown in Figure 4.4.

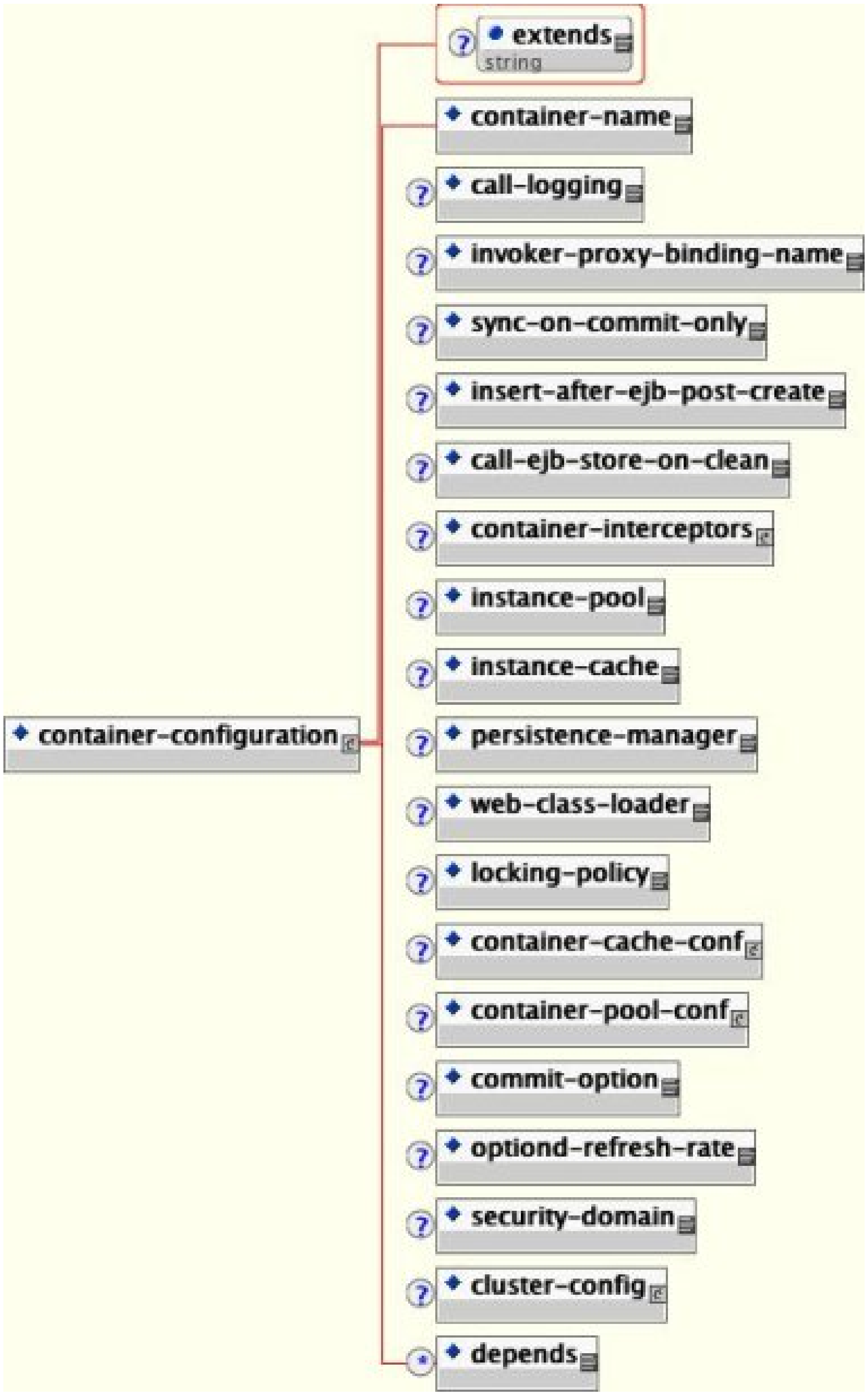


Figure 4.4. The jboss_4_0 DTD elements related to container configuration.

The `container-configuration` element and its subelements specify container configuration settings for a type of container as given by the `container-name` element. Each configuration specifies information such as the default invoker type, the container interceptor makeup, instance caches/pools and their sizes, persistence manager, security, and so on. Because this is a large amount of information that requires a detailed understanding of the JBoss container architecture, JBoss ships with a standard configuration for the four types of EJBs. This configuration file is called `standardjboss.xml` and it is located in the conf directory of any configuration file set that uses EJBs. The following is a sample of `container-configuration` from `standardjboss.xml`.

```
<container-configuration>
    <container-name>Standard CMP 2.x EntityBean</container-name>
    <call-logging>false</call-logging>
    <invoker-proxy-binding-name>entity-rmi-invoker</invoker-proxy-binding-name>
    <sync-on-commit-only>false</sync-on-commit-only>
    <insert-after-ejb-post-create>false</insert-after-ejb-post-create>
    <call-ejb-store-on-clean>true</call-ejb-store-on-clean>
    <container-interceptors>
        <interceptor>org.jboss.ejb.plugins.ProxyFactoryFinderInterceptor</interceptor>
        <interceptor>org.jboss.ejb.plugins.LogInterceptor</interceptor>
        <interceptor>org.jboss.ejb.plugins.SecurityInterceptor</interceptor>
        <interceptor>org.jboss.ejb.plugins.TxInterceptorCMT</interceptor>
        <interceptor>org.jboss.ejb.plugins.CallValidationInterceptor</interceptor>
        <interceptor metricsEnabled="true">
            org.jboss.ejb.plugins.MetricsInterceptor
        </interceptor>
        <interceptor>org.jboss.ejb.plugins.EntityCreationInterceptor</interceptor>
        <interceptor>org.jboss.ejb.plugins.EntityLockInterceptor</interceptor>
        <interceptor>org.jboss.ejb.plugins.EntityInstanceInterceptor</interceptor>
        <interceptor>org.jboss.ejb.plugins.EntityReentranceInterceptor</interceptor>
        <interceptor>
             org.jboss.resource.connectionmanager.CachedConnectionInterceptor
        </interceptor>
        <interceptor>org.jboss.ejb.plugins.EntitySynchronizationInterceptor</interceptor>
        <interceptor>org.jboss.ejb.plugins.cmp.jdbc.JDBCRelationInterceptor</interceptor>
    </container-interceptors>
    <instance-pool>org.jboss.ejb.plugins.EntityInstancePool</instance-pool>
    <instance-cache>org.jboss.ejb.plugins.InvalidableEntityInstanceCache</instance-cache>
    <persistence-manager>org.jboss.ejb.plugins.cmp.jdbc.JDBCStoreManager</persistence-manager>
    <locking-policy>org.jboss.ejb.plugins.lock.QueuedPessimisticEJBLock</locking-policy>
    <container-cache-conf>
        <cache-policy>org.jboss.ejb.plugins.LRUEnterpriseContextCachePolicy</cache-policy>
        <cache-policy-conf>
            <min-capacity>50</min-capacity>
            <max-capacity>1000000</max-capacity>
            <overager-period>300</overager-period>
            <max-bean-age>600</max-bean-age>
            <resizer-period>400</resizer-period>
            <max-cache-miss-period>60</max-cache-miss-period>
            <min-cache-miss-period>1</min-cache-miss-period>
            <cache-load-factor>0.75</cache-load-factor>
        </cache-policy-conf>
    </container-cache-conf>
    <container-pool-conf>
        <MaximumSize>100</MaximumSize>
    </container-pool-conf>
    <commit-option>B</commit-option>
</container-configuration>
```

These two examples demonstrate how extensive the container configuration options are. The container configuration information can be specified at two levels. The first is in the `standardjboss.xml` file contained in the configuration file set directory. The second is at the EJB JAR level. By placing a `jboss.xml` file in the EJB JAR `META-INF` directory, you can specify either overrides for container configurations in the `standardjboss.xml` file, or entirely new named container configurations. This provides great flexibility in the configuration of containers. As you have seen, all container configuration attributes have been externalized and as such are easily modifiable. Knowledgeable developers can even implement specialized container components, such as instance pools or caches, and easily integrate them with the standard container configurations to optimize behavior for a particular application or environment.

How an EJB deployment chooses its container configuration is based on the explicit or implict `jboss/enterprise-beans/<type>/configuration-name` element. The `configuration-name` element is a link to a `container-configurations/container-configuration` element in Figure 4.4. It specifies which container configuration to use for the referring EJB. The link is from a `configuration-name` element to a `container-name` element.

You are able to specify container configurations per class of EJB by including a `container-configuration` element in the EJB definition. Typically one does not define completely new container configurations, although this is supported. The typical usage of a `jboss.xml` level `container-configuration` is to override one or more aspects of a `container-configuration` coming from the `standardjboss.xml` descriptor. This is done by specifying `container-configuration` that references the name of an existing `standardjboss.xml container-configuration/container-name` as the value for the `container-configuration/extends` attribute. The following example shows an example of defining a new `Secured Stateless SessionBean` configuration that is an extension of the `Standard Stateless SessionBean` configuration.

```
<?xml version="1.0"?>
<jboss>
    <enterprise-beans>
        <session>
            <ejb-name>EchoBean</ejb-name>
            <configuration-name>Secured Stateless SessionBean</configuration-name>
            <!-- ... -->
        </session>
    </enterprise-beans>
    <container-configurations>
        <container-configuration extends="Standard Stateless SessionBean">
            <container-name>Secured Stateless SessionBean</container-name>
            <!-- Override the container security domain -->
            <security-domain>java:/jaas/my-security-domain</security-domain>
        </container-configuration>
    </container-configurations>
</jboss>
```

If an EJB does not provide a container configuration specification in the deployment unit EJB JAR, the container factory chooses a container configuration from the `standardjboss.xml` descriptor based on the type of the EJB. So, in reality there is an implicit `configuration-name` element for every type of EJB, and the mappings from the EJB type to default container configuration name are as follows:

- container-managed persistence entity version 2.0 = Standard CMP 2.x EntityBean
- container-managed persistence entity version 1.1 = Standard CMP EntityBean
- bean-managed persistence entity = Standard BMP EntityBean
- stateless session = Standard Stateless SessionBean
- stateful session = Standard Stateful SessionBean
- message driven = Standard Message Driven Bean

It is not necessary to indicate which container configuration an EJB is using if you want to use the default based on the bean type. It probably provides for a more self-contained descriptor to include the `configuration-name` element, but this is purely a matter of style.

Now that you know how to specify which container configuration an EJB is using and can define a deployment unit level override, we now will look at the `container-configuration` child elements in the following sections. A number of the elements specify interface class implementations whose configuration is affected by other elements, so before starting in on the configuration elements you need to understand the `org.jboss.metadata.XmlLoadable` interface.

The `XmlLoadable` interface is a simple interface that consists of a single method. The interface definition is:

```
import org.w3c.dom.Element;
public interface XmlLoadable
{
    public void importXml(Element element) throws Exception;
}
```

Classes implement this interface to allow their configuration to be specified via an XML document fragment. The root element of the document fragment is what would be passed to the `importXml` method. You will see a few examples of this as the container configuration elements are described in the following sections.

4.3.1.3.1. The container-name element

The `container-name` element specifies a unique name for a given configuration. EJBs link to a particular container configuration by setting their `configuration-name` element to the value of the `container-name` for the container configuration.

4.3.1.3.2. The call-logging element

The `call-logging` element expects a boolean (true or false) as its value to indicate whether or not the `LogInterceptor` should log method calls to a container. This is somewhat obsolete with the change to log4j, which provides a fine-grained logging API.

4.3.1.3.3. The invoker-proxy-binding-name element

The `invoker-proxy-binding-name` element specifies the name of the default invoker to use. In the absence of a bean level `invoker-bindings` specification, the `invoker-proxy-binding` whose name matches the `invoker-proxy-binding-name` element value will be used to create home and remote proxies.

4.3.1.3.4. The sync-on-commit-only element

This configures a performance optimization that will cause entity bean state to be synchronized with the database only at commit time. Normally the state of all the beans in a transaction would need to be synchronized when an finder method is called or when an remove method is called, for example.

4.3.1.3.5. insert-after-ejb-post-create

This is another entity bean optimization which cause the database insert command for a new entity bean to be delayed until the `ejbPostCreate` method is called. This allows normal CMP fields as well as CMR fields to be set in a single insert, instead of the default insert followed by an update, which allows removes the requirement for relation ship fields to allow null values.

4.3.1.3.6. call-ejb-store-on-clean

By the specification the container is required to call `ejbStore` method on an entity bean instance when transaction commits even if the instance was not modified in the transaction. Setting this to false will cause JBoss to only call `ejbStore` for dirty objects.

4.3.1.3.7. The container-interceptors Element

The `container-interceptors` element specifies one or more interceptor elements that are to be configured as the method interceptor chain for the container. The value of the interceptor element is a fully qualified class name of an `org.jboss.ejb.Interceptor` interface implementation. The container interceptors form a `linked-list` structure through which EJB method invocations pass. The first interceptor in the chain is invoked when the `MBeanServer` passes a method invocation to the container. The last interceptor invokes the business method on the bean. We will discuss the `Interceptor` interface latter in this chapter when we talk about the container plugin framework. Generally, care must be taken when changing an existing standard EJB interceptor configuration as the EJB contract regarding security, transactions, persistence, and thread safety derive from the interceptors.

4.3.1.3.8. The instance-pool element

The `instance-pool` element specifies the fully qualified class name of an `org.jboss.ejb.InstancePool` interface implementation to use as the container `InstancePool`. We will discuss the InstancePool interface in detail latter in this chapter when we talk about the container plugin framework.

4.3.1.3.9. The container-pool-conf element

The `container-pool-conf` is passed to the `InstancePool` implementation class given by the `instance-pool` element if it implements the `XmlLoadable` interface. All current JBoss `InstancePool` implementations derive from the `org.jboss.ejb.plugins.AbstractInstancePool` class which provides support for elements shown in Figure 4.5.

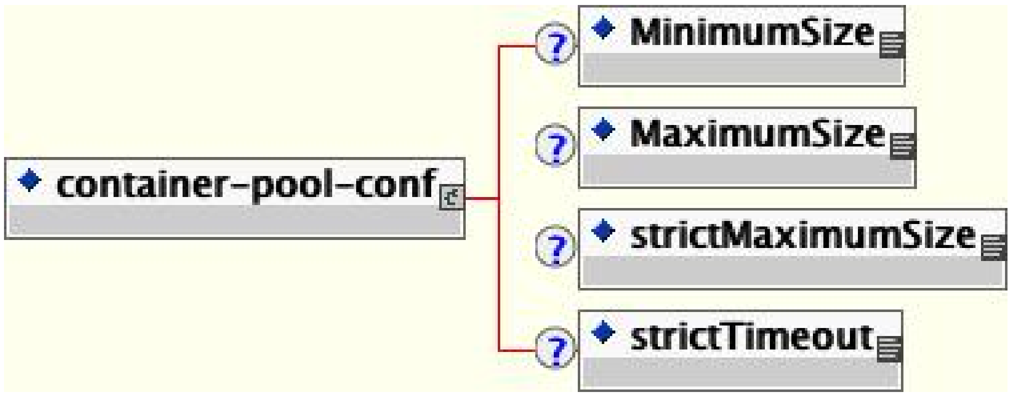


Figure 4.5. The container-pool-conf element DTD

- **MinimumSize**: The `MinimumSize` element gives the minimum number of instances to keep in the pool, although JBoss does not currently seed an `InstancePool` to the `MinimumSize` value.

- **MaximumSize**: The `MaximumSize` specifies the maximum number of pool instances that are allowed. The default use of `MaximumSize` may not be what you expect. The pool `MaximumSize` is the maximum number of EJB instances that are kept available, but additional instances can be created if the number of concurrent requests exceeds the `MaximumSize` value.

- **strictMaximumSize**: If you want to limit the maximum concurrency of an EJB to the pool `MaximumSize`, you need to set the `strictMaximumSize` element to true. When `strictMaximumSize` is true, only `MaximumSize` EJB instances may be active. When there are `MaximumSize` active instances, any subsequent requests will be blocked until an instance is freed back to the pool. The default value for `strictMaximumSize` is false.
- **strictTimeout**: How long a request blocks waiting for an instance pool object is controlled by the `strictTimeout` element. The `strictTimeout` defines the time in milliseconds to wait for an instance to be returned to the pool when there are `MaximumSize` active instances. A value less than or equal to 0 will mean not to wait at all. When a request times out waiting for an instance a `java.rmi.ServerException` is generated and the call aborted. This is parsed as a `Long` so the maximum possible wait time is 9,223,372,036,854,775,807 or about 292,471,208 years, and this is the default value.

4.3.1.3.10. The instance-cache element

The `instance-cache` element specifies the fully qualified class name of the `org.jboss.ejb.InstanceCache` interface implementation. This element is only meaningful for entity and stateful session beans as these are the only EJB types that have an associated identity. We will discuss the `InstanceCache` interface in detail latter in this chapter when we talk about the container plugin framework.

4.3.1.3.11. The container-cache-conf element

The `container-cache-conf` element is passed to the `InstanceCache` implementation if it supports the `XmlLoadable` interface. All current JBoss `InstanceCache` implementations derive from the `org.jboss.ejb.plugins.AbstractInstanceCache` class which provides support for the `XmlLoadable` interface and uses the `cache-policy` child element as the fully qualified class name of an `org.jboss.util.CachePolicy` implementation that is used as the instance cache store. The `cache-policy-conf` child element is passed to the `CachePolicy` implementation if it supports the `XmlLoadable` interface. If it does not, the `cache-policy-conf` will silently be ignored.

There are two JBoss implementations of CachePolicy used by the `standardjboss.xml` configuration that support the current array of `cache-policy-conf` child elements. The classes are `org.jboss.ejb.plugins.LRUEnterpriseContextCachePolicy` and `org.jboss.ejb.plugins.LRUStatefulContextCachePolicy`. The `LRUEnterpriseContextCachePolicy` is used by entity bean containers while the `LRUStatefulContextCachePolicy` is used by stateful session bean containers. Both cache policies support the following `cache-policy-conf` child elements, shown in Figure 4.6.

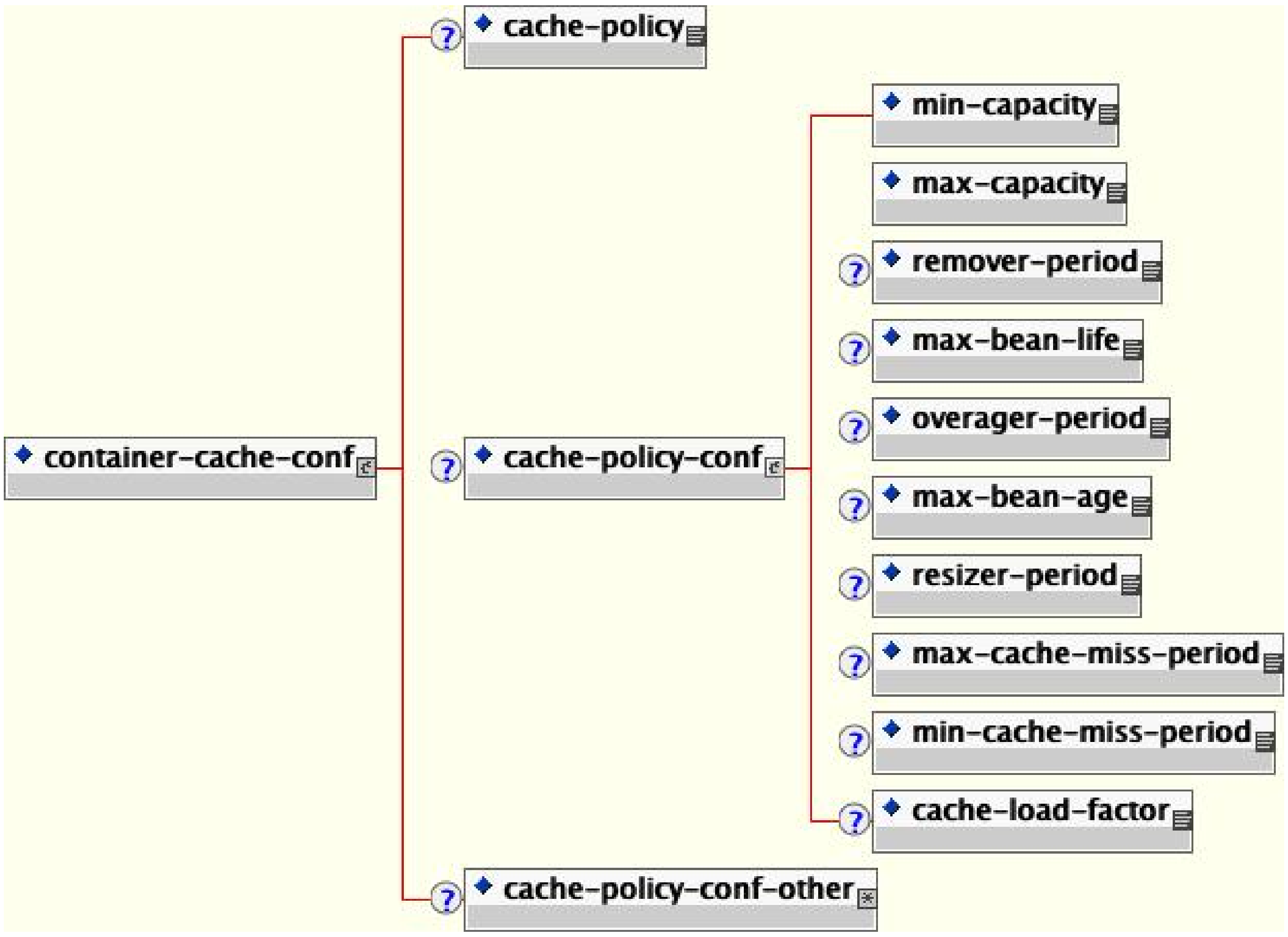


Figure 4.6. The container-cache-conf element DTD

- **min-capacity**: specifies the minimum capacity of this cache
- **max-capacity**: specifies the maximum capacity of the cache, which cannot be less than `min-capacity`.
- **overager-period**: specifies the period in seconds between runs of the overager task. The purpose of the overager task is to see if the cache contains beans with an age greater than the `max-bean-age` element value. Any beans meeting this criterion will be passivated.
- **max-bean-age**: specifies the maximum period of inactivity in seconds a bean can have before it will be passivated by the overager process.
- **resizer-period**: specifies the period in seconds between runs of the resizer task. The purpose of the resizer task is to contract or expand the cache capacity based on the remaining three element values in the following way. When the resizer task executes it checks the current period between cache misses, and if the period is less than the `min-cache-miss-period` value the cache is expanded up to the `max-capacity` value using the `cache-load-factor`. If instead the period between cache misses is greater than the `max-cache-miss-period` value the cache is contracted using the `cache-load-factor`.
- **max-cache-miss-period**: specifies the time period in seconds in which a cache miss should signal that the

cache capacity be contracted. It is equivalent to the minimum miss rate that will be tolerated before the cache is contracted.

- **min-cache-miss-period**: specifies the time period in seconds in which a cache miss should signal that the cache capacity be expanded. It is equivalent to the maximum miss rate that will be tolerated before the cache is expanded.
- **cache-load-factor**: specifies the factor by which the cache capacity is contracted and expanded. The factor should be less than 1. When the cache is contracted the capacity is reduced so that the current ratio of beans to cache capacity is equal to the cache-load-factor value. When the cache is expanded the new capacity is determined as `current-capacity * 1/cache-load-factor`. The actual expansion factor may be as high as 2 based on an internal algorithm based on the number of cache misses. The higher the cache miss rate the closer the true expansion factor will be to 2.

The `LRUStatefulContextCachePolicy` also supports the remaining child elements:

- **remover-period**: specifies the period in seconds between runs of the remover task. The remover task removes passivated beans that have not been accessed in more than `max-bean-life` seconds. This task prevents stateful session beans that were not removed by users from filling up the passivation store.
- **max-bean-life**: specifies the maximum period of inactivity in seconds that a bean can exist before being removed from the passivation store.

An alternative cache policy implementation is the `org.jboss.ejb.plugins.NoPassivationCachePolicy` class, which simply never passivates instances. It uses an in-memory `HashMap` implementation that never discards instances unless they are explicitly removed. This class does not support any of the `cache-policy-conf` configuration elements.

4.3.1.3.12. The persistence-manager element

The `persistence-manager` element value specifies the fully qualified class name of the persistence manager implementation. The type of the implementation depends on the type of EJB. For stateful session beans it must be an implementation of the `org.jboss.ejb.StatefulSessionPersistenceManager` interface. For BMP entity beans it must be an implementation of the `org.jboss.ejb.EntityPersistenceManager` interface, while for CMP entity beans it must be an implementation of the `org.jboss.ejb.EntityPersistenceStore` interface.

4.3.1.3.13. The web-class-loader Element

The `web-class-loader` element specifies a subclass of `org.jboss.web.WebClassLoader` that is used in conjunction with the `WebService` MBean to allow dynamic loading of resources and classes from deployed ears, EJB JARs and WARs. A `WebClassLoader` is associated with a `Container` and must have an `org.jboss.mx.loading.UnifiedClassLoader` as its parent. It overrides the `getURLs()` method to return a different set of URLs for remote loading than what is used for local loading.

`WebClaossLoader` has two methods meant to be overridden by subclasses: `getKey()` and `getBytes()`. The latter is a no-op in this implementation and should be overridden by subclasses with bytecode generation ability, such as the classloader used by the iiop module.

`WebClassLoader` subclasses must have a constructor with the same signature as the `WebClassLoader(ObjectName containerName, UnifiedClassLoader parent)` constructor.

4.3.1.3.14. The locking-policy element

The `locking-policy` element gives the fully qualified class name of the EJB lock implementation to use. This class must implement the `org.jboss.ejb.BeanLock` interface. The current JBoss versions include:

- **org.jboss.ejb.plugins.lock.QueuedPessimisticEJBLock**: an implementation that holds threads awaiting the transactional lock to be freed in a fair FIFO queue. Non-transactional threads are also put into this wait queue as well. This class pops the next waiting transaction from the queue and notifies only those threads waiting associated with that transaction. The `QueuedPessimisticEJBLock` is the current default used by the standard configurations.
- **org.jboss.ejb.plugins.lock.QueuedPessimisticEJBLockNoADE**: This behaves the same as the `QueuedPessimisticEJBLock` except that deadlock detection is disabled.
- **org.jboss.ejb.plugins.lock.SimpleReadWriteEJBLock**: This lock allows multiple read locks concurrently. Once a writer has requested the lock, future read-lock requests whose transactions do not already have the read lock will block until all writers are done; then all the waiting readers will concurrently go (depending on the reentrant setting / methodLock). A reader who promotes gets first crack at the write lock, ahead of other waiting writers. If there is already a reader that is promoting, we throw an inconsistent read exception. Of course, writers have to wait for all read-locks to release before taking the write lock.
- **org.jboss.ejb.plugins.lock.NoLock**: an anti-locking policy used with the instance per transaction container configurations.

Locking and deadlock detection will be discussed in more detail in Section 4.4.

4.3.1.3.15. The commit-option and optiond-refresh-rate elements

The commit-option value specifies the EJB entity bean persistent storage commit option. It must be one of `A`, `B`, `C` or `D`.

- **A**: the container caches the beans state between transactions. This option assumes that the container is the only user accessing the persistent store. This assumption allows the container to synchronize the in-memory state from the persistent storage only when absolutely necessary. This occurs before the first business method executes on a found bean or after the bean is passivated and reactivated to serve another business method. This behavior is independent of whether the business method executes inside a transaction context.
- **B**: the container caches the bean state between transactions. However, unlike option `A` the container does not assume exclusive access to the persistent store. Therefore, the container will synchronize the in-memory state at the beginning of each transaction. Thus, business methods executing in a transaction context don't see much benefit from the container caching the bean, whereas business methods executing outside a transaction context (transaction attributes Never, NotSupported or Supports) access the cached (and potentially invalid) state of the bean.
- **C**: the container does not cache bean instances. The in-memory state must be synchronized on every transaction start. For business methods executing outside a transaction the synchronization is still performed, but the `ejbLoad` executes in the same transaction context as that of the caller.
- **D**: is a JBoss-specific commit option which is not described in the EJB specification. It is a lazy read scheme

where bean state is cached between transactions as with option `A`, but the state is periodically resynchronized with that of the persistent store. The default time between reloads is 30 seconds, but may configured using the `optiond-refresh-rate` element.

4.3.1.3.16. The security-domain element

The `security-domain` element specifies the JNDI name of the object that implements the `org.jboss.security.AuthenticationManager` and `org.jboss.security.RealmMapping` interfaces. It is more typical to specify the `security-domain` under the `jboss` root element so that all EJBs in a given deployment are secured in the same manner. However, it is possible to configure the security domain for each bean configuration. The details of the security manager interfaces and configuring the security layer are discussed in Chapter 7.

4.3.1.3.17. cluster-config

The `cluster-config` element allows to specify cluster specific settings for all EJBs that use the container configuration. Specficiation of the cluster configuration may be done at the container configuration level or at the individual EJB deployment level.

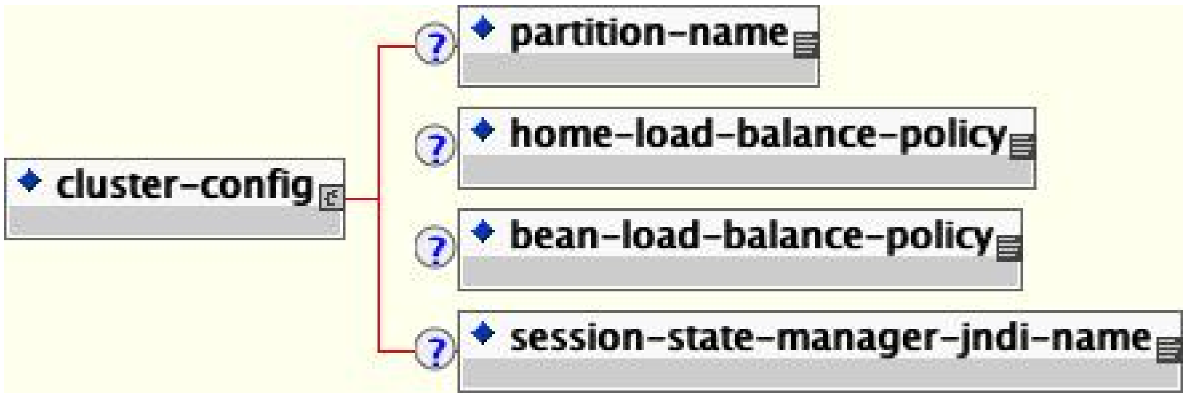


Figure 4.7. The cluster-config and related elements

- **partition-name**: The `partition-name` element indicates where to find the `org.jboss.ha.framework.interfaces.HAPartition` interface to be used by the container to exchange clustering information. This is not the full JNDI name under which `HAPartition` is bound. Rather, it should correspond to the `PartitionName` attribute of the `ClusterPartitionMBean` service that is managing the desired cluster. The actual JNDI name of the `HAPartition` binding will be formed by appending `/HASessionState/` to the partition-name value. The default value is `DefaultPartition`.
- **home-load-balance-policy**: The `home-load-balance-policy` element indicates the Java class name to be used to load balance calls made on the home proxy. The class must implement the `org.jboss.ha.framework.interface.LoadBalancePolicy` interface. The default policy is `org.jboss.ha.framework.interfaces.RoundRobin`.
- **bean-load-balance-policy**: The `bean-load-balance-policy` element indicates the java class name to be used to load balance calls in the bean proxy. The class must implement the `org.jboss.ha.framework.interface.LoadBalancePolicy` interface. For entity beans and stateful session beans, the default is `org.jboss.ha.framework.interfaces.FirstAvailavble`. For stateless session beans,

`org.jboss.ha.framework.interfaces.RoundRobin`.

- **session-state-manager-jndi-name**: The `session-state-manager-jndi-name` element indicates the name of the `org.jboss.ha.framework.interfaces.HASessionState` to be used by the container as a backend for state session management in the cluster. Unlike the partition-name element, this is a JNDI name under which the `HASessionState` implementation is bound. The default location used is `/HASessionState/Default`.

4.3.1.3.18. The depends element

The `depends` element gives a JMX `ObjectName` of a service on which the container or EJB depends. Specification of explicit dependencies on other services avoids having to rely on the deployment order being after the required services are started.

4.3.2. Container Plug-in Framework

The JBoss EJB container uses a framework pattern that allows one to change implementations of various aspects of the container behavior. The container itself does not perform any significant work other than connecting the various behavioral components together. Implementations of the behavioral components are referred to as plugins, because you can plug in a new implementation by changing a container configuration. Examples of plug-in behavior you may want to change include persistence management, object pooling, object caching, container invokers and interceptors. There are four subclasses of the `org.jboss.ejb.Container` class, each one implementing a particular bean type:

- **org.jboss.ejb.EntityContainer**: handles `javax.ejb.EntityBean` types
- **org.jboss.ejb.StatelessSessionContainer**: handles Stateless `javax.ejb.SessionBean` types
- **org.jboss.ejb.StatefulSessionContainer**: handles Stateful `javax.ejb.SessionBean` types
- **org.jboss.ejb.MessageDrivenContainer** handles `javax.ejb.MessageDrivenBean` types

The EJB containers delegate much of their behavior to components known as container plug-ins. The interfaces that make up the container plugin points include the following:

- org.jboss.ejb.ContainerPlugin
- org.jboss.ejb.ContainerInvoker
- org.jboss.ejb.Interceptor
- org.jboss.ejb.InstancePool
- org.jboss.ejb.InstanceCache
- org.jboss.ejb.EntityPersistanceManager
- org.jboss.ejb.EntityPersistanceStore
- org.jboss.ejb.StatefulSessionPersistenceManager

The container's main responsibility is to manage its plug-ins. This means ensuring that the plug-ins have all the information they need to implement their functionality.

4.3.2.1. org.jboss.ejb.ContainerPlugin

The `ContainerPlugin` interface is the parent interface of all container plug-in interfaces. It provides a callback that allows a container to provide each of its plug-ins a pointer to the container the plug-in is working on behalf of. The `ContainerPlugin` interface is given below.

Example 4.4. The org.jboss.ejb.ContainerPlugin interface

```
public interface ContainerPlugin
    extends Service, AllowedOperationsFlags
{
    /**
     * This callback is set by the container so that the plugin
     * may access its container
     *
     * @param con the container which owns the plugin
     */
    public void setContainer(Container con);
}
```

4.3.2.2. org.jboss.ejb.Interceptor

The `Interceptor` interface enables one to build a chain of method interceptors through which each EJB method invocation must pass. The `Interceptor` interface is given below.

Example 4.5. The org.jboss.ejb.Interceptor interface

```
import org.jboss.invocation.Invocation;

public interface Interceptor
    extends ContainerPlugin
{
    public void setNext(Interceptor interceptor);
    public Interceptor getNext();
    public Object invokeHome(Invocation mi) throws Exception;
    public Object invoke(Invocation mi) throws Exception;
}
```

All interceptors defined in the container configuration are created and added to the container interceptor chain by the `EJBDeployer`. The last interceptor is not added by the deployer but rather by the container itself because this is the interceptor that interacts with the EJB bean implementation.

The order of the interceptor in the chain is important. The idea behind ordering is that interceptors that are not tied to a particular `EnterpriseContext` instance are positioned before interceptors that interact with caches and pools.

Implementers of the `Interceptor` interface form a linked-list like structure through which the `Invocation` object is passed. The first interceptor in the chain is invoked when an invoker passes a `Invocation` to the container via the JMX bus. The last interceptor invokes the business method on the bean. There are usually on the order of five interceptors in a chain depending on the bean type and container configuration. `Interceptor` semantic complexity ranges from simple to complex. An example of a simple interceptor would be `LoggingInterceptor`, while a complex example is `EntitySynchronizationInterceptor`.

One of the main advantages of an interceptor pattern is flexibility in the arrangement of interceptors. Another advantage is the clear functional distinction between different interceptors. For example, logic for transaction and security is cleanly separated between the `TXInterceptor` and `SecurityInterceptor` respectively.

If any of the interceptors fail, the call is terminated at that point. This is a fail-quickly type of semantic. For example, if a secured EJB is accessed without proper permissions, the call will fail as the `SecurityInterceptor` before any transactions are started or instances caches are updated.

4.3.2.3. org.jboss.ejb.InstancePool

An `InstancePool` is used to manage the EJB instances that are not associated with any identity. The pools actually manage subclasses of the `org.jboss.ejb.EnterpriseContext` objects that aggregate unassociated bean instances and related data.

Example 4.6. The org.jboss.ejb.InstancePool interface

```
public interface InstancePool
    extends ContainerPlugin
{
    /**
     * Get an instance without identity. Can be used
     * by finders and create-methods, or stateless beans
     *
     * @return Context /w instance
     * @exception RemoteException
     */
    public EnterpriseContext get() throws Exception;

    /** Return an anonymous instance after invocation.
     *
     * @param ctx
     */
    public void free(EnterpriseContext ctx);

    /**
     * Discard an anonymous instance after invocation.
     * This is called if the instance should not be reused,
     * perhaps due to some exception being thrown from it.
     *
     * @param ctx
     */
    public void discard(EnterpriseContext ctx);

    /**
     * Return the size of the pool.
     *
     * @return the size of the pool.
     */
    public int getCurrentSize();

    /**
     * Get the maximum size of the pool.
     *
     * @return the size of the pool.
     */
    public int getMaxSize();
}
```

Depending on the configuration, a container may choose to have a certain size of the pool contain recycled instances, or it may choose to instantiate and initialize an instance on demand.

The pool is used by the `InstanceCache` implementation to acquire free instances for activation, and it is used by interceptors to acquire instances to be used for Home interface methods (create and finder calls).

4.3.2.4. org.jboss.ebj.InstanceCache

The container `InstanceCache` implementation handles all EJB-instances that are in an active state, meaning bean instances that have an identity attached to them. Only entity and stateful session beans are cached, as these are the only bean types that have state between method invocations. The cache key of an entity bean is the bean primary key. The cache key for a stateful session bean is the session id.

Example 4.7. The org.jboss.ejb.InstanceCache interface

```
public interface InstanceCache
    extends ContainerPlugin
{
    /**
     * Gets a bean instance from this cache given the identity.
     * This method may involve activation if the instance is not
     * in the cache.
     * Implementation should have O(1) complexity.
     * This method is never called for stateless session beans.
     *
     * @param id the primary key of the bean
     * @return the EnterpriseContext related to the given id
     * @exception RemoteException in case of illegal calls
     * (concurrent / reentrant), NoSuchObjectException if
     * the bean cannot be found.
     * @see #release
     */
    public EnterpriseContext get(Object id)
        throws RemoteException, NoSuchObjectException;

    /**
     * Inserts an active bean instance after creation or activation.
     * Implementation should guarantee proper locking and O(1) complexity.
     *
     * @param ctx the EnterpriseContext to insert in the cache
     * @see #remove
     */
    public void insert(EnterpriseContext ctx);

    /**
     * Releases the given bean instance from this cache.
     * This method may passivate the bean to get it out of the cache.
     * Implementation should return almost immediately leaving the
     * passivation to be executed by another thread.
     *
     * @param ctx the EnterpriseContext to release
     * @see #get
     */
    public void release(EnterpriseContext ctx);

    /**
     * Removes a bean instance from this cache given the identity.
     * Implementation should have O(1) complexity and guarantee
     * proper locking.
     *
     * @param id the pimary key of the bean
     * @see #insert
     */
    public void remove(Object id);
    /**
     * Checks whether an instance corresponding to a particular
     * id is active
     *
     * @param id the pimary key of the bean
     * @see #insert
     */
    public boolean isActive(Object id);
}
```

In addition to managing the list of active instances, the `InstanceCache` is also responsible for activating and passivating instances. If an instance with a given identity is requested, and it is not currently active, the `InstanceCache` must use the `InstancePool` to acquire a free instance, followed by the persistence manager to activate the instance. Similarly, if the `InstanceCache` decides to passivate an active instance, it must call the persistence manager to passivate it and release the instance to the `InstancePool`.

4.3.2.5. org.jboss.ejb.EntityPersistenceManager

The `EntityPersistenceManager` is responsible for the persistence of EntityBeans. This includes the following:

- Creating an EJB instance in a storage
- Loading the state of a given primary key into an EJB instance
- Storing the state of a given EJB instance
- Removing an EJB instance from storage
- Activating the state of an EJB instance
- Passivating the state of an EJB instance

Example 4.8. The org.jboss.ejb.EntityPersistenceManager interface

```
public interface EntityPersistenceManager
    extends ContainerPlugin
{
    /**
     * Returns a new instance of the bean class or a subclass of the
     * bean class.
     *
     * @return the new instance
     */
    Object createBeanClassInstance() throws Exception;

    /**
     * This method is called whenever an entity is to be created. The
     * persistence manager is responsible for calling the ejbCreate method
     * on the instance and to handle the results properly wrt the persistent
     * store.
     *
     * @param m the create method in the home interface that was
     * called
     * @param args any create parameters
     * @param instance the instance being used for this create call
     */
    void createEntity(Method m,
                      Object[] args,
                      EntityEnterpriseContext instance)
        throws Exception;
    /**
     * This method is called whenever an entity is to be created. The
     * persistence manager is responsible for calling the ejbPostCreate method
     * on the instance and to handle the results properly wrt the persistent
     * store.
     *
     * @param m the create method in the home interface that was
     * called
     * @param args any create parameters
     * @param instance the instance being used for this create call
     */
    void postCreateEntity(Method m,
                          Object[] args,
                          EntityEnterpriseContext instance)
        throws Exception;

    /**
     * This method is called when single entities are to be found. The
     * persistence manager must find out whether the wanted instance is
     * available in the persistence store, and if so it shall use the
     * ContainerInvoker plugin to create an EJBObject to the instance, which
     * is to be returned as result.
     *
     * @param finderMethod the find method in the home interface that was
     * called
     * @param args any finder parameters
     * @param instance the instance to use for the finder call
     * @return an EJBObject representing the found entity
     */
    Object findEntity(Method finderMethod,
                      Object[] args,
                      EntityEnterpriseContext instance)
        throws Exception;

    /**
     * This method is called when collections of entities are to be
     * found. The persistence manager must find out whether the wanted
     * instances are available in the persistence store, and if so it
     * shall use the ContainerInvoker plugin to create EJBObjects to
     * the instances, which are to be returned as result.
     *
     * @param finderMethod the find method in the home interface that was
     * called
     * @param args any finder parameters
     * @param instance the instance to use for the finder call
     * @return an EJBObject collection representing the found
     * entities
     */
    Collection findEntities(Method finderMethod,
                            Object[] args,
                            EntityEnterpriseContext instance)
                 throws Exception;

    /**
     * This method is called when an entity shall be activated. The
     * persistence manager must call the ejbActivate method on the
     * instance.
     *
     * @param instance the instance to use for the activation
     *
     * @throws RemoteException thrown if some system exception occurs
     */
    void activateEntity(EntityEnterpriseContext instance)
        throws RemoteException;

    /**
```

```
     * This method is called whenever an entity shall be load from the
     * underlying storage. The persistence manager must load the state
     * from the underlying storage and then call ejbLoad on the
     * supplied instance.
     *
     * @param instance the instance to synchronize
     *
     * @throws RemoteException thrown if some system exception occurs
     */
    void loadEntity(EntityEnterpriseContext instance)
        throws RemoteException;

    /**
     * This method is used to determine if an entity should be stored.
     *
     * @param instance the instance to check
     * @return true, if the entity has been modified
     * @throws Exception thrown if some system exception occurs
     */
    boolean isModified(EntityEnterpriseContext instance) throws Exception;

    /**
     * This method is called whenever an entity shall be stored to the
     * underlying storage. The persistence manager must call ejbStore
     * on the supplied instance and then store the state to the
     * underlying storage.
     *
     * @param instance the instance to synchronize
     *
     * @throws RemoteException thrown if some system exception occurs
     */
    void storeEntity(EntityEnterpriseContext instance)
        throws RemoteException;

    /**
     * This method is called when an entity shall be passivate. The
     * persistence manager must call the ejbPassivate method on the
     * instance.
     *
     * @param instance the instance to passivate
     *
     * @throws RemoteException thrown if some system exception occurs
     */
    void passivateEntity(EntityEnterpriseContext instance)
        throws RemoteException;

    /**
     * This method is called when an entity shall be removed from the
     * underlying storage. The persistence manager must call ejbRemove
     * on the instance and then remove its state from the underlying
     * storage.
     *
     * @param instance the instance to remove
     *
     * @throws RemoteException thrown if some system exception occurs
     * @throws RemoveException thrown if the instance could not be removed
     */
    void removeEntity(EntityEnterpriseContext instance)
        throws RemoteException, RemoveException;
}
```

4.3.2.6. The org.jboss.ejb.EntityPersistenceStore interface

As per the EJB 2.1 specification, JBoss supports two entity bean persistence semantics: container managed persistence (CMP) and bean managed persistence (BMP). The CMP implementation uses an implementation of the `org.jboss.ejb.EntityPersistanceStore` interface. By default this is the `org.jboss.ejb.plugins.cmp.jdbc.JDBCStoreManager` which is the entry point for the CMP2 persistence engine. The `EntityPersistanceStore` interface is shown below.

Example 4.9. The org.jboss.ejb.EntityPersistanceStore interface

```
public interface EntityPersistenceStore
    extends ContainerPlugin
{
    /**
     * Returns a new instance of the bean class or a subclass of the
     * bean class.
     *
     * @return the new instance
     *
     * @throws Exception
     */
    Object createBeanClassInstance()
        throws Exception;

    /**
     * Initializes the instance context.
     *
     * <p>This method is called before createEntity, and should
     * reset the value of all cmpFields to 0 or null.
     *
     * @param ctx
     *
     * @throws RemoteException
     */
    void initEntity(EntityEnterpriseContext ctx);

    /**
     * This method is called whenever an entity is to be created.  The
     * persistence manager is responsible for handling the results
     * properly wrt the persistent store.
     *
     * @param m the create method in the home interface that was
     * called
     * @param args any create parameters
     * @param instance the instance being used for this create call
     * @return The primary key computed by CMP PM or null for BMP
     *
     * @throws Exception
     */
    Object createEntity(Method m,
                        Object[] args,
                        EntityEnterpriseContext instance)
        throws Exception;

    /**
     * This method is called when single entities are to be found. The
     * persistence manager must find out whether the wanted instance
     * is available in the persistence store, if so it returns the
     * primary key of the object.
     *
     * @param finderMethod the find method in the home interface that was
     * called
     * @param args any finder parameters
     * @param instance the instance to use for the finder call
     * @return a primary key representing the found entity
     *
     * @throws RemoteException thrown if some system exception occurs
     * @throws FinderException thrown if some heuristic problem occurs
     */
    Object findEntity(Method finderMethod,
                      Object[] args,
                      EntityEnterpriseContext instance)
        throws Exception;

    /**
     * This method is called when collections of entities are to be
     * found. The persistence manager must find out whether the wanted
     * instances are available in the persistence store, and if so it
     * must return a collection of primaryKeys.
     *
     * @param finderMethod the find method in the home interface that was
     * called
     * @param args any finder parameters
     * @param instance the instance to use for the finder call
     * @return an primary key collection representing the found
     * entities
     *
     * @throws RemoteException thrown if some system exception occurs
     * @throws FinderException thrown if some heuristic problem occurs
     */
    Collection findEntities(Method finderMethod,
                            Object[] args,
                            EntityEnterpriseContext instance)
        throws Exception;

    /**
     * This method is called when an entity shall be activated.
     *
     * <p>With the PersistenceManager factorization most EJB
     * calls should not exists However this calls permits us to
     * introduce optimizations in the persistence store. Particularly
     * the context has a "PersistenceContext" that a PersistenceStore
     * can use (JAWS does for smart updates) and this is as good a
     * callback as any other to set it up.
     * @param instance the instance to use for the activation
     *
     * @throws RemoteException thrown if some system exception occurs
     */
    void activateEntity(EntityEnterpriseContext instance)
        throws RemoteException;

    /**
     * This method is called whenever an entity shall be load from the
     * underlying storage. The persistence manager must load the state
     * from the underlying storage and then call ejbLoad on the
     * supplied instance.
     *
     * @param instance the instance to synchronize
     *
     * @throws RemoteException thrown if some system exception occurs
     */
    void loadEntity(EntityEnterpriseContext instance)
        throws RemoteException;

    /**
     * This method is used to determine if an entity should be stored.
     *
     * @param instance the instance to check
     * @return true, if the entity has been modified
     * @throws Exception thrown if some system exception occurs
     */
    boolean isModified(EntityEnterpriseContext instance)
        throws Exception;

    /**
     * This method is called whenever an entity shall be stored to the
     * underlying storage. The persistence manager must call ejbStore
     * on the supplied instance and then store the state to the
     * underlying storage.
     *
     * @param instance the instance to synchronize
     *
     * @throws RemoteException thrown if some system exception occurs
     */
    void storeEntity(EntityEnterpriseContext instance)
        throws RemoteException;

    /**
     * This method is called when an entity shall be passivate. The
     * persistence manager must call the ejbPassivate method on the
     * instance.
     *
     * <p>See the activate discussion for the reason for
     * exposing EJB callback * calls to the store.
     *
     * @param instance the instance to passivate
     *
     * @throws RemoteException thrown if some system exception occurs
     */
    void passivateEntity(EntityEnterpriseContext instance)
        throws RemoteException;

    /**
     * This method is called when an entity shall be removed from the
     * underlying storage. The persistence manager must call ejbRemove
     * on the instance and then remove its state from the underlying
     * storage.
     *
     * @param instance the instance to remove
     *
     * @throws RemoteException thrown if some system exception occurs
     * @throws RemoveException thrown if the instance could not be removed
     */
    void removeEntity(EntityEnterpriseContext instance)
        throws RemoteException, RemoveException;
}
```

The default BMP implementation of the `EntityPersistenceManager` interface is `org.jboss.ejb.plugins.BMPPersistenceManager`. The BMP persistence manager is fairly simple since all persistence logic is in the entity bean itself. The only duty of the persistence manager is to perform container callbacks.

4.3.2.7. org.jboss.ejb.StatefulSessionPersistenceManager

The `StatefulSessionPersistenceManager` is responsible for the persistence of stateful `SessionBeans`. This includes the following:

- Creating stateful sessions in a storage
- Activating stateful sessions from a storage
- Passivating stateful sessions to a storage

- Removing stateful sessions from a storage

The `StatefulSessionPersistenceManager` interface is shown below.

Example 4.10. The org.jboss.ejb.StatefulSessionPersistenceManager interface

```
public interface StatefulSessionPersistenceManager
    extends ContainerPlugin
{
    public void createSession(Method m, Object[] args,
                              StatefulSessionEnterpriseContext ctx)
        throws Exception;

    public void activateSession(StatefulSessionEnterpriseContext ctx)
        throws RemoteException;

    public void passivateSession(StatefulSessionEnterpriseContext ctx)
        throws RemoteException;

    public void removeSession(StatefulSessionEnterpriseContext ctx)
        throws RemoteException, RemoveException;

    public void removePassivated(Object key);
}
```

The default implementation of the `StatefulSessionPersistenceManager` interface is `org.jboss.ejb.plugins.StatefulSessionFilePersistenceManager`. As its name implies, `StatefulSession-FilePersistenceManager` utilizes the file system to persist stateful session beans. More specifically, the persistence manager serializes beans in a flat file whose name is composed of the bean name and session id with a `.ser` extension. The persistence manager restores a bean's state during activation and respectively stores its state during passivation from the bean's `.ser` file.

4.4. Entity Bean Locking and Deadlock Detection

This section provides information on what entity bean locking is and how entity beans are accessed and locked within JBoss. It also describes the problems you may encounter as you use entity beans within your system and how to combat these issues. Deadlocking is formally defined and examined. And, finally, we walk you through how to fine tune your system in terms of entity bean locking.

4.4.1. Why JBoss Needs Locking

Locking is about protecting the integrity of your data. Sometimes you need to be sure that only one user can update critical data at one time. Sometimes, access to sensitive objects in your system need to be serialized so that data is not corrupted by concurrent reads and writes. Databases traditionally provide this sort of functionality with transactional scopes and table and row locking facilities.

Entity beans are a great way to provide an object-oriented interface to relational data. Beyond that, they can improve performance by taking the load off of the database through caching and delaying updates until absolutely needed so that the database efficiency can be maximized. But, with caching, data integrity is a problem, so some form of application server level locking is needed for entity beans to provide the transaction isolation properties that you are used to with traditional databases.

4.4.2. Entity Bean Lifecycle

With the default configuration of JBoss there is only one active instance of a given entity bean in memory at one time. This applies for every cache configuration and every type of `commit-option`. The lifecycle for this instance is different for every commit-option though.

- For commit option *A*, this instance is cached and used between transactions.
- For commit option *B*, this instance is cached and used between transactions, but is marked as dirty at the end of a transaction. This means that at the start of a new transaction `ejbLoad` must be called.
- For commit option *C*, this instance is marked as dirty, released from the cache, and marked for passivation at the end of a transaction.
- For commit option *D*, a background refresh thread periodically calls `ejbLoad` on stale beans within the cache. Otherwise, this option works in the same way as *A*.

When a bean is marked for passivation, the bean is placed in a passivation queue. Each entity bean container has a passivation thread that periodically passivates beans that have been placed in the passivation queue. A bean is pulled out of the passivation queue and reused if the application requests access to a bean of the same primary key.

On an exception or transaction rollback, the entity bean instance is thrown out of cache entirely. It is not put into the passivation queue and is not reused by an instance pool. Except for the passivation queue, there is no entity bean instance pooling.

4.4.3. Default Locking Behavior

Entity bean locking is totally decoupled from the entity bean instance. The logic for locking is totally isolated and managed in a separate lock object. Because there is only one allowed instance of a given entity bean active at one time, JBoss employs two types of locks to ensure data integrity and to conform to the EJB spec.

- **Method Lock**: The method lock ensures that only one thread of execution at a time can invoke on a given Entity Bean. This is required by the EJB spec.
- **Transaction Lock**: A transaction lock ensures that only one transaction at a time has access to a give Entity Bean. This ensures the ACID properties of transactions at the application server level. Since, by default, there is only one active instance of any given Entity Bean at one time, JBoss must protect this instance from dirty reads and dirty writes. So, the default entity bean locking behavior will lock an entity bean within a transaction until it completes. This means that if any method at all is invoked on an entity bean within a transaction, no other transaction can have access to this bean until the holding transaction commits or is rolled back.

4.4.4. Pluggable Interceptors and Locking Policy

We saw that the basic entity bean lifecycle and behavior is defined by the container configuration defined in `standardjboss.xml` descriptor. Let's look at the `container-interceptors` definition for the *Standard CMP 2.x EntityBean* configuration.

```
<container-interceptors>
    <interceptor>org.jboss.ejb.plugins.ProxyFactoryFinderInterceptor</interceptor>
    <interceptor>org.jboss.ejb.plugins.LogInterceptor</interceptor>
    <interceptor>org.jboss.ejb.plugins.SecurityInterceptor</interceptor>
    <interceptor>org.jboss.ejb.plugins.TxInterceptorCMT</interceptor>
    <interceptor>org.jboss.ejb.plugins.CallValidationInterceptor</interceptor>
    <interceptor metricsEnabled="true">org.jboss.ejb.plugins.MetricsInterceptor</interceptor>
    <interceptor>org.jboss.ejb.plugins.EntityCreationInterceptor</interceptor>
    <interceptor>org.jboss.ejb.plugins.EntityLockInterceptor</interceptor>
    <interceptor>org.jboss.ejb.plugins.EntityInstanceInterceptor</interceptor>
    <interceptor>org.jboss.ejb.plugins.EntityReentranceInterceptor</interceptor>
    <interceptor>org.jboss.resource.connectionmanager.CachedConnectionInterceptor</interceptor>
    <interceptor>org.jboss.ejb.plugins.EntitySynchronizationInterceptor</interceptor>
    <interceptor>org.jboss.ejb.plugins.cmp.jdbc.JDBCRelationInterceptor</interceptor>
</container-interceptors>
```

The interceptors shown above define most of the behavior of the entity bean. Below is an explanation of the interceptors that are relevant to this section.

- **EntityLockInterceptor**: This interceptor's role is to schedule any locks that must be acquired before the invocation is allowed to proceed. This interceptor is very lightweight and delegates all locking behavior to a pluggable locking policy.
- **EntityInstanceInterceptor**: The job of this interceptor is to find the entity bean within the cache or create a new one. This interceptor also ensures that there is only one active instance of a bean in memory at one time.
- **EntitySynchronizationInterceptor**: The role of this interceptor is to synchronize the state of the cache with the underlying storage. It does this with the `ejbLoad` and `ejbStore` semantics of the EJB specification. In the presence of a transaction this is triggered by transaction demarcation. It registers a callback with the underlying transaction monitor through the JTA interfaces. If there is no transaction the policy is to store state upon returning from invocation. The synchronization polices *A*, *B* and *C* of the specification are taken care of here as well as the JBoss specific commit-option *D*.

4.4.5. Deadlock

Finding deadlock problems and resolving them is the topic of this section. We will describe what deadlocking MBeans, how you can detect it within your application, and how you can resolve deadlocks. Deadlock can occur when two or more threads have locks on shared resources. Figure 4.8 illustrates a simple deadlock scenario. Here, `Thread 1` has the lock for `Bean A`, and `Thread 2` has the lock for `Bean B`. At a later time, `Thread 1` tries to lock `Bean B` and blocks because `Thread 2` has it. Likewise, as `Thread 2` tries to lock A it also blocks because `Thread 1` has the lock. At this point both threads are deadlocked waiting for access to the resource already locked by the other thread.

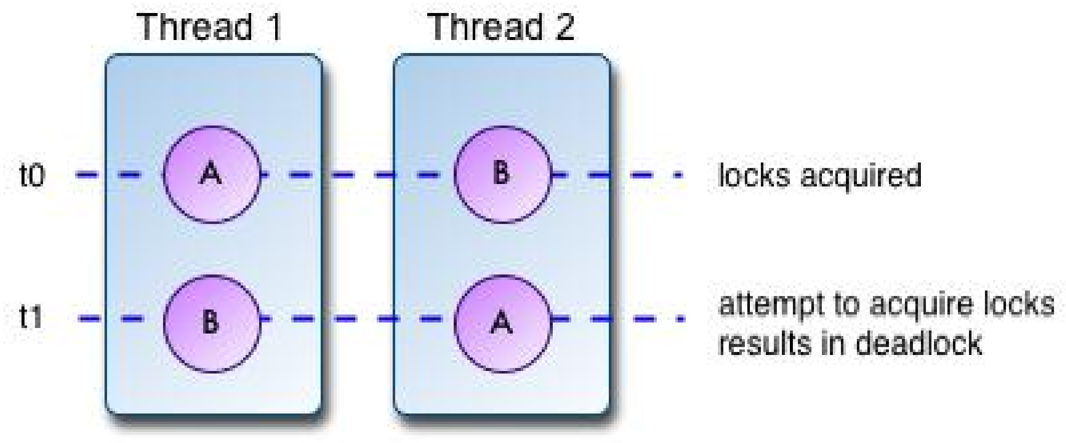


Figure 4.8. Deadlock definition example

The default locking policy of JBoss is to lock an Entity bean when an invocation occurs in the context of a transaction until the transaction completes. Because of this, it is very easy to encounter deadlock if you have long running transactions that access many entity beans, or if you are not careful about ordering the access to them. Various techniques and advanced configurations can be used to avoid deadlocking problems. They are discussed later in this section.

4.4.5.1. Deadlock Detection

Fortunately, JBoss is able to perform deadlock detection. JBoss holds a global internal graph of waiting transactions and what transactions they are blocking on. Whenever a thread determines that it cannot acquire an entity bean lock, it figures out what transaction currently holds the lock on the bean and add itself to the blocked transaction graph. An example of what the graph may look like is given in Table 4.1.

Table 4.1. An example blocked transaction table

Blocking TX	Tx that holds needed lock
Tx1	Tx2
Tx3	Tx4
Tx4	Tx1

Before the thread actually blocks it tries to detect whether there is deadlock problem. It does this by traversing the block transaction graph. As it traverses the graph, it keeps track of what transactions are blocked. If it sees a blocked node more than once in the graph, then it knows there is deadlock and will throw an `ApplicationDeadlockException`. This exception will cause a transaction rollback which will cause all locks that transaction holds to be released.

4.4.5.2. Catching ApplicationDeadlockException

Since JBoss can detect application deadlock, you should write your application so that it can retry a transaction if the invocation fails because of the `ApplicationDeadlockException`. Unfortunately, this exception can be deeply embedded within a `RemoteException`, so you have to search for it in your catch block. For example:

```
try {
    // ...
} catch (RemoteException ex) {
    Throwable cause = null;
    RemoteException rex = ex;
    while (rex.detail != null) {
        cause = rex.detail;
        if (cause instanceof ApplicationDeadlockException) {
                // ... We have deadlock, force a retry of the transaction.
            break;
        }
        if (cause instanceof RemoteException) {
            rex = (RemoteException)cause;
        }
    }
}
```

4.4.5.3. Viewing Lock Information

The `EntityLockMonitor` MBean service allows one to view basic locking statistics as well as printing out the state of the transaction locking table. To enable this monitor uncomment its configuration in the `conf/jboss-service.xml`:

```
<mbean code="org.jboss.monitor.EntityLockMonitor"
       name="jboss.monitor:name=EntityLockMonitor"/>
```

The `EntityLockMonitor` has no configurable attributes. It does have the following read-only attributes:

- **MedianWaitTime**: The median value of all times threads had to wait to acquire a lock.
- **AverageContenders**: The ratio of the total number of contentions to the sum of all threads that had to wait for a lock.
- **TotalContentions**: The total number of threads that had to wait to acquire the transaction lock. This happens when a thread attempts to acquire a lock that is associated with another transaction
- **MaxContenders**: The maximum number of threads that were waiting to acquire the transaction lock.

It also has the following operations:

- **clearMonitor**: This operation resets the lock monitor state by zeroing all counters.
- **printLockMonitor**: This operation prints out a table of all EJB locks that lists the `ejbName` of the bean, the total time spent waiting for the lock, the count of times the lock was waited on and the number of transactions that timed out waiting for the lock.

4.4.6. Advanced Configurations and Optimizations

The default locking behavior of entity beans can cause deadlock. Since access to an entity bean locks the bean into the transaction, this also can present a huge performance/throughput problem for your application. This section walks through various techniques and configurations that you can use to optimize performance and reduce the possibility of deadlock.

4.4.6.1. Short-lived Transactions

Make your transactions as short-lived and fine-grained as possible. The shorter the transaction you have, the less likelihood you will have concurrent access collisions and your application throughput will go up.

4.4.6.2. Ordered Access

Ordering the access to your entity beans can help lessen the likelihood of deadlock. This means making sure that the entity beans in your system are always accessed in the same exact order. In most cases, user applications are just too complicated to use this approach and more advanced configurations are needed.

4.4.6.3. Read-Only Beans

Entity beans can be marked as read-only. When a bean is marked as read-only, it never takes part in a transaction. This means that it is never transactionally locked. Using commit-option *D* with this option is sometimes very useful when your read-only bean's data is sometimes updated by an external source.

To mark a bean as read-only, use the `read-only` flag in the `jboss.xml` deployment descriptor.

Example 4.11. Marking an entity bean read-only using jboss.xml

```
<jboss>
    <enterprise-beans>
        <entity>
            <ejb-name>MyEntityBean</ejb-name>
            <jndi-name>MyEntityHomeRemote</jndi-name>
            <read-only>True</read-only>
        </entity>
    </enterprise-beans>
</jboss>
```

4.4.6.4. Explicitly Defining Read-Only Methods

After reading and understanding the default locking behavior of entity beans, you're probably wondering, "Why lock the bean if its not modifying the data?" JBoss allows you to define what methods on your entity bean are read only so that it will not lock the bean within the transaction if only these types of methods are called. You can define these read only methods within a `jboss.xml` deployment descriptor. Wildcards are allowed for method names. The following is an example of declaring all getter methods and the `anotherReadOnlyMethod` as read-only.

Example 4.12. Defining entity bean methods as read only

```
<jboss>
    <enterprise-beans>
        <entity>
            <ejb-name>nextgen.EnterpriseEntity</ejb-name>
            <jndi-name>nextgen.EnterpriseEntity</jndi-name>
            <method-attributes>
                <method>
```

```
                    <method-name>get*</method-name>
                    <read-only>true</read-only>
                </method>
                <method>
                    <method-name>anotherReadOnlyMethod</method-name>
                    <read-only>true</read-only>
                </method>
            </method-attributes>
        </entity>
    </enterprise-beans>
</jboss>
```

4.4.6.5. Instance Per Transaction Policy

The Instance Per Transaction policy is an advanced configuration that can totally wipe away deadlock and throughput problems caused by JBoss's default locking policy. The default Entity Bean locking policy is to only allow one active instance of a bean. The Instance Per Transaction policy breaks this requirement by allocating a new instance of a bean per transaction and dropping this instance at the end of the transaction. Because each transaction has its own copy of the bean, there is no need for transaction based locking.

This option does sound great but does have some drawbacks right now. First, the transactional isolation behavior of this option is equivalent to `READ_COMMITTED`. This can create repeatable reads when they are not desired. In other words, a transaction could have a copy of a stale bean. Second, this configuration option currently requires commit-option *B* or *C* which can be a performance drain since an ejbLoad must happen at the beginning of the transaction. But, if your application currently requires commit-option *B* or *C* anyways, then this is the way to go. The JBoss developers are currently exploring ways to allow commit-option *A* as well (which would allow the use of caching for this option).

JBoss has container configurations named `Instance Per Transaction CMP 2.x EntityBean` and `Instance Per Transaction BMP EntityBean` defined in the standardjboss.xml that implement this locking policy. To use this configuration, you just have to reference the name of the container configuration to use with your bean in the jboss.xml deployment descriptor as show below.

Example 4.13. An example of using the Instance Per Transaction policy.

```
<jboss>
    <enterprise-beans>
        <entity>
            <ejb-name>MyCMP2Bean</ejb-name>
            <jndi-name>MyCMP2</jndi-name>
            <configuration-name>
                Instance Per Transaction CMP 2.x EntityBean
            </configuration-name>
        </entity>
        <entity>
            <ejb-name>MyBMPBean</ejb-name>
            <jndi-name>MyBMP</jndi-name>
            <configuration-name>
                Instance Per Transaction BMP EntityBean
            </configuration-name>
        </entity>
    </enterprise-beans>
</jboss>
```

4.4.7. Running Within a Cluster

Currently there is no distributed locking capability for entity beans within the cluster. This functionality has been delegated to the database and must be supported by the application developer. For clustered entity beans, it is suggested to use commit-option *B* or *C* in combination with a row locking mechanism. For CMP, there is a row-locking configuration option. This option will use a SQL `select for update` when the bean is loaded from the database. With commit-option *B* or *C*, this implements a transactional lock that can be used across the cluster. For BMP, you must explicitly implement the select for update invocation within the BMP's `ejbLoad` method.

4.4.8. Troubleshooting

This section will describe some common locking problems and their solution.

4.4.8.1. Locking Behavior Not Working

Many JBoss users observe that locking does not seem to be working and see concurrent access to their beans, and thus dirty reads. Here are some common reasons for this:

- If you have custom `container-configurations`, make sure you have updated these configurations.
- Make absolutely sure that you have implemented `equals` and `hashCode` correctly from custom/complex primary key classes.
- Make absolutely sure that your custom/complex primary key classes serialize correctly. One common mistake is assuming that member variable initializations will be executed when a primary key is unmarshalled.

4.4.8.2. IllegalStateException

An IllegalStateException with the message "removing bean lock and it has tx set!" usually means that you have not implemented `equals` and/or `hashCode` correctly for your custom/complex primary key class, or that your primary key class is not implemented correctly for serialization.

4.4.8.3. Hangs and Transaction Timeouts

One long outstanding bug of JBoss is that on a transaction timeout, that transaction is only marked for a rollback and not actually rolled back. This responsibility is delegated to the invocation thread. This can cause major problems if the invocation thread hangs indefinitely since things like entity bean locks will never be released. The solution to this problem is not a good one. You really just need to avoid doing stuff within a transaction that could hang indefinitely. One common mistake is making connections across the internet or running a web-crawler within a transaction.

4.5. EJB Timer Configuration

The J2EE timer service allows for any EJB object to register for a timer callback either at a designated time in the future. Timer events can be used for auditing, reporting or other cleanup tasks that need to need to happen at some given time in the future. Timer events are intended to be persistent and should be executed even in the event of a server failure. Coding to EJB timers is a standard part of the J2EE specification, so we won't explore the programming model. We will, instead, look at the configuration of the timer service in JBoss so that you can understand how to make timers work best in your environment

The EJB timer service is configure by several related MBeans in the `ejb-deployer.xml` file. The primary MBean is the `EJBTimerService` MBean.

```
<mbean code="org.jboss.ejb.txtimer.EJBTimerServiceImpl" name="jboss.ejb:service=EJBTimerService">
    <attribute name="RetryPolicy">jboss.ejb:service=EJBTimerService,retryPolicy=fixedDelay</attribute>
    <attribute name="PersistencePolicy">jboss.ejb:service=EJBTimerService,persistencePolicy=database</att
    <attribute name="TimerIdGeneratorClassName">org.jboss.ejb.txtimer.BigIntegerTimerIdGenerator</attribu
    <attribute name="TimedObjectInvokerClassName">org.jboss.ejb.txtimer.TimedObjectInvokerImpl</attribute
</mbean>
```

The `EJBTimerService` has the following configurable attributes:

- **RetryPolicy**: This is name of the MBean that implements the retry policy. The MBean must support the `org.jboss.ejb.txtimer.RetryPolicy interface`. JBoss provides one implementation, `FixedDelayRetryPolicy`, which will be described later.
- **PersistencePolicy**: This is the name of the MBean that implements the the persistence strategy for saving timer events. The MBean must support the `org.jboss.ejb.txtimer.PersistencePolicy` interface. JBoss provides two implementations, NoopPersistencePolicy and DatabasePersistencePolicy, which will be described later.
- **TimerIdGeneratorClassName**: This is the name of a class that provides the timer ID generator strategy. This class must implement the `org.jboss.ejb.txtimer.TimerIdGenerator` interface. JBoss provides the `org.jboss.ejb.txtimer.BigIntegerTimerIdGenerator` implementation.
- **TimedObjectInvokerClassname**: This is the name of a class that provides the timer method invocation strategy. This class must implement the `org.jboss.ejb.txtimer.TimedObjectInvoker` interface. JBoss provides the `org.jboss.ejb.txtimer.TimedObjectInvokerImpl` implementation.

The retry policy MBean definition used is shown here:

```
<mbean code="org.jboss.ejb.txtimer.FixedDelayRetryPolicy"
       name="jboss.ejb:service=EJBTimerService,retryPolicy=fixedDelay">
    <attribute name="Delay">100</attribute>
</mbean>
```

The retry policy takes one configuration value:

- **Delay**: This is the delay (ms) before retrying a failed timer execution. The default delay is 100ms.

If EJB timers do not need to be persisted, the `NoopPersistence` policy can be used. This MBean is commented out by default, but when enabled will look like this:

```
<mbean code="org.jboss.ejb.txtimer.NoopPersistencePolicy"
       name="jboss.ejb:service=EJBTimerService,persistencePolicy=noop"/>
```

Most applications that use timers will want timers to be persisted. For that the `DatabasePersitencePolicy` MBean should be used.

```
<mbean code="org.jboss.ejb.txtimer.DatabasePersistencePolicy"
```

```
       name="jboss.ejb:service=EJBTimerService,persistencePolicy=database">
    <!-- DataSource JNDI name -->
    <depends optional-attribute-name="DataSource">jboss.jca:service=DataSourceBinding,name=DefaultDS</dep
    <!-- The plugin that handles database persistence -->
    <attribute name="DatabasePersistencePlugin">org.jboss.ejb.txtimer.GeneralPurposeDatabasePersistencePl
</mbean>
```

- **DataSource**: This is the MBean for the DataSource that timer data will be written to.
- **DatabasePersistencePlugin**: This is the name of the class the implements the persistence strategy. This should be `org.jboss.ejb.txtimer.GeneralPurposeDatabasePersistencePlugin`.

5

Messaging on JBoss

JMS Configuration and Architecture

The JMS API stands for Java Message Service Application Programming Interface, and it is used by applications to send asynchronous *business-quality* messages to other applications. In the messaging world, messages are not sent directly to other applications. Instead, messages are sent to destinations, known as queues or topics. Applications sending messages do not need to worry if the receiving applications are up and running, and conversely, receiving applications do not need to worry about the sending application's status. Both senders, and receivers only interact with the destinations.

The JMS API is the standardized interface to a JMS provider, sometimes called a Message Oriented Middleware (MOM) system. JBoss comes with a JMS 1.1 compliant JMS provider called JBoss Messaging or JBossMQ. When you use the JMS API with JBoss, you are using the JBoss Messaging engine transparently. JBoss Messaging fully implements the JMS specification; therefore, the best JBoss Messaging user guide is the JMS specification. For more information about the JMS API please visit the JMS Tutorial or JMS Downloads & Specifications.

This chapter focuses on the JBoss specific aspects of using JMS and message driven beans as well as the JBoss Messaging configuration and MBeans.

5.1. JMS Examples

In this section we discuss the basics needed to use the JBoss JMS implementation. JMS leaves the details of accessing JMS connection factories and destinations as provider specific details. What you need to know to use the JBoss Messaging layer is:

- The location of the queue and topic connect factories: In JBoss both connection factory implementations are located under the JNDI name `ConnectionFactory`.
- How to lookup JMS destinations (queues and topics): Destinations are configured via MBeans as we will see when we discuss the messaging MBeans. JBoss comes with a few queues and topics preconfigured. You can find them under the `jboss.mq.destination` domain in the JMX Console..
- Which JARS JMS requires: These include `concurrent.jar`, `jbossmq-client.jar`, `jboss-common-client.jar`, `jboss-system-client.jar`, `jnp-client.jar` and `log4j.jar`.

In the following sections we will look at examples of the various JMS messaging models and message driven beans. The chapter example source is located under the `src/main/org/jboss/book/jms` directory of the book examples.

5.1.1. A Point-To-Point Example

Let's start out with a point-to-point (P2P) example. In the P2P model, a sender delivers messages to a queue and a single receiver pulls the message off of the queue. The receiver does not need to be listening to the queue at the time the message is sent. Example 5.1 shows a complete P2P example that sends a `javax.jms.TextMessage` to the queue `queue/testQueue` and asynchronously receives the message from the same queue.

Example 5.1. A P2P JMS client example

```
package org.jboss.book.jms.ex1;

import javax.jms.JMSException;
import javax.jms.Message;
import javax.jms.MessageListener;
import javax.jms.Queue;
import javax.jms.QueueConnection;
import javax.jms.QueueConnectionFactory;
import javax.jms.QueueReceiver;
import javax.jms.QueueSender;
import javax.jms.QueueSession;
import javax.jms.TextMessage;
import javax.naming.InitialContext;
import javax.naming.NamingException;

import EDU.oswego.cs.dl.util.concurrent.CountDown;
import org.apache.log4j.Logger;
import org.jboss.util.ChapterExRepository;

/**
 * A complete JMS client example program that sends a
 * TextMessage to a Queue and asynchronously receives the
 * message from the same Queue.
 *
 * @author  Scott.Stark@jboss.org
 * @version $Revision: 1.2 $
 */
public class SendRecvClient
{
    static Logger log;
    static CountDown done = new CountDown(1);

    QueueConnection conn;
    QueueSession session;
    Queue que;

    public static class ExListener
        implements MessageListener
    {
        public void onMessage(Message msg)
        {
            done.release();
            TextMessage tm = (TextMessage) msg;
            try {
                log.info("onMessage, recv text=" + tm.getText());
            } catch(Throwable t) {
                t.printStackTrace();
            }
        }
    }

    public void setupPTP()
        throws JMSException,
               NamingException
    {
        InitialContext iniCtx = new InitialContext();
        Object tmp = iniCtx.lookup("ConnectionFactory");
        QueueConnectionFactory qcf = (QueueConnectionFactory) tmp;
        conn = qcf.createQueueConnection();
        que = (Queue) iniCtx.lookup("queue/testQueue");
        session = conn.createQueueSession(false,
                                          QueueSession.AUTO_ACKNOWLEDGE);
        conn.start();
    }

    public void sendRecvAsync(String text)
        throws JMSException,
               NamingException
    {
        log.info("Begin sendRecvAsync");
        // Setup the PTP connection, session
        setupPTP();

        // Set the async listener
        QueueReceiver recv = session.createReceiver(que);
        recv.setMessageListener(new ExListener());

        // Send a text msg
        QueueSender send = session.createSender(que);
        TextMessage tm = session.createTextMessage(text);
        send.send(tm);
        log.info("sendRecvAsync, sent text=" + tm.getText());
        send.close();
        log.info("End sendRecvAsync");
    }

    public void stop()
        throws JMSException
    {
        conn.stop();
        session.close();
        conn.close();
    }

    public static void main(String args[])
        throws Exception
    {
        ChapterExRepository.init(SendRecvClient.class);
        log = Logger.getLogger("SendRecvClient");

        log.info("Begin SendRecvClient, now=" + System.currentTimeMillis());
        SendRecvClient client = new SendRecvClient();
        client.sendRecvAsync("A text msg");
        client.done.acquire();
        client.stop();
        log.info("End SendRecvClient");
        System.exit(0);
    }
}
```

The client may be run using the following command line:

```
[examples]$ ant -Dchap=jms -Dex=1p2p run-example
...
run-example1p2p:
     [java] [INFO,SendRecvClient] Begin SendRecvClient, now=1102808673386
     [java] [INFO,SendRecvClient] Begin sendRecvAsync
     [java] [INFO,SendRecvClient] onMessage, recv text=A text msg
     [java] [INFO,SendRecvClient] sendRecvAsync, sent text=A text msg
     [java] [INFO,SendRecvClient] End sendRecvAsync
     [java] [INFO,SendRecvClient] End SendRecvClient
```

5.1.2. A Pub-Sub Example

The JMS publish/subscribe (Pub-Sub) message model is a one-to-many model. A publisher sends a message to a topic and all active subscribers of the topic receive the message. Subscribers that are not actively listening to the topic will miss the published message. shows a complete JMS client that sends a `javax.jms.TextMessage` to a topic and asynchronously receives the message from the same topic.

Example 5.2. A Pub-Sub JMS client example

```
package org.jboss.book.jms.ex1;

import javax.jms.JMSException;
import javax.jms.Message;
import javax.jms.MessageListener;
import javax.jms.Topic;
import javax.jms.TopicConnection;
import javax.jms.TopicConnectionFactory;
import javax.jms.TopicPublisher;
import javax.jms.TopicSubscriber;
import javax.jms.TopicSession;
import javax.jms.TextMessage;
import javax.naming.InitialContext;
import javax.naming.NamingException;

import EDU.oswego.cs.dl.util.concurrent.CountDown;

/**
 *  A complete JMS client example program that sends a TextMessage to
 *  a Topic and asynchronously receives the message from the same
 *  Topic.
 *
 *  @author Scott.Stark@jboss.org
 *  @version $Revision: 1.2 $
 */

public class TopicSendRecvClient
{
    static CountDown done = new CountDown(1);
    TopicConnection conn = null;
    TopicSession session = null;
    Topic topic = null;

    public static class ExListener implements MessageListener
    {
        public void onMessage(Message msg)
        {
            done.release();
            TextMessage tm = (TextMessage) msg;
            try {
                System.out.println("onMessage, recv text=" + tm.getText());
            } catch(Throwable t) {
                t.printStackTrace();
            }
        }
    }

    public void setupPubSub()
        throws JMSException, NamingException
    {
        InitialContext iniCtx = new InitialContext();
        Object tmp = iniCtx.lookup("ConnectionFactory");
        TopicConnectionFactory tcf = (TopicConnectionFactory) tmp;
        conn = tcf.createTopicConnection();
        topic = (Topic) iniCtx.lookup("topic/testTopic");
        session = conn.createTopicSession(false,
                                          TopicSession.AUTO_ACKNOWLEDGE);
        conn.start();
    }

    public void sendRecvAsync(String text)
        throws JMSException, NamingException
    {
        System.out.println("Begin sendRecvAsync");
        // Setup the PubSub connection, session
        setupPubSub();
        // Set the async listener

        TopicSubscriber recv = session.createSubscriber(topic);
        recv.setMessageListener(new ExListener());
        // Send a text msg
        TopicPublisher send = session.createPublisher(topic);
        TextMessage tm = session.createTextMessage(text);
        send.publish(tm);
        System.out.println("sendRecvAsync, sent text=" + tm.getText());
        send.close();
        System.out.println("End sendRecvAsync");
    }

    public void stop() throws JMSException
    {
        conn.stop();
        session.close();
        conn.close();
    }

    public static void main(String args[]) throws Exception
    {
        System.out.println("Begin TopicSendRecvClient, now=" +
                           System.currentTimeMillis());
        TopicSendRecvClient client = new TopicSendRecvClient();
        client.sendRecvAsync("A text msg, now="+System.currentTimeMillis());
        client.done.acquire();
        client.stop();
        System.out.println("End TopicSendRecvClient");
        System.exit(0);
    }

}
```

The client may be run using the following command line:

```
[examples]$ ant -Dchap=jms -Dex=1ps run-example
...
run-example1ps:
     [java] Begin TopicSendRecvClient, now=1102809427043
     [java] Begin sendRecvAsync
     [java] onMessage, recv text=A text msg, now=1102809427071
     [java] sendRecvAsync, sent text=A text msg, now=1102809427071
     [java] End sendRecvAsync
     [java] End TopicSendRecvClient
```

Now let's break the publisher and subscribers into separate programs to demonstrate that subscribers only receive messages while they are listening to a topic. Example 5.3 shows a variation of the previous pub-sub client that only publishes messages to the `topic/testTopic` topic. The subscriber only client is shown in Example 5.3.

Example 5.3. A JMS publisher client

```
package org.jboss.book.jms.ex1;

import javax.jms.JMSException;
import javax.jms.Message;
import javax.jms.MessageListener;
import javax.jms.Topic;
import javax.jms.TopicConnection;
import javax.jms.TopicConnectionFactory;
import javax.jms.TopicPublisher;
import javax.jms.TopicSlistubscriber;
import javax.jms.TopicSession;
import javax.jms.TextMessage;
import javax.naming.InitialContext;
import javax.naming.NamingException;

/**
 *  A JMS client example program that sends a TextMessage to a Topic
 *
 *  @author Scott.Stark@jboss.org
 *  @version $Revision: 1.2 $
 */
public class TopicSendClient
{
    TopicConnection conn = null;
    TopicSession session = null;
    Topic topic = null;

    public void setupPubSub()
        throws JMSException, NamingException
    {
        InitialContext iniCtx = new InitialContext();
        Object tmp = iniCtx.lookup("ConnectionFactory");
        TopicConnectionFactory tcf = (TopicConnectionFactory) tmp;
        conn = tcf.createTopicConnection();
        topic = (Topic) iniCtx.lookup("topic/testTopic");
        session = conn.createTopicSession(false,
                                          TopicSession.AUTO_ACKNOWLEDGE);
        conn.start();
    }

    public void sendAsync(String text)
        throws JMSException, NamingException
    {
        System.out.println("Begin sendAsync");
        // Setup the pub/sub connection, session
        setupPubSub();
        // Send a text msg
        TopicPublisher send = session.createPublisher(topic);
        TextMessage tm = session.createTextMessage(text);
        send.publish(tm);
        System.out.println("sendAsync, sent text=" +  tm.getText());
        send.close();
        System.out.println("End sendAsync");
    }

    public void stop()
        throws JMSException
    {
        conn.stop();
        session.close();
        conn.close();
    }

    public static void main(String args[])
        throws Exception
    {
        System.out.println("Begin TopicSendClient, now=" +
                           System.currentTimeMillis());
        TopicSendClient client = new TopicSendClient();
            client.sendAsync("A text msg, now="+System.currentTimeMillis());
        client.stop();
        System.out.println("End TopicSendClient");
        System.exit(0);
    }

}
```

Example 5.4. A JMS subscriber client

```
package org.jboss.book.jms.ex1;

import javax.jms.JMSException;
import javax.jms.Message;
import javax.jms.MessageListener;
import javax.jms.Topic;
import javax.jms.TopicConnection;
import javax.jms.TopicConnectionFactory;
import javax.jms.TopicPublisher;
import javax.jms.TopicSubscriber;
import javax.jms.TopicSession;
import javax.jms.TextMessage;
import javax.naming.InitialContext;
import javax.naming.NamingException;

/**
 * A JMS client example program that synchronously receives a message a Topic
 *
 * @author Scott.Stark@jboss.org
 * @version $Revision: 1.2 $
 */
public class TopicRecvClient
{
    TopicConnection conn = null;
    TopicSession session = null;
    Topic topic = null;

    public void setupPubSub()
        throws JMSException, NamingException
    {
        InitialContext iniCtx = new InitialContext();
        Object tmp = iniCtx.lookup("ConnectionFactory");
        TopicConnectionFactory tcf = (TopicConnectionFactory) tmp;
        conn = tcf.createTopicConnection();
        topic = (Topic) iniCtx.lookup("topic/testTopic");
        session = conn.createTopicSession(false,
                                          TopicSession.AUTO_ACKNOWLEDGE);
        conn.start();
    }
    public void recvSync()
        throws JMSException, NamingException
    {
        System.out.println("Begin recvSync");
        // Setup the pub/sub connection, session
        setupPubSub();

        // Wait upto 5 seconds for the message
        TopicSubscriber recv = session.createSubscriber(topic);
        Message msg = recv.receive(5000);
        if (msg == null) {
            System.out.println("Timed out waiting for msg");
        } else {
            System.out.println("TopicSubscriber.recv, msgt="+msg);
        }
    }

    public void stop()
        throws JMSException
    {
        conn.stop();
        session.close();
        conn.close();
    }

    public static void main(String args[])
        throws Exception
    {
        System.out.println("Begin TopicRecvClient, now=" +
                           System.currentTimeMillis());
        TopicRecvClient client = new TopicRecvClient();
        client.recvSync();
        client.stop();
        System.out.println("End TopicRecvClient");
        System.exit(0);
    }

}
```

Run the `TopicSendClient` followed by the `TopicRecvClient` as follows:

```
[examples]$ ant -Dchap=jms -Dex=1ps2 run-example
...
run-example1ps2:
     [java] Begin TopicSendClient, now=1102810007899
     [java] Begin sendAsync
     [java] sendAsync, sent text=A text msg, now=1102810007909
     [java] End sendAsync
     [java] End TopicSendClient
     [java] Begin TopicRecvClient, now=1102810011524
     [java] Begin recvSync
     [java] Timed out waiting for msg
     [java] End TopicRecvClient
```

The output shows that the topic subscriber client (`TopicRecvClient`) fails to receive the message sent by the publisher due to a timeout.

5.1.3. A Pub-Sub With Durable Topic Example

JMS supports a messaging model that is a cross between the P2P and pub-sub models. When a pub-sub client wants to receive all messages posted to the topic it subscribes to even when it is not actively listening to the topic, the client may achieve this behavior using a durable topic. Let's look at a variation of the preceding subscriber client that uses a durable topic to ensure that it receives all messages, include those published when the client is not listening to the topic. Example 5.5 shows the durable topic client with the key differences between the Example 5.4 client highlighted in bold.

Example 5.5. A durable topic JMS client example

```
package org.jboss.book.jms.ex1;

import javax.jms.JMSException;
import javax.jms.Message;
import javax.jms.MessageListener;
import javax.jms.Topic;
import javax.jms.TopicConnection;
import javax.jms.TopicConnectionFactory;
import javax.jms.TopicPublisher;
import javax.jms.TopicSubscriber;
import javax.jms.TopicSession;
import javax.jms.TextMessage;
import javax.naming.InitialContext;
import javax.naming.NamingException;

/**
 *  A JMS client example program that synchronously receives a message a Topic
 *
 *  @author Scott.Stark@jboss.org
 *  @version $Revision: 1.2 $
 */
public class DurableTopicRecvClient
{
    TopicConnection conn = null;
    TopicSession session = null;
    Topic topic = null;

    public void setupPubSub()
        throws JMSException, NamingException
    {
        InitialContext iniCtx = new InitialContext();
        Object tmp = iniCtx.lookup("ConnectionFactory");

        TopicConnectionFactory tcf = (TopicConnectionFactory) tmp;
        conn = tcf.createTopicConnection("john", "needle");
        topic = (Topic) iniCtx.lookup("topic/testTopic");

        session = conn.createTopicSession(false,
                                          TopicSession.AUTO_ACKNOWLEDGE);
        conn.start();
    }

    public void recvSync()
        throws JMSException, NamingException
    {
        System.out.println("Begin recvSync");
        // Setup the pub/sub connection, session
        setupPubSub();
        // Wait upto 5 seconds for the message
        TopicSubscriber recv = session.createDurableSubscriber(topic, "jms-ex1dtps");
        Message msg = recv.receive(5000);
        if (msg == null) {
            System.out.println("Timed out waiting for msg");
        } else {
            System.out.println("DurableTopicRecvClient.recv, msgt=" + msg);
        }
    }

    public void stop()
        throws JMSException
    {
        conn.stop();
        session.close();
        conn.close();
    }

    public static void main(String args[])
        throws Exception
    {
        System.out.println("Begin DurableTopicRecvClient, now=" +
                           System.currentTimeMillis());
        DurableTopicRecvClient client = new DurableTopicRecvClient();
        client.recvSync();
        client.stop();
        System.out.println("End DurableTopicRecvClient");
        System.exit(0);
    }

}
```

Now run the previous topic publisher with the durable topic subscriber as follows:

```
[examples]$ ant -Dchap=jms -Dex=1psdt run-example
...
run-example1psdt:
     [java] Begin DurableTopicSetup
     [java] End DurableTopicSetup
     [java] Begin TopicSendClient, now=1102899834273
     [java] Begin sendAsync
     [java] sendAsync, sent text=A text msg, now=1102899834345
     [java] End sendAsync
     [java] End TopicSendClient
     [java] Begin DurableTopicRecvClient, now=1102899840043
     [java] Begin recvSync
     [java] DurableTopicRecvClient.recv, msgt=SpyTextMessage {
     [java] Header {
     [java]    jmsDestination  : TOPIC.testTopic.DurableSubscription[
               clientId=DurableSubscriberExample name=jms-ex1dtps selector=null]
     [java]    jmsDeliveryMode : 2
     [java]    jmsExpiration   : 0
     [java]    jmsPriority     : 4
     [java]    jmsMessageID    : ID:3-11028998375501
     [java]    jmsTimeStamp    : 1102899837550
     [java]    jmsCorrelationID: null
     [java]    jmsReplyTo      : null
     [java]    jmsType         : null
     [java]    jmsRedelivered  : false
     [java]    jmsProperties   : {}
     [java]    jmsPropReadWrite: false
     [java]    msgReadOnly     : true
     [java]    producerClientId: ID:3
     [java] }
     [java] Body {
     [java]    text            :A text msg, now=1102899834345
     [java] }
     [java] }
     [java] End DurableTopicRecvClient
```

Items of note for the durable topic example include:

- The `TopicConnectionFactory` creation in the durable topic client used a username and password, and the `TopicSubscriber` creation was done using the `createDurableSubscriber(Topic, String)` method. This is a requirement of durable topic subscribers. The messaging server needs to know what client is requesting the durable topic and what the name of the durable topic subscription is. We will discuss the details of durable topic setup in the configuration section.
- An `org.jboss.book.jms.DurableTopicSetup` client was run prior to the `TopicSendClient`. The reason for this is a durable topic subscriber must have registered a subscription at some point in the past in order for the messaging server to save messages. JBoss supports dynamic durable topic subscribers and the `DurableTopicSetup` client simply creates a durable subscription receiver and the exits. This leaves an active durable topic subscriber on the `topic/testTopic` and the messaging server knows that any messages posted to this topic must be saved for latter delivery.
- The `TopicSendClient` does not change for the durable topic. The notion of a durable topic is a subscriber only notion.
- The `DurableTopicRecvClient` sees the message published to the `topic/testTopic` even though it was not listening to the topic at the time the message was published.

5.1.4. A Point-To-Point With MDB Example

Example 5.6 shows an message driven bean (MDB) that transforms the `TextMessages` it receives and sends the transformed messages to the queue found in the incoming message `JMSReplyTo` header.

Example 5.6. A TextMessage processing MDB

```
package org.jboss.book.jms.ex2;

import javax.ejb.MessageDrivenBean;
import javax.ejb.MessageDrivenContext;
import javax.ejb.EJBException;
import javax.jms.JMSException;
import javax.jms.Message;
import javax.jms.MessageListener;
import javax.jms.Queue;
import javax.jms.QueueConnection;
import javax.jms.QueueConnectionFactory;
import javax.jms.QueueSender;
import javax.jms.QueueSession;
import javax.jms.TextMessage;
import javax.naming.InitialContext;
import javax.naming.NamingException;

/**
 * An MDB that transforms the TextMessages it receives and send the
 * transformed messages to the Queue found in the incoming message
 * JMSReplyTo header.
 *
 * @author Scott.Stark@jboss.org
 * @version $Revision: 1.2 $
 */
public class TextMDB
```

```
    implements MessageDrivenBean, MessageListener
{
    private MessageDrivenContext ctx = null;
    private QueueConnection conn;
    private QueueSession session;

    public TextMDB()
    {
        System.out.println("TextMDB.ctor, this="+hashCode());
    }

    public void setMessageDrivenContext(MessageDrivenContext ctx)
    {
        this.ctx = ctx;
        System.out.println("TextMDB.setMessageDrivenContext, this=" +
                           hashCode());
    }

    public void ejbCreate()
    {
        System.out.println("TextMDB.ejbCreate, this="+hashCode());
        try {
            setupPTP();
        } catch (Exception e) {
            throw new EJBException("Failed to init TextMDB", e);
        }
    }

    public void ejbRemove()
    {
        System.out.println("TextMDB.ejbRemove, this="+hashCode());
        ctx = null;
        try {
            if (session != null) {
                session.close();
            }
            if (conn != null) {
                conn.close();
            }
        } catch(JMSException e) {
            e.printStackTrace();
        }
    }

    public void onMessage(Message msg)
    {
        System.out.println("TextMDB.onMessage, this="+hashCode());
        try {
            TextMessage tm = (TextMessage) msg;
            String text = tm.getText() + "processed by: "+hashCode();
            Queue dest = (Queue) msg.getJMSReplyTo();
            sendReply(text, dest);
        } catch(Throwable t) {
            t.printStackTrace();
        }
    }

    private void setupPTP()
        throws JMSException, NamingException
    {
        InitialContext iniCtx = new InitialContext();
        Object tmp = iniCtx.lookup("java:comp/env/jms/QCF");
        QueueConnectionFactory qcf = (QueueConnectionFactory) tmp;
        conn = qcf.createQueueConnection();
        session = conn.createQueueSession(false,
                                          QueueSession.AUTO_ACKNOWLEDGE);
        conn.start();
    }

    private void sendReply(String text, Queue dest)
        throws JMSException
    {
        System.out.println("TextMDB.sendReply, this=" +
                           hashCode() + ", dest="+dest);
        QueueSender sender = session.createSender(dest);
        TextMessage tm = session.createTextMessage(text);
        sender.send(tm);
        sender.close();
    }
}
```

The MDB `ejb-jar.xml` and `jboss.xml` deployment descriptors are shown in Example 5.7 and Example 5.8.

Example 5.7. The MDB ejb-jar.xml descriptor

```
<?xml version="1.0"?>
<!DOCTYPE ejb-jar PUBLIC
          "-//Sun Microsystems, Inc.//DTD Enterprise JavaBeans 2.0//EN"
          "http://java.sun.com/dtd/ejb-jar_2_0.dtd">
<ejb-jar>
    <enterprise-beans>
        <message-driven>
            <ejb-name>TextMDB</ejb-name>
            <ejb-class>org.jboss.book.jms.ex2.TextMDB</ejb-class>
            <transaction-type>Container</transaction-type>
            <acknowledge-mode>AUTO_ACKNOWLEDGE</acknowledge-mode>
            <message-driven-destination>
                <destination-type>javax.jms.Queue</destination-type>
            </message-driven-destination>
            <res-ref-name>jms/QCF</res-ref-name>
            <resource-ref>
                <res-type>javax.jms.QueueConnectionFactory</res-type>
                <res-auth>Container</res-auth>
            </resource-ref>
        </message-driven>
    </enterprise-beans>
</ejb-jar>
```

Example 5.8. The MDB jboss.xml descriptor

```
<?xml version="1.0"?>
<jboss>
    <enterprise-beans>
        <message-driven>
            <ejb-name>TextMDB</ejb-name>
            <destination-jndi-name>queue/B</destination-jndi-name>
            <resource-ref>
                <res-ref-name>jms/QCF</res-ref-name>
                <jndi-name>ConnectionFactory</jndi-name>
            </resource-ref>
        </message-driven>
    </enterprise-beans>
</jboss>
```

Example 5.9 shows a variation of the P2P client that sends several messages to the `queue/B` destination and asynchronously receives the messages as modified by `TextMDB` from queue `A`.

Example 5.9. A JMS client that interacts with the TextMDB

```
package org.jboss.book.jms.ex2;

import javax.jms.JMSException;
import javax.jms.Message;
import javax.jms.MessageListener;
import javax.jms.Queue;
import javax.jms.QueueConnection;
import javax.jms.QueueConnectionFactory;
import javax.jms.QueueReceiver;
import javax.jms.QueueSender;
import javax.jms.QueueSession;
import javax.jms.TextMessage;
import javax.naming.InitialContext;
import javax.naming.NamingException;

import EDU.oswego.cs.dl.util.concurrent.CountDown;

/**
 *  A complete JMS client example program that sends N TextMessages to
 *  a Queue B and asynchronously receives the messages as modified by
 *  TextMDB from Queue A.
 *
 *  @author Scott.Stark@jboss.org
 *  @version $Revision: 1.2 $
 */
public class SendRecvClient
{
    static final int N = 10;
    static CountDown done = new CountDown(N);

    QueueConnection conn;
    QueueSession session;
    Queue queA;
    Queue queB;

    public static class ExListener
        implements MessageListener
    {
        public void onMessage(Message msg)
        {
            done.release();
            TextMessage tm = (TextMessage) msg;
            try {
                System.out.println("onMessage, recv text="+tm.getText());
            } catch(Throwable t) {
                t.printStackTrace();
            }
        }
    }

    public void setupPTP()
        throws JMSException, NamingException
    {
        InitialContext iniCtx = new InitialContext();
        Object tmp = iniCtx.lookup("ConnectionFactory");
        QueueConnectionFactory qcf = (QueueConnectionFactory) tmp;
        conn = qcf.createQueueConnection();
        queA = (Queue) iniCtx.lookup("queue/A");
        queB = (Queue) iniCtx.lookup("queue/B");
        session = conn.createQueueSession(false,
                                          QueueSession.AUTO_ACKNOWLEDGE);
        conn.start();
    }

    public void sendRecvAsync(String textBase)
        throws JMSException, NamingException, InterruptedException
    {
        System.out.println("Begin sendRecvAsync");

        // Setup the PTP connection, session
        setupPTP();

        // Set the async listener for queA
        QueueReceiver recv = session.createReceiver(queA);
        recv.setMessageListener(new ExListener());

        // Send a few text msgs to queB
        QueueSender send = session.createSender(queB);

        for(int m = 0; m < 10; m ++) {
            TextMessage tm = session.createTextMessage(textBase+"#"+m);
            tm.setJMSReplyTo(queA);
            send.send(tm);
            System.out.println("sendRecvAsync, sent text=" + tm.getText());
        }
        System.out.println("End sendRecvAsync");
    }

    public void stop()
        throws JMSException
    {
        conn.stop();
        session.close();
        conn.close();
    }

    public static void main(String args[])
        throws Exception
    {
        System.out.println("Begin SendRecvClient,now=" +
                           System.currentTimeMillis());
        SendRecvClient client = new SendRecvClient();
        client.sendRecvAsync("A text msg");
        client.done.acquire();
        client.stop();
        System.exit(0);
        System.out.println("End SendRecvClient");
    }

}
```

Run the client as follows:

```
[examples]$ ant -Dchap=jms -Dex=2 run-example
...
run-example2:
...
     [java] Begin SendRecvClient, now=1102900541558
     [java] Begin sendRecvAsync
     [java] sendRecvAsync, sent text=A text msg#0
     [java] sendRecvAsync, sent text=A text msg#1
     [java] sendRecvAsync, sent text=A text msg#2
     [java] sendRecvAsync, sent text=A text msg#3
     [java] sendRecvAsync, sent text=A text msg#4
     [java] sendRecvAsync, sent text=A text msg#5
     [java] sendRecvAsync, sent text=A text msg#6
     [java] sendRecvAsync, sent text=A text msg#7
     [java] sendRecvAsync, sent text=A text msg#8
     [java] sendRecvAsync, sent text=A text msg#9
     [java] End sendRecvAsync
     [java] onMessage, recv text=A text msg#0processed by: 12855623
     [java] onMessage, recv text=A text msg#5processed by: 9399816
     [java] onMessage, recv text=A text msg#9processed by: 6598158
     [java] onMessage, recv text=A text msg#3processed by: 8153998
     [java] onMessage, recv text=A text msg#4processed by: 10118602
     [java] onMessage, recv text=A text msg#2processed by: 1792333
     [java] onMessage, recv text=A text msg#7processed by: 14251014
     [java] onMessage, recv text=A text msg#1processed by: 10775981
     [java] onMessage, recv text=A text msg#8processed by: 6056676
     [java] onMessage, recv text=A text msg#6processed by: 15679078
```

The corresponding JBoss server console output is:

```
19:15:40,232 INFO  [EjbModule] Deploying TextMDB
19:15:41,498 INFO  [EJBDeployer] Deployed: file:/jboss-4.0.5.GA/server/default/deploy/
  jms-ex2.jar
19:15:45,606 INFO  [TextMDB] TextMDB.ctor, this=10775981
19:15:45,620 INFO  [TextMDB] TextMDB.ctor, this=1792333
19:15:45,627 INFO  [TextMDB] TextMDB.setMessageDrivenContext, this=10775981
19:15:45,638 INFO  [TextMDB] TextMDB.ejbCreate, this=10775981
19:15:45,640 INFO  [TextMDB] TextMDB.setMessageDrivenContext, this=1792333
19:15:45,640 INFO  [TextMDB] TextMDB.ejbCreate, this=1792333
19:15:45,649 INFO  [TextMDB] TextMDB.ctor, this=12855623
19:15:45,658 INFO  [TextMDB] TextMDB.setMessageDrivenContext, this=12855623
19:15:45,661 INFO  [TextMDB] TextMDB.ejbCreate, this=12855623
19:15:45,742 INFO  [TextMDB] TextMDB.ctor, this=8153998
19:15:45,744 INFO  [TextMDB] TextMDB.setMessageDrivenContext, this=8153998
19:15:45,744 INFO  [TextMDB] TextMDB.ejbCreate, this=8153998
19:15:45,763 INFO  [TextMDB] TextMDB.ctor, this=10118602
19:15:45,764 INFO  [TextMDB] TextMDB.setMessageDrivenContext, this=10118602
19:15:45,764 INFO  [TextMDB] TextMDB.ejbCreate, this=10118602
19:15:45,777 INFO  [TextMDB] TextMDB.ctor, this=9399816
19:15:45,779 INFO  [TextMDB] TextMDB.setMessageDrivenContext, this=9399816
19:15:45,779 INFO  [TextMDB] TextMDB.ejbCreate, this=9399816
19:15:45,792 INFO  [TextMDB] TextMDB.ctor, this=15679078
19:15:45,798 INFO  [TextMDB] TextMDB.setMessageDrivenContext, this=15679078
19:15:45,799 INFO  [TextMDB] TextMDB.ejbCreate, this=15679078
19:15:45,815 INFO  [TextMDB] TextMDB.ctor, this=14251014
19:15:45,816 INFO  [TextMDB] TextMDB.setMessageDrivenContext, this=14251014
19:15:45,817 INFO  [TextMDB] TextMDB.ejbCreate, this=14251014
19:15:45,829 INFO  [TextMDB] TextMDB.ctor, this=6056676
19:15:45,831 INFO  [TextMDB] TextMDB.setMessageDrivenContext, this=6056676
19:15:45,864 INFO  [TextMDB] TextMDB.ctor, this=6598158
19:15:45,903 INFO  [TextMDB] TextMDB.ejbCreate, this=6056676
19:15:45,906 INFO  [TextMDB] TextMDB.setMessageDrivenContext, this=6598158
19:15:45,906 INFO  [TextMDB] TextMDB.ejbCreate, this=6598158
19:15:46,236 INFO  [TextMDB] TextMDB.onMessage, this=12855623
19:15:46,238 INFO  [TextMDB] TextMDB.sendReply, this=12855623, dest=QUEUE.A
19:15:46,734 INFO  [TextMDB] TextMDB.onMessage, this=9399816
19:15:46,736 INFO  [TextMDB] TextMDB.onMessage, this=8153998
19:15:46,737 INFO  [TextMDB] TextMDB.onMessage, this=6598158
19:15:46,768 INFO  [TextMDB] TextMDB.sendReply, this=9399816, dest=QUEUE.A
19:15:46,768 INFO  [TextMDB] TextMDB.sendReply, this=6598158, dest=QUEUE.A
19:15:46,774 INFO  [TextMDB] TextMDB.sendReply, this=8153998, dest=QUEUE.A
19:15:46,903 INFO  [TextMDB] TextMDB.onMessage, this=10118602
19:15:46,904 INFO  [TextMDB] TextMDB.sendReply, this=10118602, dest=QUEUE.A
19:15:46,927 INFO  [TextMDB] TextMDB.onMessage, this=1792333
```

```
19:15:46,928 INFO  [TextMDB] TextMDB.sendReply, this=1792333, dest=QUEUE.A
19:15:47,002 INFO  [TextMDB] TextMDB.onMessage, this=14251014
19:15:47,007 INFO  [TextMDB] TextMDB.sendReply, this=14251014, dest=QUEUE.A
19:15:47,051 INFO  [TextMDB] TextMDB.onMessage, this=10775981
19:15:47,051 INFO  [TextMDB] TextMDB.sendReply, this=10775981, dest=QUEUE.A
19:15:47,060 INFO  [TextMDB] TextMDB.onMessage, this=6056676
19:15:47,061 INFO  [TextMDB] TextMDB.sendReply, this=6056676, dest=QUEUE.A
19:15:47,064 INFO  [TextMDB] TextMDB.onMessage, this=15679078
19:15:47,065 INFO  [TextMDB] TextMDB.sendReply, this=15679078, dest=QUEUE.A
```

Items of note in this example include:

- The JMS client has no explicit knowledge that it is dealing with an MDB. The client simply uses the standard JMS APIs to send messages to a queue and receive messages from another queue.
- The MDB declares whether it will listen to a queue or topic in the `ejb-jar.xml` descriptor. The name of the queue or topic must be specified using a `jboss.xml` descriptor. In this example the MDB also sends messages to a JMS queue. MDBs may act as queue senders or topic publishers within their `onMessage` callback.
- The messages received by the client include a "processed by: NNN" suffix, where NNN is the `hashCode` value of the MDB instance that processed the message. This shows that many MDBs may actively process messages posted to a destination. Concurrent processing is one of the benefits of MDBs.

5.2. JBoss Messaging Overview

JBossMQ is composed of several services working together to provide JMS API level services to client applications. The services that make up the JBossMQ JMS implementation are introduced in this section.

5.2.1. Invocation Layer

The Invocation Layer (IL) services are responsible for handling the communication protocols that clients use to send and receive messages. JBossMQ can support running different types of Invocation Layers concurrently. All Invocation Layers support bidirectional communication which allows clients to send and receive messages concurrently. ILs only handle the transport details of messaging. They delegate messages to the JMS server JMX gateway service known as the invoker. This is similar to how the detached invokers expose the EJB container via different transports.

Each IL service binds a JMS connection factory to a specific location in the JNDI tree. Clients choose the protocol they wish to use by the JNDI location used to obtain the JMS connection factory. JBossMQ currently has several different invocation layers.

- **UIL2 IL**: The Unified Invocation Layer version 2(UIL2) is the preferred invocation layer for remote messaging. A multiplexing layer is used to provide bidirectional communication. The multiplexing layer creates two virtual sockets over one physical socket. This allows communication with clients that cannot have a connection created from the server back to the client due to firewall or other restrictions. Unlike the older UIL invocation layer which used a blocking round-trip message at the socket level, the UIL2 protocol uses true asynchronous send and receive messaging at the transport level, providing for improved throughput and utilization.
- **JVM IL**: The Java Virtual Machine (JVM) Invocation Layer was developed to cut out the TCP/IP overhead

when the JMS client is running in the same JVM as the server. This IL uses direct method calls for the server to service the client requests. This increases efficiency since no sockets are created and there is no need for the associated worker threads. This is the IL that should be used by Message Driven Beans (MDB) or any other component that runs in the same virtual machine as the server such as servlets, MBeans, or EJBs.

- **HTTP IL**: The HTTP Invocation Layer (HTTPIL) allows for accessing the JBossMQ service over the HTTP or HTTPS protocols. This IL relies on the servlet deployed in the `deploy/jms/jbossmq-httpil.sar` to handle the http traffic. This IL is useful for access to JMS through a firewall when the only port allowed requires HTTP.

5.2.2. Security Manager

The JBossMQ `SecurityManager` is the service that enforces an access control list to guard access to your destinations. This subsystem works closely with the `StateManager` service.

5.2.3. Destination Manager

The `DestinationManager` can be thought as being the central service in JBossMQ. It keeps track of all the destinations that have been created on the server. It also keeps track of the other key services such as the `MessageCache`, `StateManager`, and `PersistenceManager`.

5.2.4. Message Cache

Messages created in the server are passed to the `MessageCache` for memory management. JVM memory usage goes up as messages are added to a destination that does not have any receivers. These messages are held in the main memory until the receiver picks them up. If the `MessageCache` notices that the JVM memory usage starts passing the defined limits, the `MessageCache` starts moving those messages from memory to persistent storage on disk. The `MessageCache` uses a least recently used (LRU) algorithm to determine which messages should go to disk.

5.2.5. State Manager

The `StateManager` (SM) is in charge of keeping track of who is allowed to log into the server and what their durable subscriptions are.

5.2.6. Persistence Manager

The `PersistenceManager` (PM) is used by a destination to store messages marked as being persistent. JBossMQ has several different implementations of the persistent manager, but only one can be enabled per server instance. You should enable the persistence manager that best matches your requirements.

- **JDBC2 persistence manager**: The JDBC2 persistence manager allows you to store persistent messages to a relational database using JDBC. The performance of this PM is directly related to the performance that can be obtained from the database. This PM has a very low memory overhead compared to the other persistence managers. Furthermore it is also highly integrated with the `MessageCache` to provide efficient persistence on a system that has a very active `MessageCache`.
- **Null Persistence Manager**: A wrapper persistence manager that can delegate to a real persistence manager.

Configuration on the destinations decide whether persistence and caching is actually performed. The example configuration can be found in `docs/examples/jms`. To use the null persistence manager backed by a real persistence manager, you need to change the `ObjectName` of the real persistence manager and link the new name to the null persistence manager.

5.2.7. Destinations

A destination is the object on the JBossMQ server that clients use to send and receive messages. There are two types of destination objects, `Queues` and `Topics`. References to the destinations created by JBossMQ are stored in JNDI.

5.2.7.1. Queues

Clients that are in the point-to-point paradigm typically use queues. They expect that message sent to a queue will be receive by only one other client once and only once. If multiple clients are receiving messages from a single queue, the messages will be load balanced across the receivers. Queue objects, by default, will be stored under the JNDI `queue/` sub context.

5.2.7.2. Topics

Topics are used in the publish-subscribe paradigm. When a client publishes a message to a topic, he expects that a copy of the message will be delivered to each client that has subscribed to the topic. Topic messages are delivered in the same manner a television show is delivered. Unless you have the TV on and are watching the show, you will miss it. Similarly, if the client is not up, running and receiving messages from the topics, it will miss messages published to the topic. To get around this problem of missing messages, clients can start a durable subscription. This is like having a VCR record a show you cannot watch at its scheduled time so that you can see what you missed when you turn your TV back on.

5.3. JBoss Messaging Configuration and MBeans

This section defines the MBean services that correspond to the components introduced in the previous section along with their MBean attributes. The configuration and service files that make up the JBossMQ system include:

- **deploy/hsqldb-jdbc-state-service.xml**: This configures the JDBC state service for storing state in the embedded Hypersonic database.
- **deploy/jms/hsqldb-jdbc2-service.xml**: This service descriptor configures the `DestinationManager`, `MessageCache`, and jdbc2 `PersistenceManager` for the embedded Hypersonic database.
- **deploy/jms/jbossmq-destinations-service.xml**: This service describes defines default JMS queue and topic destination configurations used by the testsuite unit tests. You can add/remove destinations to this file, or deploy another `*-service.xml` descriptor with the destination configurations.
- **jbossmq-httpil.sar**: This SAR file configures the HTTP invocation layer.
- **deploy/jms/jbossmq-service.xml**: This service descriptor configures the core JBossMQ MBeans like the `Invoker`, `SecurityManager`, `DynamicStateManager`, and core interceptor stack. It also defines the MDB default

dead letter queue `DLQ`.

- **deploy/jms/jms-ds.xml**: This is a JCA connection factory and JMS provider MDB integration services configuration which sets JBossMQ as the JMS provider.
- **deploy/jms/jms-ra.rar**: This is a JCA resource adaptor for JMS providers.
- **deploy/jms/jvm-il-service.xml**: This service descriptor configures the `JVMServerILService` which provides the JVM IL transport.
- **deploy/jms/rmi-il-service.xml**: This service descriptor configures the `RMIServerILService` which provides the RMI IL. The queue and topic connection factory for this IL is bound under the name `RMIConnectionFactory`.
- **deploy/jms/uil2-service.xml**: This service descriptor configures the `UILServerILService` which provides the UIL2 transport. The queue and topic connection factory for this IL is bound under the name `UIL2ConnectionFactory` as well as `UILConnectionFactory` to replace the deprecated version 1 UIL service.

We will discuss the associated MBeans in the following subsections.

5.3.1. org.jboss.mq.il.jvm.JVMServerILService

The `org.jboss.mq.il.jvm.JVMServerILService` MBean is used to configure the JVM IL. The configurable attributes are as follows:

- **Invoker**: This attribute specifies JMX ObjectName of the JMS entry point service that is used to pass incoming requests to the JMS server. This is not something you would typically change from the `jboss.mq:service=Invoker` setting unless you change the entry point service.
- **ConnectionFactoryJNDIRef**: The JNDI location that this IL will bind a `ConnectionFactory` setup to use this IL.
- **XAConnectionFactoryJNDIRef**: The JNDI location that this IL will bind a `XAConnectionFactory` setup to use this IL.
- **PingPeriod**: How often, in milliseconds, the client should send a ping message to the server to validate that the connection is still valid. If this is set to zero, then no ping message will be sent. Since it is impossible for JVM IL connection to go bad, it is recommended that you keep this set to 0.

5.3.2. org.jboss.mq.il.uil2.UILServerILService

The `org.jboss.mq.il.uil2.UILServerILService` is used to configure the UIL2 IL. The configurable attributes are as follows:

- **Invoker**: This attribute specifies JMX `ObjectName` of the JMS entry point service that is used to pass incoming requests to the JMS server. This is not something you would typically change from the `jboss.mq:service=Invoker` setting unless you change the entry point service.
- **ConnectionFactoryJNDIRef**: The JNDI location that this IL will bind a `ConnectionFactory` setup to use this IL.

- **XAConnectionFactoryJNDIRef**: The JNDI location that this IL will bind a `XAConnectionFactory` setup to use this IL.
- **PingPeriod**: How often, in milliseconds, the client should send a ping message to the server to validate that the connection is still valid. If this is set to zero, then no ping message will be sent.
- **ReadTimeout**: The period in milliseconds is passed onto as the `SoTimeout` value of the UIL2 socket. This allows detection of dead sockets that are not responsive and are not capable of receiving ping messages. Note that this setting should be longer in duration than the `PingPeriod` setting.
- **BufferSize**: The size in bytes used as the buffer over the basic socket streams. This corresponds to the `java.io.BufferedOutputStream` buffer size.
- **ChunkSize**: The size in bytes between stream listener notifications. The UIL2 layer uses the `org.jboss.util.stream.NotifyingBufferedOutputStream` and `NotifyingBufferedInputStream` implementations that support the notion of a heartbeat that is triggered based on data read/written to the stream. Whenever `ChunkSize` bytes are read/written to a stream. This allows serves as a ping or keepalive notification when large reads or writes require a duration greater than the `PingPeriod`.
- **ServerBindPort**: The protocol listening port for this IL. If not specified default is 0, which means that a random port will be chosen.
- **BindAddress**: The specific address this IL listens on. This can be used on a multi-homed host for a `java.net.ServerSocket` that will only accept connection requests on one of its addresses.
- **EnableTcpNoDelay**: `TcpNoDelay` causes TCP/IP packets to be sent as soon as the request is flushed. This may improve request response times. Otherwise request packets may be buffered by the operating system to create larger IP packets.
- **ServerSocketFactory**: The `javax.net.ServerSocketFactory` implementation class name to use to create the service `java.net.ServerSocket`. If not specified the default factory will be obtained from `javax.net.ServerSocketFactory.getDefault()`.
- **ClientAddress**: The address passed to the client as the address that should be used to connect to the server.
- **ClientSocketFactory**: The `javax.net.SocketFactory` implementation class name to use on the client. If not specified the default factory will be obtained from `javax.net.SocketFactory.getDefault()`.
- **SecurityDomain**: Specify the security domain name to use with JBoss SSL aware socket factories. This is the JNDI name of the security manager implementation as described for the `security-domain` element of the `jboss.xml` and `jboss-web.xml` descriptors in Section 7.3.1.

5.3.2.1. Configuring UIL2 for SSL

The UIL2 service support the use of SSL through custom socket factories that integrate JSSE using the security domain associated with the IL service. An example UIL2 service descriptor fragment that illustrates the use of the custom JBoss SSL socket factories is shown in Example 5.10.

Example 5.10. An example UIL2 config fragment for using SSL

```
<mbean code="org.jboss.mq.il.uil2.UILServerILService"
    name="jboss.mq:service=InvocationLayer,type=HTTPSUIL2">
    <depends optional-attribute-name="Invoker">jboss.mq:service=Invoker</depends>
    <attribute name="ConnectionFactoryJNDIRef">SSLConnectionFactory</attribute>
    <attribute name="XAConnectionFactoryJNDIRef">SSLXAConnectionFactory</attribute>

    <!-- ... -->

    <!-- SSL Socket Factories -->
    <attribute name="ClientSocketFactory">
        org.jboss.security.ssl.ClientSocketFactory
    </attribute>
    <attribute name="ServerSocketFactory">
        org.jboss.security.ssl.DomainServerSocketFactory
    </attribute>
    <!-- Security domain - see below -->
    <attribute name="SecurityDomain">java:/jaas/SSL</attribute>
</mbean>

<!-- Configures the keystore on the "SSL" security domain
     This mbean is better placed in conf/jboss-service.xml where it
     can be used by other services, but it will work from anywhere.
     Use keytool from the sdk to create the keystore. -->

<mbean code="org.jboss.security.plugins.JaasSecurityDomain"
       name="jboss.security:service=JaasSecurityDomain,domain=SSL">
    <!-- This must correlate with the java:/jaas/SSL above -->
    <constructor>
        <arg type="java.lang.String" value="SSL"/>
    </constructor>
    <!-- The location of the keystore resource: loads from the
         classpath and the server conf dir is a good default -->
    <attribute name="KeyStoreURL">resource:uil2.keystore</attribute>
    <attribute name="KeyStorePass">changeme</attribute>
</mbean>
```

5.3.2.2. JMS client properties for the UIL2 transport

There are several system properties that a JMS client using the UIL2 transport can set to control the client connection back to the server

- **org.jboss.mq.il.uil2.useServerHost**: This system property allows a client to connect to the server `InetAddress.getHostName` rather than the`InetAddress.getHostAddress` value. This will only make a difference if name resolution differs between the server and client environments.
- **org.jboss.mq.il.uil2.localAddr**: This system property allows a client to define the local interface to which its sockets should be bound.
- **org.jboss.mq.il.uil2.localPort**: This system property allows a client to define the local port to which its sockets should be bound
- **org.jboss.mq.il.uil2.serverAddr**: This system property allows a client to override the address to which it attempts to connect to. This is useful for networks where NAT is occcurring between the client and JMS server.
- **org.jboss.mq.il.uil2.serverPort**: This system property allows a client to override the port to which it attempts to connect. This is useful for networks where port forwarding is occurring between the client and jms server.

- **org.jboss.mq.il.uil2.retryCount**: This system property controls the number of attempts to retry connecting to the JMS server. Retries are only made for `java.net.ConnectException` failures. A value <= 0 means no retry attempts will be made.
- **org.jboss.mq.il.uil2.retryDelay**: This system property controls the delay in milliseconds between retries due to `ConnectException` failures.

5.3.3. org.jboss.mq.il.http.HTTPServerILService

The `org.jboss.mq.il.http.HTTPServerILService` is used to manage the HTTP/S IL. This IL allows for the use of the JMS service over HTTP or HTTPS connections. The relies on the servlet deployed in the `deploy/jms/jbossmq-httpil.sar` to handle the HTTP traffic. The configurable attributes are as follows:

- **TimeOut**: The default timeout in seconds that the client HTTP requests will wait for messages. This can be overridden on the client by setting the system property `org.jboss.mq.il.http.timeout` to the number of seconds.
- **RestInterval**: The number of seconds the client will sleep after each request. The default is 0, but you can set this value in conjunction with the `TimeOut` value to implement a pure timed based polling mechanism. For example, you could simply do a short lived request by setting the `TimeOut` value to 0 and then setting the `RestInterval` to 60. This would cause the client to send a single non-blocking request to the server, return any messages if available, then sleep for 60 seconds, before issuing another request. Like the `TimeOut` value, this can be explicitly overridden on a given client by specifying the `org.jboss.mq.il.http.restinterval` with the number of seconds you wish to wait between requests.
- **URL**: Set the servlet URL. This value takes precedence over any individual values set (i.e. the `URLPrefix`, `URLSuffix`, `URLPort`, etc.) It my be a actual URL or a property name which will be used on the client side to resolve the proper URL by calling `System.getProperty(propertyname)`. If not specified the URL will be formed from `URLPrefix + URLHostName + ":" + URLPort + "/" + URLSuffix`.
- **URLPrefix**: The prefix portion of the servlet URL.
- **URLHostName**: The hostname portion of the servlet URL.
- **URLPort**: The port portion of the URL.
- **URLSuffix**: The trailing path portion of the URL.
- **UseHostName**: A flag that if set to true the default setting for the `URLHostName` attribute will be taken from `InetAddress.getLocalHost().getHostName()`. If false the default setting for the `URLHostName` attribute will be taken from `InetAddress.getLocalHost().getHostAddress()`.

5.3.4. org.jboss.mq.server.jmx.Invoker

The `org.jboss.mq.server.jmx.Invoker` is used to pass IL requests down to the destination manager service through an interceptor stack. The configurable attributes are as follows:

- **NextInterceptor**: The JMX `ObjectName` of the next request interceptor. This attribute is used by all the interceptors to create the interceptor stack. The last interceptor in the chain should be the `DestinationManager`.

5.3.5. org.jboss.mq.server.jmx.InterceptorLoader

The `org.jboss.mq.server.jmx.InterceptorLoader` is used to load a generic interceptor and make it part of the interceptor stack. This MBean is typically used to load custom interceptors like `org.jboss.mq.server.TracingInterceptor`, which is can be used to efficiently log all client requests via trace level log messages. The configurable attributes are as follows:

- **NextInterceptor**: The JMX `ObjectName` of the next request interceptor. This attribute is used by all the interceptors to create the interceptor stack. The last interceptor in the chain should be the `DestinationManager`. This attribute should be setup via a `<depends optional-attribute-name="NextInterceptor">` XML tag.
- **InterceptorClass**: The class name of the interceptor that will be loaded and made part of the interceptor stack. This class specified here must extend the `org.jboss.mq.server.JMSServerInterceptor` class.

5.3.6. org.jboss.mq.sm.jdbc.JDBCStateManager

The `JDBCStateManager` MBean is used as the default state manager assigned to the DestinationManager service. It stores user and durable subscriber information in the database. The configurable attributes are as follows:

- **ConnectionManager**: This is the `ObjectName` of the datasource that the JDBC state manager will write to. For Hypersonic, it is `jboss.jca:service=DataSourceBinding,name=DefaultDS`.
- **SqlProperties**: The `SqlProperties` define the SQL statements to be used to persist JMS state data. If the underlying database is changed, the SQL statements used may need to change.

5.3.7. org.jboss.mq.security.SecurityManager

If the `org.jboss.mq.security.SecurityManager` is part of the interceptor stack, then it will enforce the access control lists assigned to the destinations. The `SecurityManager` uses JAAS, and as such requires that at application policy be setup for in the JBoss `login-config.xml` file. The default configuration is shown below.

```
<application-policy name="jbossmq">
    <authentication>
        <login-module code="org.jboss.security.auth.spi.DatabaseServerLoginModule"
                      flag="required">
            <module-option name="unauthenticatedIdentity">guest</module-option>
            <module-option name="dsJndiName">java:/DefaultDS</module-option>
            <module-option name="principalsQuery">SELECT PASSWD FROM JMS_USERS
                WHERE USERID=?</module-option>
            <module-option name="rolesQuery">SELECT ROLEID, 'Roles' FROM
                JMS_ROLES WHERE USERID=?</module-option>
        </login-module>
    </authentication>
</application-policy>
```

The configurable attributes of the SecurityManager are as follows:

- **NextInterceptor**: The JMX `ObjectName` of the next request interceptor. This attribute is used by all the interceptors to create the interceptor stack. The last interceptor in the chain should be the `DestinationManager`.
- **SecurityDomain**: Specify the security domain name to use for authentication and role based authorization. This is the JNDI name of the JAAS domain to be used to perform authentication and authorization against.
- **DefaultSecurityConfig**: This element specifies the default security configuration settings for destinations. This applies to temporary queues and topics as well as queues and topics that do not specifically specify a security configuration. The `DefaultSecurityConfig` should declare some number of `role` elements which represent each role that is allowed access to a destination. Each `role` should have the following attributes:
    - **name**: The `name` attribute defines the name of the role.
    - **create**: The `create` attribute is a true/false value that indicates whether the role has the ability to create durable subscriptions on the topic.
    - **read**: The `read` attribute is a true/false value that indicates whether the role can receive messages from the destination.
    - **write**: The `write` attribute is a true/false value that indicates whether the role can send messages to the destination.

5.3.8. org.jboss.mq.server.jmx.DestinationManager

The `org.jboss.mq.server.jmx.DestinationManager` must be the last interceptor in the interceptor stack. The configurable attributes are as follows:

- **PersistenceManager**: The JMX `ObjectName` of the persistence manager service the server should use.
- **StateManager**: The JMX `ObjectName` of the state manager service the server should use.
- **MessageCache**: The JMX `ObjectName` of the message cache service the server should use.

Additional read-only attributes and operations that support monitoring include:

- **ClientCount**: The number of clients connected to the server.
- **Clients**: A `java.util.Map<org.jboss.mq.ConnectionToken, org.jboss.mq.server.ClientConsumer>` instances for the clients connected to the server.
- **MessageCounter**: An array of org.jboss.mq.server.MessageCounter instances that provide statistics for a JMS destination.
- **listMessageCounter()**: This operation generates an HTML table that contains:
    - **Type**: Either `Queue` or `Topic` indicating the destination type.
    - **Name**: The name of the destination.

    - **Subscription**: The subscription ID for a topic.
    - **Durable**: A boolean indicating if the topic subscription is durable.
    - **Count**: The number of message delivered to the destination.
    - **CountDelta**: The change in message count since the previous access of count.
    - **Depth**: The number of messages in the destination.
    - **DepthDelta**: The change in the number of messages in the destination since the previous access of depth.
    - **Last Add**: The date/time string in `DateFormat.SHORT`/`DateFormat.MEDIUM` format of the last time a message was added to the destination.

- **resetMessageCounter()**: This zeros all destination counts and last added times.

Queues and topics can be created and destroyed at runtime through the `DestinationManager` MBean. The `DestinationManager` provides `createQueue` and `createTopic` operations for this. Both methods have a one argument version which takes the destination name and a two argument version which takes the destination and the JNDI name of the destination. Queues and topics can be removed using the `destroyQueue` and `destroyTopic` operations, both of which take a destination name is input.

5.3.9. org.jboss.mq.server.MessageCache

The server determines when to move messages to secondary storage by using the `org.jboss.mq.server.MessageCache` MBean. The configurable attributes are as follows:

- **CacheStore**: The JMX `ObjectName` of the service that will act as the cache store. The cache store is used by the `MessageCache` to move messages to persistent storage. The value you set here typically depends on the type of persistence manager you are using.
- **HighMemoryMark**: The amount of JVM heap memory in megabytes that must be reached before the `MessageCache` starts to move messages to secondary storage.
- **MaxMemoryMark**: The maximum amount of JVM heap memory in megabytes that the `MessageCache` considers to be the max memory mark. As memory usage approaches the max memory mark, the `MessageCache` will move messages to persistent storage so that the number of messages kept in memory approaches zero.
- **MakeSoftReferences**: This controls whether or not the message cache will keep soft references to messages that need to be removed. The default is true.
- **MinimumHard**: The minimum number of the in memory cache. JBoss won't try to go below this number of messages in the cache. The default value is 1.
- **MaximumHard**: The upper bound on the number of hard references to messages in the cache. JBoss will soften messages to reduce the number of hard references to this level. A value of 0 means that there is no size based upper bound. The default is 0.
- **SoftenWaitMillis**: The maximum wait time before checking whether messages need softening. The default is

1000 milliseconds (1 second).

- **SoftenNoMoreOftenThanMillis**: The minimum amount of time between checks to soften messages. A value of 0 means that this check should be skipped. The default is 0 milliseconds.
- **SoftenAtLeastEveryMillis**: The maximum amount of time between checks to soften messages. A value of 0 means that this check should be skipped. The default is 0.

Additional read-only cache attribute that provide statistics include:

- **CacheHits**: The number of times a hard referenced message was accessed
- **CacheMisses**: The number of times a softened message was accessed.
- **HardRefCacheSize**: The number of messages in the cache that are not softened.
- **SoftRefCacheSize**: The number of messages that are currently softened.
- **SoftenedSize**: The total number of messages softened since the last boot.
- **TotalCacheSize**: The total number of messages that are being managed by the cache.

5.3.10. org.jboss.mq.pm.jdbc2.PersistenceManager

The `org.jboss.mq.pm.jdbc.PersistenceManager` should be used as the persistence manager assigned to the `DestinationManager` if you wish to store messages in a database. This PM has been tested against the HypersonSQL, MS SQL, Oracle, MySQL and Postgres databases. The configurable attributes are as follows:

- **MessageCache**: The JMX `ObjectName` of the `MessageCache` that has been assigned to the `DestinationManager`..
- **ConnectionManager**: The JMX `ObjectName` of the JCA data source that will be used to obtain JDBC connections.
- **ConnectionRetryAttempts**: An integer count used to allow the PM to retry attempts at getting a connection to the JDBC store. There is a 1500 millisecond delay between each connection failed connection attempt and the next attempt. This must be greater than or equal to 1 and defaults to 5.
- **SqlProperties**: A property list is used to define the SQL Queries and other JDBC2 Persistence Manager options. You will need to adjust these properties if you which to run against another database other than Hypersonic. Example 5.11 shows default setting for this attribute for the Hypersonic database.

Example 5.11. Default JDBC2 PeristenceManager SqlProperties

```
<attribute name="SqlProperties">
      CREATE_TABLES_ON_STARTUP = TRUE
      CREATE_USER_TABLE = CREATE TABLE JMS_USERS \
           (USERID VARCHAR(32) NOT NULL, PASSWD VARCHAR(32) NOT NULL, \
           CLIENTID VARCHAR(128), PRIMARY KEY(USERID))
      CREATE_ROLE_TABLE = CREATE TABLE JMS_ROLES \
           (ROLEID VARCHAR(32) NOT NULL, USERID VARCHAR(32) NOT NULL, \
                    PRIMARY KEY(USERID, ROLEID))
      CREATE_SUBSCRIPTION_TABLE = CREATE TABLE JMS_SUBSCRIPTIONS \
           (CLIENTID VARCHAR(128) NOT NULL, \
           SUBNAME VARCHAR(128) NOT NULL, TOPIC VARCHAR(255) NOT NULL, \
           SELECTOR VARCHAR(255), PRIMARY KEY(CLIENTID, SUBNAME))
      GET_SUBSCRIPTION = SELECT TOPIC, SELECTOR FROM JMS_SUBSCRIPTIONS \
           WHERE CLIENTID=? AND SUBNAME=?
      LOCK_SUBSCRIPTION = SELECT TOPIC, SELECTOR FROM JMS_SUBSCRIPTIONS \
           WHERE CLIENTID=? AND SUBNAME=?
      GET_SUBSCRIPTIONS_FOR_TOPIC =
           SELECT CLIENTID, SUBNAME, SELECTOR FROM JMS_SUBSCRIPTIONS WHERE TOPIC=?
      INSERT_SUBSCRIPTION = \
           INSERT INTO JMS_SUBSCRIPTIONS (CLIENTID, SUBNAME, TOPIC, SELECTOR) VALUES(?,?,?,?)
      UPDATE_SUBSCRIPTION = \
           UPDATE JMS_SUBSCRIPTIONS SET TOPIC=?, SELECTOR=? WHERE CLIENTID=? AND SUBNAME=?
      REMOVE_SUBSCRIPTION = DELETE FROM JMS_SUBSCRIPTIONS WHERE CLIENTID=? AND SUBNAME=?
      GET_USER_BY_CLIENTID = SELECT USERID, PASSWD, CLIENTID FROM JMS_USERS WHERE CLIENTID=?
      GET_USER = SELECT PASSWD, CLIENTID FROM JMS_USERS WHERE USERID=?
      POPULATE.TABLES.01 = INSERT INTO JMS_USERS (USERID, PASSWD) \
                    VALUES ('guest', 'guest')
      POPULATE.TABLES.02 = INSERT INTO JMS_USERS (USERID, PASSWD) \
                    VALUES ('j2ee', 'j2ee')
      POPULATE.TABLES.03 = INSERT INTO JMS_USERS (USERID, PASSWD, CLIENTID) \
                    VALUES ('john', 'needle', 'DurableSubscriberExample')
      POPULATE.TABLES.04 = INSERT INTO JMS_USERS (USERID, PASSWD) \
                    VALUES ('nobody', 'nobody')
      POPULATE.TABLES.05 = INSERT INTO JMS_USERS (USERID, PASSWD) \
                    VALUES ('dynsub', 'dynsub')
      POPULATE.TABLES.06 = INSERT INTO JMS_ROLES (ROLEID, USERID) \
                    VALUES ('guest','guest')
      POPULATE.TABLES.07 = INSERT INTO JMS_ROLES (ROLEID, USERID) \
                    VALUES ('j2ee','guest')
      POPULATE.TABLES.08 = INSERT INTO JMS_ROLES (ROLEID, USERID) \
                    VALUES ('john','guest')
      POPULATE.TABLES.09 = INSERT INTO JMS_ROLES (ROLEID, USERID) \
                    VALUES ('subscriber','john')
      POPULATE.TABLES.10 = INSERT INTO JMS_ROLES (ROLEID, USERID) \
                    VALUES ('publisher','john')
      POPULATE.TABLES.11 = INSERT INTO JMS_ROLES (ROLEID, USERID) \
                    VALUES ('publisher','dynsub')
      POPULATE.TABLES.12 = INSERT INTO JMS_ROLES (ROLEID, USERID) \
                    VALUES ('durpublisher','john')
      POPULATE.TABLES.13 = INSERT INTO JMS_ROLES (ROLEID, USERID) \
                    VALUES ('durpublisher','dynsub')
      POPULATE.TABLES.14 = INSERT INTO JMS_ROLES (ROLEID, USERID) \
                    VALUES ('noacc','nobody')
</attribute>
```

Example 5.12 shows an alternate setting for Oracle.

Example 5.12. A sample JDBC2 PeristenceManager SqlProperties for Oracle

```
<attribute name="SqlProperties">
      BLOB_TYPE=BINARYSTREAM_BLOB
      INSERT_TX = INSERT INTO JMS_TRANSACTIONS (TXID) values(?)
      INSERT_MESSAGE = \
          INSERT INTO JMS_MESSAGES (MESSAGEID, DESTINATION, MESSAGEBLOB, TXID, TXOP) \
          VALUES(?,?,?,?,?)
      SELECT_ALL_UNCOMMITED_TXS = SELECT TXID FROM JMS_TRANSACTIONS
      SELECT_MAX_TX = SELECT MAX(TXID) FROM JMS_MESSAGES
      SELECT_MESSAGES_IN_DEST = \
          SELECT MESSAGEID, MESSAGEBLOB FROM JMS_MESSAGES WHERE DESTINATION=?
      SELECT_MESSAGE = \
          SELECT MESSAGEID, MESSAGEBLOB FROM JMS_MESSAGES WHERE MESSAGEID=? AND DESTINATION=?
      MARK_MESSAGE = \
          UPDATE JMS_MESSAGES SET TXID=?, TXOP=? WHERE MESSAGEID=? AND DESTINATION=?
      UPDATE_MESSAGE = \
          UPDATE JMS_MESSAGES SET MESSAGEBLOB=? WHERE MESSAGEID=? AND DESTINATION=?
      UPDATE_MARKED_MESSAGES = UPDATE JMS_MESSAGES SET TXID=?, TXOP=? WHERE TXOP=?
      UPDATE_MARKED_MESSAGES_WITH_TX = \
          UPDATE JMS_MESSAGES SET TXID=?, TXOP=? WHERE TXOP=? AND TXID=?
      DELETE_MARKED_MESSAGES_WITH_TX = \
          DELETE FROM JMS_MESSAGES MESS WHERE TXOP=:1 AND EXISTS \
          (SELECT TXID FROM JMS_TRANSACTIONS TX WHERE TX.TXID = MESS.TXID)
      DELETE_TX = DELETE FROM JMS_TRANSACTIONS WHERE TXID = ?
      DELETE_MARKED_MESSAGES = DELETE FROM JMS_MESSAGES WHERE TXID=? AND TXOP=?
      DELETE_TEMPORARY_MESSAGES = DELETE FROM JMS_MESSAGES WHERE TXOP='T'
      DELETE_MESSAGE = DELETE FROM JMS_MESSAGES WHERE MESSAGEID=? AND DESTINATION=?
      CREATE_MESSAGE_TABLE = CREATE TABLE JMS_MESSAGES ( MESSAGEID INTEGER NOT NULL, \
         DESTINATION VARCHAR(255) NOT NULL, TXID INTEGER, TXOP CHAR(1), \
         MESSAGEBLOB BLOB, PRIMARY KEY (MESSAGEID, DESTINATION) )
      CREATE_IDX_MESSAGE_TXOP_TXID = \
         CREATE INDEX JMS_MESSAGES_TXOP_TXID ON JMS_MESSAGES (TXOP, TXID)
      CREATE_IDX_MESSAGE_DESTINATION = \
         CREATE INDEX JMS_MESSAGES_DESTINATION ON JMS_MESSAGES (DESTINATION)
      CREATE_TX_TABLE = CREATE TABLE JMS_TRANSACTIONS ( TXID INTEGER, PRIMARY KEY (TXID) )
      CREATE_TABLES_ON_STARTUP = TRUE
</attribute>
```

Additional examples can be found in the `docs/examples/jms` directory of the distribution.

5.3.11. Destination MBeans

This section describes the destination MBeans used in the `jbossmq-destinations-service.xml` and `jbossmq-service.xml` descriptors.

5.3.11.1. org.jboss.mq.server.jmx.Queue

The `Queue` is used to define a queue destination in JBoss. The following shows the configuration of one of the default JBoss queues.

```
<mbean code="org.jboss.mq.server.jmx.Queue"
       name="jboss.mq.destination:service=Queue,name=testQueue">
    <depends optional-attribute-name="DestinationManager">
        jboss.mq:service=DestinationManager
    </depends>
    <depends optional-attribute-name="SecurityManager">
        jboss.mq:service=SecurityManager
    </depends>
    <attribute name="MessageCounterHistoryDayLimit">-1</attribute>
    <attribute name="SecurityConf">
        <security>
            <role name="guest"     read="true"  write="true"/>
            <role name="publisher" read="true"  write="true" create="false"/>
            <role name="noacc"     read="false" write="false" create="false"/>
        </security>
    </attribute>
</mbean>
```

The `name` attribute of the JMX object name of this MBean is used to determine the destination name. For example. In the case of the queue we just looked at, the name of the queue is `testQueue`. The configurable attributes are as follows:

- **DestinationManager**: The JMX ObjectName of the destination manager service for the server. This attribute should be set via a `<depends optional-attribute-name="DestinationManager">` XML tag.
- **SecurityManager**: The JMX `ObjectName` of the security manager service that is being used to validate client requests.
- **SecurityConf**: This element specifies a XML fragment which describes the access control list to be used by the `SecurityManager` to authorize client operations against the destination. The content model is the same as for the `SecurityManager` `SecurityConf` attribute.
- **JNDIName**: The location in JNDI to which the queue object will be bound. If this is not set it will be bound under the `queue` context using the name of the queue. For the `testQueue` shown above, the JNDI name would be `queue/testQueue`.
- **MaxDepth**: The `MaxDepth` is an upper limit to the backlog of messages that can exist for a destination. If exceeded, attempts to add new messages will result in a `org.jboss.mq.DestinationFullException`. The `MaxDepth` can still be exceeded in a number of situations, e.g. when a message is placed back into the queue. Also transactions performing read committed processing, look at the current size of queue, ignoring any messages that may be added as a result of the current transaction or other transactions. This is because we don't want the transaction to fail during the commit phase when the message is physically added to the queue.
- **MessageCounterHistoryDayLimit**: Sets the destination message counter history day limit with a value less than 0 indicating unlimited history, a 0 value disabling history and a value greater than 0 giving the history days count.

Additional read-only attributes that provide statistics information include:

- **MessageCounter**: An array of `org.jboss.mq.server.MessageCounter` instances that provide statistics for this destination.
- **QueueDepth**: The current backlog of waiting messages.
- **ReceiversCount**: The number of receivers currently associated with the queue.
- **ScheduledMessageCount**: The number of messages waiting in the queue for their scheduled delivery time to arrive.

The following are some of the operations available on queues.

- **listMessageCounter()**: This operation generates an HTML table that contains the same data we as the `listMessageCounter` operation on the `DestinationManager`, but only for this one queue.
- **resetMessageCounter()**: This zeros all destination counts and last added times.
- **listMessageCounterHistory()**: This operation display an HTML table showing the hourly message counts per hour for each day in the history.

- **resetMessageCounterHistory()**: This operation resets the day history message counts.
- **removeAllMessages()**: This method removes all the messages on the queue.

5.3.11.2. org.jboss.mq.server.jmx.Topic

The `org.jboss.mq.server.jmx.Topic` is used to define a topic destination in JBoss. The following shows the configuration of one of the default JBoss topics.

```
<mbean code="org.jboss.mq.server.jmx.Topic"
       name="jboss.mq.destination:service=Topic,name=testTopic">
    <depends optional-attribute-name="DestinationManager">
        jboss.mq:service=DestinationManager
    </depends>
    <depends optional-attribute-name="SecurityManager">
        jboss.mq:service=SecurityManager
    </depends>
    <attribute name="SecurityConf">
        <security>
            <role name="guest"        read="true" write="true" />
            <role name="publisher"    read="true" write="true" create="false" />
            <role name="durpublisher" read="true" write="true" create="true" />
        </security>
    </attribute>
</mbean>
```

The `name` attribute of the JMX object name of this MBean is used to determine the destination name. For example, in the case of the topic we just looked at, the name of the topic is `testTopic`. The configurable attributes are as follows:

- **DestinationManager**: The JMX object name of the destination manager configured for the server.
- **SecurityManager**: The JMX object name of the security manager that is being used to validate client requests.
- **SecurityConf**: This element specifies a XML fragment which describes the access control list to be used by the `SecurityManager` to authorize client operations against the destination. The content model is the same as that for the `SecurityManager` `SecurityConf` attribute.
- **JNDIName**: The location in JNDI to which the topic object will be bound. If this is not set it will be bound under the `topic` context using the name of the queue. For the `testTopic` shown above, the JNDI name would be `topic/testTopic`.
- **MaxDepth**: The `MaxDepth` is an upper limit to the backlog of messages that can exist for a destination, and if exceeded, attempts to add new messages will result in a `org.jboss.mq.DestinationFullException`. The `MaxDepth` can still be exceeded in a number of situations, e.g. when a message is knacked back into the queue. Also transactions performing read committed processing, look at the current size of queue, ignoring any messages that may be added as a result of the current transaction or other transactions. This is because we don't want the transaction to fail during the commit phase when the message is physically added to the topic.
- **MessageCounterHistoryDayLimit**: Sets the destination message counter history day limit with a value < 0 indicating unlimited history, a 0 value disabling history, and a value > 0 giving the history days count.

Additional read-only attributes that provide statistics information include:

- **AllMessageCount**: The message count across all queue types associated with the topic.
- **AllSubscriptionsCount**: The count of durable and non-durable subscriptions.
- **DurableMessageCount**: The count of messages in durable subscription queues.
- d **DurableSubscriptionsCount**: The count of durable subscribers.
- **MessageCounter**: An array of `org.jboss.mq.server.MessageCounter` instances that provide statistics for this destination.
- **NonDurableMessageCount**: The count on messages in non-durable subscription queues.
- **NonDurableSubscriptionsCount**: The count of non-durable subscribers.

The following are some of the operations available on topics.

- **listMessageCounter()**: This operation generates an HTML table that contains the same data we as the `listMessageCounter` operation on the `DestinationManager`, but only for this one topic. Message counters are only maintained for each active subscription, durable or otherwise.
- **resetMessageCounter()**: This zeros all destination counts and last added times.
- **listMessageCounterHistory()**: This operation display an HTML table showing the hourly message counts per hour for each day of history.
- **resetMessageCounterHistory()**: This operation resets the day history message counts.

5.4. Specifying the MDB JMS Provider

Up to this point we have looked at the standard JMS client/server architecture. The JMS specification defines an advanced set of interfaces that allow for concurrent processing of a destination's messages, and collectively this functionality is referred to as application server facilities (ASF). Two of the interfaces that support concurrent message processing, `javax.jms.ServerSessionPool` and `javax.jms.ServerSession`, must be provided by the application server in which the processing will occur. Thus, the set of components that make up the JBossMQ ASF involves both JBossMQ components as well as JBoss server components. The JBoss server MDB container utilizes the JMS service's ASF to concurrently process messages sent to MDBs.

The responsibilities of the ASF domains are well defined by the JMS specification and so we won't go into a discussion of how the ASF components are implemented. Rather, we want to discuss how ASF components used by the JBoss MDB layer are integrated using MBeans that allow either the application server interfaces, or the JMS provider interfaces to be replaced with alternate implementations.

Let's start with the `org.jboss.jms.jndi.JMSProviderLoader` MBean. This MBean is responsible for loading an instance of the `org.jboss.jms.jndi.JMSProviderAdaptor` interface into the JBoss server and binding it into JNDI. The `JMSProviderAdaptor` interface is an abstraction that defines how to get the root JNDI context for the JMS provider, and an interface for getting and setting the JNDI names for the `Context.PROVIDER_URL` for the root `InitialContext`, and the `QueueConnectionFactory` and `TopicConnectionFactory` locations in the root context. This is all that is really necessary to bootstrap use of a JMS provider. By abstracting this information into an interface, alternate JMS ASF provider implementations can be used with the JBoss MDB container. The `org.jboss.jms.jndi.JBossMQProvider` is the default implementation of `JMSProviderAdaptor` interface, and provides the adaptor for the JBossMQ JMS provider. To replace the JBossMQ provider with an alternate JMS ASF implementation, simply create an implementation of the `JMSProviderAdaptor` interface and configure the JMSProviderLoader with the class name of the implementation. We'll see an example of this in the configuration section.

In addition to being able to replace the JMS provider used for MDBs, you can also replace the javax.jms.ServerSessionPool interface implementation. This is possible by configuring the class name of the `org.jboss.jms.asf.ServerSessionPoolFactory` implementation using the `org.jboss.jms.asf.ServerSessionPoolLoader` MBean `PoolFactoryClass` attribute. The default `ServerSessionPoolFactory` factory implementation is the JBoss `org.jboss.jms.asf.StdServerSessionPoolFactory` class.

5.4.1. org.jboss.jms.jndi.JMSProviderLoader MBean

The `JMSProviderLoader` MBean service creates a JMS provider adaptor and binds it into JNDI. A JMS provider adaptor is a class that implements the `org.jboss.jms.jndi.JMSProviderAdapter` interface. It is used by the message driven bean container to access a JMS service provider in a provider independent manner. The configurable attributes of the `JMSProviderLoader` service are:

- **ProviderName**: A unique name for the JMS provider. This will be used to bind the `JMSProviderAdapter` instance into JNDI under `java:/<ProviderName>` unless overridden by the `AdapterJNDIName` attribute.
- **ProviderAdapterClass**: The fully qualified class name of the org.jboss.jms.jndi.JMSProviderAdapter interface to create an instance of.
- **FactoryRef**: The JNDI name under which the provider `javax.jms.ConnectionFactory` will be bound.
- **QueueFactoryRef**: The JNDI name under which the provider `javax.jms.QueueConnectionFactory` will be bound.
- **TopicFactoryRef**: The JNDI name under which the `javax.jms.TopicConnectionFactory` will be bound.
- **Properties**: The JNDI properties of the initial context used to look up the factories.

Example 5.13. A JMSProviderLoader for accessing a remote JBossMQ server

```
<mbean code="org.jboss.jms.jndi.JMSProviderLoader"
       name="jboss.mq:service=JMSProviderLoader,name=RemoteJBossMQProvider">
    <attribute name="ProviderName">RemoteJMSProvider</attribute>
    <attribute name="ProviderUrl"></attribute>
    <attribute name="ProviderAdapterClass">
        org.jboss.jms.jndi.JBossMQProvider
    </attribute>
    <attribute name="FactoryRef">XAConnectionFactory</attribute>
    <attribute name="QueueFactoryRef">XAConnectionFactory</attribute>
    <attribute name="TopicFactoryRef">XAConnectionFactory</attribute>
    <attribute name="Properties">
        java.naming.factory.initial=org.jnp.interfaces.NamingContextFactory
        java.naming.factory.url.pkgs=org.jboss.naming:org.jnp.interfaces
        java.naming.provider.url=jnp://remotehost:1099
    </attribute>
</mbean>
```

The RemoteJMSProvider can be referenced on the MDB invoker config as shown in the `jboss.xml` fragment given in Example 5.14.

Example 5.14. A jboss.xml fragment for specifying the MDB JMS provider adaptor

```
<proxy-factory-config>
    <JMSProviderAdapterJNDI>RemoteJMSProvider</JMSProviderAdapterJNDI>
    <ServerSessionPoolFactoryJNDI>StdJMSPool</ServerSessionPoolFactoryJNDI>
    <MaximumSize>15</MaximumSize>
    <MaxMessages>1</MaxMessages>
    <MDBConfig>
        <ReconnectIntervalSec>10</ReconnectIntervalSec>
        <DLQConfig>
            <DestinationQueue>queue/DLQ</DestinationQueue>
            <MaxTimesRedelivered>10</MaxTimesRedelivered>
            <TimeToLive>0</TimeToLive>
        </DLQConfig>
    </MDBConfig>
</proxy-factory-config>
```

Incidentally, because one can specify multiple `invoker-proxy-binding` elements, this allows an MDB to listen to the same queue/topic on multiple servers by configuring multiple bindings with different `JMSProviderAdapterJNDI` settings.

Alternatively, one can integrate the JMS provider using JCA configuration like that shown in Example 5.15.

Example 5.15. A jms-ds.xml descriptor for integrating a JMS provider adaptor via JCA

```
<tx-connection-factory>
    <jndi-name>RemoteJmsXA</jndi-name>
    <xa-transaction/>
    <adapter-display-name>JMS Adapter</adapter-display-name>
    <config-property name="JMSProviderAdapterJNDI"
                     type="java.lang.String">RemoteJMSProvider</config-property>
    <config-property name="SessionDefaultType"
                     type="java.lang.String">javax.jms.Topic</config-property>

    <security-domain-and-application>JmsXARealm</security-domain-and-application>
</tx-connection-factory>
```

5.4.2. org.jboss.jms.asf.ServerSessionPoolLoader MBean

The `ServerSessionPoolLoader` MBean service manages a factory for `javax.jms.ServerSessionPool` objects used by the message driven bean container. The configurable attributes of the `ServerSessionPoolLoader` service are:

- **PoolName**: A unique name for the session pool. This will be used to bind the `ServerSessionPoolFactory` instance into JNDI under `java:/PoolName`.
- **PoolFactoryClass**: The fully qualified class name of the `org.jboss.jms.asf.ServerSessionPoolFactory` interface to create an instance of.

- **XidFactory**: The JMX `ObjectName` of the service to use for generating `javax.transaction.xa.Xid` values for local transactions when two phase commit is not required. The `XidFactory` MBean must provide an `Instance` operation which returns a `org.jboss.tm.XidFactoryMBean` instance.

5.4.3. Integrating non-JBoss JMS Providers

We have mentioned that one can replace the JBossMQ JMS implementation with a foreign implementation. Here we summarize the various approaches one can take to do the replacement:

- Replace the JMSProviderLoader JBossMQProvider class with one that instantiates the correct JNDI context for communicating with the foreign JMS providers managed objects.
- Use the `ExternalContext` MBean to federate the foreign JMS providers managed objects into the JBoss JNDI tree.
- Use MBeans to instantiate the foreign JMS objects into the JBoss JNDI tree. An example of this approach can be found for Websphere MQ at http://wiki.jboss.org/wiki/Wiki.jsp?page=IntegrationWithWebSphereMQSeries.

6

Connectors on JBoss

The JCA Configuration and Architecture

This chapter discusses the JBoss server implementation of the J2EE Connector Architecture (JCA). JCA is a resource manager integration API whose goal is to standardize access to non-relational resources in the same way the JDBC API standardized access to relational data. The purpose of this chapter is to introduce the utility of the JCA APIs and then describe the architecture of JCA in JBoss

6.1. JCA Overview

J2EE 1.4 contains a connector architecture (JCA) specification that allows for the integration of transacted and secure resource adaptors into a J2EE application server environment. The JCA specification describes the notion of such resource managers as Enterprise Information Systems (EIS). Examples of EIS systems include enterprise resource planning packages, mainframe transaction processing, non-Java legacy applications, etc.

The reason for focusing on EIS is primarily because the notions of transactions, security, and scalability are requirements in enterprise software systems. However, the JCA is applicable to any resource that needs to integrate into JBoss in a secure, scalable and transacted manner. In this introduction we will focus on resource adapters as a generic notion rather than something specific to the EIS environment.

The connector architecture defines a standard SPI (Service Provider Interface) for integrating the transaction, security and connection management facilities of an application server with those of a resource manager. The SPI defines the system level contract between the resource adaptor and the application server.

The connector architecture also defines a Common Client Interface (CCI) for accessing resources. The CCI is targeted at EIS development tools and other sophisticated users of integrated resources. The CCI provides a way to minimize the EIS specific code required by such tools. Typically J2EE developers will access a resource using such a tool, or a resource specific interface rather than using CCI directly. The reason is that the CCI is not a type specific API. To be used effectively it must be used in conjunction with metadata that describes how to map from the generic CCI API to the resource manager specific data types used internally by the resource manager.

The purpose of the connector architecture is to enable a resource vendor to provide a standard adaptor for its product. A resource adaptor is a system-level software driver that is used by a Java application to connect to resource. The resource adaptor plugs into an application server and provides connectivity between the resource manager, the application server, and the enterprise application. A resource vendor need only implement a JCA compliant adaptor once to allow use of the resource manager in any JCA capable application server.

An application server vendor extends its architecture once to support the connector architecture and is then assured of seamless connectivity to multiple resource managers. Likewise, a resource manager vendor provides one standard resource adaptor and it has the capability to plug in to any application server that supports the connector architecture.

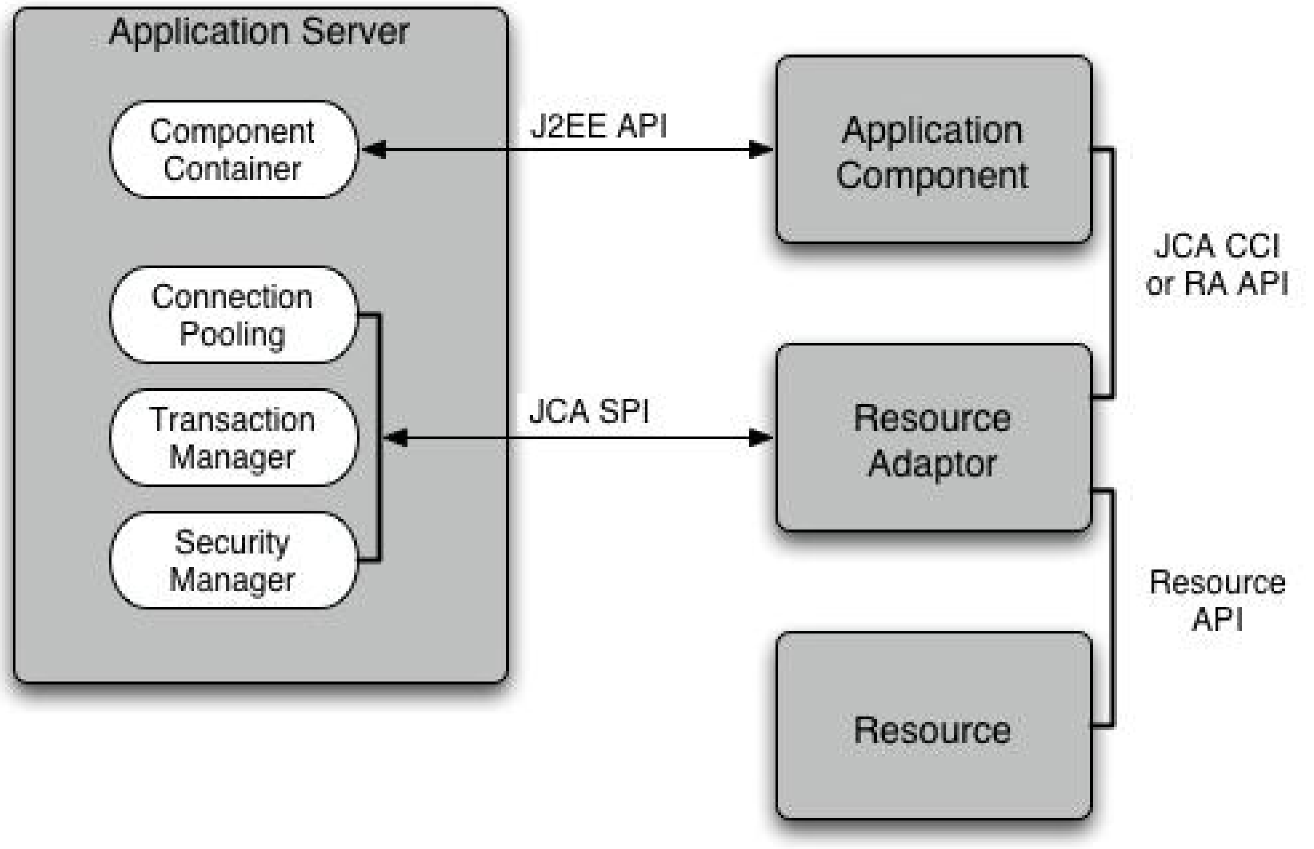


Figure 6.1. The relationship between a J2EE application server and a JCA resource adaptor

Figure 6.1 illustrates that the application server is extended to provide support for the JCA SPI to allow a resource adaptor to integrate with the server connection pooling, transaction management and security management facilities. This integration API defines a three-part system contract.

- **Connection management**: a contract that allows the application server to pool resource connections. The purpose of the pool management is to allow for scalability. Resource connections are typically expense objects to create and pooling them allows for more effective reuse and management.
- **Transaction Management**: a contract that allows the application server transaction manager to manage transactions that engage resource managers.
- **Security Management**: a contract that enables secured access to resource managers.

The resource adaptor implements the resource manager side of the system contract. This entails using the application server connection pooling, providing transaction resource information and using the security integration information. The resource adaptor also exposes the resource manager to the application server components. This can be done using the CCI and/or a resource adaptor specific API.

The application component integrates into the application server using a standard J2EE container to component contract. For an EJB component this contract is defined by the EJB specification. The application component interacts with the resource adaptor in the same way as it would with any other standard resource factory, for example, a `javax.sql.DataSource` JDBC resource factory. The only difference with a JCA resource adaptor is that the client has the option of using the resource adaptor independent CCI API if the resource adaptor supports this.

Figure 6.2 (from the JCA 1.5 specification) illustrates the relationship between the JCA architecture participants in terms of how they relate to the JCA SPI, CCI and JTA packages.

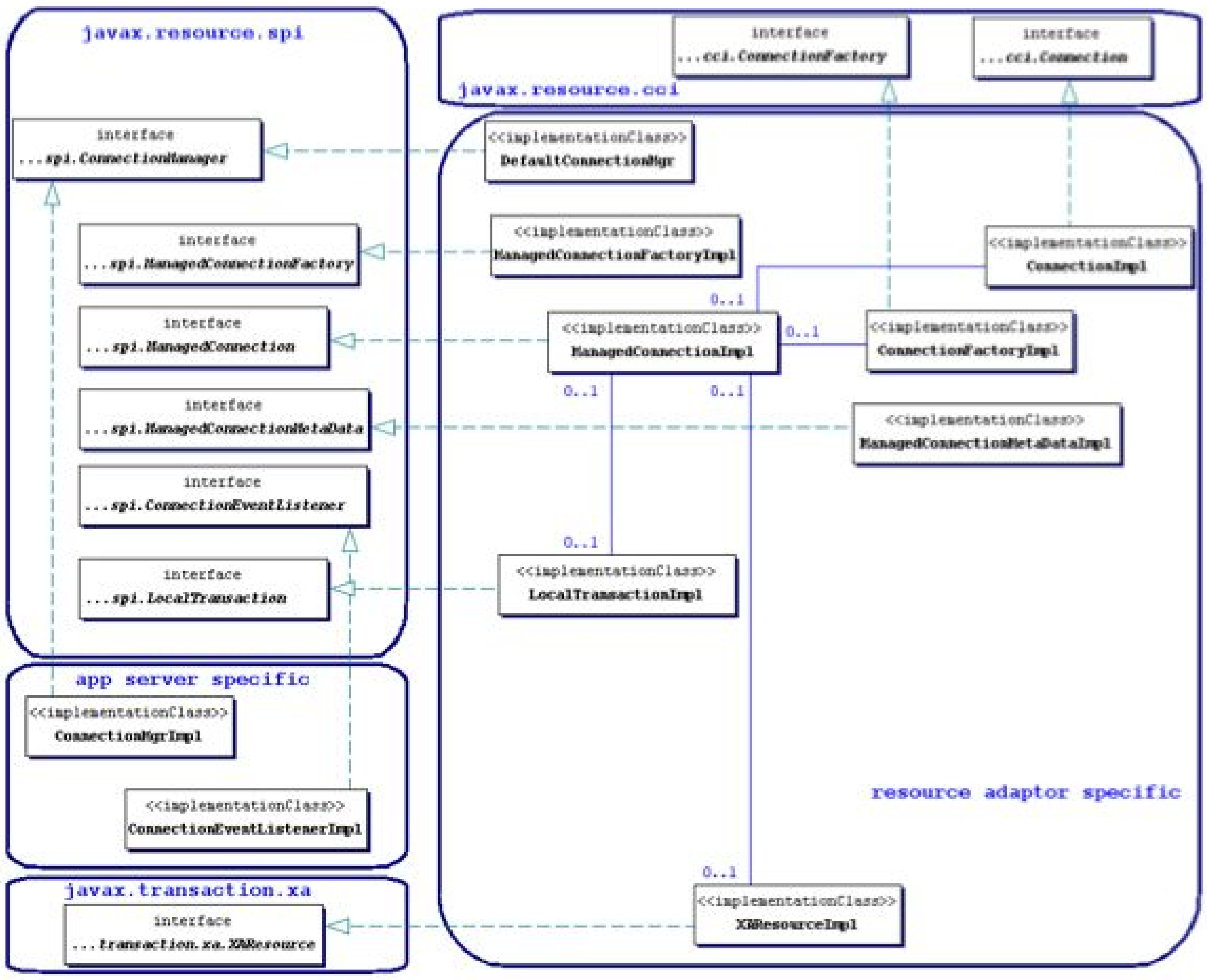

javax.resource.spi
interface ...spi.ConnectionManager
interface ...spi.ManagedConnectionFactory
interface ...spi.ManagedConnection
interface ...spi.ManagedConnectionMetaData
interface ...spi.ConnectionEventListener
interface ...spi.LocalTransaction
javax.resource.cci
interface ...cci.ConnectionFactory
interface ...cci.Connection
<<implementationClass>> DefaultConnectionMgr
<<implementationClass>> ManagedConnectionFactoryImpl
<<implementationClass>> ConnectionImpl
<<implementationClass>> ManagedConnectionImpl
<<implementationClass>> ConnectionFactoryImpl
<<implementationClass>> ManagedConnectionMetaDataImpl
<<implementationClass>> LocalTransactionImpl
0..1
app server specific
<<implementationClass>> ConnectionMgrImpl
<<implementationClass>> ConnectionEventListenerImpl
javax.transaction.xa
interface ...transaction.xa.XAResource
<<implementationClass>> XAResourceImpl
resource adaptor specific

Figure 6.2. The JCA 1.0 specification class diagram for the connection management architecture.

The JBossCX architecture provides the implementation of the application server specific classes. Figure 6.2 shows that this comes down to the implementation of the `javax.resource.spi.ConnectionManager` and `javax.resource.spi.ConnectionEventListener` interfaces. The key aspects of this implementation are discussed in the following section on the JBossCX architecture.

6.2. An Overview of the JBossCX Architecture

The JBossCX framework provides the application server architecture extension required for the use of JCA resource adaptors. This is primarily a connection pooling and management extension along with a number of MBeans for loading resource adaptors into the JBoss server.

There are three coupled MBeans that make up a RAR deployment. These are the `org.jboss.resource.deployment.RARDeployment`, `org.jboss.resource.connectionmanager.RARDeployment`, and `org.jboss.resource.connectionmanager.BaseConnectionManager2`. The `org.jboss.resource.deployment.RARDeployment` is simply an encapsulation of the metadata of a RAR `META-INF/ra.xml` descriptor. It exposes this information as a DynamicMBean simply to make it available to the `org.jboss.resource.connectionmanager.RARDeployment` MBean.

The RARDeployer service handles the deployment of archives files containing resource adaptors (RARs). It creathes the `org.jboss.resource.deployment.RARDeployment` MBeans when a RAR file is deployed. Deploying the RAR file is the first step in making the resource adaptor available to application components. For each deployed RAR, one or more connection factories must be configured and bound into JNDI. This task performed using a JBoss service descriptor that sets up a `org.jboss.resource.connectionmanager.BaseConnectionManager2` MBean implementation with a `org.jboss.resource.connectionmgr.RARDeployment` dependent.

6.2.1. BaseConnectionManager2 MBean

The `org.jboss.resource.connectionmanager.BaseConnectionManager2` MBean is a base class for the various types of connection managers required by the JCA spec. Subclasses include `NoTxConnectionManager`, `LocalTxConnectionManager` and `XATxConnectionManager`. These correspond to resource adaptors that support no transactions, local transaction and XA transaction respectively. You choose which subclass to use based on the type of transaction semantics you want, provided the JCA resource adaptor supports the corresponding transaction capability.

The common attributes supported by the BaseConnectionManager2 MBean are:

- **ManagedConnectionPool**: This specifies the ObjectName of the MBean representing the pool for this connection manager. The MBean must have an `ManagedConnectionPool` attribute that is an implementation of the `org.jboss.resource.connectionmanager.ManagedConnectionPool` interface. Normally it will be an embedded MBean in a depends tag rather than an `ObjectName` reference to an existing MBean. The default MBean for use is the `org.jboss.resource.connectionmanager.JBossManagedConnectionPool`. Its configurable attributes are discussed below.

- **CachedConnectionManager**: This specifies the `ObjectName` of the `CachedConnectionManager` MBean implementation used by the connection manager. Normally this is specified using a depends tag with the `ObjectName` of the unique `CachedConnectionManager` for the server. The name `jboss.jca:service=CachedConnectionManager` is the standard setting to use.

- **SecurityDomainJndiName**: This specifies the JNDI name of the security domain to use for authentication and authorization of resource connections. This is typically of the form `java:/jaas/<domain>` where the `<domain>` value is the name of an entry in the `conf/login-config.xml` JAAS login module configuration file. This defines which JAAS login modules execute to perform authentication. Chapter 7 has more information on the security settings.

- **JaasSecurityManagerService**: This is the `ObjectName` of the security manager service. This should be set to the security manager MBean name as defined in the `conf/jboss-service.xml` descriptor, and currently this is `jboss.security:service=JaasSecurityManager`. This attribute will likely be removed in the future.

6.2.2. RARDeployment MBean

The `org.jboss.resource.connectionmanager.RARDeployment` MBean manages configuration and instantiation

ManagedConnectionFactory instance. It does this using the resource adaptor metadata settings from the RAR META-INF/ra.xml descriptor along with the RARDeployment attributes. The configurable attributes are:

- **OldRarDeployment**: This is the ObjectName of the org.jboss.resource.RarDeployment MBean that contains the resource adaptor metadata. The form of this name is jboss.jca:service=RARDeployment,name=<ra-display-name> where the <ra-display-name> is the ra.xml descriptor display-name attribute value. The RARDeployer creates this when it deploys a RAR file. This attribute will likely be removed in the future.

- **ManagedConnectionFactoryProperties**: This is a collection of (name, type, value) triples that define attributes of the ManagedConnectionFactory instance. Therefore, the names of the attributes depend on the resource adaptor ManagedConnectionFactory instance. The following example shows the structure of the content of this attribute.

```
<properties>
    <config-property>
        <config-property-name>Attr0Name</config-property-name>
        <config-property-type>Attr0Type</config-property-type>
        <config-property-value>Attr0Value</config-property-value>
    </config-property>
    <config-property>
        <config-property-name>Attr1Name</config-property-name>
        <config-property-type>Attr2Type</config-property-type>
        <config-property-value>Attr2Value</config-property-value>
    </config-property>
    ...
</properties>
```

  AttrXName is the Xth attribute name, AttrXType is the fully qualified Java type of the attribute, and AttrXValue is the string representation of the value. The conversion from string to AttrXType is done using the java.beans.PropertyEditor class for the AttrXType.

- **JndiName**: This is the JNDI name under which the resource adaptor will be made available. Clients of the resource adaptor use this name to obtain either the javax.resource.cci.ConnectionFactory or resource adaptor specific connection factory. The full JNDI name will be java:/<JndiName> meaning that the JndiName attribute value will be prefixed with java:/. This prevents use of the connection factory outside of the JBoss server VM. In the future this restriction may be configurable.

6.2.3. JBossManagedConnectionPool MBean

The org.jboss.resource.connectionmanager.JBossManagedConnectionPool MBean is a connection pooling MBean. It is typically used as the embedded MBean value of the BaseConnectionManager2 ManagedConnectionPool attribute. When you setup a connection manager MBean you typically embed the pool configuration in the connection manager descriptor. The configurable attributes of the JBossManagedConnectionPool are:

- **ManagedConnectionFactoryName**: This specifies the ObjectName of the MBean that creates javax.resource.spi.ManagedConnectionFactory instances. Normally this is configured as an embedded MBean in a depends element rather than a separate MBean reference using the RARDeployment MBean. The MBean must provide an appropriate startManagedConnectionFactory operation.

- **MinSize**: This attribute indicates the minimum number of connections this pool should hold. These are not created until a Subject is known from a request for a connection. MinSize connections will be created for each sub-pool.

- **MaxSize**: This attribute indicates the maximum number of connections for a pool. No more than MaxSize connections will be created in each sub-pool.

- **BlockingTimeoutMillis**: This attribute indicates the maximum time to block while waiting for a connection before throwing an exception. Note that this blocks only while waiting for a permit for a connection, and will never throw an exception if creating a new connection takes an inordinately long time.

- **IdleTiemoutMinutes**: This attribute indicates the maximum time a connection may be idle before being closed. The actual maximum time depends also on the idle remover thread scan time, which is 1/2 the smallest idle timeout of any pool.

- **NoTxSeparatePools**: Setting this to true doubles the available pools. One pool is for connections used outside a transaction the other inside a transaction. The actual pools are lazily constructed on first use. This is only relevant when setting the pool parameters associated with the `LocalTxConnectionManager` and `XATxConnectionManager`. Its use case is for Oracle (and possibly other vendors) XA implementations that don't like using an XA connection with and without a JTA transaction.

- **Criteria**: This attribute indicates if the JAAS `javax.security.auth.Subject` from security domain associated with the connection, or app supplied parameters (such as from `getConnection(user, pw)`) are used to distinguish connections in the pool. The allowed values are:

  - **ByContainer**: use `Subject`
  - **ByApplication**: use application supplied parameters only
  - **ByContainerAndApplication**: use both
  - **ByNothing**: all connections are equivalent, usually if adapter supports reauthentication

6.2.4. CachedConnectionManager MBean

The `org.jboss.resource.connectionmanager.CachedConnectionManager` MBean manages associations between meta-aware objects (those accessed through interceptor chains) and connection handles, as well as between user transactions and connection handles. Normally there should only be one such MBean, and this is configured in the core `jboss-service.xml` descriptor. It is used by `CachedConnectionInterceptor`, JTA `UserTransaction` implementation and all `BaseConnectionManager2` instances. The configurable attributes of the `CachedConnectionManager` MBean are:

- **SpecCompliant**: Enable this boolean attribute for spec compliant non-shareable connections reconnect processing. This allows a connection to be opened in one call and used in another. Note that specifying this behavior disables connection close processing.

- **Debug**: Enable this boolean property for connection close processing. At the completion of an EJB method invocation, unclosed connections are registered with a transaction synchronization. If the transaction ends without the connection being closed, an error is reported and JBoss closes the connection. This is a development feature that should be turned off in production for optimal performance.

- **TransactionManagerServiceName**: This attribute specifies the JMX `ObjectName` of the JTA transaction manager service. Connection close processing is now synchronized with the transaction manager and this attribute specifies the transaction manager to use.

6.2.5. A Sample Skeleton JCA Resource Adaptor

To conclude our discussion of the JBoss JCA framework we will create and deploy a single non-transacted resource adaptor that simply provides a skeleton implementation that stubs out the required interfaces and logs all method calls. We will not discuss the details of the requirements of a resource adaptor provider as these are discussed in detail in the JCA specification. The purpose of the adaptor is to demonstrate the steps required to create and deploy a RAR in JBoss, and to see how JBoss interacts with the adaptor.

The adaptor we will create could be used as the starting point for a non-transacted file system adaptor. The source to the example adaptor can be found in the `src/main/org/jboss/book/jca/ex1` directory of the book examples. A class diagram that shows the mapping from the required `javax.resource.spi` interfaces to the resource adaptor implementation is given in Figure 6.3.

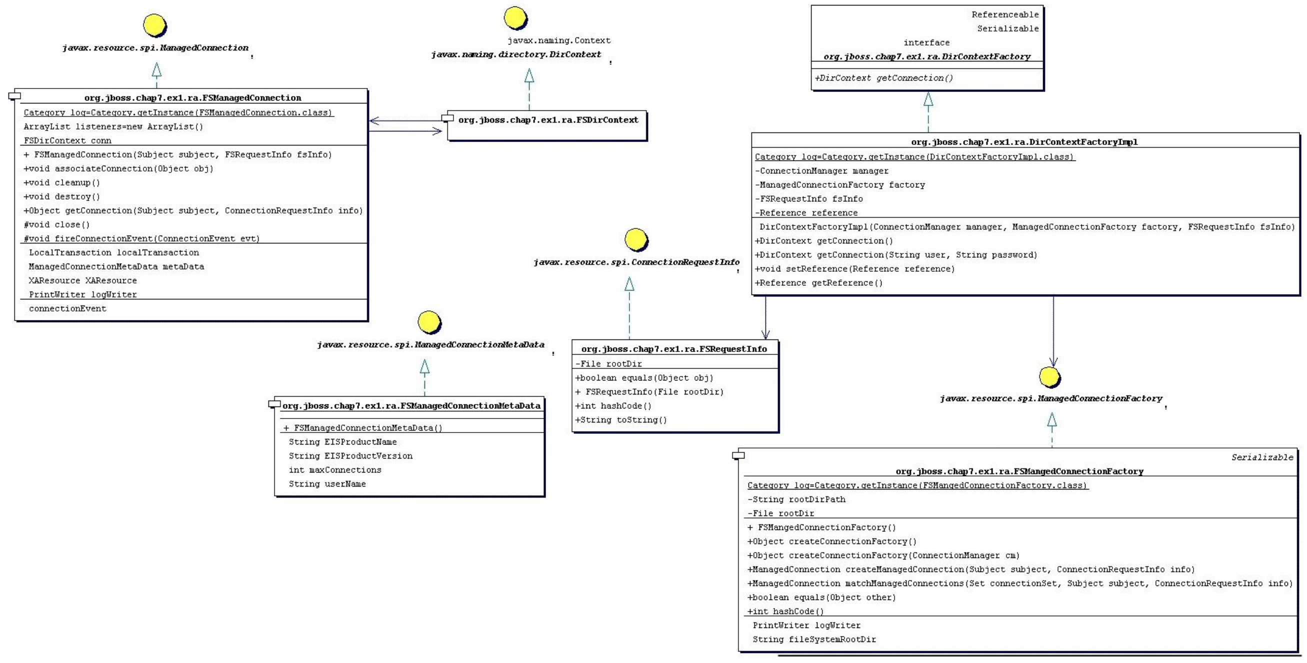

javax.resource.spi.ManagedConnection
org.jboss.chap7.ex1.ra.FSManagedConnection
Category log=Category.getInstance(FSManagedConnection.class)
ArrayList listeners=new ArrayList()
FSDirContext conn
+ FSManagedConnection(Subject subject, FSRequestInfo fsInfo)
+void associateConnection(Object obj)
+void cleanup()
+void destroy()
+Object getConnection(Subject subject, ConnectionRequestInfo info)
#void close()
#void fireConnectionEvent(ConnectionEvent evt)
LocalTransaction localTransaction
ManagedConnectionMetaData metaData
XAResource XAResource
PrintWriter logWriter
connectionEvent
javax.naming.Context
javax.naming.directory.DirContext
org.jboss.chap7.ex1.ra.FSDirContext
Referenceable
Serializable
interface
org.jboss.chap7.ex1.ra.DirContextFactory
+DirContext getConnection()
org.jboss.chap7.ex1.ra.DirContextFactoryImpl
Category log=Category.getInstance(DirContextFactoryImpl.class)
-ConnectionManager manager
-ManagedConnectionFactory factory
-FSRequestInfo fsInfo
-Reference reference
DirContextFactoryImpl(ConnectionManager manager, ManagedConnectionFactory factory, FSRequestInfo fsInfo)
+DirContext getConnection()
+DirContext getConnection(String user, String password)
+void setReference(Reference reference)
+Reference getReference()
javax.resource.spi.ConnectionRequestInfo
javax.resource.spi.ManagedConnectionMetaData
org.jboss.chap7.ex1.ra.FSManagedConnectionMetaData
+ FSManagedConnectionMetaData()
String EISProductName
String EISProductVersion
int maxConnections
String userName
org.jboss.chap7.ex1.ra.FSRequestInfo
-File rootDir
+boolean equals(Object obj)
+ FSRequestInfo(File rootDir)
+int hashCode()
+String toString()
javax.resource.spi.ManagedConnectionFactory
Serializable
org.jboss.chap7.ex1.ra.FSMangedConnectionFactory
Category log=Category.getInstance(FSMangedConnectionFactory.class)
-String rootDirPath
-File rootDir
+ FSMangedConnectionFactory()
+Object createConnectionFactory()
+Object createConnectionFactory(ConnectionManager cm)
+ManagedConnection createManagedConnection(Subject subject, ConnectionRequestInfo info)
+ManagedConnection matchManagedConnections(Set connectionSet, Subject subject, ConnectionRequestInfo info)
+boolean equals(Object other)
+int hashCode()
PrintWriter logWriter
String fileSystemRootDir

Figure 6.3. The file system RAR class diagram

We will build the adaptor, deploy it to the JBoss server and then run an example client against an EJB that uses the resource adaptor to demonstrate the basic steps in a complete context. We'll then take a look at the JBoss server log to see how the JBoss JCA framework interacts with the resource adaptor to help you better understand the components in the JCA system level contract.

To build the example and deploy the RAR to the JBoss server `deploy/lib` directory, execute the following Ant command in the book examples directory.

```
[examples]$ ant -Dchap=jca build-chap
```

The deployed files include a `jca-ex1.sar` and a `notxfs-service.xml` service descriptor. The example resource adaptor deployment descriptor is shown in Example 6.1.

Example 6.1. The nontransactional file system resource adaptor deployment descriptor.

```
<?xml version="1.0" encoding="UTF-8"?>
<connector xmlns="http://java.sun.com/xml/ns/j2ee"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://java.sun.com/xml/ns/j2ee
                        http://java.sun.com/xml/ns/j2ee/connector_1_5.xsd" version="1.5">
    <display-name>File System Adapter</display-name>
    <vendor-name>JBoss</vendor-name>
    <eis-type>FileSystem</eis-type>
    <resourceadapter-version>1.0</resourceadapter-version>
    <license>
        <description>LGPL</description>
        <license-required>false</license-required>
    </license>
    <resourceadapter>
        <resourceadapter-class>
            org.jboss.resource.deployment.DummyResourceAdapter
        </resourceadapter-class>
        <outbound-resourceadapter>
            <connection-definition>
                <managedconnectionfactory-class>
                    org.jboss.book.jca.ex1.ra.FSManagedConnectionFactory
                </managedconnectionfactory-class>
                <config-property>
                    <config-property-name>FileSystemRootDir</config-property-name>
                    <config-property-type>java.lang.String</config-property-type>
                    <config-property-value>/tmp/db/fs_store</config-property-value>
                </config-property>
                <config-property>
                    <config-property-name>UserName</config-property-name>
                    <config-property-type>java.lang.String</config-property-type>
                    <config-property-value/>
                </config-property>
                <config-property>
                    <config-property-name>Password</config-property-name>
                    <config-property-type>java.lang.String</config-property-type>
                    <config-property-value/>
                </config-property>
                <connectionfactory-interface>
                    org.jboss.book.jca.ex1.ra.DirContextFactory
                </connectionfactory-interface>
                <connectionfactory-impl-class>
                    org.jboss.book.jca.ex1.ra.DirContextFactoryImpl
                </connectionfactory-impl-class>
                <connection-interface>
                    javax.naming.directory.DirContext
                </connection-interface>
                <connection-impl-class>
                    org.jboss.book.jca.ex1.ra.FSDirContext
                </connection-impl-class>
            </connection-definition>
            <transaction-support>NoTransaction</transaction-support>
            <authentication-mechanism>
                <authentication-mechanism-type>BasicPassword</authentication-mechanism-type>
                <credential-interface>
                    javax.resource.spi.security.PasswordCredential
                </credential-interface>
            </authentication-mechanism>
            <reauthentication-support>true</reauthentication-support>
        </outbound-resourceadapter>
        <security-permission>
            <description> Read/Write access is required to the contents of the
                FileSystemRootDir </description>
            <security-permission-spec> permission java.io.FilePermission
                "/tmp/db/fs_store/*", "read,write";
            </security-permission-spec>
        </security-permission>
    </resourceadapter>
</connector>
```

The key items in the resource adaptor deployment descriptor are highlighted in bold. These define the classes of the resource adaptor, and the elements are:

- **managedconnectionfactory-class**: The implementation of the `ManagedConnectionFactory` interface, `org.jboss.book.jca.ex1.ra.FSManagedConnectionFactory`
- **connectionfactory-interface**: This is the interface that clients will obtain when they lookup the connection factory instance from JNDI, here a proprietary resource adaptor value, `org.jboss.book.jca.ex1.ra.DirContextFactory`. This value will be needed when we create the JBoss `ds.xml` to use the resource.
- **connectionfactory-impl-class**: This is the class that provides the implementation of the `connectionfactory-interface`, `org.jboss.book.jca.ex1.ra.DirContextFactoryImpl`.
- **connection-interface**: This is the interface for the connections returned by the resource adaptor connection factory, here the JNDI `javax.naming.directory.DirContext` interface.
- **connection-impl-class**: This is he class that provides the `connection-interface` implementation, `org.jboss.book.jca.ex1.ra.FSDirContext`.
- **transaction-support**: The level of transaction support, here defined as `NoTransaction`, meaning the file system resource adaptor does not do transactional work.

The RAR classes and deployment descriptor only define a resource adaptor. To use the resource adaptor it must be integrated into the JBoss application server using a `ds.xml` descriptor file. An example of this for the file system adaptor is shown in Example 6.2.

Example 6.2. The notxfs-ds.xml resource adaptor MBeans service descriptor.

```
<!DOCTYPE connection-factories PUBLIC
          "-//JBoss//DTD JBOSS JCA Config 1.5//EN"
          "http://www.jboss.org/j2ee/dtd/jboss-ds_1_5.dtd">
<!--
       The non-transaction FileSystem resource adaptor service configuration
-->
<connection-factories>
    <no-tx-connection-factory>
        <jndi-name>NoTransFS</jndi-name>
        <rar-name>jca-ex1.rar</rar-name>
        <connection-definition>
             org.jboss.book.jca.ex1.ra.DirContextFactory
        </connection-definition>
        <config-property name="FileSystemRootDir"
                         type="java.lang.String">/tmp/db/fs_store</config-property>
    </no-tx-connection-factory>
</connection-factories>
```

The main attributes are:

- **jndi-name**: This specifies where the connection factory will be bound into JNDI. For this deployment that binding will be `java:/NoTransFS`.
- **rar-name**: This is the name of the RAR file that contains the definition for the resource we want to provide. For nested RAR files, the name would look like `myapplication.ear#my.rar`. In this example, it is simply `jca-ex1.rar`.
- **connection-definition**: This is the connection factory interface class. It should match the `connectionfactory-interface` in the `ra.xml` file. Here our connection factory interface is `org.jboss.book.jca.ex1.ra.DirContextFactory`.
- **config-property**: This can be used to provide non-default settings to the resource adaptor connection factory. Here the `FileSystemRootDir` is being set to `/tmp/db/fs_store`. This overrides the default value in the `ra.xml` file.

To deploy the RAR and connection manager configuration to the JBoss server, run the following:

```
[examples]$ ant -Dchap=jca config
```

The server console will display some logging output indicating that the resource adaptor has been deployed.

Now we want to test access of the resource adaptor by a J2EE component. To do this we have created a trivial stateless session bean that has a single method called `echo`. Inside of the `echo` method the EJB accesses the resource adaptor connection factory, creates a connection, and then immediately closes the connection. The `echo` method code is shown below.

Example 6.3. The stateless session bean echo method code that shows the access of the resource adaptor connection factory.

```
public String echo(String arg)
{
    log.info("echo, arg="+arg);
    try {
        InitialContext ctx = new InitialContext();
        Object         ref = ctx.lookup("java:comp/env/ra/DirContextFactory");
        log.info("echo, ra/DirContextFactory=" + ref);

        DirContextFactory dcf = (DirContextFactory) ref;
        log.info("echo, found dcf=" + dcf);

        DirContext dc = dcf.getConnection();
        log.info("echo, lookup dc=" + dc);

        dc.close();
    } catch(NamingException e) {
        log.error("Failed during JNDI access", e);
    }
    return arg;
}
```

The EJB is not using the CCI interface to access the resource adaptor. Rather, it is using the resource adaptor specific API based on the proprietary `DirContextFactory` interface that returns a JNDI `DirContext` object as the connection object. The example EJB is simply exercising the system contract layer by looking up the resource adaptor connection factory, creating a connection to the resource and closing the connection. The EJB does not actually do anything with the connection, as this would only exercise the resource adaptor implementation since this is a non-transactional resource.

Run the test client which calls the `EchoBean.echo` method by running Ant as follows from the examples directory:

```
[examples]$ ant -Dchap=jca -Dex=1 run-example
```

You'll see some output from the bean in the system console, but much more detailed logging output can be found in the `server/default/log/server.log` file. Don't worry if you see exceptions. They are just stack traces to highlight the call path into parts of the adaptor. To help understand the interaction between the adaptor and the JBoss JCA layer, we'll summarize the events seen in the log using a sequence diagram. Figure 6.4 is a sequence diagram that summarizes the events that occur when the `EchoBean` accesses the resource adaptor connection factory from JNDI and creates a connection.

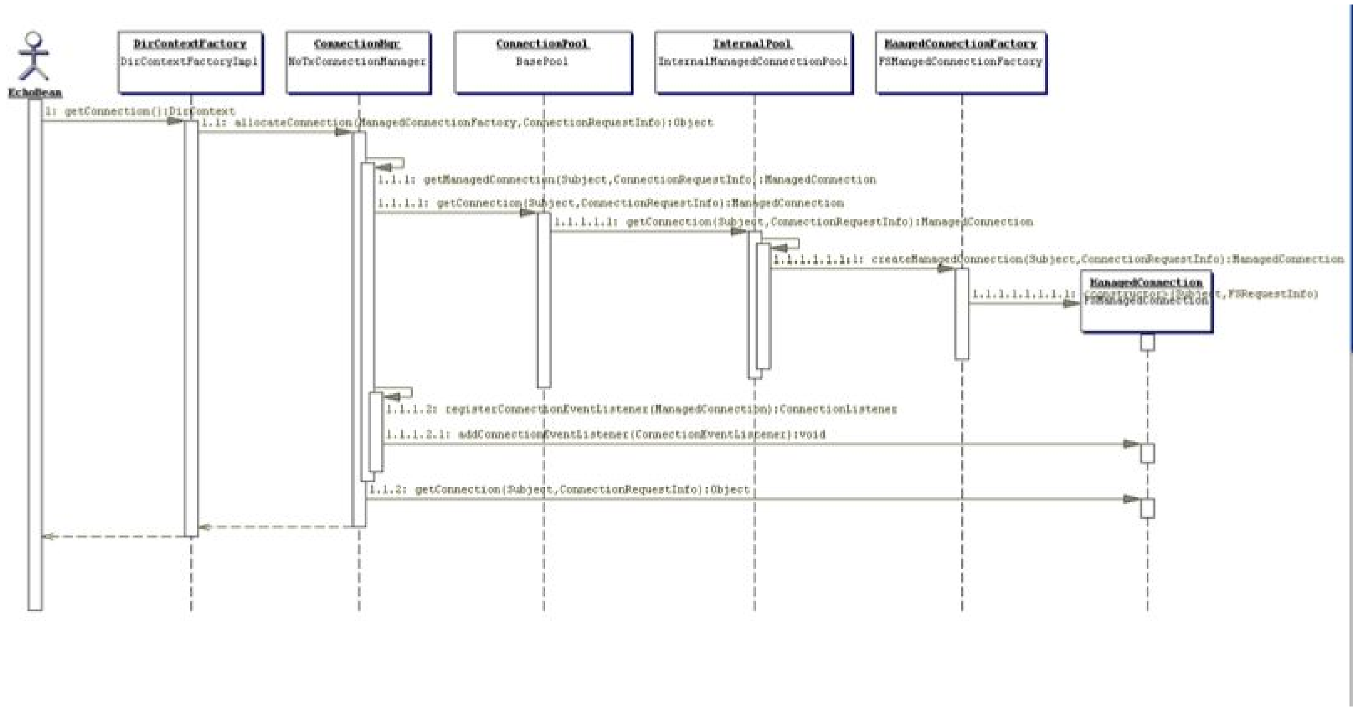

EchoBean
DirContextFactory
DirContextFactoryImpl
ConnectionMgr
NoTxConnectionManager
ConnectionPool
BasePool
InternalPool
InternalManagedConnectionPool
ManagedConnectionFactory
FSMangedConnectionFactory
ManagedConnection
FSManagedConnection
1: getConnection():DirContext
1.1: allocateConnection(ManagedConnectionFactory,ConnectionRequestInfo):Object
1.1.1: getManagedConnection(Subject,ConnectionRequestInfo):ManagedConnection
1.1.1.1: getConnection(Subject,ConnectionRequestInfo):ManagedConnection
1.1.1.1.1: getConnection(Subject,ConnectionRequestInfo):ManagedConnection
1.1.1.1.1.1.1: createManagedConnection(Subject,ConnectionRequestInfo):ManagedConnection
1.1.1.1.1.1.1.1: constructor()(Subject,FSRequestInfo)
1.1.1.2: registerConnectionEventListener(ManagedConnection):ConnectionListener
1.1.1.2.1: addConnectionEventListener(ConnectionEventListener):void
1.1.2: getConnection(Subject,ConnectionRequestInfo):Object

Figure 6.4. A sequence diagram illustrating the key interactions between the JBossCX framework and the example resource adaptor that result when the EchoBean accesses the resource adaptor connection factory.

The starting point is the client's invocation of the `EchoBean.echo` method. For the sake of conciseness of the diagram, the client is shown directly invoking the EchoBean.echo method when in reality the JBoss EJB container handles the invocation. There are three distinct interactions between the `EchoBean` and the resource adaptor; the lookup of the connection factory, the creation of a connection, and the close of the connection.

The lookup of the resource adaptor connection factory is illustrated by the 1.1 sequences of events. The events are:

- 1, the echo method invokes the `getConnection` method on the resource adaptor connection factory obtained from the JNDI lookup on the `java:comp/env/ra/DirContextFactory` name which is a link to the `java:/NoTransFS` location.

- 1.1, the `DirContextFactoryImpl` class asks its associated `ConnectionManager` to allocate a connection. It passes in the `ManagedConnectionFactory` and `FSRequestInfo` that were associated with the `DirContextFactoryImpl` during its construction.
- 1.1.1, the `ConnectionManager` invokes its `getManagedConnection` method with the current `Subject` and `FSRequestInfo`.
- 1.1.1.1, the `ConnectionManager` asks its object pool for a connection object. The `JBossManagedConnectionPool$BasePool` is get the key for the connection and then asks the matching `InternalPool` for a connection.
- 1.1.1.1.1, Since no connections have been created the pool must create a new connection. This is done by requesting a new managed connection from the `ManagedConnectionFactory`. The `Subject` associated with the pool as well as the `FSRequestInfo` data are passed as arguments to the `createManagedConnection` method invocation.
- 1.1.1.1.1.1, the `ConnectionFactory` creates a new `FSManagedConnection` instance and passes in the `Subject` and `FSRequestInfo` data.
- 1.1.1.2, a `javax.resource.spi.ConnectionListener` instance is created. The type of listener created is based on the type of `ConnectionManager`. In this case it is an `org.jboss.resource.connectionmgr.BaseConnectionManager2$NoTransactionListener` instance.
- 1.1.1.2.1, the listener registers as a `javax.resource.spi.ConnectionEventListener` with the `ManagedConnection` instance created in 1.2.1.1.
- 1.1.2, the `ManagedConnection` is asked for the underlying resource manager connection. The `Subject` and `FSRequestInfo` data are passed as arguments to the `getConnection` method invocation.
- The resulting connection object is cast to a `javax.naming.directory.DirContext` instance since this is the public interface defined by the resource adaptor.
- After the `EchoBean` has obtained the `DirContext` for the resource adaptor, it simply closes the connection to indicate its interaction with the resource manager is complete.

This concludes the resource adaptor example. Our investigation into the interaction between the JBossCX layer and a trivial resource adaptor should give you sufficient understanding of the steps required to configure any resource adaptor. The example adaptor can also serve as a starting point for the creation of your own custom resource adaptors if you need to integrate non-JDBC resources into the JBoss server environment.

6.3. Configuring JDBC DataSources

Rather than configuring the connection manager factory related MBeans discussed in the previous section via a mbean services deployment descriptor, JBoss provides a simplified datasource centric descriptor. This is transformed into the standard `jboss-service.xml` MBean services deployment descriptor using a XSL transform applied by the `org.jboss.deployment.XSLSubDeployer` included in the `jboss-jca.sar` deployment. The simplified configuration descriptor is deployed the same as other deployable components. The descriptor must be named using a `*-ds.xml` pattern in order to be recognized by the `XSLSubDeployer`.

The schema for the top-level datasource elements of the `*-ds.xml` configuration deployment file is shown in Figure 6.5.

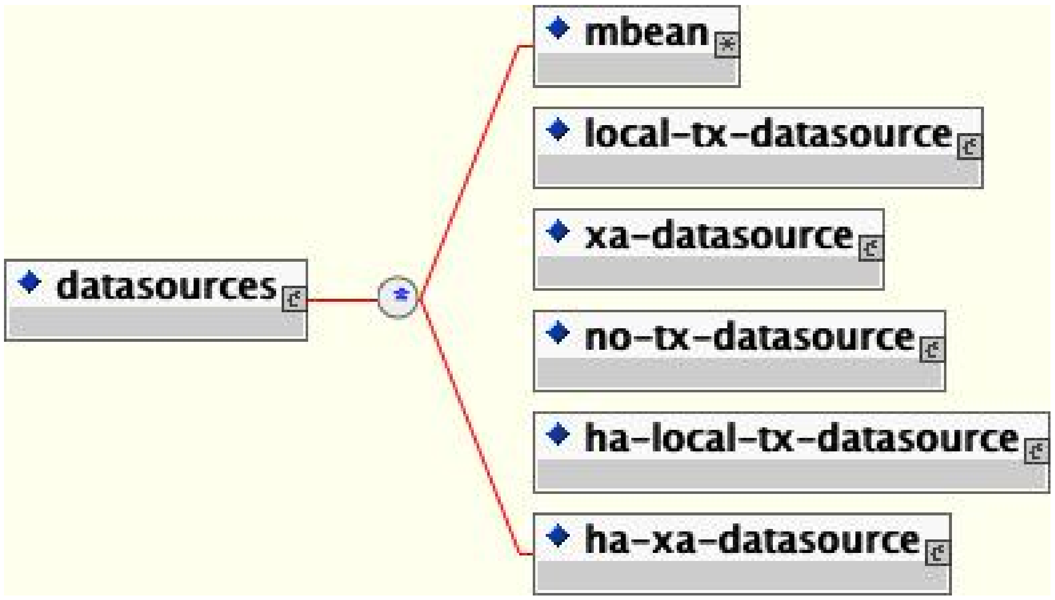


Figure 6.5. The simplified JCA DataSource configuration descriptor top-level schema elements

Multiple datasource configurations may be specified in a configuration deployment file. The child elements of the datasources root are:

- **mbean**: Any number mbean elements may be specified to define MBean services that should be included in the `jboss-service.xml` descriptor that results from the transformation. This may be used to configure services used by the datasources.
- **no-tx-datasource**: This element is used to specify the (`org.jboss.resource.connectionmanager`) `NoTxConnectionManager` service configuration. `NoTxConnectionManager` is a JCA connection manager with no transaction support. The `no-tx-datasource` child element schema is given in Figure 6.6.
- **local-tx-datasource**: This element is used to specify the (`org.jboss.resource.connectionmanager`) `LocalTxConnectionManager` service configuration. `LocalTxConnectionManager` implements a `ConnectionEventListener` that implements `XAResource` to manage transactions through the transaction manager. To ensure that all work in a local transaction occurs over the same `ManagedConnection`, it includes a xid to `ManagedConnection` map. When a Connection is requested or a transaction started with a connection handle in use, it checks to see if a `ManagedConnection` already exists enrolled in the global transaction and uses it if found. Otherwise, a free `ManagedConnection` has its `LocalTransaction` started and is used. The `local-tx-datasource` child element schema is given in Figure 6.7
- **xa-datasource**: This element is used to specify the (`org.jboss.resource.connectionmanager`) `XATxConnectionManager` service configuration. `XATxConnectionManager` implements a `ConnectionEventListener` that obtains the `XAResource` to manage transactions through the transaction manager from the adaptor `ManagedConnection`. To ensure that all work in a local transaction occurs over the same `ManagedConnection`, it includes a xid to `ManagedConnection` map. When a `Connection` is requested or a transaction started with a connection handle in use, it checks to see if a `ManagedConnection` already exists enrolled in the global transaction and uses it if found. Otherwise, a free `ManagedConnection` has its `LocalTransaction` started and is used. The `xa-datasource` child element schema is given in Figure 6.8.

- **ha-local-tx-datasource**: This element is identical to `local-tx-datasource`, with the addition of the experimental datasource failover capability allowing JBoss to failover to an alternate database in the event of a database failure.
- **ha-xa-datasource**: This element is identical to `xa-datasource`, with the addition of the experimental datasource failover capability allowing JBoss to failover to an alternate database in the event of a database failure.

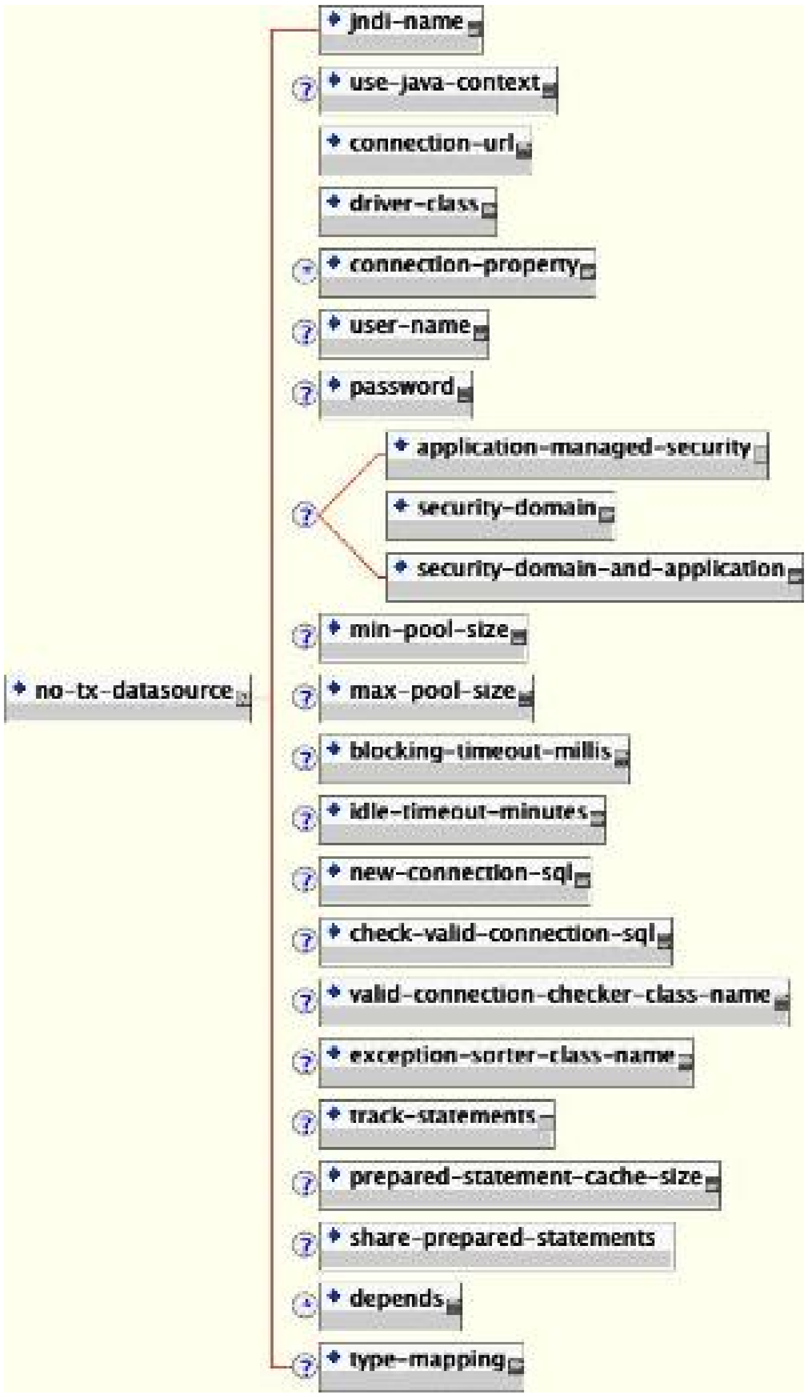


Figure 6.6. The non-transactional DataSource configuration schema

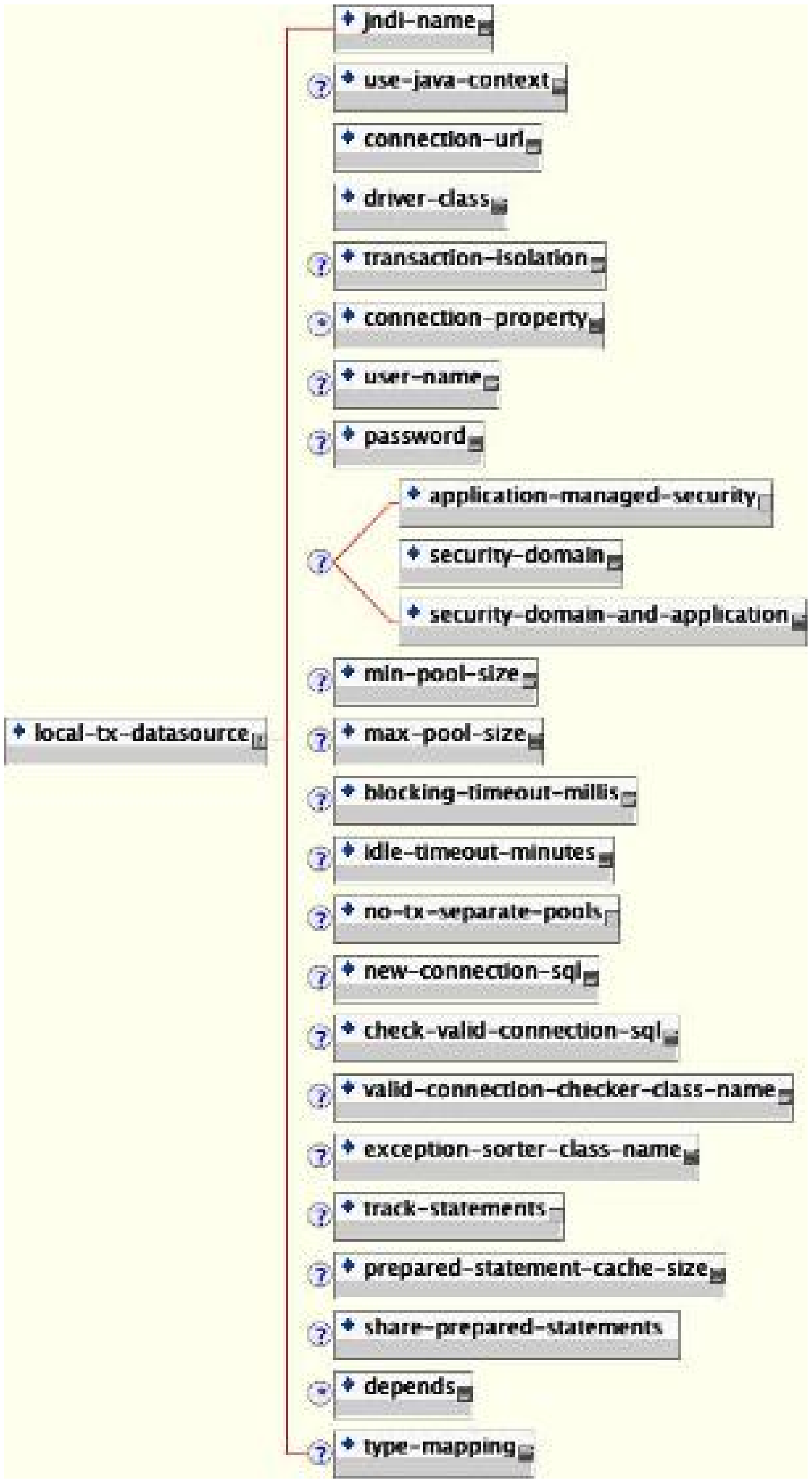


Figure 6.7. The non-XA DataSource configuration schema

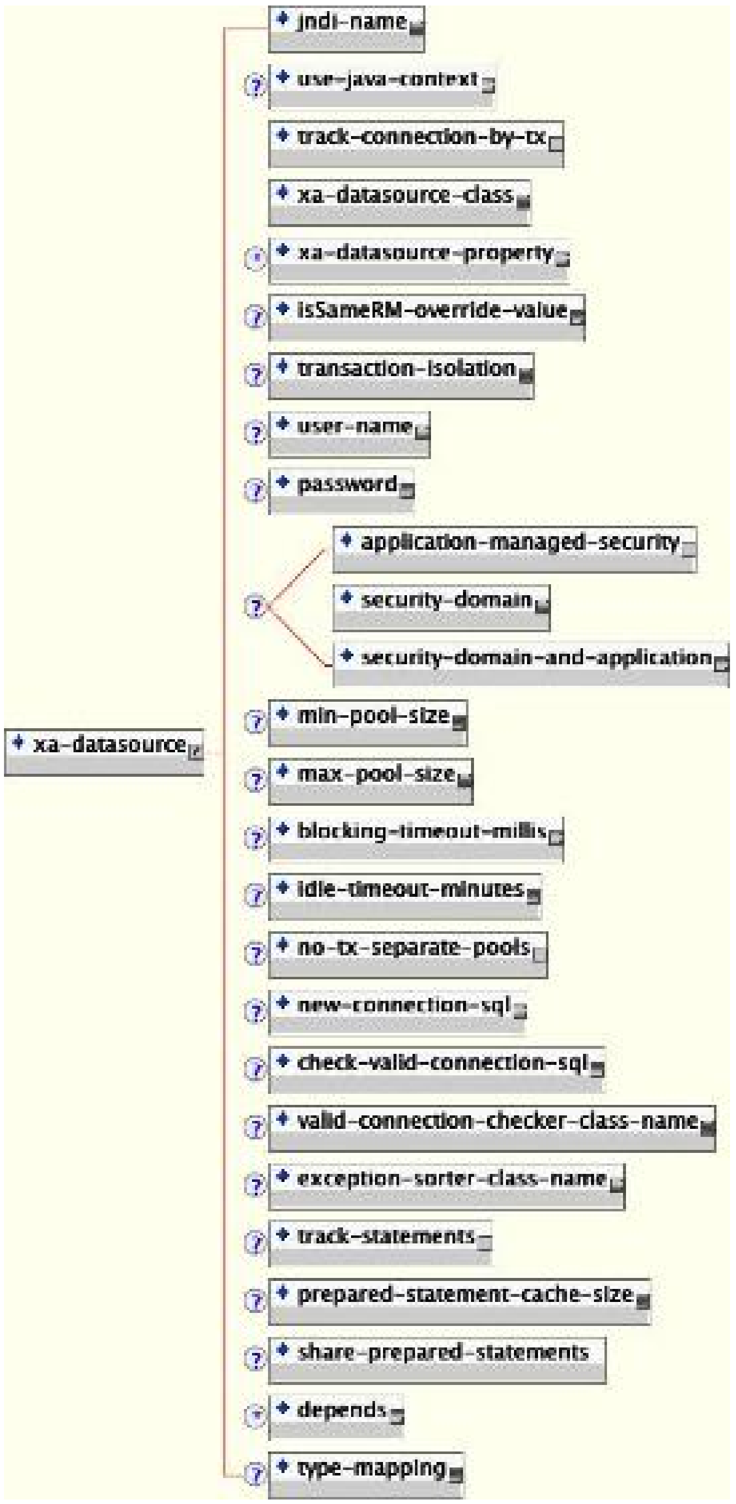


Figure 6.8. The XA DataSource configuration schema

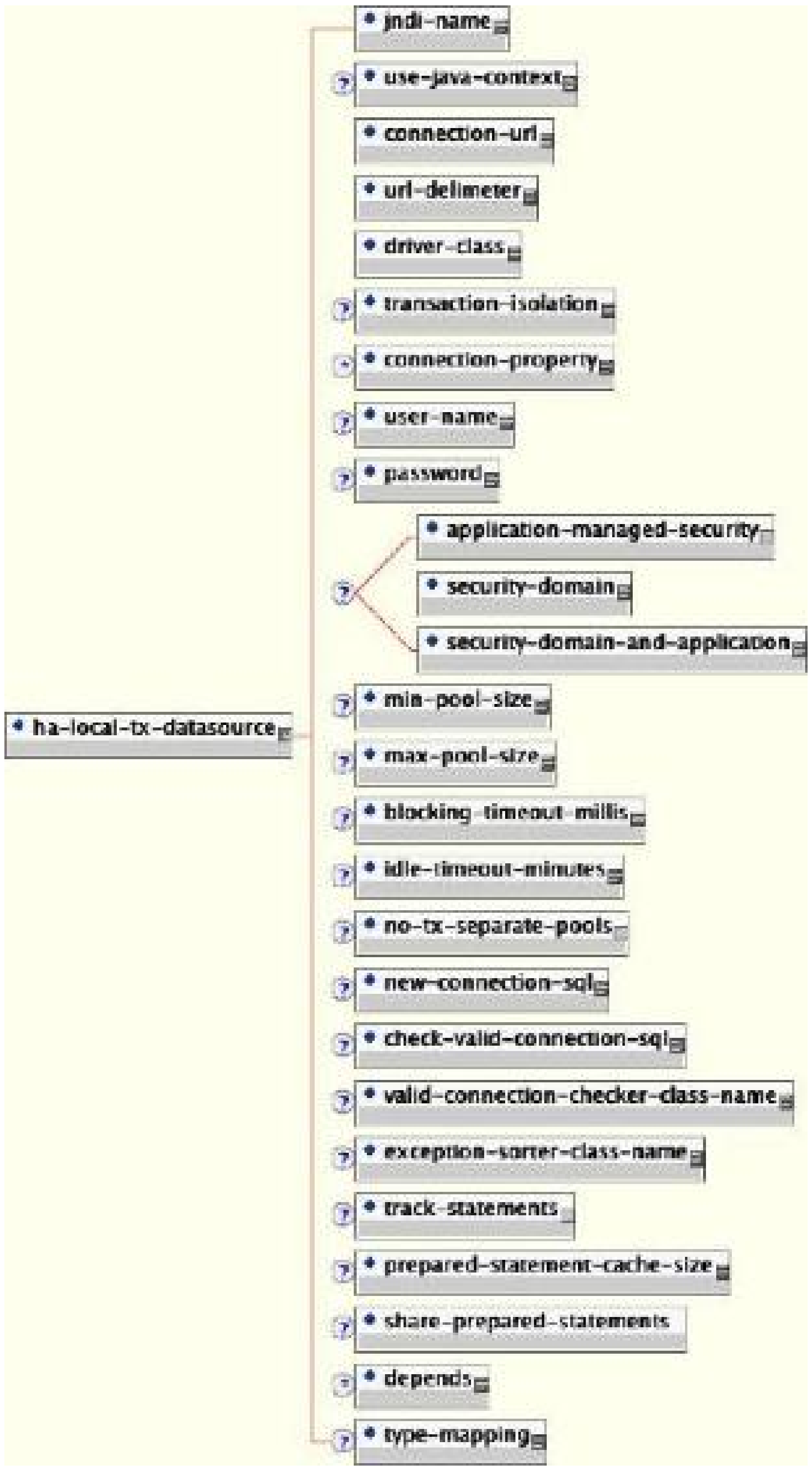


Figure 6.9. The schema for the experimental non-XA DataSource with failover

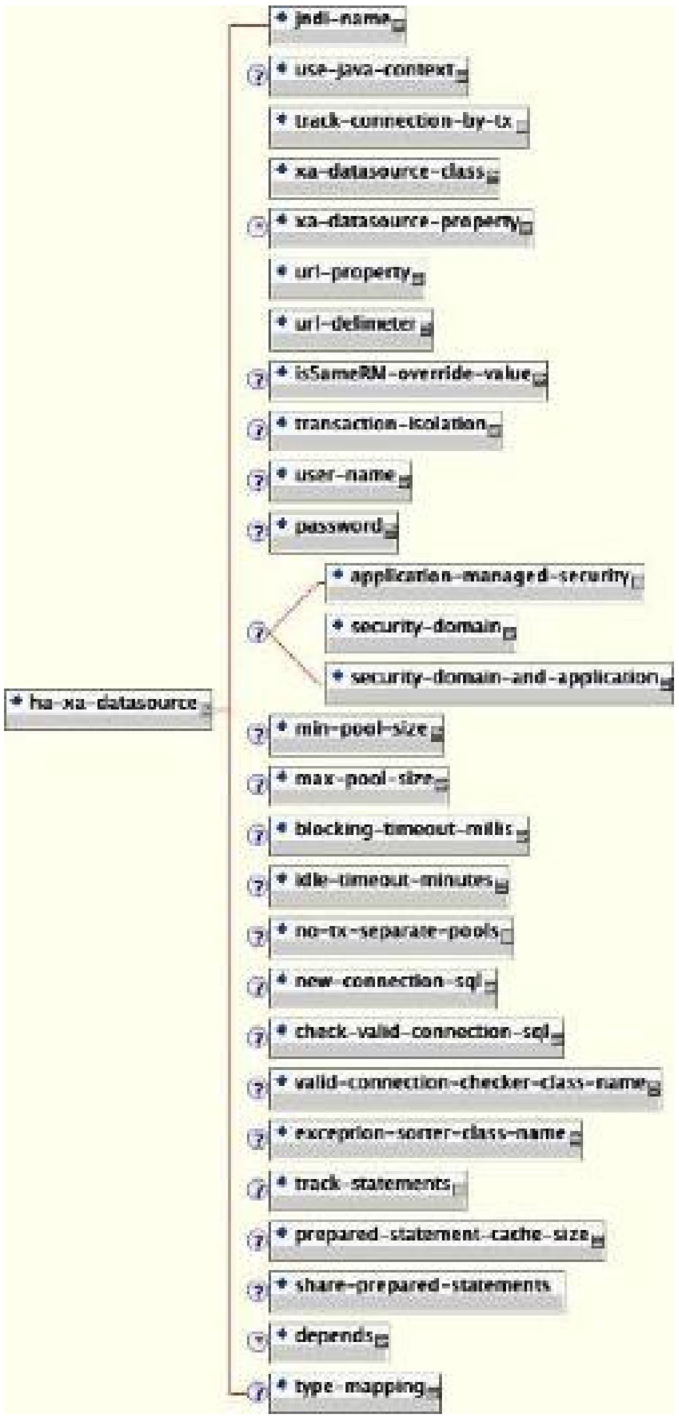


Figure 6.10. The schema for the experimental XA Datasource with failover

Elements that are common to all datasources include:

- **jndi-name**: The JNDI name under which the `DataSource` wrapper will be bound. Note that this name is relative to the `java:/` context, unless `use-java-context` is set to false. `DataSource` wrappers are not usable outside of the server VM, so they are normally bound under the `java:/`, which isn't shared outside the local VM.
- **use-java-context**: If this is set to false the the datasource will be bound in the global JNDI context rather than

the `java:` context.

- **user-name**: This element specifies the default username used when creating a new connection. The actual username may be overridden by the application code `getConnection` parameters or the connection creation context JAAS Subject.

- **password**: This element specifies the default password used when creating a new connection. The actual password may be overridden by the application code `getConnection` parameters or the connection creation context JAAS Subject.

- **application-managed-security**: Specifying this element indicates that connections in the pool should be distinguished by application code supplied parameters, such as from `getConnection(user, pw)`.

- **security-domain**: Specifying this element indicates that connections in the pool should be distinguished by JAAS Subject based information. The content of the `security-domain` is the name of the JAAS security manager that will handle authentication. This name correlates to the JAAS `login-config.xml` descriptor `application-policy/name` attribute.

- **security-domain-and-application**: Specifying this element indicates that connections in the pool should be distinguished both by application code supplied parameters and JAAS Subject based information. The content of the `security-domain` is the name of the JAAS security manager that will handle authentication. This name correlates to the JAAS `login-config.xml` descriptor `application-policy/name` attribute.

- **min-pool-size**: This element specifies the minimum number of connections a pool should hold. These pool instances are not created until an initial request for a connection is made. This default to 0.

- **max-pool-size**: This element specifies the maximum number of connections for a pool. No more than the `max-pool-size` number of connections will be created in a pool. This defaults to 20.

- **blocking-timeout-millis**: This element specifies the maximum time in milliseconds to block while waiting for a connection before throwing an exception. Note that this blocks only while waiting for a permit for a connection, and will never throw an exception if creating a new connection takes an inordinately long time. The default is 5000.

- **idle-timeout-minutes**: This element specifies the maximum time in minutes a connection may be idle before being closed. The actual maximum time depends also on the `IdleRemover` scan time, which is 1/2 the smallest idle-timeout-minutes of any pool.

- **new-connection-sql**: This is a SQL statement that should be executed when a new connection is created. This can be used to configure a connection with database specific settings not configurable via connection properties.

- **check-valid-connection-sql**: This is a SQL statement that should be run on a connection before it is returned from the pool to test its validity to test for stale pool connections. An example statement could be: `select count(*) from x`.

- **exception-sorter-class-name**: This specifies a class that implements the `org.jboss.resource.adapter.jdbc.ExceptionSorter` interface to examine database exceptions to determine whether or not the exception indicates a connection error. Current implementations include:

  - org.jboss.resource.adapter.jdbc.vendor.OracleExceptionSorter

- org.jboss.resource.adapter.jdbc.vendor.MySQLExceptionSorter
- org.jboss.resource.adapter.jdbc.vendor.SybaseExceptionSorter
- org.jboss.resource.adapter.jdbc.vendor.InformixExceptionSorte

- **valid-connection-checker-class-name**: This specifies a class that implements the `org.jboss.resource.adapter.jdbc.ValidConnectionChecker` interface to provide a `SQLException isValidConnection(Connection e)` method that is called with a connection that is to be returned from the pool to test its validity. This overrides the `check-valid-connection-sql` when present. The only provided implementation is `org.jboss.resource.adapter.jdbc.vendor.OracleValidConnectionChecker`.

- **track-statements**: This boolean element specifies whether to check for unclosed statements when a connection is returned to the pool. If true, a warning message is issued for each unclosed statement. If the log4j category `org.jboss.resource.adapter.jdbc.WrappedConnection` has trace level enabled, a stack trace of the connection close call is logged as well. This is a debug feature that can be turned off in production.

- **prepared-statement-cache-size**: This element specifies the number of prepared statements per connection in an LRU cache, which is keyed by the SQL query. Setting this to zero disables the cache.

- **depends**: The `depends` element specifies the JMX `ObjectName` string of a service that the connection manager services depend on. The connection manager service will not be started until the dependent services have been started.

- **type-mapping**: This element declares a default type mapping for this datasource. The type mapping should match a `type-mapping/name` element from `standardjbosscmp-jdbc.xml`.

Additional common child elements for both `no-tx-datasource` and `local-tx-datasource` include:

- **connection-url**: This is the JDBC driver connection URL string, for example, `jdbc:hsqldb:hsql://localhost:1701`.

- **driver-class**: This is the fully qualified name of the JDBC driver class, for example, `org.hsqldb.jdbcDriver`.

- **connection-property**: The `connection-property` element allows you to pass in arbitrary connection properties to the `java.sql.Driver.connect(url, props)` method. Each `connection-property` specifies a string name/value pair with the property name coming from the name attribute and the value coming from the element content.

Elements in common to the `local-tx-datasource` and `xa-datasource` are:

- **transaction-isolation**: This element specifies the `java.sql.Connection` transaction isolation level to use. The constants defined in the Connection interface are the possible element content values and include:
  - TRANSACTION_READ_UNCOMMITTED
  - TRANSACTION_READ_COMMITTED
  - TRANSACTION_REPEATABLE_READ
  - TRANSACTION_SERIALIZABLE
  - TRANSACTION_NONE

- **no-tx-separate-pools**: The presence of this element indicates that two connection pools are required to isolate connections used with JTA transaction from those used without a JTA transaction. The pools are lazily constructed on first use. Its use case is for Oracle (and possibly other vendors) XA implementations that don't like using an XA connection with and without a JTA transaction.

The unique `xa-datasource` child elements are:

- **track-connection-by-tx**: Specifying a true value for this element makes the connection manager keep an xid to connection map and only put the connection back in the pool when the transaction completes and all the connection handles are closed or disassociated (by the method calls returning). As a side effect, we never suspend and resume the xid on the connection's `XAResource`. This is the same connection tracking behavior used for local transactions.

  The XA spec implies that any connection may be enrolled in any transaction using any xid for that transaction at any time from any thread (suspending other transactions if necessary). The original JCA implementation assumed this and aggressively delisted connections and put them back in the pool as soon as control left the EJB they were used in or handles were closed. Since some other transaction could be using the connection the next time work needed to be done on the original transaction, there is no way to get the original connection back. It turns out that most `XADataSource` driver vendors do not support this, and require that all work done under a particular xid go through the same connection.

- **xa-datasource-class**: The fully qualified name of the `javax.sql.XADataSource` implementation class, for example, `com.informix.jdbcx.IfxXADataSource`.

- **xa-datasource-property**: The `xa-datasource-property` element allows for specification of the properties to assign to the `XADataSource` implementation class. Each property is identified by the name attribute and the property value is given by the `xa-datasource-property` element content. The property is mapped onto the `XADataSource` implementation by looking for a JavaBeans style getter method for the property name. If found, the value of the property is set using the JavaBeans setter with the element text translated to the true property type using the `java.beans.PropertyEditor` for the type.

- **isSameRM-override-value**: A boolean flag that allows one to override the behavior of the `javax.transaction.xa.XAResource.isSameRM(XAResource xaRes)` method behavior on the XA managed connection. If specified, this value is used unconditionally as the `isSameRM(xaRes)` return value regardless of the `xaRes` parameter.

The failover options common to `ha-xa-datasource` and `ha-local-tx-datasource` are:

- **url-delimeter**: This element specifies a character used to separate multiple JDBC URLs.

- **url-property**: In the case of XA datasources, this property specifies the name of the `xa-datasource-property` that contains the list of JDBC URLs to use.

Example configurations for many third-party JDBC drivers are included in the `JBOSS_DIST/docs/examples/jca` directory. Current example configurations include:

- asapxcess-jb3.2-ds.xml
- cicsr9s-service.xml
- db2-ds.xml
- db2-xa-ds.xml
- facets-ds.xml

- fast-objects-jboss32-ds.xml
- firebird-ds.xml
- firstsql-ds.xml
- firstsql-xa-ds.xml
- generic-ds.xml
- hsqldb-ds.xml
- informix-ds.xml
- informix-xa-ds.xml
- jdatastore-ds.xml
- jms-ds.xml
- jsql-ds.xml
- lido-versant-service.xml
- mimer-ds.xml
- mimer-xa-ds.xml
- msaccess-ds.xml
- mssql-ds.xml
- mssql-xa-ds.xml
- mysql-ds.xml
- oracle-ds.xml
- oracle-xa-ds.xml
- postgres-ds.xml
- sapdb-ds.xml
- sapr3-ds.xml
- solid-ds.xml
- sybase-ds.xml

6.4. Configuring Generic JCA Adaptors

The XSLSubDeployer also supports the deployment of arbitrary non-JDBC JCA resource adaptors. The schema for the top-level connection factory elements of the `*-ds.xml` configuration deployment file is shown in Figure 6.11.

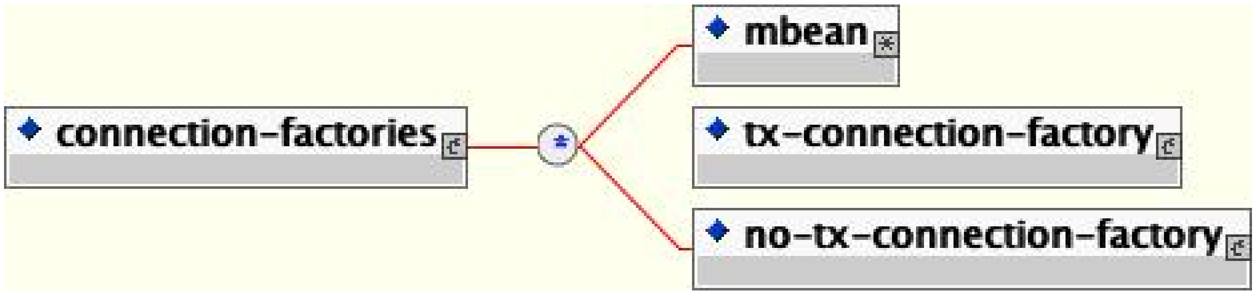


Figure 6.11. The simplified JCA adaptor connection factory configuration descriptor top-level schema elements

Multiple connection factory configurations may be specified in a configuration deployment file. The child elements of the `connection-factories` root are:

- **mbean**: Any number mbean elements may be specified to define MBean services that should be included in the `jboss-service.xml` descriptor that results from the transformation. This may be used to configure additional services used by the adaptor.

- **no-tx-connection-factory**: this element is used to specify the (`org.jboss.resource.connectionmanager`) `NoTxConnectionManager` service configuration. `NoTxConnectionManager` is a JCA connection manager with no transaction support. The `no-tx-connection-factory` child element schema is given in Figure 6.12.
- **tx-connection-factory**: this element is used to specify the (`org.jboss.resource.connectionmanager`) `TxConnectionManager` service configuration. The `tx-connection-factory` child element schema is given in Figure 6.13.

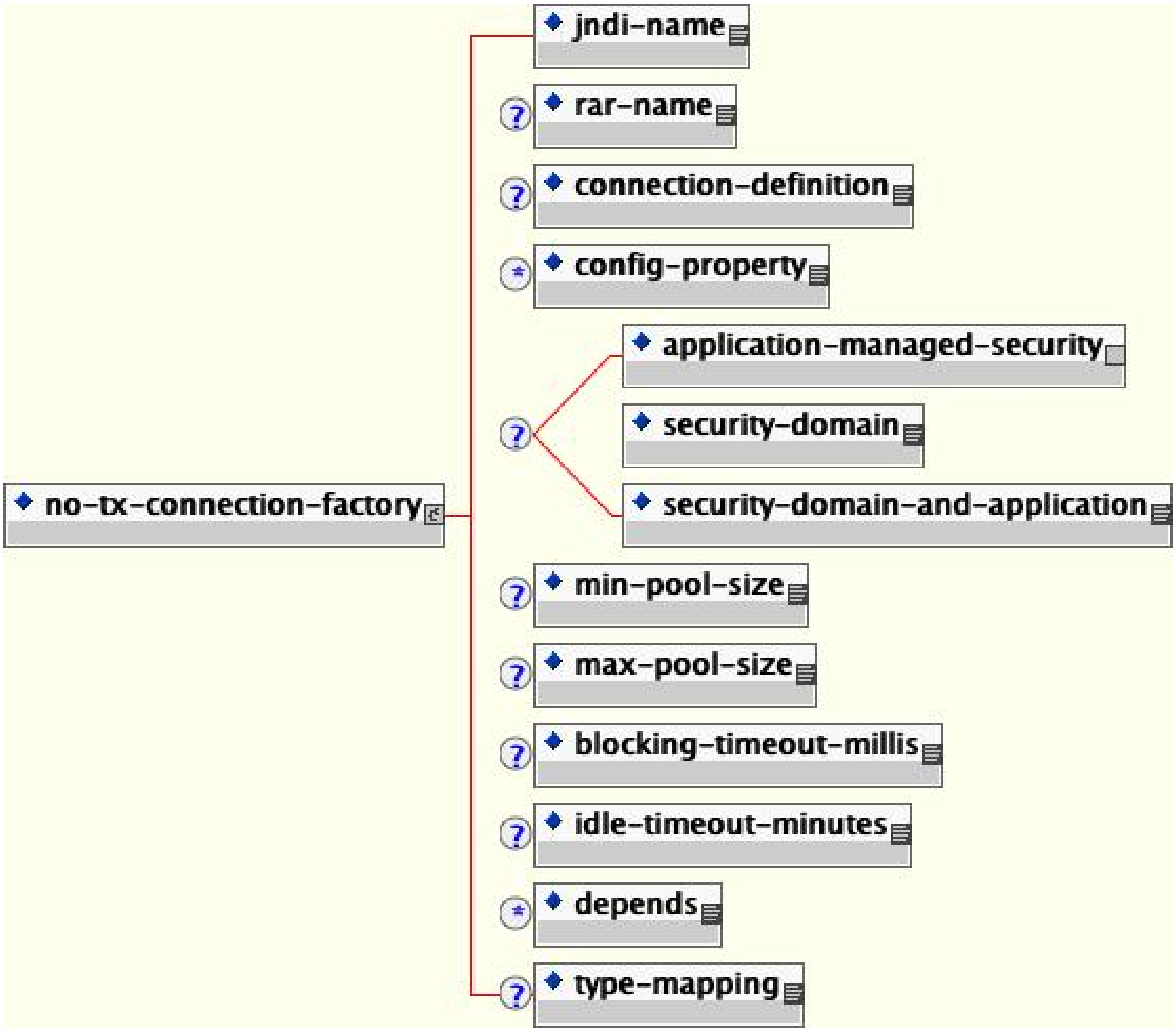


Figure 6.12. The no-tx-connection-factory element schema

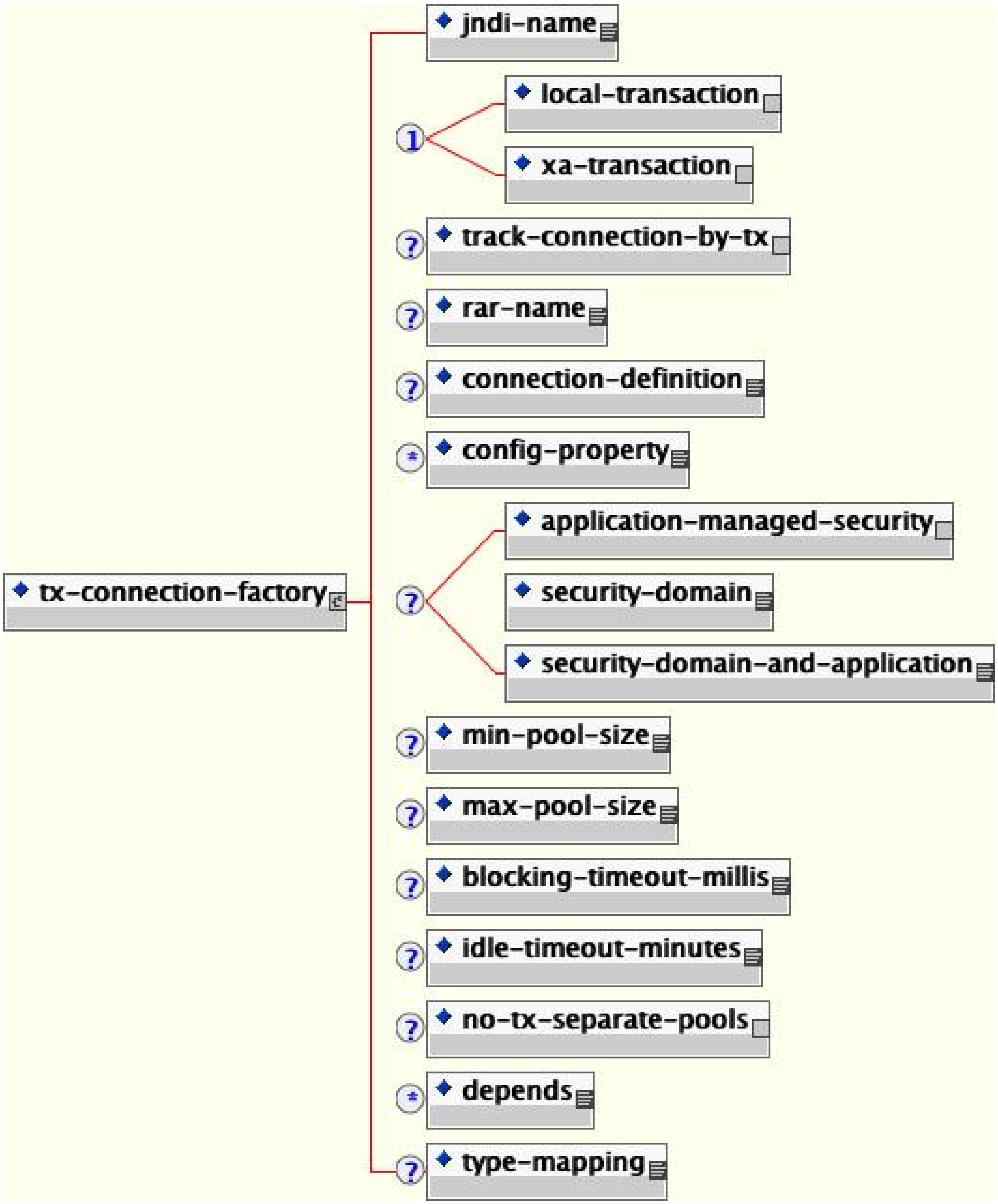


Figure 6.13. The tx-connection-factory element schema

The majority of the elements are the same as those of the datasources configuration. The element unique to the connection factory configuration include:

- **adaptor-display-name**: A human readable display name to assign to the connection manager MBean.
- **local-transaction**: This element specifies that the `tx-connection-factory` supports local transactions.
- **xa-transaction**: This element specifies that the `tx-connection-factory` supports XA transactions.
- **track-connection-by-tx**: This element specifies that a connection should be used only on a single transaction and that a transaction should only be associated with one connection.
- **rar-name**: This is the name of the RAR file that contains the definition for the resource we want to provide. For nested RAR files, the name would look like `myapplication.ear#my.rar`.
- **connection-definition**: This is the connection factory interface class. It should match the `connectionfactory-interface` in the `ra.xml` file.
- **config-property**: Any number of properties to supply to the `ManagedConnectionFactory` (MCF) MBean service configuration. Each `config-property` element specifies the value of a MCF property. The `config-property` element has two required attributes:

  - **name**: The name of the property
  - **type**: The fully qualified type of the property

  The content of the `config-property` element provides the string representation of the property value. This will be converted to the true property type using the associated type `PropertyEditor`.

7

Security on JBoss

J2EE Security Configuration and Architecture

Security is a fundamental part of any enterprise application. You need to be able to restrict who is allowed to access your applications and control what operations application users may perform. The J2EE specifications define a simple role-based security model for EJBs and web components. The JBoss component framework that handles security is the JBossSX extension framework. The JBossSX security extension provides support for both the role-based declarative J2EE security model and integration of custom security via a security proxy layer. The default implementation of the declarative security model is based on Java Authentication and Authorization Service (JAAS) login modules and subjects. The security proxy layer allows custom security that cannot be described using the declarative model to be added to an EJB in a way that is independent of the EJB business object. Before getting into the JBoss security implementation details, we will review EJB and servlet specification security models, as well as JAAS to establish the foundation for these details.

7.1. J2EE Declarative Security Overview

The J2EE security model declarative in that you describe the security roles and permissions in a standard XML descriptor rather than embedding security into your business component. This isolates security from business-level code because security tends to be more a function of where the component is deployed than an inherent aspect of the component's business logic. For example, consider an ATM component that is to be used to access a bank account. The security requirements, roles and permissions will vary independently of how you access the bank account, based on what bank is managing the account, where the ATM is located, and so on.

Securing a J2EE application is based on the specification of the application security requirements via the standard J2EE deployment descriptors. You secure access to EJBs and web components in an enterprise application by using the `ejb-jar.xml` and `web.xml` deployment descriptors. The following sections look at the purpose and usage of the various security elements.

7.1.1. Security References

Both EJBs and servlets can declare one or more `security-role-ref` elements as shown in Figure 7.1. This element declares that a component is using the `role-name` value as an argument to the `isCallerInRole(String)` method. By using the `isCallerInRole` method, a component can verify whether the caller is in a role that has been declared with a `security-role-ref/role-name` element. The `role-name` element value must link to a `security-role` element through the `role-link` element. The typical use of `isCallerInRole` is to perform a security check that cannot be defined by using the role-based `method-permissions` elements.

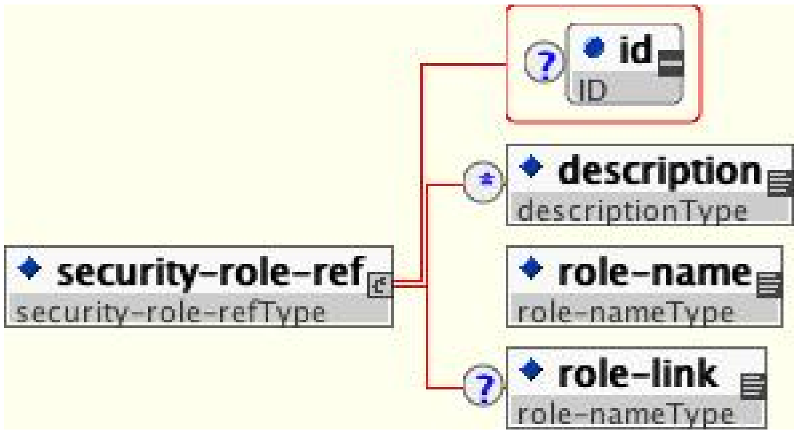


Figure 7.1. The security-role-ref element

Example 7.1 shows the use of `security-role-ref` in an `ejb-jar.xml`.

Example 7.1. An ejb-jar.xml descriptor fragment that illustrates the security-role-ref element usage.

```
<!-- A sample ejb-jar.xml fragment -->
<ejb-jar>
  <enterprise-beans>
    <session>
      <ejb-name>ASessionBean</ejb-name>
      ...
      <security-role-ref>
          <role-name>TheRoleICheck</role-name>
          <role-link>TheApplicationRole</role-link>
      </security-role-ref>
    </session>
  </enterprise-beans>
  ...
</ejb-jar>
```

Example 7.2 shows the use of `security-role-ref` in a `web.xml`.

Example 7.2. An example web.xml descriptor fragment that illustrates the security-role-ref element usage.

```
<web-app>
    <servlet>
        <servlet-name>AServlet</servlet-name>
        ...
        <security-role-ref>
            <role-name>TheServletRole</role-name>
            <role-link>TheApplicationRole</role-link>
        </security-role-ref>
    </servlet>
    ...
</web-app>
```

7.1.2. Security Identity

An EJB has the capability to specify what identity an EJB should use when it invokes methods on other components using the `security-identity` element, shown in Figure 7.2

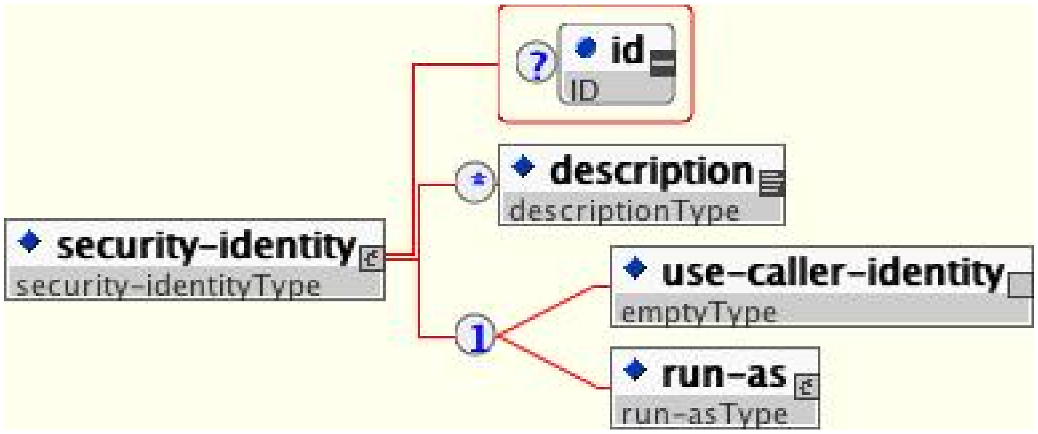


Figure 7.2. The security-identity element

The invocation identity can be that of the current caller, or it can be a specific role. The application assembler uses the `security-identity` element with a `use-caller-identity` child element to indicate that the current caller's identity should be propagated as the security identity for method invocations made by the EJB. Propagation of the caller's identity is the default used in the absence of an explicit `security-identity` element declaration.

Alternatively, the application assembler can use the `run-as/role-name` child element to specify that a specific security role given by the `role-name` value should be used as the security identity for method invocations made by the EJB. Note that this does not change the caller's identity as seen by the `EJBContext.getCallerPrincipal()` method. Rather, the caller's security roles are set to the single role specified by the `run-as/role-name` element value. One use case for the `run-as` element is to prevent external clients from accessing internal EJBs. You accomplish this by assigning the internal EJB `method-permission` elements that restrict access to a role never assigned to an external client. EJBs that need to use internal EJB are then configured with a `run-as/role-name` equal to the restricted role. The following descriptor fragment that illustrates `security-identity` element usage.

```
<!-- A sample ejb-jar.xml fragment -->
<ejb-jar>
    <enterprise-beans>
        <session>
            <ejb-name>ASessionBean</ejb-name>
            <!-- ... -->
            <security-identity>
                <use-caller-identity/>
            </security-identity>
        </session>
        <session>
            <ejb-name>RunAsBean</ejb-name>
            <!-- ... -->
            <security-identity>
                <run-as>
                    <description>A private internal role</description>
                    <role-name>InternalRole</role-name>
                </run-as>
            </security-identity>
        </session>
    </enterprise-beans>
    <!-- ... -->
</ejb-jar>
```

When you use `run-as` to assign a specific role to outgoing calls, JBoss associates a principal named `anonymous`. If you want another prinicipal to be associated with the call, you need to associate a `run-as-principal` with the bean in the `jboss.xml` file. The following fragment associates a principal named `internal` with `RunAsBean` from the prior example.

```
<session>
    <ejb-name>RunAsBean</ejb-name>
    <security-identity>
        <run-as-principal>internal</run-as-principal>
    </security-identity>
</session>
```

The `run-as` element is also available in servlet definitions in a `web.xml` file. The following example shows how to assign the role `InternalRole` to a servlet:

```
<servlet>
    <servlet-name>AServlet</servlet-name>
    <!-- ... -->
    <run-as>
        <role-name>InternalRole</role-name>
    </run-as>
</servlet>
```

Calls from this servlet will be associated with the anonymous `principal`. The `run-as-principal` element is available in the `jboss-web.xml` file to assign a specific principal to go along with the `run-as` role. The following fragment shows how to associate a principal named `internal` to the servlet in the prior example.

```
<servlet>
    <servlet-name>AServlet</servlet-name>
    <run-as-principal>internal</run-as-principal>
</servlet>
```

7.1.3. Security roles

The security role name referenced by either the `security-role-ref` or `security-identity` element needs to map to one of the application's declared roles. An application assembler defines logical security roles by declaring `security-role` elements. The `role-name` value is a logical application role name like Administrator, Architect, SalesManager, etc.

The J2EE specifications note that it is important to keep in mind that the security roles in the deployment descriptor are used to define the logical security view of an application. Roles defined in the J2EE deployment descriptors should not be confused with the user groups, users, principals, and other concepts that exist in the target enterprise's operational environment. The deployment descriptor roles are application constructs with application domain-specific names. For example, a banking application might use role names such as BankManager, Teller, or Customer.

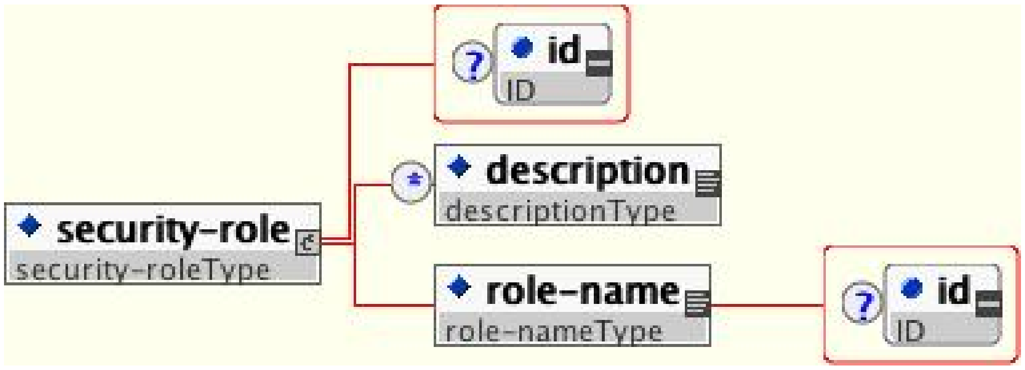


Figure 7.3. The security-role element

In JBoss, a `security-role` element is only used to map `security-role-ref/role-name` values to the logical role that the component role references. The user's assigned roles are a dynamic function of the application's security manager, as you will see when we discuss the JBossSX implementation details. JBoss does not require the definition of `security-role` elements in order to declare method permissions. However, the specification of `security-role` elements is still a recommended practice to ensure portability across application servers and for deployment descriptor maintenance. Example 7.3 shows the usage of the `security-role` in an `ejb-jar.xml` file.

Example 7.3. An ejb-jar.xml descriptor fragment that illustrates the security-role element usage.

```
<!-- A sample ejb-jar.xml fragment -->
<ejb-jar>
    <!-- ... -->
    <assembly-descriptor>
        <security-role>
            <description>The single application role</description>
            <role-name>TheApplicationRole</role-name>
        </security-role>
    </assembly-descriptor>
</ejb-jar>
```

Example 7.4 shows the usage of the `security-role` in an `web.xml` file.

Example 7.4. An example web.xml descriptor fragment that illustrates the security-role element usage.

```
<!-- A sample web.xml fragment -->
<web-app>
    <!-- ... -->
    <security-role>
        <description>The single application role</description>
        <role-name>TheApplicationRole</role-name>
    </security-role>
</web-app>
```

7.1.4. EJB method permissions

An application assembler can set the roles that are allowed to invoke an EJB's home and remote interface methods through method-permission element declarations.

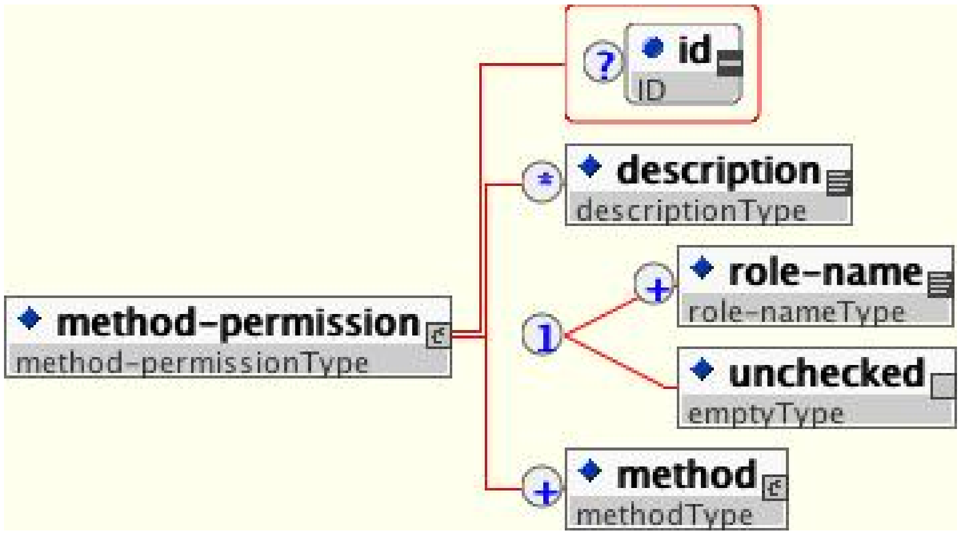


Figure 7.4. The method-permissions element

Each `method-permission` element contains one or more role-name child elements that define the logical roles that are allowed to access the EJB methods as identified by method child elements. You can also specify an `unchecked` element instead of the `role-name` element to declare that any authenticated user can access the methods identified by method child elements. In addition, you can declare that no one should have access to a method that has the `exclude-list` element. If an EJB has methods that have not been declared as accessible by a role using a `method-permission` element, the EJB methods default to being excluded from use. This is equivalent to defaulting the methods into the `exclude-list`.

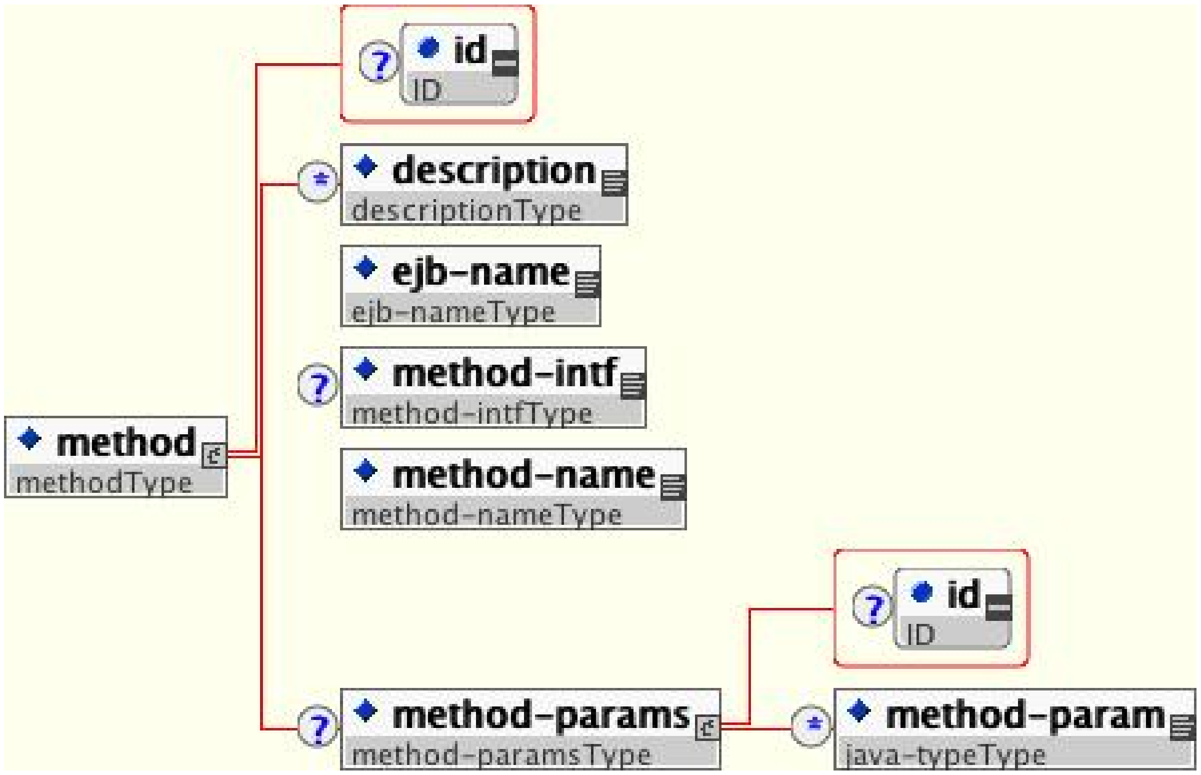


Figure 7.5. The method element

There are three supported styles of method element declarations.

The first is used for referring to all the home and component interface methods of the named enterprise bean:

```
<method>
    <ejb-name>EJBNAME</ejb-name>
    <method-name>*</method-name>
</method>
```

The second style is used for referring to a specified method of the home or component interface of the named enterprise bean:

```
<method>
    <ejb-name>EJBNAME</ejb-name>
    <method-name>METHOD</method-name>
                </method>
```

If there are multiple methods with the same overloaded name, this style refers to all of the overloaded methods.

The third style is used to refer to a specified method within a set of methods with an overloaded name:

```
<method>
    <ejb-name>EJBNAME</ejb-name>
    <method-name>METHOD</method-name>
    <method-params>
        <method-param>PARAMETER_1</method-param>
        <!-- ... -->
        <method-param>PARAMETER_N</method-param>
    </method-params>
</method>
```

The method must be defined in the specified enterprise bean's home or remote interface. The method-param element values are the fully qualified name of the corresponding method parameter type. If there are multiple methods with the same overloaded signature, the permission applies to all of the matching overloaded methods.

The optional `method-intf` element can be used to differentiate methods with the same name and signature that are defined in both the home and remote interfaces of an enterprise bean.

Example 7.5 provides complete examples of the `method-permission` element usage.

Example 7.5. An ejb-jar.xml descriptor fragment that illustrates the method-permission element usage.

```
<ejb-jar>
    <assembly-descriptor>
        <method-permission>
            <description>The employee and temp-employee roles may access any
                method of the EmployeeService bean </description>
            <role-name>employee</role-name>
            <role-name>temp-employee</role-name>
            <method>
                <ejb-name>EmployeeService</ejb-name>
                <method-name>*</method-name>
            </method>
        </method-permission>
        <method-permission>
            <description>The employee role may access the findByPrimaryKey,
                getEmployeeInfo, and the updateEmployeeInfo(String) method of
                the AardvarkPayroll bean </description>
            <role-name>employee</role-name>
            <method>
                <ejb-name>AardvarkPayroll</ejb-name>
                <method-name>findByPrimaryKey</method-name>
            </method>
            <method>
                <ejb-name>AardvarkPayroll</ejb-name>
                <method-name>getEmployeeInfo</method-name>
            </method>
            <method>
                <ejb-name>AardvarkPayroll</ejb-name>
                <method-name>updateEmployeeInfo</method-name>
                <method-params>
                    <method-param>java.lang.String</method-param>
                </method-params>
            </method>
        </method-permission>
        <method-permission>
            <description>The admin role may access any method of the
                EmployeeServiceAdmin bean </description>
            <role-name>admin</role-name>
            <method>
                <ejb-name>EmployeeServiceAdmin</ejb-name>
                <method-name>*</method-name>
            </method>
        </method-permission>
        <method-permission>
            <description>Any authenticated user may access any method of the
                EmployeeServiceHelp bean</description>
            <unchecked/>
            <method>
                <ejb-name>EmployeeServiceHelp</ejb-name>
                <method-name>*</method-name>
            </method>
        </method-permission>
        <exclude-list>
            <description>No fireTheCTO methods of the EmployeeFiring bean may be
                used in this deployment</description>
            <method>
                <ejb-name>EmployeeFiring</ejb-name>
                <method-name>fireTheCTO</method-name>
            </method>
        </exclude-list>
    </assembly-descriptor>
</ejb-jar>
```

7.1.5. Web Content Security Constraints

In a web application, security is defined by the roles that are allowed access to content by a URL pattern that identifies the protected content. This set of information is declared by using the `web.xml` `security-constraint` element.

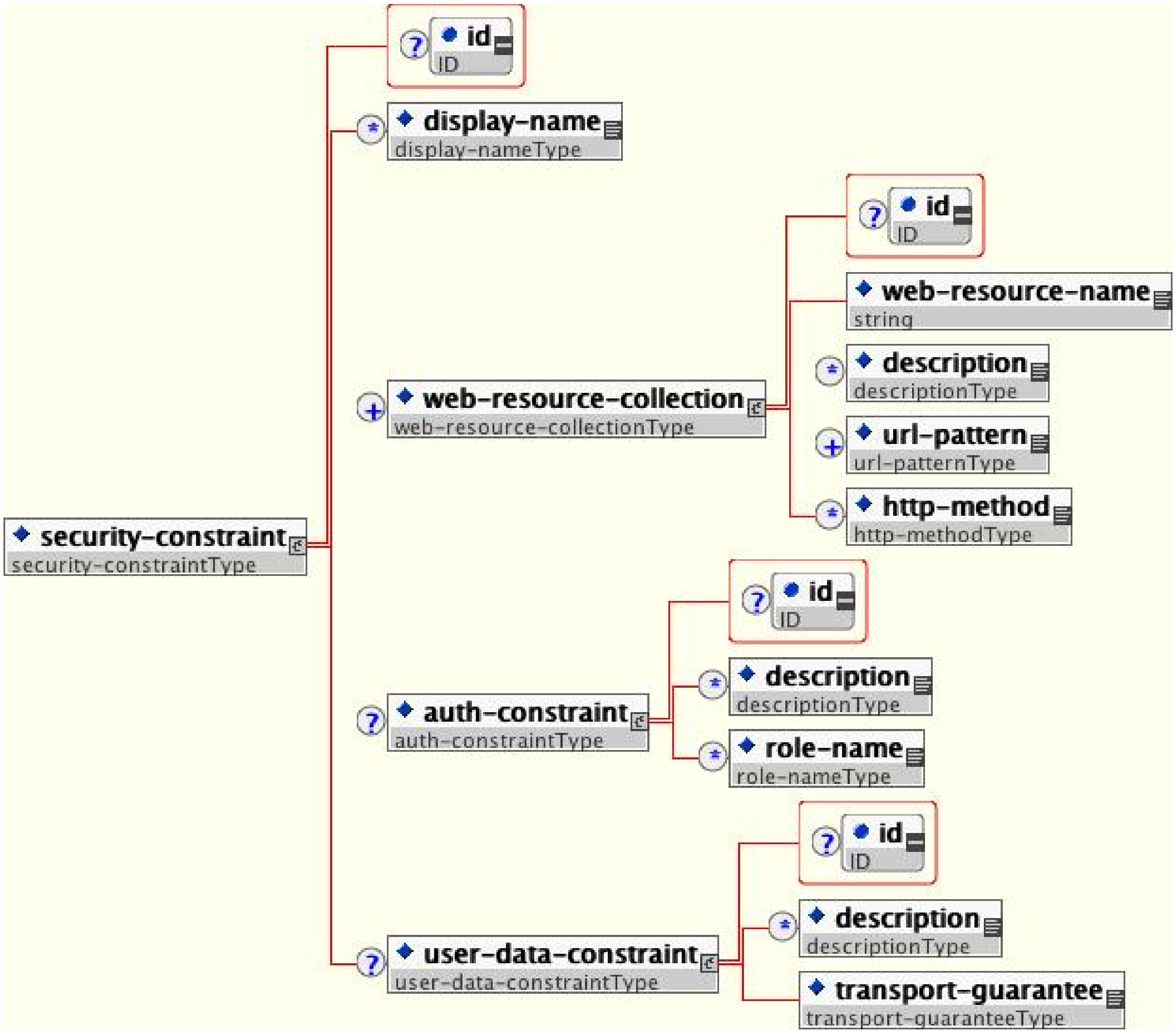


Figure 7.6. The security-constraint element

The content to be secured is declared using one or more `web-resource-collection` elements. Each `web-resource-collection` element contains an optional series of `url-pattern` elements followed by an optional series of `http-method` elements. The `url-pattern` element value specifies a URL pattern against which a request URL must match for the request to correspond to an attempt to access secured content. The `http-method` element value specifies a type of HTTP request to allow.

The optional `user-data-constraint` element specifies the requirements for the transport layer of the client to server connection. The requirement may be for content integrity (preventing data tampering in the communication process) or for confidentiality (preventing reading while in transit). The transport-guarantee element value specifies the degree to which communication between the client and server should be protected. Its values are `NONE`, `INTEGRAL`, and `CONFIDENTIAL`. A value of `NONE` means that the application does not require any transport guarantees. A value of `INTEGRAL` means that the application requires the data sent between the client and server to be sent in such a way that it can't be changed in transit. A value of `CONFIDENTIAL` means that the application requires the data to be transmitted in a fashion that prevents other entities from observing the contents of the transmission. In most cases, the presence of the `INTEGRAL` or `CONFIDENTIAL` flag indicates that the use of SSL is required.

The optional `login-config` element is used to configure the authentication method that should be used, the realm name that should be used for rhw application, and the attributes that are needed by the form login mechanism.

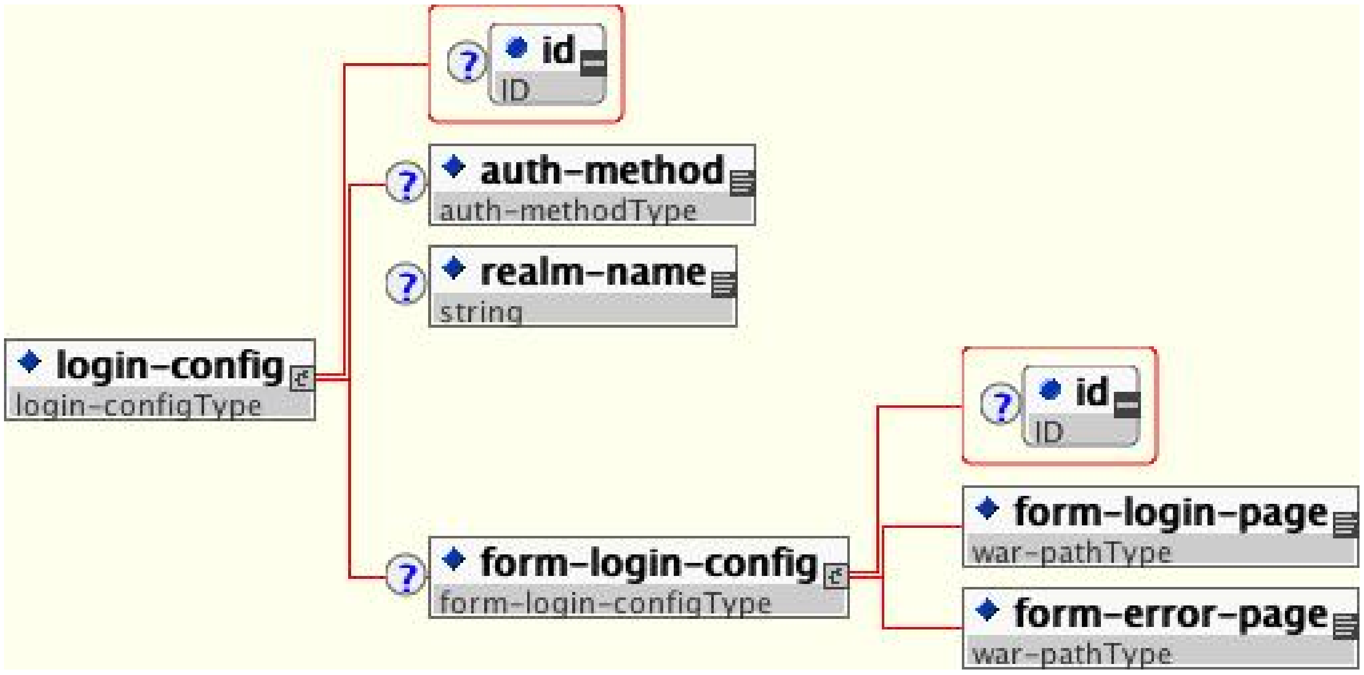


Figure 7.7. The login-config element

The `auth-method` child element specifies the authentication mechanism for the web application. As a prerequisite to gaining access to any web resources that are protected by an authorization constraint, a user must have authenticated using the configured mechanism. Legal `auth-method` values are `BASIC`, `DIGEST`, `FORM`, and `CLIENT-CERT`. The `realm-name` child element specifies the realm name to use in HTTP basic and digest authorization. The `form-login-config` child element specifies the log in as well as error pages that should be used in form-based login. If the `auth-method` value is not `FORM`, then `form-login-config` and its child elements are ignored.

As an example, the `web.xml` descriptor fragment given in Example 7.6 indicates that any URL lying under the web application's `/restricted` path requires an `AuthorizedUser` role. There is no required transport guarantee and the authentication method used for obtaining the user identity is BASIC HTTP authentication.

Example 7.6. A web.xml descriptor fragment which illustrates the use of the security-constraint and related elements.

```
<web-app>
    <!-- ... -->
    <security-constraint>
        <web-resource-collection>
            <web-resource-name>Secure Content</web-resource-name>
            <url-pattern>/restricted/*</url-pattern>
        </web-resource-collection>
        <auth-constraint>
            <role-name>AuthorizedUser</role-name>
        </auth-constraint>
        <user-data-constraint>
            <transport-guarantee>NONE</transport-guarantee>
        </user-data-constraint>
    </security-constraint>
    <!-- ... -->
    <login-config>
        <auth-method>BASIC</auth-method>
        <realm-name>The Restricted Zone</realm-name>
    </login-config>
    <!-- ... -->
    <security-role>
        <description>The role required to access restricted content </description>
        <role-name>AuthorizedUser</role-name>
    </security-role>
</web-app>
```

7.1.6. Enabling Declarative Security in JBoss

The J2EE security elements that have been covered so far describe the security requirements only from the application's perspective. Because J2EE security elements declare logical roles, the application deployer maps the roles from the application domain onto the deployment environment. The J2EE specifications omit these application server-specific details. In JBoss, mapping the application roles onto the deployment environment entails specifying a security manager that implements the J2EE security model using JBoss server specific deployment descriptors. The details behind the security configuration are discussed in Section 7.3.

7.2. An Introduction to JAAS

The JBossSX framework is based on the JAAS API. It is important that you understand the basic elements of the JAAS API to understand the implementation details of JBossSX. The following sections provide an introduction to JAAS to prepare you for the JBossSX architecture discussion later in this chapter.

7.2.1. What is JAAS?

The JAAS 1.0 API consists of a set of Java packages designed for user authentication and authorization. It implements a Java version of the standard Pluggable Authentication Module (PAM) framework and compatibly extends the Java 2 Platform's access control architecture to support user-based authorization. JAAS was first released as an extension package for JDK 1.3 and is bundled with JDK 1.4+. Because the JBossSX framework uses only the authentication capabilities of JAAS to implement the declarative role-based J2EE security model, this introduction focuses on only that topic.

JAAS authentication is performed in a pluggable fashion. This permits Java applications to remain independent from underlying authentication technologies and allows the JBossSX security manager to work in different security infrastructures. Integration with a security infrastructure can be achieved without changing the JBossSX security manager implementation. All that needs to change is the configuration of the authentication stack that JAAS uses.

7.2.1.1. The JAAS Core Classes

The JAAS core classes can be broken down into three categories: common, authentication, and authorization. The following list presents only the common and authentication classes because these are the specific classes used to implement the functionality of JBossSX covered in this chapter.

The are the common classes:

- `Subject` (`javax.security.auth.Subject`)
- `Principal` (`java.security.Principal`)

These are the authentication classes:

- `Callback` (`javax.security.auth.callback.Callback`)
- `CallbackHandler` (`javax.security.auth.callback.CallbackHandler`)
- `Configuration` (`javax.security.auth.login.Configuration`)
- `LoginContext` (`javax.security.auth.login.LoginContext`)
- `LoginModule` (`javax.security.auth.spi.LoginModule`)

7.2.1.1.1. The Subject and Principal Classes

To authorize access to resources, applications first need to authenticate the request's source. The JAAS framework defines the term subject to represent a request's source. The `Subject` class is the central class in JAAS. A `Subject` represents information for a single entity, such as a person or service. It encompasses the entity's principals, public credentials, and private credentials. The JAAS APIs use the existing Java 2 `java.security.Principal` interface to represent a principal, which is essentially just a typed name.

During the authentication process, a subject is populated with associated identities, or principals. A subject may have many principals. For example, a person may have a name principal (John Doe), a social security number principal (123-45-6789), and a username principal (johnd), all of which help distinguish the subject from other subjects. To retrieve the principals associated with a subject, two methods are available:

```
public Set getPrincipals() {...}
public Set getPrincipals(Class c) {...}
```

The first method returns all principals contained in the subject. The second method returns only those principals that are instances of class `c` or one of its subclasses. An empty set is returned if the subject has no matching principals. Note that the `java.security.acl.Group` interface is a subinterface of `java.security.Principal`, so an instance in the principals set may represent a logical grouping of other principals or groups of principals.

7.2.1.1.2. Authentication of a Subject

Authentication of a subject requires a JAAS login. The login procedure consists of the following steps:

1. An application instantiates a `LoginContext` and passes in the name of the login configuration and a `CallbackHandler` to populate the `Callback` objects, as required by the configuration `LoginModules`.

2. The `LoginContext` consults a `Configuration` to load all the `LoginModules` included in the named login configuration. If no such named configuration exists the `other` configuration is used as a default.

3. The application invokes the `LoginContext.login` method.

4. The login method invokes all the loaded `LoginModules`. As each `LoginModule` attempts to authenticate the subject, it invokes the handle method on the associated `CallbackHandler` to obtain the information required for the authentication process. The required information is passed to the handle method in the form of an array

of `Callback` objects. Upon success, the `LoginModules` associate relevant principals and credentials with the subject.

5. The `LoginContext` returns the authentication status to the application. Success is represented by a return from the login method. Failure is represented through a LoginException being thrown by the login method.

6. If authentication succeeds, the application retrieves the authenticated subject using the `LoginContext.getSubject` method.

7. After the scope of the subject authentication is complete, all principals and related information associated with the subject by the login method can be removed by invoking the `LoginContext.logout` method.

The `LoginContext` class provides the basic methods for authenticating subjects and offers a way to develop an application that is independent of the underlying authentication technology. The `LoginContext` consults a `Configuration` to determine the authentication services configured for a particular application. `LoginModule` classes represent the authentication services. Therefore, you can plug different login modules into an application without changing the application itself. The following code shows the steps required by an application to authenticate a subject.

```
CallbackHandler handler = new MyHandler();
LoginContext lc = new LoginContext("some-config", handler);

try {
    lc.login();
    Subject subject = lc.getSubject();
} catch(LoginException e) {
    System.out.println("authentication failed");
    e.printStackTrace();
}

// Perform work as authenticated Subject
// ...

// Scope of work complete, logout to remove authentication info
try {
    lc.logout();
} catch(LoginException e) {
    System.out.println("logout failed");
    e.printStackTrace();
}

// A sample MyHandler class
class MyHandler
    implements CallbackHandler
{
    public void handle(Callback[] callbacks) throws
        IOException, UnsupportedCallbackException
    {
        for (int i = 0; i < callbacks.length; i++) {
            if (callbacks[i] instanceof NameCallback) {
                NameCallback nc = (NameCallback)callbacks[i];
                nc.setName(username);
            } else if (callbacks[i] instanceof PasswordCallback) {
                PasswordCallback pc = (PasswordCallback)callbacks[i];
                pc.setPassword(password);
            } else {
                throw new UnsupportedCallbackException(callbacks[i],
                                                       "Unrecognized Callback");
            }
        }
    }
}
```

Developers integrate with an authentication technology by creating an implementation of the `LoginModule` interface. This allows an administrator to plug different authentication technologies into an application. You can chain together multiple `LoginModules` to allow for more than one authentication technology to participate in the authentication process. For example, one `LoginModule` may perform username/password-based authentication, while another may interface to hardware devices such as smart card readers or biometric authenticators.

The life cycle of a `LoginModule` is driven by the `LoginContext` object against which the client creates and issues the login method. The process consists of two phases. The steps of the process are as follows:

- The `LoginContext` creates each configured `LoginModule` using its public no-arg constructor.
- Each `LoginModule` is initialized with a call to its initialize method. The `Subject` argument is guaranteed to be non-null. The signature of the initialize method is: `public void initialize(Subject subject, CallbackHandler callbackHandler, Map sharedState, Map options)`.
- The `login` method is called to start the authentication process. For example, a method implementation might prompt the user for a username and password and then verify the information against data stored in a naming service such as NIS or LDAP. Alternative implementations might interface to smart cards and biometric devices, or simply extract user information from the underlying operating system. The validation of user identity by each `LoginModule` is considered phase 1 of JAAS authentication. The signature of the `login` method is `boolean login() throws LoginException`. A `LoginException` indicates failure. A return value of true indicates that the method succeeded, whereas a return valueof false indicates that the login module should be ignored.
- If the `LoginContext`'s overall authentication succeeds, `commit` is invoked on each `LoginModule`. If phase 1 succeeds for a `LoginModule`, then the commit method continues with phase 2 and associates the relevant principals, public credentials, and/or private credentials with the subject. If phase 1 fails for a `LoginModule`, then `commit` removes any previously stored authentication state, such as usernames or passwords. The signature of the `commit` method is: `boolean commit() throws LoginException`. Failure to complete the commit phase is indicated by throwing a `LoginException`. A return of true indicates that the method succeeded, whereas a return of false indicates that the login module should be ignored.
- If the `LoginContext`'s overall authentication fails, then the `abort` method is invoked on each `LoginModule`. The `abort` method removes or destroys any authentication state created by the login or initialize methods. The signature of the `abort` method is `boolean abort() throws LoginException`. Failure to complete the `abort` phase is indicated by throwing a `LoginException`. A return of true indicates that the method succeeded, whereas a return of false indicates that the login module should be ignored.
- To remove the authentication state after a successful login, the application invokes `logout` on the `LoginContext`. This in turn results in a `logout` method invocation on each `LoginModule`. The `logout` method removes the principals and credentials originally associated with the subject during the `commit` operation. Credentials should be destroyed upon removal. The signature of the `logout` method is: `boolean logout() throws LoginException`. Failure to complete the logout process is indicated by throwing a `LoginException`. A return of true indicates that the method succeeded, whereas a return of false indicates that the login module should be ignored.

When a `LoginModule` must communicate with the user to obtain authentication information, it uses a `CallbackHandler` object. Applications implement the `CallbackHandler` interface and pass it to the LoginContext, which forwards it directly to the underlying login modules. Login modules use the `CallbackHandler` both to gather input from users, such as a password or smart card PIN, and to supply information to users, such as status information. By allowing the application to specify the `CallbackHandler`, underlying `LoginModules` remain independent from the different ways applications interact with users. For example, a `CallbackHandler`'s implementation for a GUI application might display a window to solicit user input. On the other hand, a `callbackhandler`'s implementation for a non-GUI environment, such as an application server, might simply obtain credential information by using an application server API. The `callbackhandler` interface has one method to implement:

```
void handle(Callback[] callbacks)
    throws java.io.IOException,
           UnsupportedCallbackException;
```

The `Callback` interface is the last authentication class we will look at. This is a tagging interface for which several default implementations are provided, including the `NameCallback` and `PasswordCallback` used in an earlier example. A `LoginModule` uses a `Callback` to request information required by the authentication mechanism. `LoginModules` pass an array of `Callbacks` directly to the `CallbackHandler.handle` method during the authentication's login phase. If a `callbackhandler` does not understand how to use a `Callback` object passed into the handle method, it throws an `UnsupportedCallbackException` to abort the login call.

7.3. The JBoss Security Model

Similar to the rest of the JBoss architecture, security at the lowest level is defined as a set of interfaces for which alternate implementations may be provided. Three basic interfaces define the JBoss server security layer: `org.jboss.security.AuthenticationManager`, `org.jboss.security.RealmMapping`, and `org.jboss.security.SecurityProxy`. Figure 7.8 shows a class diagram of the security interfaces and their relationship to the EJB container architecture.

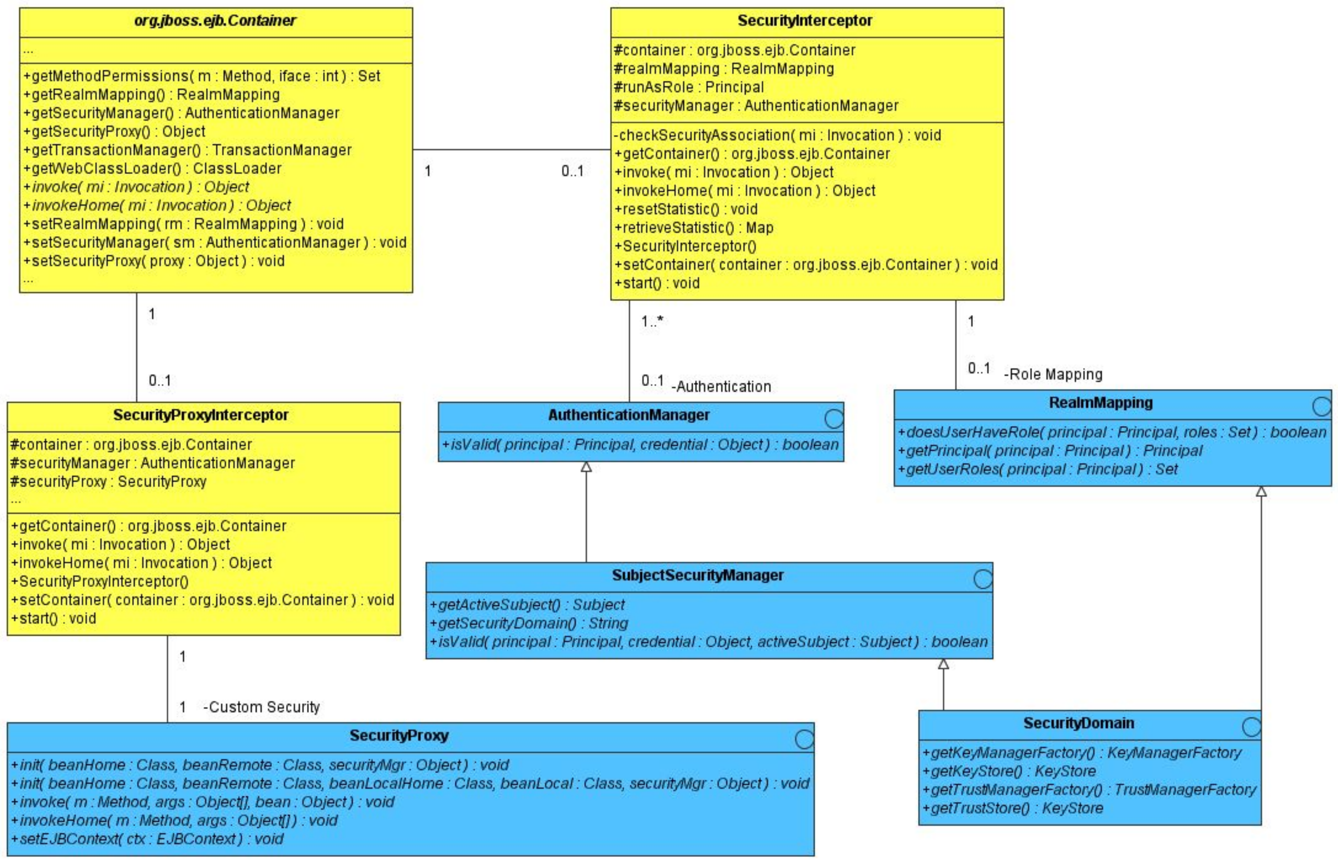

org.jboss.ejb.Container
...
+getMethodPermissions(m : Method, iface : int) : Set
+getRealmMapping() : RealmMapping
+getSecurityManager() : AuthenticationManager
+getSecurityProxy() : Object
+getTransactionManager() : TransactionManager
+getWebClassLoader() : ClassLoader
+invoke(mi : Invocation) : Object
+invokeHome(mi : Invocation) : Object
+setRealmMapping(rm : RealmMapping) : void
+setSecurityManager(sm : AuthenticationManager) : void
+setSecurityProxy(proxy : Object) : void
...
SecurityInterceptor
#container : org.jboss.ejb.Container
#realmMapping : RealmMapping
#runAsRole : Principal
#securityManager : AuthenticationManager
-checkSecurityAssociation(mi : Invocation) : void
+getContainer() : org.jboss.ejb.Container
+invoke(mi : Invocation) : Object
+invokeHome(mi : Invocation) : Object
+resetStatistic() : void
+retrieveStatistic() : Map
+SecurityInterceptor()
+setContainer(container : org.jboss.ejb.Container) : void
+start() : void
1
0..1
1
0..1
1..*
0..1 -Authentication
1
0..1 -Role Mapping
SecurityProxyInterceptor
#container : org.jboss.ejb.Container
#securityManager : AuthenticationManager
#securityProxy : SecurityProxy
...
+getContainer() : org.jboss.ejb.Container
+invoke(mi : Invocation) : Object
+invokeHome(mi : Invocation) : Object
+SecurityProxyInterceptor()
+setContainer(container : org.jboss.ejb.Container) : void
+start() : void
AuthenticationManager
+isValid(principal : Principal, credential : Object) : boolean
RealmMapping
+doesUserHaveRole(principal : Principal, roles : Set) : boolean
+getPrincipal(principal : Principal) : Principal
+getUserRoles(principal : Principal) : Set
SubjectSecurityManager
+getActiveSubject() : Subject
+getSecurityDomain() : String
+isValid(principal : Principal, credential : Object, activeSubject : Subject) : boolean
1
1 -Custom Security
SecurityProxy
+init(beanHome : Class, beanRemote : Class, securityMgr : Object) : void
+init(beanHome : Class, beanRemote : Class, beanLocalHome : Class, beanLocal : Class, securityMgr : Object) : void
+invoke(m : Method, args : Object[], bean : Object) : void
+invokeHome(m : Method, args : Object[]) : void
+setEJBContext(ctx : EJBContext) : void
SecurityDomain
+getKeyManagerFactory() : KeyManagerFactory
+getKeyStore() : KeyStore
+getTrustManagerFactory() : TrustManagerFactory
+getTrustStore() : KeyStore

Figure 7.8. The key security model interfaces and their relationship to the JBoss server EJB container elements.

The light blue classes represent the security interfaces while the yellow classes represent the EJB container layer. The two interfaces required for the implementation of the J2EE security model are `org.jboss.security.AuthenticationManager` and `org.jboss.security.RealmMapping`. The roles of the security interfaces presented in Figure 7.8 are summarized in the following list.

- **AuthenticationManager**: This interface is responsible for validating credentials associated with principals. Principals are identities, such as usernames, employee numbers, and social security numbers. Credentials are proof of the identity, such as passwords, session keys, and digital signatures. The `isValid` method is invoked to determine whether a user identity and associated credentials as known in the operational environment are valid proof of the user's identity.

- **RealmMapping**: This interface is responsible for principal mapping and role mapping. The `getPrincipal` method takes a user identity as known in the operational environment and returns the application domain identity. The `doesUserHaveRole` method validates that the user identity in the operation environment has been assigned the indicated role from the application domain.

- **SecurityProxy**: This interface describes the requirements for a custom `SecurityProxyInterceptor` plugin. A `SecurityProxy` allows for the externalization of custom security checks on a per-method basis for both the EJB home and remote interface methods.

- **SubjectSecurityManager**: This is a subinterface of `AuthenticationManager` that adds accessor methods for obtaining the security domain name of the security manager and the current thread's authenticated `Subject`.

- **SecurityDomain**: This is an extension of the `AuthenticationManager`, `RealmMapping`, and `SubjectSecurityManager` interfaces. It is a move to a comprehensive security interface based on the JAAS Subject, a `java.security.KeyStore`, and the JSSE `com.sun.net.ssl.KeyManagerFactory` and `com.sun.net.ssl.TrustManagerFactory` interfaces. This interface is a work in progress that will be the basis of a multi-domain security architecture that will better support ASP style deployments of applications and resources.

Note that the `AuthenticationManager`, `RealmMapping` and `SecurityProxy` interfaces have no association to JAAS related classes. Although the JBossSX framework is heavily dependent on JAAS, the basic security interfaces required for implementation of the J2EE security model are not. The JBossSX framework is simply an implementation of the basic security plug-in interfaces that are based on JAAS. The component diagram presented in Figure 7.9 illustrates this fact. The implication of this plug-in architecture is that you are free to replace the JAAS-based JBossSX implementation classes with your own custom security manager implementation that does not make use of JAAS, if you so desire. You'll see how to do this when you look at the JBossSX MBeans available for the configuration of JBossSX in Figure 7.9.

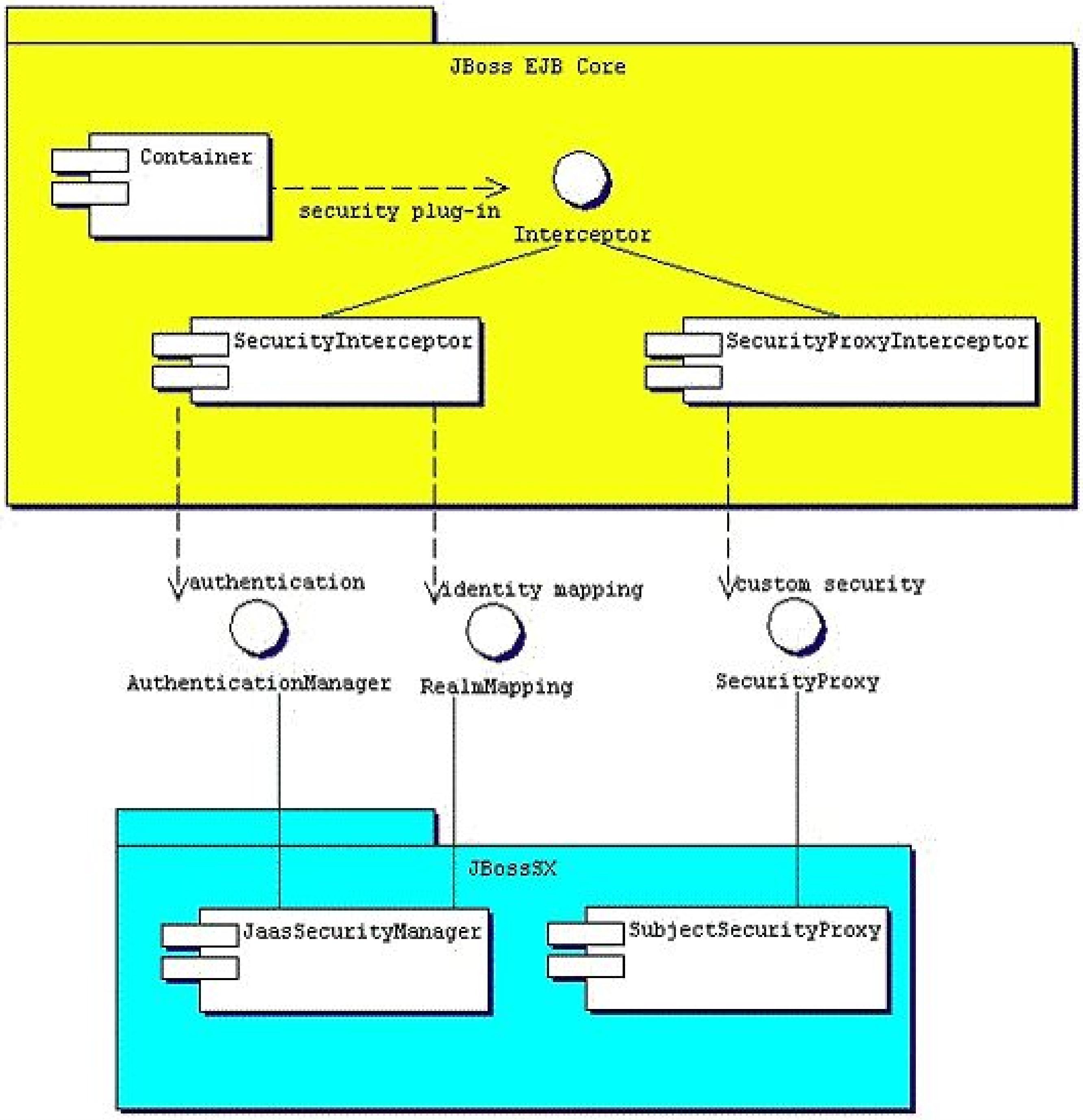


Figure 7.9. The relationship between the JBossSX framework implementation classes and the JBoss server EJB container layer.

7.3.1. Enabling Declarative Security in JBoss Revisited

Earlier in this chapter, the discussion of the J2EE standard security model ended with a requirement for the use of JBoss server-specific deployment descriptor to enable security. The details of this configuration are presented here. Figure 7.10 shows the JBoss-specific EJB and web application deployment descriptor's security-related elements.

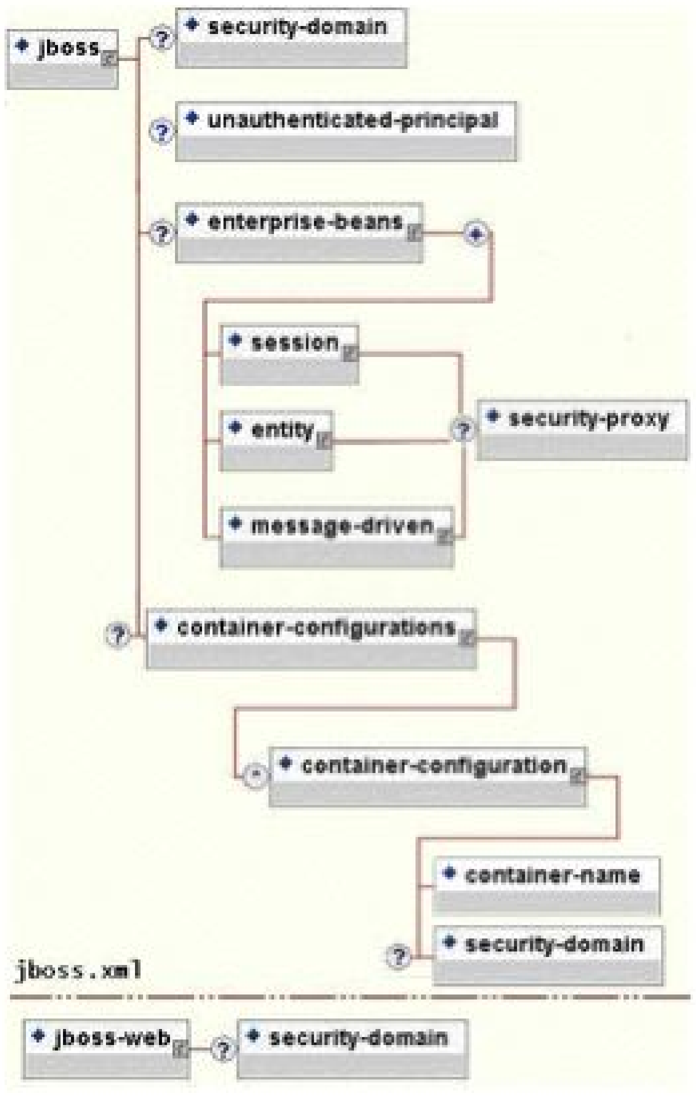


Figure 7.10. The security element subsets of the JBoss server jboss.xml and jboss-web.xml deployment descriptors.

The value of a `security-domain` element specifies the JNDI name of the security manager interface implementation that JBoss uses for the EJB and web containers. This is an object that implements both of the `AuthenticationManager` and `RealmMapping` interfaces. When specified as a top-level element it defines what security domain in effect for all EJBs in the deployment unit. This is the typical usage because mixing security managers within a deployment unit complicates inter-component operation and administration.

To specify the security domain for an individual EJB, you specify the `security-domain` at the container configuration level. This will override any top-level security-domain element.

The `unauthenticated-principal` element specifies the name to use for the `Principal` object returned by the `EJBContext.getUserPrincipal` method when an unauthenticated user invokes an EJB. Note that this conveys no special permissions to an unauthenticated caller. Its primary purpose is to allow unsecured servlets and JSP pages to invoke unsecured EJBs and allow the target EJB to obtain a non-null `Principal` for the caller using the `getUserPrincipal` method. This is a J2EE specification requirement.

The `security-proxy` element identifies a custom security proxy implementation that allows per-request security checks outside the scope of the EJB declarative security model without embedding security logic into the EJB implementation. This may be an implementation of the `org.jboss.security.SecurityProxy` interface, or just an object that implements methods in the home, remote, local home or local interfaces of the EJB to secure without implementing any common interface. If the given class does not implement the `SecurityProxy` interface, the instance must be wrapped in a `SecurityProxy` implementation that delegates the method invocations to the object. The `org.jboss.security.SubjectSecurityProxy` is an example `SecurityProxy` implementation used by the default JBossSX installation.

Take a look at a simple example of a custom `SecurityProxy` in the context of a trivial stateless session bean. The custom `SecurityProxy` validates that no one invokes the bean's `echo` method with a four-letter word as its argument. This is a check that is not possible with role-based security; you cannot define a `FourLetterEchoInvoker` role because the security context is the method argument, not a property of the caller. The code for the custom `SecurityProxy` is given in Example 7.7, and the full source code is available in the `src/main/org/jboss/book/security/ex1` directory of the book examples.

Example 7.7. The example 1 custom EchoSecurityProxy implementation that enforces the echo argument-based security constraint.

```
package org.jboss.book.security.ex1;

import java.lang.reflect.Method;
import javax.ejb.EJBContext;

import org.apache.log4j.Category;

import org.jboss.security.SecurityProxy;

/** A simple example of a custom SecurityProxy implementation
 *  that demonstrates method argument based security checks.
 * @author Scott.Stark@jboss.org
 * @version $Revision: 1.2 $
 */
public class EchoSecurityProxy implements SecurityProxy
{
    Category log = Category.getInstance(EchoSecurityProxy.class);
    Method echo;

    public void init(Class beanHome, Class beanRemote,
                     Object securityMgr)
        throws InstantiationException
    {
        log.debug("init, beanHome="+beanHome
                  + ", beanRemote="+beanRemote
                  + ", securityMgr="+securityMgr);
        // Get the echo method for equality testing in invoke
        try {
            Class[] params = {String.class};
            echo = beanRemote.getDeclaredMethod("echo", params);
        } catch(Exception e) {
            String msg = "Failed to finde an echo(String) method";
            log.error(msg, e);
            throw new InstantiationException(msg);
        }
    }

    public void setEJBContext(EJBContext ctx)
    {
        log.debug("setEJBContext, ctx="+ctx);
    }

    public void invokeHome(Method m, Object[] args)
        throws SecurityException
    {
        // We don't validate access to home methods
    }

    public void invoke(Method m, Object[] args, Object bean)
        throws SecurityException
    {
        log.debug("invoke, m="+m);
        // Check for the echo method
        if (m.equals(echo)) {
            // Validate that the msg arg is not 4 letter word
            String arg = (String) args[0];
            if (arg == null || arg.length() == 4)
                throw new SecurityException("No 4 letter words");
        }
        // We are not responsible for doing the invoke
    }
}
```

The `EchoSecurityProxy` checks that the method to be invoked on the bean instance corresponds to the `echo(String)` method loaded the init method. If there is a match, the method argument is obtained and its length compared against 4 or null. Either case results in a `SecurityException` being thrown. Certainly this is a contrived example, but only in its application. It is a common requirement that applications must perform security checks based on the value of method arguments. The point of the example is to demonstrate how custom security beyond the scope of the standard declarative security model can be introduced independent of the bean implementation. This allows the specification and coding of the security requirements to be delegated to security experts. Since the security proxy layer can be done independent of the bean implementation, security can be changed to match the deployment environment requirements.

The associated `jboss.xml` descriptor that installs the `EchoSecurityProxy` as the custom proxy for the `EchoBean` is given in Example 7.8.

Example 7.8. The jboss.xml descriptor, which configures the EchoSecurityProxy as the custom security proxy for the EchoBean.

```
<jboss>
    <security-domain>java:/jaas/other</security-domain>

    <enterprise-beans>
        <session>
            <ejb-name>EchoBean</ejb-name>
            <security-proxy>org.jboss.book.security.ex1.EchoSecurityProxy</security-proxy>
        </session>
    </enterprise-beans>
</jboss>
```

Now test the custom proxy by running a client that attempts to invoke the `EchoBean.echo` method with the arguments `Hello` and `Four` as illustrated in this fragment:

```
public class ExClient
{
    public static void main(String args[])
        throws Exception
    {
        Logger log = Logger.getLogger("ExClient");
        log.info("Looking up EchoBean");

        InitialContext iniCtx = new InitialContext();
        Object ref = iniCtx.lookup("EchoBean");
        EchoHome home = (EchoHome) ref;
        Echo echo = home.create();

        log.info("Created Echo");
        log.info("Echo.echo('Hello') = "+echo.echo("Hello"));
        log.info("Echo.echo('Four') = "+echo.echo("Four"));
    }
}
```

The first call should succeed, while the second should fail due to the fact that `Four` is a four-letter word. Run the client as follows using Ant from the examples directory:

```
[examples]$ ant -Dchap=security -Dex=1 run-example
run-example1:
...
     [echo] Waiting for 5 seconds for deploy...
     [java] [INFO,ExClient] Looking up EchoBean
     [java] [INFO,ExClient] Created Echo
     [java] [INFO,ExClient] Echo.echo('Hello') = Hello
     [java] Exception in thread "main" java.rmi.AccessException: SecurityException; nested exception is:
     [java]     java.lang.SecurityException: No 4 letter words
...
     [java] Caused by: java.lang.SecurityException: No 4 letter words
...
```

The result is that the `echo('Hello')` method call succeeds as expected and the `echo('Four')` method call results in a rather messy looking exception, which is also expected. The above output has been truncated to fit in the book. The key part to the exception is that the `SecurityException("No 4 letter words")` generated by the `EchoSecurityProxy` was thrown to abort the attempted method invocation as desired.

7.4. The JBoss Security Extension Architecture

The preceding discussion of the general JBoss security layer has stated that the JBossSX security extension framework is an implementation of the security layer interfaces. This is the primary purpose of the JBossSX framework. The details of the implementation are interesting in that it offers a great deal of customization for integration into existing security infrastructures. A security infrastructure can be anything from a database or LDAP server to a sophisticated security software suite. The integration flexibility is achieved using the pluggable authentication model available in the JAAS framework.

The heart of the JBossSX framework is `org.jboss.security.plugins.JaasSecurityManager`. This is the default implementation of the `AuthenticationManager` and `RealmMapping` interfaces. Figure 7.11 shows how the `JaasSecurityManager` integrates into the EJB and web container layers based on the `security-domain` element of the corresponding component deployment descriptor.

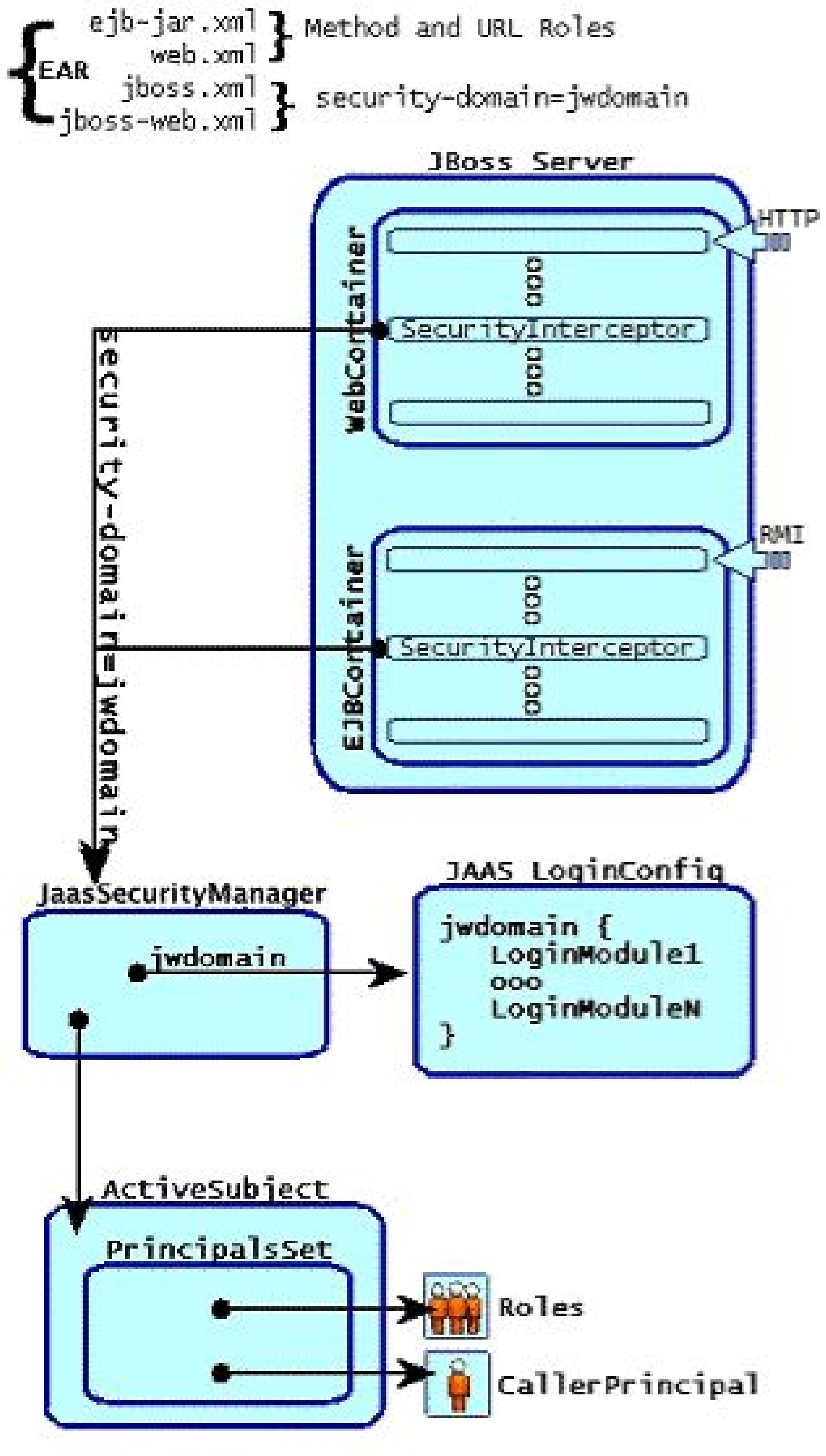


Figure 7.11. The relationship between the security-domain component deployment descriptor value, the component container and the JaasSecurityManager.

Figure 7.11 depicts an enterprise application that contains both EJBs and web content secured under the security domain `jwdomain`. The EJB and web containers have a request interceptor architecture that includes a security interceptor, which enforces the container security model. At deployment time, the `security-domain` element value in the `jboss.xml` and `jboss-web.xml` descriptors is used to obtain the security manager instance associated with the container. The security interceptor then uses the security manager to perform its role. When a secured component is requested, the security interceptor delegates security checks to the security manager instance associated with the container.

The JBossSX `JaasSecurityManager` implementation performs security checks based on the information associated with the `Subject` instance that results from executing the JAAS login modules configured under the name matching the `security-domain` element value. We will drill into the `JaasSecurityManager` implementation and its use of JAAS in the following section.

7.4.1. How the JaasSecurityManager Uses JAAS

The `JaasSecurityManager` uses the JAAS packages to implement the `AuthenticationManager` and `RealmMapping` interface behavior. In particular, its behavior derives from the execution of the login module instances that are configured under the name that matches the security domain to which the `JaasSecurityManager` has been assigned. The login modules implement the security domain's principal authentication and role-mapping behavior. Thus, you can use the `JaasSecurityManager` across different security domains simply by plugging in different login module configurations for the domains.

To illustrate the details of the `JaasSecurityManager`'s usage of the JAAS authentication process, you will walk through a client invocation of an EJB home method invocation. The prerequisite setting is that the EJB has been deployed in the JBoss server and its home interface methods have been secured using `method-permission` elements in the `ejb-jar.xml` descriptor, and it has been assigned a security domain named `jwdomain` using the `jboss.xml` descriptor `security-domain` element.

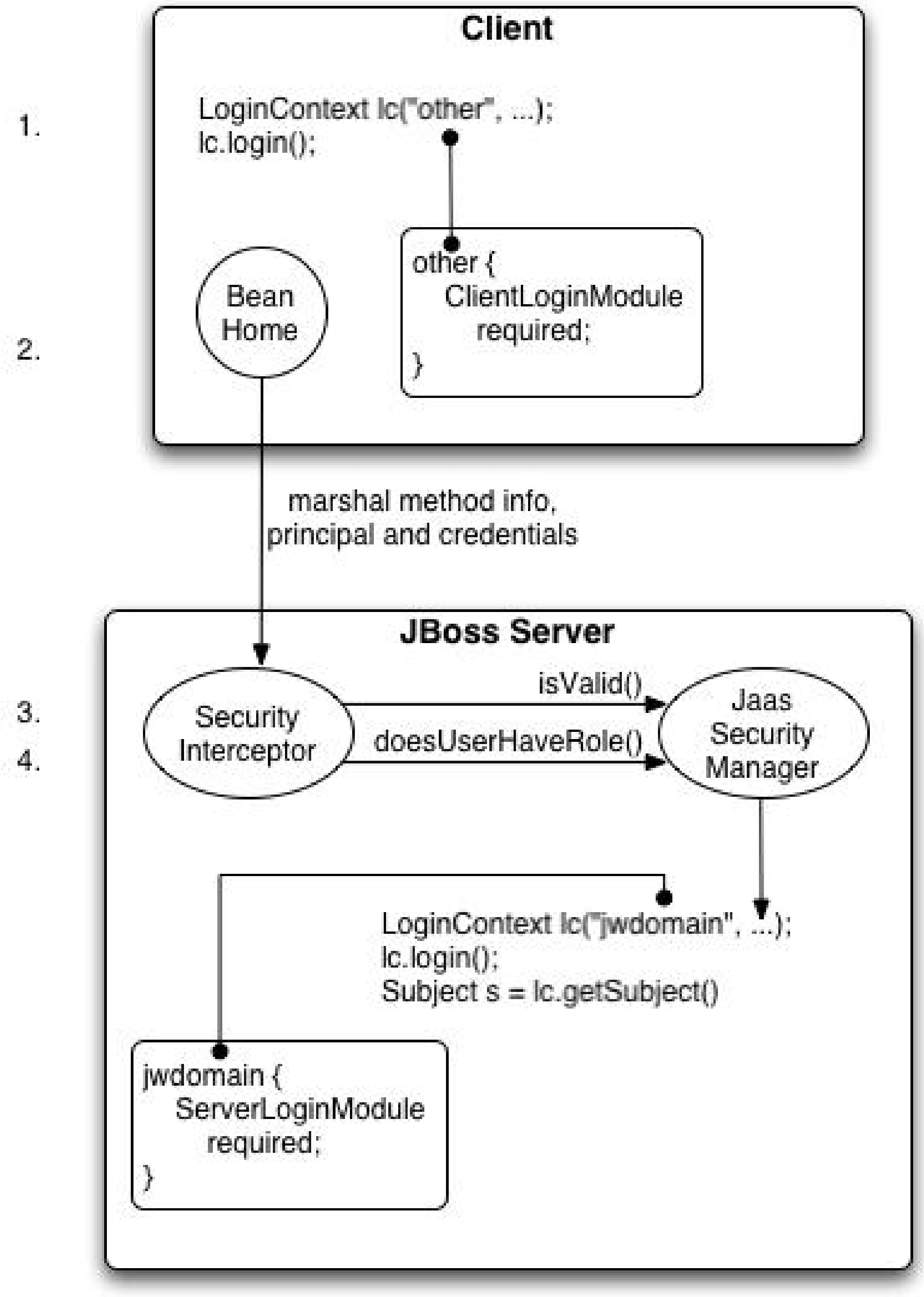


Figure 7.12. An illustration of the steps involved in the authentication and authorization of a secured EJB home method invocation.

Figure 7.12 provides a view of the client to server communication we will discuss. The numbered steps shown are:

1. The client first has to perform a JAAS login to establish the principal and credentials for authentication, and this is labeled *Client Side Login* in the figure. This is how clients establish their login identities in JBoss. Sup-

port for presenting the login information via JNDI `InitialContext` properties is provided via an alternate configuration. A JAAS login entails creating a `LoginContext` instance and passing the name of the configuration to use. The configuration name is `other`. This one-time login associates the login principal and credentials with all subsequent EJB method invocations. Note that the process might not authenticate the user. The nature of the client-side login depends on the login module configuration that the client uses. In this example, the `other` client-side login configuration entry is set up to use the `ClientLoginModule` module (an `org.jboss.security.ClientLoginModule`). This is the default client side module that simply binds the username and password to the JBoss EJB invocation layer for later authentication on the server. The identity of the client is not authenticated on the client.

2. Later, the client obtains the EJB home interface and attempts to create a bean. This event is labeled as *Home Method Invocation*. This results in a home interface method invocation being sent to the JBoss server. The invocation includes the method arguments passed by the client along with the user identity and credentials from the client-side JAAS login performed in step 1.

3. On the server side, the security interceptor first requires authentication of the user invoking the call, which, as on the client side, involves a JAAS login.

4. The security domain under which the EJB is secured determines the choice of login modules. The security domain name is used as the login configuration entry name passed to the `LoginContext` constructor. The EJB security domain is `jwdomain`. If the JAAS login authenticates the user, a JAAS `Subject` is created that contains the following in its `PrincipalsSet`:

    - A `java.security.Principal` that corresponds to the client identity as known in the deployment security environment.

    - A `java.security.acl.Group` named `Roles` that contains the role names from the application domain to which the user has been assigned. `org.jboss.security.SimplePrincipal` objects are used to represent the role names; `SimplePrincipal` is a simple string-based implementation of `Principal`. These roles are used to validate the roles assigned to methods in `ejb-jar.xml` and the `EJBContext.isCallerInRole(String)` method implementation.

    - An optional `java.security.acl.Group` named `CallerPrincipal`, which contains a single `org.jboss.security.SimplePrincipal` that corresponds to the identity of the application domain's caller. The `CallerPrincipal` sole group member will be the value returned by the `EJBContext.getCallerPrincipal()` method. The purpose of this mapping is to allow a `Principal` as known in the operational security environment to map to a `Principal` with a name known to the application. In the absence of a `CallerPrincipal` mapping the deployment security environment principal is used as the `getCallerPrincipal` method value. That is, the operational principal is the same as the application domain principal.

5. The final step of the security interceptor check is to verify that the authenticated user has permission to invoke the requested method This is labeled as *Server Side Authorization* in Figure 7.12. Performing the authorization this entails the following steps:

    - Obtain the names of the roles allowed to access the EJB method from the EJB container. The role names are determined by `ejb-jar.xml` descriptor role-name elements of all `method-permission` elements containing the invoked method.

- If no roles have been assigned, or the method is specified in an `exclude-list` element, then access to the method is denied. Otherwise, the `doesUserHaveRole` method is invoked on the security manager by the security interceptor to see if the caller has one of the assigned role names. This method iterates through the role names and checks if the authenticated user's Subject `Roles` group contains a `SimplePrincipal` with the assigned role name. Access is allowed if any role name is a member of the `Roles` group. Access is denied if none of the role names are members.

- If the EJB was configured with a custom security proxy, the method invocation is delegated to it. If the security proxy wants to deny access to the caller, it will throw a `java.lang.SecurityException`. If no `SecurityException` is thrown, access to the EJB method is allowed and the method invocation passes to the next container interceptor. Note that the `SecurityProxyInterceptor` handles this check and this interceptor is not shown.

Every secured EJB method invocation, or secured web content access, requires the authentication and authorization of the caller because security information is handled as a stateless attribute of the request that must be presented and validated on each request. This can be an expensive operation if the JAAS login involves client-to-server communication. Because of this, the `JaasSecurityManager` supports the notion of an authentication cache that is used to store principal and credential information from previous successful logins. You can specify the authentication cache instance to use as part of the `JaasSecurityManager` configuration as you will see when the associated MBean service is discussed in following section. In the absence of any user-defined cache, a default cache that maintains credential information for a configurable period of time is used.

7.4.2. The JaasSecurityManagerService MBean

The `JaasSecurityManagerService` MBean service manages security managers. Although its name begins with *Jaas*, the security managers it handles need not use JAAS in their implementation. The name arose from the fact that the default security manager implementation is the `JaasSecurityManager`. The primary role of the `JaasSecurityManagerService` is to externalize the security manager implementation. You can change the security manager implementation by providing an alternate implementation of the `AuthenticationManager` and `RealmMapping` interfaces.

The second fundamental role of the `JaasSecurityManagerService` is to provide a JNDI `javax.naming.spi.ObjectFactory` implementation to allow for simple code-free management of the JNDI name to security manager implementation mapping. It has been mentioned that security is enabled by specifying the JNDI name of the security manager implementation via the `security-domain` deployment descriptor element. When you specify a JNDI name, there has to be an object-binding there to use. To simplify the setup of the JNDI name to security manager bindings, the `JaasSecurityManagerService` manages the association of security manager instances to names by binding a next naming system reference with itself as the JNDI ObjectFactory under the name `java:/jaas`. This allows one to use a naming convention of the form `java:/jaas/XYZ` as the value for the `security-domain` element, and the security manager instance for the `XYZ` security domain will be created as needed for you. The security manager for the domain `XYZ` is created on the first lookup against the `java:/jaas/XYZ` binding by creating an instance of the class specified by the `SecurityManagerClassName` attribute using a constructor that takes the name of the security domain. For example, consider the following container security configuration snippet:

```
<jboss>
    <!-- Configure all containers to be secured under the "hades" security domain -->
    <security-domain>java:/jaas/hades</security-domain>
    <!-- ... -->
```

```
</jboss>
```

Any lookup of the name `java:/jaas/hades` will return a security manager instance that has been associated with the security domain named `hades`. This security manager will implement the AuthenticationManager and RealmMapping security interfaces and will be of the type specified by the `JaasSecurityManagerService` `SecurityManagerClassName` attribute.

The `JaasSecurityManagerService` MBean is configured by default for use in the standard JBoss distribution, and you can often use the default configuration as is. The configurable attributes of the `JaasSecurityManagerService` include:

- **SecurityManagerClassName**: The name of the class that provides the security manager implementation. The implementation must support both the `org.jboss.security.AuthenticationManager` and `org.jboss.security.RealmMapping` interfaces. If not specified this defaults to the JAAS-based `org.jboss.security.plugins.JaasSecurityManager`.

- **CallbackHandlerClassName**: The name of the class that provides the `javax.security.auth.callback.CallbackHandler` implementation used by the `JaasSecurityManager`. You can override the handler used by the `JaasSecurityManager` if the default implementation (`org.jboss.security.auth.callback.SecurityAssociationHandler`) does not meet your needs. This is a rather deep configuration that generally should not be set unless you know what you are doing.

- **SecurityProxyFactoryClassName**: The name of the class that provides the `org.jboss.security.SecurityProxyFactory` implementation. If not specified this defaults to `org.jboss.security.SubjectSecurityProxyFactory`.

- **AuthenticationCacheJndiName**: Specifies the location of the security credential cache policy. This is first treated as an `ObjectFactory` location capable of returning `CachePolicy` instances on a per-security-domain basis. This is done by appending the name of the security domain to this name when looking up the `CachePolicy` for a domain. If this fails, the location is treated as a single `CachePolicy` for all security domains. As a default, a timed cache policy is used.

- **DefaultCacheTimeout**: Specifies the default timed cache policy timeout in seconds. The default value is 1800 seconds (30 minutes). The value you use for the timeout is a tradeoff between frequent authentication operations and how long credential information may be out of synch with respect to the security information store. If you want to disable caching of security credentials, set this to 0 to force authentication to occur every time. This has no affect if the `AuthenticationCacheJndiName` has been changed from the default value.

- **DefaultCacheResolution**: Specifies the default timed cache policy resolution in seconds. This controls the interval at which the cache current timestamp is updated and should be less than the `DefaultCacheTimeout` in order for the timeout to be meaningful. The default resolution is 60 seconds(1 minute). This has no affect if the `AuthenticationCacheJndiName` has been changed from the default value.

- **DefaultUnauthenticatedPrincipal**: Specifies the principal to use for unauthenticated users. This setting makes it possible to set default permissions for users who have not been authenticated.

The `JaasSecurityManagerService` also supports a number of useful operations. These include flushing any security domain authentication cache at runtime, getting the list of active users in a security domain authentication cache, and any of the security manager interface methods.

Flushing a security domain authentication cache can be used to drop all cached credentials when the underlying store has been updated and you want the store state to be used immediately. The MBean operation signature is: `public void flushAuthenticationCache(String securityDomain)`.

This can be invoked programmatically using the following code snippet:

```
MBeanServer server = ...;
String jaasMgrName = "jboss.security:service=JaasSecurityManager";
ObjectName jaasMgr = new ObjectName(jaasMgrName);
Object[] params = {domainName};
String[] signature = {"java.lang.String"};
server.invoke(jaasMgr, "flushAuthenticationCache", params, signature);
```

Getting the list of active users provides a snapshot of the `Principals` keys in a security domain authentication cache that are not expired. The MBean operation signature is: `public List getAuthenticationCachePrincipals(String securityDomain)`.

This can be invoked programmatically using the following code snippet:

```
MBeanServer server = ...;
String jaasMgrName = "jboss.security:service=JaasSecurityManager";
ObjectName jaasMgr = new ObjectName(jaasMgrName);
Object[] params = {domainName};
String[] signature = {"java.lang.String"};
List users = (List) server.invoke(jaasMgr, "getAuthenticationCachePrincipals",
                                  params, signature);
```

The security manager has a few additional access methods.

```
public boolean isValid(String securityDomain, Principal principal, Object credential);
public Principal getPrincipal(String securityDomain, Principal principal);
public boolean doesUserHaveRole(String securityDomain, Principal principal,
                                Object credential, Set roles);
public Set getUserRoles(String securityDomain, Principal principal, Object credential);
```

They provide access to the corresponding `AuthenticationManager` and `RealmMapping` interface method of the associated security domain named by the `securityDomain` argument.

7.4.3. The JaasSecurityDomain MBean

The `org.jboss.security.plugins.JaasSecurityDomain` is an extension of `JaasSecurityManager` that adds the notion of a `KeyStore`, a JSSE `KeyManagerFactory` and a `TrustManagerFactory` for supporting SSL and other cryptographic use cases. The additional configurable attributes of the `JaasSecurityDomain` include:

- **KeyStoreType**: The type of the `KeyStore` implementation. This is the type argument passed to the `java.security.KeyStore.getInstance(String type)` factory method. The default is `JKS`.
- **KeyStoreURL**: A URL to the location of the `KeyStore` database. This is used to obtain an `InputStream` to initialize the `KeyStore`. If the string is not a value URL, it is treated as a file.
- **KeyStorePass**: The password associated with the `KeyStore` database contents. The `KeyStorePass` is also used in combination with the `Salt` and `IterationCount` attributes to create a PBE secret key used with the encode/decode operations. The `KeyStorePass` attribute value format is one of the following:

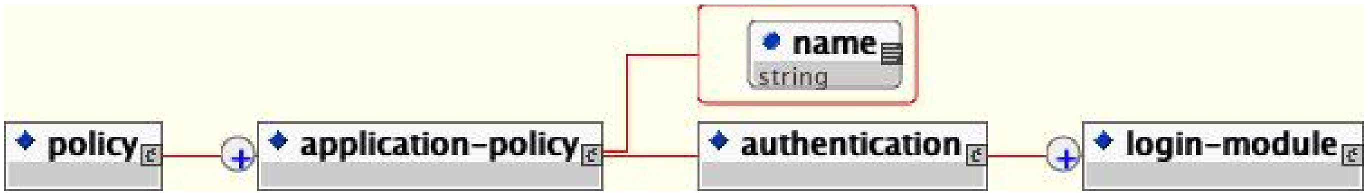
    - The plaintext password for the `KeyStore` The `toCharArray()` value of the string is used without any manipulation.
    - A command to execute to obtain the plaintext password. The format is `{EXT}...` where the `...` is the exact command line that will be passed to the `Runtime.exec(String)` method to execute a platform-specific command. The first line of the command output is used as the password.
    - A class to create to obtain the plaintext password. The format is `{CLASS}classname[:ctorarg]` where the `[:ctorarg]` is an optional string that will be passed to the constructor when instantiating the `classname`. The password is obtained from classname by invoking a `toCharArray()` method if found, otherwise, the `toString()` method is used.

- **Salt**: The `PBEParameterSpec` salt value.
- **IterationCount**: The `PBEParameterSpec` iteration count value.
- **TrustStoreType**: The type of the `TrustStore` implementation. This is the type argument passed to the `java.security.KeyStore.getInstance(String type)` factory method. The default is `JKS`.
- **TrustStoreURL**: A URL to the location of the `TrustStore` database. This is used to obtain an `InputStream` to initialize the `KeyStore`. If the string is not a value URL, it is treated as a file.
- **TrustStorePass**: The password associated with the trust store database contents. The `TrustStorePass` is a simple password and doesn't have the same configuration options as the `KeyStorePass`.
- **ManagerServiceName**: Sets the JMX object name string of the security manager service MBean. This is used to register the defaults to register the `JaasSecurityDomain` as a the security manager under `java:/jaas/<domain>` where `<domain>` is the name passed to the MBean constructor. The name defaults to `jboss.security:service=JaasSecurityManager`.

7.5. Defining Security Domains

The standard way of configuring security domains for authentication and authorization in JBoss is to use the XML login configuration file. The login configuration policy defines a set of named security domains that each define a stack of login modules that will be called upon to authenticate and authorize users.

The XML configuration file conforms to the DTD given by Figure 7.13. This DTD can be found in `docs/dtd/security_config.dtd`.



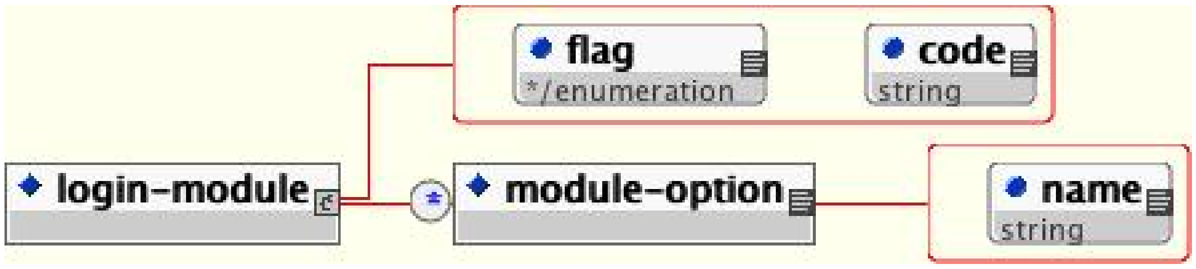


Figure 7.13. The XMLLoginConfig DTD

The following example shows a simple configuration named jmx-console that is backed by a single login module. The login module is configured by a simple set of name/value configuration pairs that have meaning to the login module in question. We'll see what these options mean later, for now we'll just be concerned with the structure of the configuration file.

```
<application-policy name="jmx-console">
    <authentication>
        <login-module code="org.jboss.security.auth.spi.UsersRolesLoginModule" flag="required">
            <module-option name="usersProperties">props/jmx-console-users.properties</module-option>
            <module-option name="rolesProperties">props/jmx-console-roles.properties</module-option>
        </login-module>
    </authentication>
</application-policy>
```

The `name` attribute of the `application-policy` is the login configuration name. Applications policy elements will be bound by that name in JNDI under the the `java:/jaas` context. Applications will link to security domains through this JNDI name in their deployment descriptors. (See the `security-domain` elements in `jboss.xml`, `jboss-web.xml` and `jboss-service.xml` files for examples)

The `code` attribute of the `login-module` element specifies the class name of the login module implementation. The `required` flag attribute controls the overall behavior of the authentication stack. The allowed values and meanings are:

- **required**: The login module is required to succeed for the authentication to be successful. If any required module fails, the authentication will fail. The remaining login modules in the stack will be called regardless of the outcome of the authentication.
- **requisite**: The login module is required to succeed. If it succeeds, authentication continues down the login stack. If it fails, control immediately returns to the application.
- **sufficient**: The login module is not required to succeed. If it does succeed, control immediately returns to the application. If it fails, authentication continues down the login stack.
- **optional**: The login module is not required to succeed. Authentication still continues to proceed down the login stack regardless of whether the login module succeeds or fails.

The following example shows the definition of a security domain that uses multiple login modules. Since both modules are marked as sufficient, only one of them need to succeed for login to proceed.

```
<application-policy name="todo">
    <authentication>
        <login-module code="org.jboss.security.auth.spi.LdapLoginModule"
```

```
                      flag="sufficient">
            <!-- LDAP configuration -->
        </login-module>
        <login-module code="org.jboss.security.auth.spi.DatabaseServerLoginModule"
                      flag="sufficient">
            <!-- database configuration -->
        </login-module>
    </authentication>
</application-policy>
```

Each login module has its own set of configuration options. These are set as name/value pairs using the `module-option` elements. We'll cover module options in more depth when we look at the individual login modules available in JBoss AS.

7.5.1. Loading Security Domains

Authentication security domains are configured statically in the `conf/login-config.xml` file. The `XMLLoginConfig` MBean is resp onsible for loading security configurations from this configurations from a local configuration file. The MBean is defined as shown below.

```
<mbean code="org.jboss.security.auth.login.XMLLoginConfig"
       name="jboss.security:service=XMLLoginConfig">
    <attribute name="ConfigResource">login-config.xml</attribute>
</mbean>
```

The MBean supports the following attributes:

- **ConfigURL**: specifies the URL of the XML login configuration file that should be loaded by this MBean on startup. This must be a valid URL string representation.
- **ConfigResource**: specifies the resource name of the XML login configuration file that should be loaded by this MBean on startup. The name is treated as a classpath resource for which a URL is located using the thread context class loader.
- **ValidateDTD**: a flag indicating if the XML configuration should be validated against its DTD. This defaults to true.

The MBean also supports the following operations that allow one to dynamically extend the login configurations at runtime. Note that any operation that attempts to alter login configuration requires a `javax.security.auth.AuthPermission("refreshLoginConfiguration")` when running with a security manager. The `org.jboss.book.security.service.SecurityConfig` service demonstrates how this can be used to add/remove a deployment specific security configuration dynamically.

- `void addAppConfig(String appName, AppConfigurationEntry[] entries)`: this adds the given login module configuration stack to the current configuration under the given `appName`. This replaces any existing entry under that name.
- `void removeAppConfig(String appName)`: this removes the login module configuration registered under the given `appName`.
- `String[] loadConfig(URL configURL) throws Exception`: this loads one or more login configurations from

a URL representing either an XML or legacy Sun login configuration file. Note that all login configurations must be added or none will be added. It returns the names of the login configurations that were added.

- `void removeConfigs(String[] appNames)`: this removes the login configurations specified `appNames` array.
- `String displayAppConfig(String appName)`: this operation displays a simple string format of the named configuration if it exists.

The `SecurityConfig` MBean is responsible for selecting the `javax.security.auth.login.Configuration` to be used. The default configuration simply references the `XMLLoginConfig` MBean.

```
  <mbean code="org.jboss.security.plugins.SecurityConfig"
       name="jboss.security:service=SecurityConfig">
    <attribute name="LoginConfig">jboss.security:service=XMLLoginConfig</attribute>
                 </mbean>
```

There is one configurable attribute:

- **LoginConfig**: Specifies the JMX `ObjectName` string of the MBean that provides the default JAAS login configuration. When the `SecurityConfig` is started, this MBean is queried for its `javax.security.auth.login.Configuration` by calling its `getConfiguration(Configuration currentConfig)` operation. If the `LoginConfig` attribute is not specified then the default Sun `Configuration` implementation described in the `Configuration` class JavaDocs is used.

In addition to allowing for a custom JAAS login configuration implementation, this service allows configurations to be chained together in a stack at runtime. This allows one to push a login configuration onto the stack and latter pop it. This is a feature used by the security unit tests to install custom login configurations into a default JBoss installation. Pushing a new configuration is done using:

```
public void pushLoginConfig(String objectName) throws
                JMException, MalformedObjectNameException;
```

The `objectName` parameters specifies an MBean similar to the `LoginConfig` attribute. The current login configuration may be removed using:

```
public void popLoginConfig() throws JMException;
```

7.5.2. The DynamicLoginConfig service

Security domains defined in the `login-config.xml` file are essentially static. They are read when JBoss starts up, but there is no easy way to add a new security domain or change the definition for an existing one. The `DynamicLoginConfig` service allows you to dynamically deploy security domains. This allows you to specify JAAS login configuration as part of a deployment (or just as a standalone service) rather than having to edit the static `login-config.xml` file.

The service supports the following attributes:

- **AuthConfig**: The resource path to the JAAS login configuration file to use. This defaults to `login-config.xml`
- **LoginConfigService**: the `XMLLoginConfig` service name to use for loading. This service must support a `String`

`loadConfig(URL)` operation to load the configurations.

- **SecurityManagerService**: The `SecurityManagerService` name used to flush the registered security domains. This service must support a `flushAuthenticationCache(String)` operation to flush the case for the argument security domain. Setting this triggers the flush of the authentication caches when the service is stopped.

Here is an example MBean definition using the `DynamicLoginConfig` service.

```
<server>
    <mbean code="org.jboss.security.auth.login.DynamicLoginConfig" name="...">
        <attribute name="AuthConfig">login-config.xml</attribute>

        <!-- The service which supports dynamic processing of login-config.xml
         configurations.
        -->
        <depends optional-attribute-name="LoginConfigService">
            jboss.security:service=XMLLoginConfig </depends>

        <!-- Optionally specify the security mgr service to use when
         this service is stopped to flush the auth caches of the domains
         registered by this service.
        -->
        <depends optional-attribute-name="SecurityManagerService">
            jboss.security:service=JaasSecurityManager </depends>
    </mbean>
</server>
```

This will load the specified `AuthConfig` resource using the specified `LoginConfigService` MBean by invoking `loadConfig` with the appropriate resource URL. When the service is stopped the configurations are removed. The resource specified may be either an XML file, or a Sun JAAS login configuration.

7.5.3. Using JBoss Login Modules

JBoss includes several bundled login modules suitable for most user management needs. JBoss can read user information from a relational database, an LDAP server or flat files. In addition to these core login modules, JBoss provides several other login modules that provide user information for very customized needs in JBoss. Before we explore the individual login modules, let's take a look at a few login module configuration options that are common to multiple modules.

7.5.3.1. Password Stacking

Multiple login modules can be chained together in a stack, with each login module providing both the authentication and authorization components. This works for many use cases, but sometimes authentication and authorization are split across multiple user management stores. A previous example showed how to combine LDAP and a relational database, allowing a user to be authenticated by either system. However, consider the case where users are managed in a central LDAP server but application-specific roles are stored in the application's relational database. The password-stacking module option captures this relationship.

- **password-stacking**: When `password-stacking` option is set to `useFirstPass`, this module first looks for a shared username and password under the property names `javax.security.auth.login.name` and `javax.security.auth.login.password` respectively in the login module shared state map. If found these are used as the principal name and password. If not found the principal name and password are set by this login module and stored under the property names `javax.security.auth.login.name` and `javax.security.auth.login.password` respectively.

To use password stacking, each login module should set `password-stacking` to `useFirstPass`. If a previous module configured for password stacking has authenticated the user, all the other stacking modules will consider the user authenticated and only attempt to provide a set of roles for the authorization step.

The following listing shows how password stacking could be used:

```
<application-policy name="todo">
    <authentication>
        <login-module code="org.jboss.security.auth.spi.LdapLoginModule"
                      flag="required">
            <!-- LDAP configuration -->
            <module-option name="password-stacking">useFirstPass</module-option>
        </login-module>
        <login-module code="org.jboss.security.auth.spi.DatabaseServerLoginModule"
                      flag="required">
            <!-- database configuration -->
            <module-option name="password-stacking">useFirstPass</module-option>
        </login-module>
    </authentication>
</application-policy>
```

When using password stacking, it is usually appropriate to set all modules to be required to make sure that all modules are considered and have chance to contribute roles to the authorization process.

7.5.3.2. Password Hashing

Most of the login modules need to compare a client-supplied password to a password stored in a user management system. These modules generally work with plain text passwords, but can also be configured to support hashed passwords to prevent plain text passwords from being stored on the server side.

- **hashAlgorithm**: The name of the `java.security.MessageDigest` algorithm to use to hash the password. There is no default so this option must be specified to enable hashing. Typical values are `MD5` and `SHA`.
- **hashEncoding**: The string format for the hashed pass and must be either `base64`, `hex` or `rfc2617`. The default is `base64`.
- **hashCharset**: The encoding used to convert the clear text password to a byte array. The platform default encoding is the default.
- **hashUserPassword**: This indicates that the hashing algorithm should be applied to the password the user submits. The hashed user password will be compared against the value in the login module, which is expected to be a hash of the password. The default is true.
- **hashStorePassword**: This indicates that the hashing algorithm should be applied to the password stored on the server side. This is used for digest authentication where the user submits a hash of the user password along with a request-specific tokens from the server to be comare. JBoss uses the hash algorithm (for digest, this would be `rfc2617`) to compute a server-side hash that should match the hashed value sent from the client.

The following is an login module configuration that assigns unauthenticated users the principal name `nobody` and contains based64-encoded, MD5 hashes of the passwords in a `usersb64.properties` file.

```
<policy>
    <application-policy name="testUsersRoles">
        <authentication>
            <login-module code="org.jboss.security.auth.spi.UsersRolesLoginModule"
                          flag="required">
                <module-option name="hashAlgorithm">MD5</module-option>
                <module-option name="hashEncoding">base64</module-option>
            </login-module>
        </authentication>
    </application-policy>
</policy>
```

If you need to generate passwords in code, `the org.jboss.security.Util` class provides a static helper method that will hash a password using a given encoding.

```
String hashedPassword = Util.createPasswordHash("MD5",
                                                Util.BASE64_ENCODING,
                                                null,
                                                null,
                                                "password");
```

OpenSSL provides an alternative way to quickly generate hashed passwords.

```
echo -n password | openssl dgst -md5 -binary | openssl base64
```

In both cases, the text password should hash to "X03MO1qnZdYdgyfeuILPmQ==". This is the value that would need to be stored in the user store.

7.5.3.3. Unauthenticated Identity

Not all requests come in authenticated. The unauthenticated identity is a login module configuration option that assigns a specific identity (guest, for example) to requests that are made with no associated authentication information. This can be used to allow unprotected servlets to invoke methods on EJBs that do not require a specific role. Such a principal has no associated roles and so can only access either unsecured EJBs or EJB methods that are associated with the unchecked permission constraint.

- **unauthenticatedIdentity**: This defines the principal name that should be assigned to requests that contain no authentication information.

7.5.3.4. UsersRolesLoginModule

The `UsersRolesLoginModule` is a simple login module that supports multiple users and user roles loaded from Java properties files. The username-to-password mapping file is called `users.properties` and the username-to-roles mapping file is called `roles.properties`. The properties files are loaded during initialization using the initialize method thread context class loader. This means that these files can be placed into the J2EE deployment JAR, the JBoss configuration directory, or any directory on the JBoss server or system classpath. The primary purpose of this login module is to easily test the security settings of multiple users and roles using properties files deployed with the application.

The `users.properties` file uses a `username=password` format with each user entry on a separate line as show here:

```
username1=password1
username2=password2
```

```
...
```

The `roles.properties` file uses as `username=role1,role2,...` format with an optional group name value. For example:

```
username1=role1,role2,...
username1.RoleGroup1=role3,role4,...
username2=role1,role3,...
```

The `username.XXX` form of property name is used to assign the username roles to a particular named group of roles where the `XXX` portion of the property name is the group name. The `username=...` form is an abbreviation for `username.Roles=...`, where the `Roles` group name is the standard name the `JaasSecurityManager` expects to contain the roles which define the users permissions.

The following would be equivalent definitions for the `jduke` username:

```
jduke=TheDuke,AnimatedCharacter
jduke.Roles=TheDuke,AnimatedCharacter
```

The supported login module configuration options include the following:

- **usersProperties**: The name of the properties resource containing the username to password mappings. This defaults to `users.properties`.
- **rolesProperties**: The name of the properties resource containing the username to roles mappings. This defaults to `roles.properties`.

This login module supports password stacking, password hashing and unauthenticated identity.

7.5.3.5. LdapLoginModule

The `LdapLoginModule` is a `LoginModule` implementation that authenticates against an LDAP server. You would use the `LdapLoginModule` if your username and credentials are stored in an LDAP server that is accessible using a JNDI LDAP provider.

The LDAP connectivity information is provided as configuration options that are passed through to the environment object used to create JNDI initial context. The standard LDAP JNDI properties used include the following:

- **java.naming.factory.initial**: The classname of the `InitialContextFactory` implementation. This defaults to the Sun LDAP provider implementation `com.sun.jndi.ldap.LdapCtxFactory`.
- **java.naming.provider.url**: The LDAP URL for the LDAP server
- **java.naming.security.authentication**: The security level to use. This defaults to `simple`.
- **java.naming.security.protocol**: The transport protocol to use for secure access, such as, SSL.
- **java.naming.security.principal**: The principal for authenticating the caller to the service. This is built from other properties as described below.
- **java.naming.security.credentials**: The value of the property depends on the authentication scheme. For ex-

ample, it could be a hashed password, clear-text password, key, certificate, and so on.

The supported login module configuration options include the following:

- **principalDNPrefix**: A prefix to add to the username to form the user distinguished name. See `principalDN-Suffix` for more info.
- **principalDNSuffix**: A suffix to add to the username when forming the user distinguished name. This is useful if you prompt a user for a username and you don't want the user to have to enter the fully distinguished name. Using this property and `principalDNSuffix` the `userDN` will be formed as `principalDNPrefix + username + principalDNSuffix`
- **useObjectCredential**: A true/false value that indicates that the credential should be obtained as an opaque `Object` using the `org.jboss.security.auth.callback.ObjectCallback` type of `Callback` rather than as a `char[]` password using a JAAS `PasswordCallback`. This allows for passing non-`char[]` credential information to the LDAP server.
- **rolesCtxDN**: The fixed distinguished name to the context to search for user roles.
- **userRolesCtxDNAttributeName**: The name of an attribute in the user object that contains the distinguished name to the context to search for user roles. This differs from `rolesCtxDN` in that the context to search for a user's roles can be unique for each user.
- **roleAttributeID**: The name of the attribute that contains the user roles. If not specified this defaults to `roles`.
- **roleAttributeIsDN**: A flag indicating whether the `roleAttributeID` contains the fully distinguished name of a role object, or the role name. If false, the role name is taken from the value of `roleAttributeID`. If true, the role attribute represents the distinguished name of a role object. The role name is taken from the value of the `roleNameAttributeId` attribute of the context name by the distinguished name. In certain directory schemas (e.g., MS ActiveDirectory), role attributes in the user object are stored as DNs to role objects instead of as simple names, in which case, this property should be set to true. The default is false.
- **roleNameAttributeID**: The name of the attribute of the context pointed to by the `roleCtxDN` distinguished name value which contains the role name. If the `roleAttributeIsDN` property is set to true, this property is used to find the role object's name attribute. The default is `group`.
- **uidAttributeID**: The name of the attribute in the object containing the user roles that corresponds to the userid. This is used to locate the user roles. If not specified this defaults to `uid`.
- **matchOnUserDN**: A true/false flag indicating if the search for user roles should match on the user's fully distinguished name. If false, just the username is used as the match value against the `uidAttributeName` attribute. If true, the full `userDN` is used as the match value.
- **unauthenticatedIdentity**: The principal name that should be assigned to requests that contain no authentication information. This behavior is inherited from the `UsernamePasswordLoginModule` superclass.
- **allowEmptyPasswords**: A flag indicating if empty (length 0) passwords should be passed to the LDAP server. An empty password is treated as an anonymous login by some LDAP servers and this may not be a desirable feature. Set this to false to reject empty passwords or true to have the LDAP server validate the empty password. The default is true.

The authentication of a user is performed by connecting to the LDAP server based on the login module configuration options. Connecting to the LDAP server is done by creating an `InitialLdapContext` with an environment composed of the LDAP JNDI properties described previously in this section. The `Context.SECURITY_PRINCIPAL` is set to the distinguished name of the user as obtained by the callback handler in combination with the `principalDNPrefix` and `principalDNSuffix` option values, and the `Context.SECURITY_CREDENTIALS` property is either set to the `String` password or the `Object` credential depending on the `useObjectCredential` option.

Once authentication has succeeded by virtue of being able to create an `InitialLdapContext` instance, the user's roles are queried by performing a search on the `rolesCtxDN` location with search attributes set to the `roleAttributeName` and `uidAttributeName` option values. The roles names are obtaining by invoking the `toString` method on the role attributes in the search result set.

The following is a sample `login-config.xml` entry.

```
    <application-policy name="testLDAP">
        <authentication>
            <login-module code="org.jboss.security.auth.spi.LdapLoginModule"
                          flag="required">
                <module-option name="java.naming.factory.initial">
                    com.sun.jndi.ldap.LdapCtxFactory
                    </module-option>
                <module-option name="java.naming.provider.url">
                    ldap://ldaphost.jboss.org:1389/
                </module-option>
                <module-option name="java.naming.security.authentication">
                    simple
                </module-option>
                <module-option name="principalDNPrefix">uid=</module-option>
                <module-option name="principalDNSuffix">
                    ,ou=People,dc=jboss,dc=org
                </module-option>

                <module-option name="rolesCtxDN">
                    ou=Roles,dc=jboss,dc=org
                </module-option>
                <module-option name="uidAttributeID">member</module-option>
                <module-option name="matchOnUserDN">true</module-option>

                <module-option name="roleAttributeID">cn</module-option>
                <module-option name="roleAttributeIsDN">false </module-option>
            </login-module>
        </authentication>
    </application-policy>
```

An LDIF file representing the structure of the directory this data operates against is shown below.

```
dn: dc=jboss,dc=org
objectclass: top
objectclass: dcObject
objectclass: organization
dc: jboss
o: JBoss

dn: ou=People,dc=jboss,dc=org
objectclass: top
objectclass: organizationalUnit
ou: People

dn: uid=jduke,ou=People,dc=jboss,dc=org
objectclass: top
```

```
objectclass: uidObject
objectclass: person
uid: jduke
cn: Java Duke
sn: Duke
userPassword: theduke

dn: ou=Roles,dc=jboss,dc=org
objectclass: top
objectclass: organizationalUnit
ou: Roles

dn: cn=JBossAdmin,ou=Roles,dc=jboss,dc=org
objectclass: top
objectclass: groupOfNames
cn: JBossAdmin
member: uid=jduke,ou=People,dc=jboss,dc=org
description: the JBossAdmin group
```

Looking back at the `testLDAP` login module configuration, the `java.naming.factory.initial`, `java.naming.factory.url` and `java.naming.security` options indicate the Sun LDAP JNDI provider implementation will be used, the LDAP server is located on host `ldaphost.jboss.org` on port 1389, and that the LDAP simple authentication method will be use to connect to the LDAP server.

The login module attempts to connect to the LDAP server using a DN representing the user it is trying to authenticate. This DN is constructed from the `principalDNPrefix`, passed in, the username of the user and the `principalDNSuffix` as described above. In this example, the username `jduke` would map to `uid=jduke,ou=People,dc=jboss,dc=org`. We've assumed the LDAP server authenticates users using the `userPassword` attribute of the user's entry (`theduke` in this example). This is the way most LDAP servers work, however, if your LDAP server handles authentication differently you will need to set the authentication credentials in a way that makes sense for your server.

Once authentication succeeds, the roles on which authorization will be based are retrieved by performing a subtree search of the `rolesCtxDN` for entries whose `uidAttributeID` match the user. If `matchOnUserDN` is true the search will be based on the full DN of the user. Otherwise the search will be based on the actual user name entered. In this example, the search is under `ou=Roles,dc=jboss,dc=org` for any entries that have a `member` attribute equal to `uid=jduke,ou=People,dc=jboss,dc=org`. The search would locate `cn=JBossAdmin` under the roles entry.

The search returns the attribute specified in the `roleAttributeID` option. In this example, the attribute is `cn`. The value returned would be `JBossAdmin`, so the jduke user is assigned to the `JBossAdmin` role.

It's often the case that a local LDAP server provides identity and authentication services but is unable to use the authorization services. This is because application roles don't always map well onto LDAP groups, and LDAP administrators are often hesitant to allow external application-specific data in central LDAP servers. For this reason, the LDAP authentication module is often paired with another login module, such as the database login module, that can provide roles more suitable to the application being developed.

This login module also supports unauthenticated identity and password stacking.

7.5.3.6. DatabaseServerLoginModule

The `DatabaseServerLoginModule` is a JDBC based login module that supports authentication and role mapping. You would use this login module if you have your username, password and role information relational database. The `DatabaseServerLoginModule` is based on two logical tables:

```
Table Principals(PrincipalID text, Password text)
Table Roles(PrincipalID text, Role text, RoleGroup text)
```

The `Principals` table associates the user `PrincipalID` with the valid password and the `Roles` table associates the user `PrincipalID` with its role sets. The roles used for user permissions must be contained in rows with a `RoleGroup` column value of `Roles`. The tables are logical in that you can specify the SQL query that the login module uses. All that is required is that the `java.sql.ResultSet` has the same logical structure as the `Principals` and `Roles` tables described previously. The actual names of the tables and columns are not relevant as the results are accessed based on the column index. To clarify this notion, consider a database with two tables, `Principals` and `Roles`, as already declared. The following statements build the tables to contain a `PrincipalID` `java` with a `Password` of `echoman` in the `Principals` table, a `PrincipalID` `java` with a role named `Echo` in the `Roles` `RoleGroup` in the `Roles` table, and a `PrincipalID` `java` with a role named `caller_java` in the `CallerPrincipal` `RoleGroup` in the `Roles` table:

```
INSERT INTO Principals VALUES('java', 'echoman')
INSERT INTO Roles VALUES('java', 'Echo', 'Roles')
INSERT INTO Roles VALUES('java', 'caller_java', 'CallerPrincipal')
```

The supported login module configuration options include the following:

- **dsJndiName**: The JNDI name for the `DataSource` of the database containing the logical `Principals` and `Roles` tables. If not specified this defaults to `java:/DefaultDS`.
- **principalsQuery**: The prepared statement query equivalent to: `select Password from Principals where PrincipalID=?`. If not specified this is the exact prepared statement that will be used.
- **rolesQuery**: The prepared statement query equivalent to: `select Role, RoleGroup from Roles where PrincipalID=?`. If not specified this is the exact prepared statement that will be used.
- **ignorePasswordCase**: A boolean flag indicating if the password comparison should ignore case. This can be useful for hashed password encoding where the case of the hashed password is not significant.
- **principalClass**: An option that specifies a `Principal` implementation class. This must support a constructor taking a string argument for the principal name.

As an example `DatabaseServerLoginModule` configuration, consider a custom table schema like the following:

```
CREATE TABLE Users(username VARCHAR(64) PRIMARY KEY, passwd VARCHAR(64))
CREATE TABLE UserRoles(username VARCHAR(64), userRoles VARCHAR(32))
```

A corresponding `login-config.xml` entry would be:

```
<policy>
    <application-policy name="testDB">
        <authentication>
            <login-module code="org.jboss.security.auth.spi.DatabaseServerLoginModule"
                             flag="required">
                <module-option name="dsJndiName">java:/MyDatabaseDS</module-option>
                <module-option name="principalsQuery">
                    select passwd from Users username where username=?</module-option>
                <module-option name="rolesQuery">
                    select userRoles, 'Roles' from UserRoles where username=?</module-option>
            </login-module>
        </authentication>
    </application-policy>
</policy>
```

This module supports password stacking, password hashing and unathenticated identity.

7.5.3.7. BaseCertLoginModule

This is a login module which authenticates users based on X509 certificates. A typical use case for this login module is `CLIENT-CERT` authentication in the web tier. This login module only performs authentication. You need to combine it with another login module capable of acquiring the authorization roles to completely define access to a secured web or EJB component. Two subclasses of this login module, `CertRolesLoginModule` and `DatabaseCertLoginModule` extend the behavior to obtain the authorization roles from either a properties file or database.

The `BaseCertLoginModule` needs a `KeyStore` to perform user validation. This is obtained through a `org.jboss.security.SecurityDomain` implementation. Typically, the `SecurityDomain` implementation is configured using the `org.jboss.security.plugins.JaasSecurityDomain` MBean as shown in this `jboss-service.xml` configuration fragment:

```
<mbean code="org.jboss.security.plugins.JaasSecurityDomain"
       name="jboss.ch8:service=SecurityDomain">
    <constructor>
        <arg type="java.lang.String" value="jmx-console"/>
    </constructor>
    <attribute name="KeyStoreURL">resource:localhost.keystore</attribute>
    <attribute name="KeyStorePass">unit-tests-server</attribute>
</mbean>
```

This creates a security domain with the name `jmx-console` whose `SecurityDomain` implementation is available via JNDI under the name `java:/jaas/jmx-console` following the JBossSX security domain naming pattern. To secure a web application such as the `jmx-console.war` using client certs and role based authorization, one would first modify the `web.xml` to declare the resources to be secured, along with the allowed roles and security domain to be used for authentication and authorization.

```
<?xml version="1.0"?>
<!DOCTYPE web-app PUBLIC
                  "-//Sun Microsystems, Inc.//DTD Web Application 2.3//EN"
                  "http://java.sun.com/dtd/web-app_2_3.dtd">
<web-app>
    ...
    <security-constraint>
        <web-resource-collection>
            <web-resource-name>HtmlAdaptor</web-resource-name>
            <description>An example security config that only allows users with
                the role JBossAdmin to access the HTML JMX console web
                application </description>
            <url-pattern>/*</url-pattern>
            <http-method>GET</http-method>
            <http-method>POST</http-method>
        </web-resource-collection>
        <auth-constraint>
            <role-name>JBossAdmin</role-name>
        </auth-constraint>
    </security-constraint>
    <login-config>
        <auth-method>CLIENT-CERT</auth-method>
        <realm-name>JBoss JMX Console</realm-name>
    </login-config>
    <security-role>
```

```
        <role-name>JBossAdmin</role-name>
    </security-role>
</web-app>
```

Next we, need to specify the JBoss security domain in `jboss-web.xml`:

```
<jboss-web>
    <security-domain>java:/jaas/jmx-console</security-domain>
</jboss-web>
```

Finally, you need to define the login module configuration for the jmx-console security domain you just specified. This is done in the `conf/login-config.xml` file.

```
<application-policy name="jmx-console">
    <authentication>
        <login-module code="org.jboss.security.auth.spi.BaseCertLoginModule"
                      flag="required">
            <module-option name="password-stacking">useFirstPass</module-option>
            <module-option name="securityDomain">java:/jaas/jmx-console</module-option>
        </login-module>
        <login-module code="org.jboss.security.auth.spi.UsersRolesLoginModule"
                      flag="required">
            <module-option name="password-stacking">useFirstPass</module-option>
            <module-option name="usersProperties">jmx-console-users.properties</module-option>
            <module-option name="rolesProperties">jmx-console-roles.properties</module-option>
        </login-module>
    </authentication>
</application-policy>
```

Here the `BaseCertLoginModule` is used for authentication of the client cert, and the `UsersRolesLoginModule` is only used for authorization due to the `password-stacking=useFirstPass` option. Both the `localhost.keystore` and the `jmx-console-roles.properties` need an entry that maps to the principal associated with the client cert. By default, the principal is created using the client certificate distinguished name. Consider the following certificate:

```
[starksm@banshee9100 conf]$ keytool -printcert -file unit-tests-client.export
Owner: CN=unit-tests-client, OU=JBoss Inc., O=JBoss Inc., ST=Washington, C=US
Issuer: CN=jboss.com, C=US, ST=Washington, L=Snoqualmie Pass, EMAILADDRESS=admin
@jboss.com, OU=QA, O=JBoss Inc.
Serial number: 100103
Valid from: Wed May 26 07:34:34 PDT 2004 until: Thu May 26 07:34:34 PDT 2005
Certificate fingerprints:
         MD5:  4A:9C:2B:CD:1B:50:AA:85:DD:89:F6:1D:F5:AF:9E:AB
         SHA1: DE:DE:86:59:05:6C:00:E8:CC:C0:16:D3:C2:68:BF:95:B8:83:E9:58
```

The `localhost.keystore` would need this cert stored with an alias of `CN=unit-tests-client, OU=JBoss Inc., O=JBoss Inc., ST=Washington, C=US` and the `jmx-console-roles.properties` would also need an entry for the same entry. Since the DN contains many characters that are normally treated as delimiters, you will need to escape the problem characters using a backslash ('\') as shown here:

```
# A sample roles.properties file for use with the UsersRolesLoginModule
CN\=unit-tests-client,\ OU\=JBoss\ Inc.,\ O\=JBoss\ Inc.,\ ST\=Washington,\ C\=US=JBossAdmin
admin=JBossAdmin
```

7.5.3.8. IdentityLoginModule

The `IdentityLoginModule` is a simple login module that associates a hard-coded user name a to any subject authenticated against the module. It creates a `SimplePrincipal` instance using the name specified by the `principal` option. This login module is useful when you need to provide a fixed identity to a service and in development environments when you want to test the security associated with a given principal and associated roles.

The supported login module configuration options include:

- **principal**: This is the name to use for the `SimplePrincipal` all users are authenticated as. The principal name defaults to `guest` if no principal option is specified.
- **roles**: This is a comma-delimited list of roles that will be assigned to the user.

A sample XMLLoginConfig configuration entry that would authenticate all users as the principal named `jduke` and assign role names of `TheDuke`, and `AnimatedCharacter` is:

```
<policy>
    <application-policy name="testIdentity">
        <authentication>
            <login-module code="org.jboss.security.auth.spi.IdentityLoginModule"
                          flag="required">
                <module-option name="principal">jduke</module-option>
                <module-option name="roles">TheDuke,AnimatedCharater</module-option>
            </login-module>
        </authentication>
    </application-policy>
</policy>
```

This module supports password stacking.

7.5.3.9. RunAsLoginModule

JBoss has a helper login module called `RunAsLoginModule` that pushes a run as role for the duration of the login phase of authentication, and pops the run as role in either the commit or abort phase. The purpose of this login module is to provide a role for other login modules that need to access secured resources in order to perform their authentication. An example would be a login module that accesses an secured EJB. This login module must be configured ahead of the login module(s) that need a run as role established.

The only login module configuration option is:

- **roleName**: the name of the role to use as the run as role during login phase. If not specified a default of `nobody` is used.

7.5.3.10. ClientLoginModule

The `ClientLoginModule` is an implementation of `LoginModule` for use by JBoss clients for the establishment of the caller identity and credentials. This simply sets the `org.jboss.security.SecurityAssociation.principal` to the value of the `NameCallback` filled in by the `callbackhandler`, and the `org.jboss.security.SecurityAssociation.credential` to the value of the `PasswordCallback` filled in by the `callbackhandler`. This is the only supported mechanism for a client to establish the current thread's caller. Both stand-alone client applications and server environments, acting as JBoss EJB clients where the security environment has not been configured to use JBossSX transparently, need to use the `ClientLoginModule`. Of course, you could always set the `org.jboss.security.SecurityAssociation` information directly, but this is considered an internal API that is subject to change without notice.

Note that this login module does not perform any authentication. It merely copies the login information provided to it into the JBoss server EJB invocation layer for subsequent authentication on the server. If you need to perform client-side authentication of users you would need to configure another login module in addition to the `ClientLoginModule`.

The supported login module configuration options include the following:

- **multi-threaded**: When the multi-threaded option is set to true, each login thread has its own principal and credential storage. This is useful in client environments where multiple user identities are active in separate threads. When true, each separate thread must perform its own login. When set to false the login identity and credentials are global variables that apply to all threads in the VM. The default for this option is false.
- **password-stacking**: When `password-stacking` option is set to `useFirstPass`, this module first looks for a shared username and password using `javax.security.auth.login.name` and `javax.security.auth.login.password` respectively in the login module shared state map. This allows a module configured prior to this one to establish a valid username and password that should be passed to JBoss. You would use this option if you want to perform client-side authentication of clients using some other login module such as the `LdapLoginModule`.
- **restore-login-identity**: When `restore-login-identity` is true, the `SecurityAssociation` principal and credential seen on entry to the `login()` method are saved and restored on either abort or logout. When false (the default), the abort and logout simply clear the `SecurityAssociation`. A `restore-login-identity` of true is needed if one need to change identities and then restore the original caller identity.

A sample login configuration for `ClientLoginModule` is the default configuration entry found in the JBoss distribution `client/auth.conf` file. The configuration is:

```
other {
    // Put your login modules that work without jBoss here

    // jBoss LoginModule
    org.jboss.security.ClientLoginModule required;

    // Put your login modules that need jBoss here
};
```

7.5.4. Writing Custom Login Modules

If the login modules bundled with the JBossSX framework do not work with your security environment, you can write your own custom login module implementation that does. Recall from the section on the `JaasSecurityManager` architecture that the `JaasSecurityManager` expected a particular usage pattern of the `Subject` principals set. You need to understand the JAAS Subject class's information storage features and the expected usage of these features to be able to write a login module that works with the `JaasSecurityManager`. This section examines this requirement and introduces two abstract base `LoginModule` implementations that can help you implement your own custom login modules.

You can obtain security information associated with a `Subject` in six ways in JBoss using the following methods:

```
java.util.Set getPrincipals()
java.util.Set getPrincipals(java.lang.Class c)
java.util.Set getPrivateCredentials()
java.util.Set getPrivateCredentials(java.lang.Class c)
java.util.Set getPublicCredentials()
java.util.Set getPublicCredentials(java.lang.Class c)
```

For `Subject` identities and roles, JBossSX has selected the most natural choice: the principals sets obtained via `getPrincipals()` and `getPrincipals(java.lang.Class)`. The usage pattern is as follows:

- User identities (username, social security number, employee ID, and so on) are stored as `java.security.Principal` objects in the `Subject` `Principals` set. The `Principal` implementation that represents the user identity must base comparisons and equality on the name of the principal. A suitable implementation is available as the `org.jboss.security.SimplePrincipal` class. Other `Principal` instances may be added to the `Subject` `Principals` set as needed.

- The assigned user roles are also stored in the `Principals` set, but they are grouped in named role sets using `java.security.acl.Group` instances. The `Group` interface defines a collection of `Principals` and/or `Groups`, and is a subinterface of `java.security.Principal`. Any number of role sets can be assigned to a `Subject`. Currently, the JBossSX framework uses two well-known role sets with the names `Roles` and `CallerPrincipal`. The `Roles` Group is the collection of `Principals` for the named roles as known in the application domain under which the `Subject` has been authenticated. This role set is used by methods like the `EJBContext.isCallerInRole(String)`, which EJBs can use to see if the current caller belongs to the named application domain role. The security interceptor logic that performs method permission checks also uses this role set. The `CallerPrincipal` `Group` consists of the single `Principal` identity assigned to the user in the application domain. The `EJBContext.getCallerPrincipal()` method uses the `CallerPrincipal` to allow the application domain to map from the operation environment identity to a user identity suitable for the application. If a `Subject` does not have a `CallerPrincipal` `Group`, the application identity is the same as operational environment identity.

7.5.4.1. Support for the Subject Usage Pattern

To simplify correct implementation of the `Subject` usage patterns described in the preceding section, JBossSX includes two abstract login modules that handle the population of the authenticated `Subject` with a template pattern that enforces correct `Subject` usage. The most generic of the two is the `org.jboss.security.auth.spi.AbstractServerLoginModule` class. It provides a concrete implementation of the `javax.security.auth.spi.LoginModule` interface and offers abstract methods for the key tasks specific to an operation environment security infrastructure. The key details of the class are highlighted in the following class fragment. The JavaDoc comments detail the responsibilities of subclasses.

```
package org.jboss.security.auth.spi;
/**
 *  This class implements the common functionality required for a JAAS
 *  server-side LoginModule and implements the JBossSX standard
 *  Subject usage pattern of storing identities and roles. Subclass
 *  this module to create your own custom LoginModule and override the
 *  login(), getRoleSets(), and getIdentity() methods.
 */
public abstract class AbstractServerLoginModule
    implements javax.security.auth.spi.LoginModule
{
    protected Subject subject;
    protected CallbackHandler callbackHandler;
    protected Map sharedState;
    protected Map options;
    protected Logger log;

    /** Flag indicating if the shared credential should be used */
    protected boolean useFirstPass;
    /**
     * Flag indicating if the login phase succeeded. Subclasses that
     * override the login method must set this to true on successful
     * completion of login
     */
    protected boolean loginOk;

    // ...
    /**
     * Initialize the login module. This stores the subject,
     * callbackHandler and sharedState and options for the login
     * session. Subclasses should override if they need to process
     * their own options. A call to super.initialize(...)  must be
     * made in the case of an override.
     *
     * <p>
     * The options are checked for the  <em>password-stacking</em> parameter.
     * If this is set to "useFirstPass", the login identity will be taken from the
     * <code>javax.security.auth.login.name</code> value of the sharedState map,
     * and the proof of identity from the
     * <code>javax.security.auth.login.password</code> value of the sharedState map.
     *
     * @param subject the Subject to update after a successful login.
     * @param callbackHandler the CallbackHandler that will be used to obtain the
     * the user identity and credentials.
     * @param sharedState a Map shared between all configured login module instances
     * @param options the parameters passed to the login module.
     */
    public void initialize(Subject subject,
                           CallbackHandler callbackHandler,
                           Map sharedState,
                           Map options)
    {
        // ...
    }


    /**
     *  Looks for javax.security.auth.login.name and
     *  javax.security.auth.login.password values in the sharedState
     *  map if the useFirstPass option was true and returns true if
     *  they exist. If they do not or are null this method returns
     *  false.
     *  Note that subclasses that override the login method
     *  must set the loginOk var to true if the login succeeds in
     *  order for the commit phase to populate the Subject. This
     *  implementation sets loginOk to true if the login() method
     *  returns true, otherwise, it sets loginOk to false.
     */
    public boolean login()
        throws LoginException
    {
        // ...
    }

    /**
     *  Overridden by subclasses to return the Principal that
     *  corresponds to the user primary identity.
     */
    abstract protected Principal getIdentity();
    /**
     *  Overridden by subclasses to return the Groups that correspond
     *  to the role sets assigned to the user. Subclasses should
     *  create at least a Group named "Roles" that contains the roles
     *  assigned to the user.  A second common group is
     *  "CallerPrincipal," which provides the application identity of
     *  the user rather than the security domain identity.
     *
     *  @return Group[] containing the sets of roles
     */
    abstract protected Group[] getRoleSets() throws LoginException;
}
```

You'll need to pay attention to the `loginOk` instance variable. This must be set to true if the login succeeds, false otherwise by any subclasses that override the login method. Failure to set this variable correctly will result in the commit method either not updating the subject when it should, or updating the subject when it should not. Tracking the outcome of the login phase was added to allow login modules to be chained together with control flags that do not require that the login module succeed in order for the overall login to succeed.

The second abstract base login module suitable for custom login modules is the `org.jboss.security.auth.spi.UsernamePasswordLoginModule`. This login module further simplifies custom login module implementation by enforcing a string-based username as the user identity and a `char[]` password as the authentication credentials. It also supports the mapping of anonymous users (indicated by a null username and password) to a principal with no roles. The key details of the class are highlighted in the following class fragment. The JavaDoc comments detail the responsibilities of subclasses.

```
package org.jboss.security.auth.spi;

/**
 *  An abstract subclass of AbstractServerLoginModule that imposes a
 *  an identity == String username, credentials == String password
 *  view on the login process. Subclasses override the
 *  getUsersPassword() and getUsersRoles() methods to return the
 *  expected password and roles for the user.
 */
public abstract class UsernamePasswordLoginModule
    extends AbstractServerLoginModule
{
    /** The login identity */
    private Principal identity;
    /** The proof of login identity */
    private char[] credential;
    /** The principal to use when a null username and password are seen */
    private Principal unauthenticatedIdentity;

    /**
     * The message digest algorithm used to hash passwords. If null then
     * plain passwords will be used. */
    private String hashAlgorithm = null;

    /**
     *  The name of the charset/encoding to use when converting the
     * password String to a byte array. Default is the platform's
     * default encoding.
     */
     private String hashCharset = null;

    /** The string encoding format to use. Defaults to base64. */
    private String hashEncoding = null;

    // ...
    /**
     *  Override the superclass method to look for an
     *  unauthenticatedIdentity property. This method first invokes
     *  the super version.
     *
     *  @param options,
     *  @option unauthenticatedIdentity: the name of the principal to
     *  assign and authenticate when a null username and password are
     *  seen.
     */
    public void initialize(Subject subject,
                           CallbackHandler callbackHandler,
                           Map sharedState,
                           Map options)
    {
        super.initialize(subject, callbackHandler, sharedState,
                         options);
        // Check for unauthenticatedIdentity option.
        Object option = options.get("unauthenticatedIdentity");
        String name = (String) option;
        if (name != null) {
            unauthenticatedIdentity = new SimplePrincipal(name);
        }
    }

    // ...

    /**
     *  A hook that allows subclasses to change the validation of the
     *  input password against the expected password. This version
     *  checks that neither inputPassword or expectedPassword are null
     *  and that inputPassword.equals(expectedPassword) is true;
     *
     *  @return true if the inputPassword is valid, false otherwise.
     */
    protected boolean validatePassword(String inputPassword,
                                       String expectedPassword)
    {
        if (inputPassword == null || expectedPassword == null) {
            return false;
        }
        return inputPassword.equals(expectedPassword);
    }

    /**
     *  Get the expected password for the current username available
     * via the getUsername() method. This is called from within the
     * login() method after the CallbackHandler has returned the
     * username and candidate password.
     *
     * @return the valid password String
     */
    abstract protected String getUsersPassword()
        throws LoginException;
}
```

The choice of subclassing the `AbstractServerLoginModule` versus `UsernamePasswordLoginModule` is simply based on whether a string-based username and credentials are usable for the authentication technology you are writing the login module for. If the string-based semantic is valid, then subclass `UsernamePasswordLoginModule`, otherwise subclass `AbstractServerLoginModule`.

The steps you are required to perform when writing a custom login module are summarized in the following depending on which base login module class you choose. When writing a custom login module that integrates with your security infrastructure, you should start by subclassing `AbstractServerLoginModule` or `UsernamePasswordLoginModule` to ensure that your login module provides the authenticated `Principal` information in the form expected by the JBossSX security manager.

When subclassing the `AbstractServerLoginModule`, you need to override the following:

- `void initialize(Subject, CallbackHandler, Map, Map)`: if you have custom options to parse.
- `boolean login()`: to perform the authentication activity. Be sure to set the `loginOk` instance variable to true if login succeeds, false if it fails.
- `Principal getIdentity()`: to return the `Principal` object for the user authenticated by the `log()` step.
- `Group[] getRoleSets()`: to return at least one `Group` named `Roles` that contains the roles assigned to the `Principal` authenticated during `login()`. A second common `Group` is named `CallerPrincipal` and provides the user's application identity rather than the security domain identity.

When subclassing the `UsernamePasswordLoginModule`, you need to override the following:

- `void initialize(Subject, CallbackHandler, Map, Map)`: if you have custom options to parse.
- `Group[] getRoleSets()`: to return at least one `Group` named `Roles` that contains the roles assigned to the `Principal` authenticated during `login()`. A second common `Group` is named `CallerPrincipal` and provides the user's application identity rather than the security domain identity.
- `String getUsersPassword()`: to return the expected password for the current username available via the `getUsername()` method. The `getUsersPassword()` method is called from within `login()` after the `callbackhandler` returns the username and candidate password.

7.5.4.2. A Custom LoginModule Example

In this section we will develop a custom login module example. It will extend the `UsernamePasswordLoginModule` and obtains a user's password and role names from a JNDI lookup. The idea is that there is a JNDI context that will return a user's password if you perform a lookup on the context using a name of the form `password/<username>` where `<username>` is the current user being authenticated. Similarly, a lookup of the form `roles/<username>` returns the requested user's roles.

The source code for the example is located in the `src/main/org/jboss/book/security/ex2` directory of the book examples. Example 7.9 shows the source code for the `JndiUserAndPass` custom login module. Note that because this extends the JBoss `UsernamePasswordLoginModule`, all the `JndiUserAndPass` does is obtain the user's password and roles from the JNDI store. The `JndiUserAndPass` does not concern itself with the JAAS `LoginModule` operations.

Example 7.9. A JndiUserAndPass custom login module

```
package org.jboss.book.security.ex2;

import java.security.acl.Group;
import java.util.Map;
import javax.naming.InitialContext;
import javax.naming.NamingException;
import javax.security.auth.Subject;
import javax.security.auth.callback.CallbackHandler;
import javax.security.auth.login.LoginException;

import org.jboss.security.SimpleGroup;
import org.jboss.security.SimplePrincipal;
import org.jboss.security.auth.spi.UsernamePasswordLoginModule;

/**
 *  An example custom login module that obtains passwords and roles
 *  for a user from a JNDI lookup.
 *
 *  @author Scott.Stark@jboss.org
 *  @version $Revision: 1.2 $
*/
public class JndiUserAndPass
    extends UsernamePasswordLoginModule
{
    /** The JNDI name to the context that handles the password/username lookup */
    private String userPathPrefix;
    /** The JNDI name to the context that handles the roles/ username lookup */
    private String rolesPathPrefix;

    /**
     * Override to obtain the userPathPrefix and rolesPathPrefix options.
     */
    public void initialize(Subject subject, CallbackHandler callbackHandler,
                           Map sharedState, Map options)
    {
        super.initialize(subject, callbackHandler, sharedState, options);
        userPathPrefix = (String) options.get("userPathPrefix");
        rolesPathPrefix = (String) options.get("rolesPathPrefix");
    }

    /**
     *  Get the roles the current user belongs to by querying the
     * rolesPathPrefix + '/' + super.getUsername() JNDI location.
     */
    protected Group[] getRoleSets() throws LoginException
    {
        try {
            InitialContext ctx = new InitialContext();
            String rolesPath = rolesPathPrefix + '/' + super.getUsername();

            String[] roles = (String[]) ctx.lookup(rolesPath);
            Group[] groups = {new SimpleGroup("Roles")};
            log.info("Getting roles for user="+super.getUsername());
            for(int r = 0; r < roles.length; r ++) {
                SimplePrincipal role = new SimplePrincipal(roles[r]);
                log.info("Found role="+roles[r]);
                groups[0].addMember(role);
            }
            return groups;
        } catch(NamingException e) {
            log.error("Failed to obtain groups for
                        user="+super.getUsername(), e);
            throw new LoginException(e.toString(true));
        }
    }

    /**
     * Get the password of the current user by querying the
     * userPathPrefix + '/' + super.getUsername() JNDI location.
     */
    protected String getUsersPassword()
        throws LoginException
    {
        try {
            InitialContext ctx = new InitialContext();
            String userPath = userPathPrefix + '/' + super.getUsername();
            log.info("Getting password for user="+super.getUsername());
            String passwd = (String) ctx.lookup(userPath);
            log.info("Found password="+passwd);
            return passwd;
        } catch(NamingException e) {
            log.error("Failed to obtain password for
                        user="+super.getUsername(), e);
            throw new LoginException(e.toString(true));
        }
    }
}
```

The details of the JNDI store are found in the `org.jboss.book.security.ex2.service.JndiStore` MBean. This service binds an `ObjectFactory` that returns a `javax.naming.Context` proxy into JNDI. The proxy handles lookup operations done against it by checking the prefix of the lookup name against `password` and `roles`. When the name begins with `password`, a user's password is being requested. When the name begins with `roles` the user's roles are being requested. The example implementation always returns a password of `theduke` and an array of roles names equal to `{"TheDuke", "Echo"}` regardless of what the username is. You can experiment with other implementations as you wish.

The example code includes a simple session bean for testing the custom login module. To build, deploy and run the example, execute the following command in the examples directory.

```
[examples]$ ant -Dchap=security -Dex=2 run-example
...
run-example2:
     [echo] Waiting for 5 seconds for deploy...
     [java] [INFO,ExClient] Login with username=jduke, password=theduke
     [java] [INFO,ExClient] Looking up EchoBean2
     [java] [INFO,ExClient] Created Echo
     [java] [INFO,ExClient] Echo.echo('Hello') = Hello
```

The choice of using the `JndiUserAndPass` custom login module for the server side authentication of the user is determined by the login configuration for the example security domain. The EJB JAR `META-INF/jboss.xml` descriptor sets the security domain

```
<?xml version="1.0"?>
<jboss>
    <security-domain>java:/jaas/security-ex2</security-domain>
</jboss>
```

The SAR `META-INF/login-config.xml` descriptor defines the login module configuration.

```
<application-policy name = "security-ex2">
    <authentication>
        <login-module code="org.jboss.book.security.ex2.JndiUserAndPass"
                      flag="required">
            <module-option name = "userPathPrefix">/security/store/password</module-option>
            <module-option name = "rolesPathPrefix">/security/store/roles</module-option>
        </login-module>
    </authentication>
</application-policy>
```

7.6. The Secure Remote Password (SRP) Protocol

The SRP protocol is an implementation of a public key exchange handshake described in the Internet standards working group request for comments 2945(RFC2945). The RFC2945 abstract states:

This document describes a cryptographically strong network authentication mechanism known as the Secure Remote Password (SRP) protocol. This mechanism is suitable for negotiating secure connections using a user-supplied password, while eliminating the security problems traditionally associated with reusable passwords. This system also performs a secure key exchange in the process of authentication, allowing security layers (privacy and/or integrity protection) to be enabled during the session. Trusted key servers and certificate infrastructures are not required, and clients are not required to store or manage any long-term keys. SRP offers both security and deployment advantages over existing challenge-response techniques, making it an ideal drop-in replacement where secure password authentication is needed.

Note: The complete RFC2945 specification can be obtained from http://www.rfc-editor.org/rfc.html. Additional information on the SRP algorithm and its history can be found at http://www-cs-students.stanford.edu/~tjw/srp/.

SRP is similar in concept and security to other public key exchange algorithms, such as Diffie-Hellman and RSA. SRP is based on simple string passwords in a way that does not require a clear text password to exist on the server. This is in contrast to other public key-based algorithms that require client certificates and the corresponding certificate management infrastructure.

Algorithms like Diffie-Hellman and RSA are known as public key exchange algorithms. The concept of public key algorithms is that you have two keys, one public that is available to everyone, and one that is private and known only to you. When someone wants to send encrypted information to you, then encrpyt the information using your public key. Only you are able to decrypt the information using your private key. Contrast this with the more traditional shared password based encryption schemes that require the sender and receiver to know the shared password. Public key algorithms eliminate the need to share passwords.

The JBossSX framework includes an implementation of SRP that consists of the following elements:

- An implementation of the SRP handshake protocol that is independent of any particular client/server protocol
- An RMI implementation of the handshake protocol as the default client/server SRP implementation
- A client side JAAS `LoginModule` implementation that uses the RMI implementation for use in authenticating clients in a secure fashion
- A JMX MBean for managing the RMI server implementation. The MBean allows the RMI server implementation to be plugged into a JMX framework and externalizes the configuration of the verification information store. It also establishes an authentication cache that is bound into the JBoss server JNDI namespace.
- A server side JAAS `LoginModule` implementation that uses the authentication cache managed by the SRP JMX MBean.

Figure 7.14 gives a diagram of the key components involved in the JBossSX implementation of the SRP client/server framework.

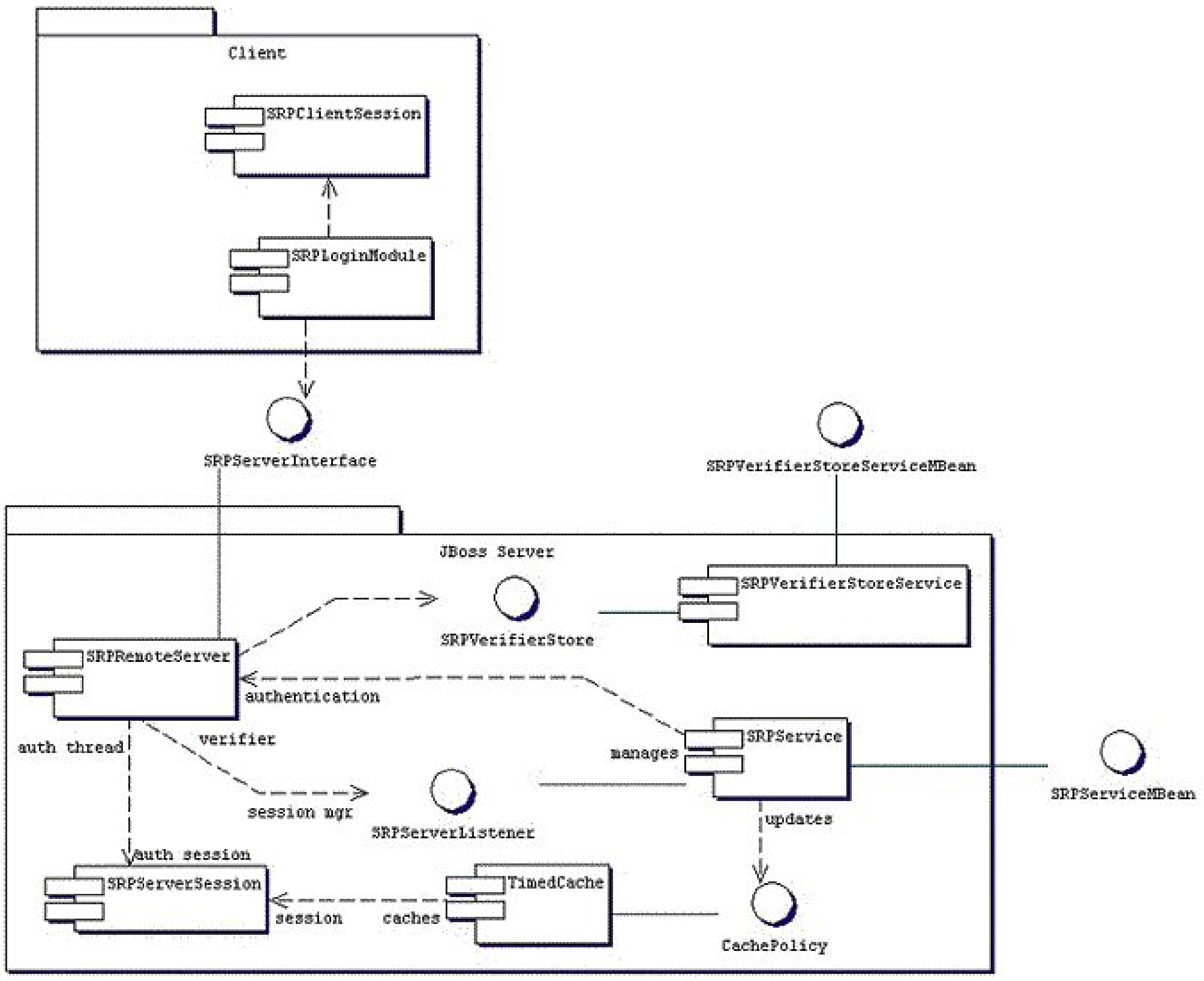


Figure 7.14. The JBossSX components of the SRP client-server framework.

On the client side, SRP shows up as a custom JAAS `LoginModule` implementation that communicates to the authentication server through an `org.jboss.security.srp.SRPServerInterface` proxy. A client enables authentication using SRP by creating a login configuration entry that includes the `org.jboss.security.srp.jaas.SRPLoginModule`. This module supports the following configuration options:

- **principalClassName**: This option is no longer supported. The principal class is now always `org.jboss.security.srp.jaas.SRPPrincipal`.
- **srpServerJndiName**: The JNDI name of the `SRPServerInterface` object to use for communicating with the SRP authentication server. If both `srpServerJndiName` and `srpServerRmiUrl` options are specified, the `srpServerJndiName` is tried before `srpServerRmiUrl`.
- **srpServerRmiUrl**: The RMI protocol URL string for the location of the `SRPServerInterface` proxy to use for communicating with the SRP authentication server.

- **externalRandomA**: A true/false flag indicating if the random component of the client public key A should come from the user callback. This can be used to input a strong cryptographic random number coming from a hardware token for example.

- **hasAuxChallenge**: A true/false flag indicating that a string will be sent to the server as an additional challenge for the server to validate. If the client session supports an encryption cipher then a temporary cipher will be created using the session private key and the challenge object sent as a `javax.crypto.SealedObject`.

- **multipleSessions**: a true/false flag indicating if a given client may have multiple SRP login sessions active simultaneously.

Any other options passed in that do not match one of the previous named options is treated as a JNDI property to use for the environment passed to the `InitialContext` constructor. This is useful if the SRP server interface is not available from the default `InitialContext`.

The `SRPLoginModule` needs to be configured along with the standard `ClientLoginModule` to allow the SRP authentication credentials to be used for validation of access to security J2EE components. An example login configuration entry that demonstrates such a setup is:

```
srp {
    org.jboss.security.srp.jaas.SRPLoginModule required
    srpServerJndiName="SRPServerInterface"
    ;

    org.jboss.security.ClientLoginModule required
    password-stacking="useFirstPass"
    ;
};
```

On the JBoss server side, there are two MBeans that manage the objects that collectively make up the SRP server. The primary service is the `org.jboss.security.srp.SRPService` MBean, and it is responsible for exposing an RMI accessible version of the SRPServerInterface as well as updating the SRP authentication session cache. The configurable SRPService MBean attributes include the following:

- **JndiName**: The JNDI name from which the SRPServerInterface proxy should be available. This is the location where the `SRPService` binds the serializable dynamic proxy to the `SRPServerInterface`. If not specified it defaults to `srp/SRPServerInterface`.

- **VerifierSourceJndiName**: The JNDI name of the `SRPVerifierSource` implementation that should be used by the `SRPService`. If not set it defaults to `srp/DefaultVerifierSource`.

- **AuthenticationCacheJndiName**: The JNDI name under which the authentication `org.jboss.util.CachePolicy` implementation to be used for caching authentication information is bound. The SRP session cache is made available for use through this binding. If not specified it defaults to `srp/AuthenticationCache`.

- **ServerPort**: RMI port for the `SRPRemoteServerInterface`. If not specified it defaults to 10099.

- **ClientSocketFactory**: An optional custom `java.rmi.server.RMIClientSocketFactory` implementation class name used during the export of the `SRPServerInterface`. If not specified the default `RMIClientSocketFactory` is used.

- **ServerSocketFactory**: An optional custom `java.rmi.server.RMIServerSocketFactory` implementation class name used during the export of the `SRPServerInterface`. If not specified the default `RMIServerSocketFactory` is used.
- **AuthenticationCacheTimeout**: Specifies the timed cache policy timeout in seconds. If not specified this defaults to 1800 seconds(30 minutes).
- **AuthenticationCacheResolution**: Specifies the timed cache policy resolution in seconds. This controls the interval between checks for timeouts. If not specified this defaults to 60 seconds(1 minute).
- **RequireAuxChallenge**: Set if the client must supply an auxiliary challenge as part of the verify phase. This gives control over whether the `SRPLoginModule` configuration used by the client must have the `useAuxChallenge` option enabled.
- **OverwriteSessions**: A flag indicating if a successful user auth for an existing session should overwrite the current session. This controls the behavior of the server SRP session cache when clients have not enabled the multiple session per user mode. The default is false meaning that the second attempt by a user to authentication will succeed, but the resulting SRP session will not overwrite the previous SRP session state.

The one input setting is the `VerifierSourceJndiName` attribute. This is the location of the SRP password information store implementation that must be provided and made available through JNDI. The `org.jboss.security.srp SRPVerifierStoreService` is an example MBean service that binds an implementation of the `SRPVerifierStore` interface that uses a file of serialized objects as the persistent store. Although not realistic for a production environment, it does allow for testing of the SRP protocol and provides an example of the requirements for an `SRPVerifierStore` service. The configurable `SRPVerifierStoreService` MBean attributes include the following:

- **JndiName**: The JNDI name from which the `SRPVerifierStore` implementation should be available. If not specified it defaults to `srp/DefaultVerifierSource`.
- **StoreFile**: The location of the user password verifier serialized object store file. This can be either a URL or a resource name to be found in the classpath. If not specified it defaults to `SRPVerifierStore.ser`.

The `SRPVerifierStoreService` MBean also supports `addUser` and `delUser` operations for addition and deletion of users. The signatures are:

```
public void addUser(String username, String password) throws IOException;
public void delUser(String username) throws IOException;
```

An example configuration of these services is presented in Section 7.6.

7.6.1. Providing Password Information for SRP

The default implementation of the `SRPVerifierStore` interface is not likely to be suitable for you production security environment as it requires all password hash information to be available as a file of serialized objects. You need to provide an MBean service that provides an implementation of the `SRPVerifierStore` interface that integrates with your existing security information stores. The `SRPVerifierStore` interface is shown in.

Example 7.10. The SRPVerifierStore interface

```
package org.jboss.security.srp;

import java.io.IOException;
import java.io.Serializable;
import java.security.KeyException;

public interface SRPVerifierStore
{
    public static class VerifierInfo implements Serializable
    {
        /**
         * The username the information applies to. Perhaps redundant
         * but it makes the object self contained.
         */
        public String username;

        /** The SRP password verifier hash */
        public byte[] verifier;
        /** The random password salt originally used to verify the password */
        public byte[] salt;
        /** The SRP algorithm primitive generator */
        public byte[] g;
        /** The algorithm safe-prime modulus */
        public byte[] N;
    }

    /**
     *  Get the indicated user's password verifier information.
     */
    public VerifierInfo getUserVerifier(String username)
        throws KeyException, IOException;
    /**
     *  Set the indicated users' password verifier information. This
     *  is equivalent to changing a user's password and should
     *  generally invalidate any existing SRP sessions and caches.
     */
    public void setUserVerifier(String username, VerifierInfo info)
        throws IOException;

    /**
     * Verify an optional auxiliary challenge sent from the client to
     * the server.  The auxChallenge object will have been decrypted
     * if it was sent encrypted from the client. An example of a
     * auxiliary challenge would be the validation of a hardware token
     * (SafeWord, SecureID, iButton) that the server validates to
     * further strengthen the SRP password exchange.
     */
     public void verifyUserChallenge(String username, Object auxChallenge)
         throws SecurityException;
}
```

The primary function of a `SRPVerifierStore` implementation is to provide access to the `SRPVerifier-Store.VerifierInfo` object for a given username. The `getUserVerifier(String)` method is called by the `SRPService` at that start of a user SRP session to obtain the parameters needed by the SRP algorithm. The elements of the `VerifierInfo` objects are:

- **username**: The user's name or id used to login.
- **verifier**: This is the one-way hash of the password or PIN the user enters as proof of their identity. The `org.jboss.security.Util` class has a `calculateVerifier` method that performs that password hashing algorithm. The output password `H(salt | H(username | ':' | password))` as defined by RFC2945. Here `H` is

the SHA secure hash function. The username is converted from a string to a `byte[]` using the UTF-8 encoding.

- **salt**: This is a random number used to increase the difficulty of a brute force dictionary attack on the verifier password database in the event that the database is compromised. It is a value that should be generated from a cryptographically strong random number algorithm when the user's existing clear-text password is hashed.
- **g**: The SRP algorithm primitive generator. In general this can be a well known fixed parameter rather than a per-user setting. The `org.jboss.security.srp.SRPConf` utility class provides several settings for g including a good default which can obtained via `SRPConf.getDefaultParams().g()`.
- **N**: The SRP algorithm safe-prime modulus. In general this can be a well known fixed parameter rather than a per-user setting. The `org.jboss.security.srp.SRPConf` utility class provides several settings for `N` including a good default which can obtained via `SRPConf.getDefaultParams().N()`.

So, step 1 of integrating your existing password store is the creation of a hashed version of the password information. If your passwords are already store in an irreversible hashed form, then this can only be done on a per-user basis as part of an upgrade procedure for example. Note that the `setUserVerifier(String, VerifierInfo)` method is not used by the current SRPSerivce and may be implemented as no-op method, or even one that throws an exception stating that the store is read-only.

Step 2 is the creation of the custom `SRPVerifierStore` interface implementation that knows how to obtain the `VerifierInfo` from the store you created in step 1. The `verifyUserChallenge(String, Object)` method of the interface is only called if the client `SRPLoginModule` configuration specifies the `hasAuxChallenge` option. This can be used to integrate existing hardware token based schemes like SafeWord or Radius into the SRP algorithm.

Step 3 is the creation of an MBean that makes the step 2 implementation of the `SRPVerifierStore` interface available via JNDI, and exposes any configurable parameters you need. In addition to the default `org.jboss.security.srp.SRPVerifierStoreService` example, the SRP example presented later in this chapter provides a Java properties file based `SRPVerifierStore` implementation. Between the two examples you should have enough to integrate your security store.

7.6.2. Inside of the SRP algorithm

The appeal of the SRP algorithm is that is allows for mutual authentication of client and server using simple text passwords without a secure communication channel. You might be wondering how this is done. If you want the complete details and theory behind the algorithm, refer to the SRP references mentioned in a note earlier. There are six steps that are performed to complete authentication:

1. The client side `SRPLoginModule` retrieves the SRPServerInterface instance for the remote authentication server from the naming service.
2. The client side `SRPLoginModule` next requests the SRP parameters associated with the username attempting the login. There are a number of parameters involved in the SRP algorithm that must be chosen when the user password is first transformed into the verifier form used by the SRP algorithm. Rather than hard-coding the parameters (which could be done with minimal security risk), the JBossSX implementation allows a user to retrieve this information as part of the exchange protocol. The `getSRPParameters(username)` call retrieves the SRP parameters for the given username.

3. The client side `SRPLoginModule` begins an SRP session by creating an `SRPClientSession` object using the login username, clear-text password, and SRP parameters obtained from step 2. The client then creates a random number A that will be used to build the private SRP session key. The client then initializes the server side of the SRP session by invoking the `SRPServerInterface.init` method and passes in the username and client generated random number `A`. The server returns its own random number `B`. This step corresponds to the exchange of public keys.

4. The client side `SRPLoginModule` obtains the private SRP session key that has been generated as a result of the previous messages exchanges. This is saved as a private credential in the login `Subject`. The server challenge response `M2` from step 4 is verified by invoking the `SRPClientSession.verify` method. If this succeeds, mutual authentication of the client to server, and server to client have been completed. The client side `SRPLoginModule` next creates a challenge `M1` to the server by invoking `SRPClientSession.response` method passing the server random number `B` as an argument. This challenge is sent to the server via the `SRPServerInterface.verify` method and server's response is saved as `M2`. This step corresponds to an exchange of challenges. At this point the server has verified that the user is who they say they are.

5. The client side `SRPLoginModule` saves the login username and `M1` challenge into the `LoginModule` sharedState map. This is used as the Principal name and credentials by the standard JBoss `ClientLoginModule`. The `M1` challenge is used in place of the password as proof of identity on any method invocations on J2EE components. The `M1` challenge is a cryptographically strong hash associated with the SRP session. Its interception via a third partly cannot be used to obtain the user's password.

6. At the end of this authentication protocol, the SRPServerSession has been placed into the SRPService authentication cache for subsequent use by the `SRPCacheLoginModule`.

Although SRP has many interesting properties, it is still an evolving component in the JBossSX framework and has some limitations of which you should be aware. Issues of note include the following:

- Because of how JBoss detaches the method transport protocol from the component container where authentication is performed, an unauthorized user could snoop the SRP `M1` challenge and effectively use the challenge to make requests as the associated username. Custom interceptors that encrypt the challenge using the SRP session key can be used to prevent this issue.

- The SRPService maintains a cache of SRP sessions that time out after a configurable period. Once they time out, any subsequent J2EE component access will fail because there is currently no mechanism for transparently renegotiating the SRP authentication credentials. You must either set the authentication cache timeout very long (up to 2,147,483,647 seconds, or approximately 68 years), or handle re-authentication in your code on failure.

- By default there can only be one SRP session for a given username. Because the negotiated SRP session produces a private session key that can be used for encryption/decryption between the client and server, the session is effectively a stateful one. JBoss supports for multiple SRP sessions per user, but you cannot encrypt data with one session key and then decrypt it with another.

To use end-to-end SRP authentication for J2EE component calls, you need to configure the security domain under which the components are secured to use the `org.jboss.security.srp.jaas.SRPCacheLoginModule`. The `SRPCacheLoginModule` has a single configuration option named `cacheJndiName` that sets the JNDI location of the SRP authentication `CachePolicy` instance. This must correspond to the `AuthenticationCacheJndiName` attribute value of the `SRPService` MBean. The `SRPCacheLoginModule` authenticates user credentials by obtaining the client challenge from the `SRPServerSession` object in the authentication cache and comparing this to the challenge passed as the user credentials. Figure 7.15 illustrates the operation of the SRPCacheLoginModule.login method implementation.

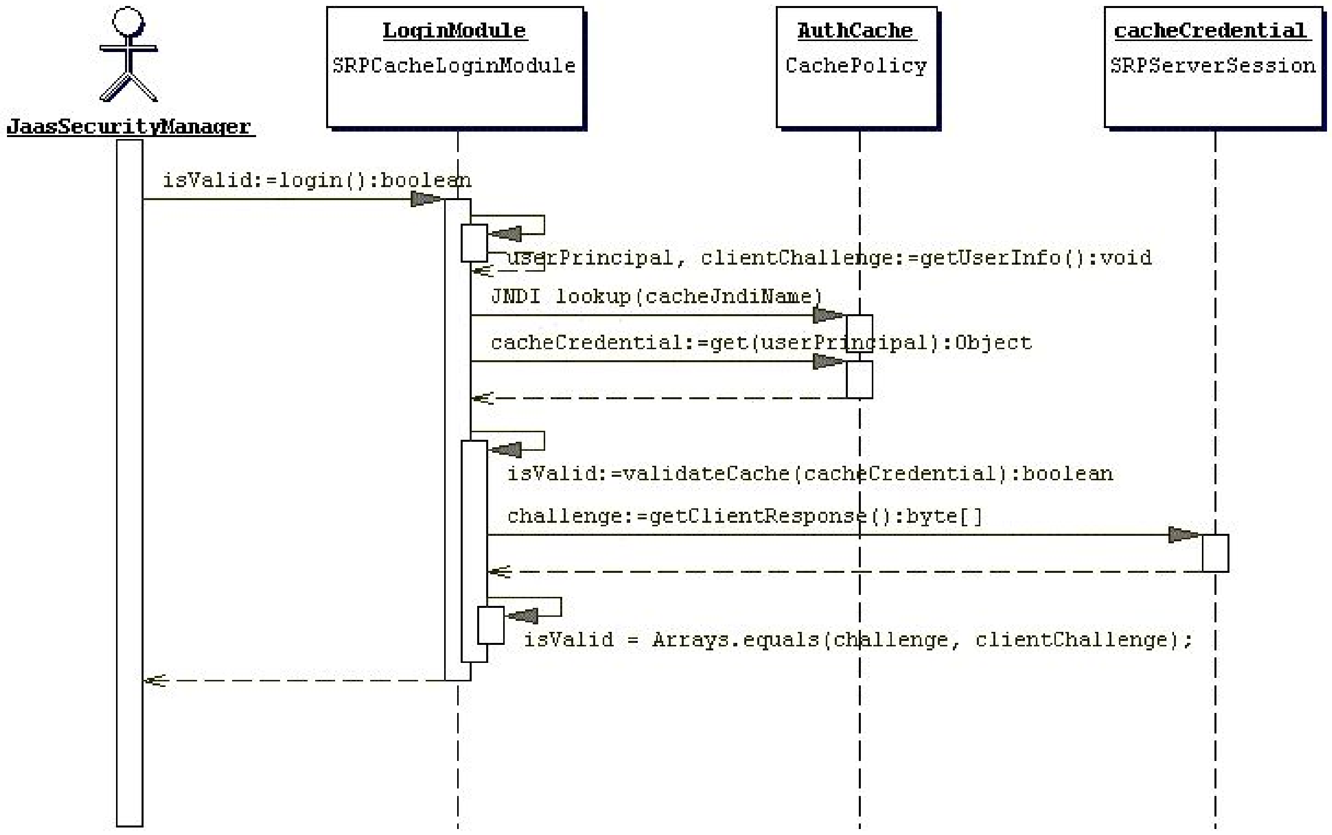

LoginModule
SRPCacheLoginModule
AuthCache
CachePolicy
cacheCredential
SRPServerSession
JaasSecurityManager
isValid:=login():boolean
userPrincipal, clientChallenge:=getUserInfo():void
JNDI lookup(cacheJndiName)
cacheCredential:=get(userPrincipal):Object
isValid:=validateCache(cacheCredential):boolean
challenge:=getClientResponse():byte[]
isValid = Arrays.equals(challenge, clientChallenge);

Figure 7.15. A sequence diagram illustrating the interaction of the SRPCacheLoginModule with the SRP session cache.

7.6.2.1. An SRP example

We have covered quite a bit of material on SRP and now its time to demonstrate SRP in practice with an example. The example demonstrates client side authentication of the user via SRP as well as subsequent secured access to a simple EJB using the SRP session challenge as the user credential. The test code deploys an EJB JAR that includes a SAR for the configuration of the server side login module configuration and SRP services. As in the previous examples we will dynamically install the server side login module configuration using the `SecurityConfig` MBean. In this example we also use a custom implementation of the `SRPVerifierStore` interface that uses an in memory store that is seeded from a Java properties file rather than a serialized object store as used by the `SRPVerifierStoreService`. This custom service is `org.jboss.book.security.ex3.service.PropertiesVerifierStore`. The following shows the contents of the JAR that contains the example EJB and SRP services.

```
[examples]$ jar tf output/security/security-ex3.jar
META-INF/MANIFEST.MF
META-INF/ejb-jar.xml
META-INF/jboss.xml
org/jboss/book/security/ex3/Echo.class
org/jboss/book/security/ex3/EchoBean.class
org/jboss/book/security/ex3/EchoHome.class
roles.properties
users.properties
```

```
security-ex3.sar
```

The key SRP related items in this example are the SRP MBean services configuration, and the SRP login module configurations. The `jboss-service.xml` descriptor of the `security-ex3.sar` is given in Example 7.11, while Example 7.12 and Example 7.13 give the example client side and server side login module configurations.

Example 7.11. The security-ex3.sar jboss-service.xml descriptor for the SRP services

```
<server>
    <!-- The custom JAAS login configuration that installs
         a Configuration capable of dynamically updating the
         config settings -->

    <mbean code="org.jboss.book.security.service.SecurityConfig"
           name="jboss.docs.security:service=LoginConfig-EX3">
        <attribute name="AuthConfig">META-INF/login-config.xml</attribute>
        <attribute name="SecurityConfigName">jboss.security:name=SecurityConfig</attribute>
    </mbean>

    <!-- The SRP service that provides the SRP RMI server and server side
         authentication cache -->
    <mbean code="org.jboss.security.srp.SRPService"
           name="jboss.docs.security:service=SRPService">
        <attribute name="VerifierSourceJndiName">srp-test/security-ex3</attribute>
        <attribute name="JndiName">srp-test/SRPServerInterface</attribute>
        <attribute name="AuthenticationCacheJndiName">srp-test/AuthenticationCache</attribute>
        <attribute name="ServerPort">0</attribute>
        <depends>jboss.docs.security:service=PropertiesVerifierStore</depends>
    </mbean>

    <!-- The SRP store handler service that provides the user password verifier
         information -->
    <mbean code="org.jboss.security.ex3.service.PropertiesVerifierStore"
           name="jboss.docs.security:service=PropertiesVerifierStore">
        <attribute name="JndiName">srp-test/security-ex3</attribute>
    </mbean>
</server>
```

Example 7.12. The client side standard JAAS configuration

```
srp {
    org.jboss.security.srp.jaas.SRPLoginModule required
    srpServerJndiName="srp-test/SRPServerInterface"
    ;

    org.jboss.security.ClientLoginModule required
    password-stacking="useFirstPass"
    ;
};
```

Example 7.13. The server side XMLLoginConfig configuration

```
<application-policy name="security-ex3">
    <authentication>
```

```
        <login-module code="org.jboss.security.srp.jaas.SRPCacheLoginModule"
                      flag = "required">
            <module-option name="cacheJndiName">srp-test/AuthenticationCache</module-option>
        </login-module>
        <login-module code="org.jboss.security.auth.spi.UsersRolesLoginModule"
                      flag = "required">
            <module-option name="password-stacking">useFirstPass</module-option>
        </login-module>
    </authentication>
</application-policy>
```

The example services are the `ServiceConfig` and the `PropertiesVerifierStore` and `SRPService` MBeans. Note that the `JndiName` attribute of the `PropertiesVerifierStore` is equal to the `VerifierSourceJndiName` attribute of the `SRPService`, and that the `SRPService` depends on the `PropertiesVerifierStore`. This is required because the `SRPService` needs an implementation of the `SRPVerifierStore` interface for accessing user password verification information.

The client side login module configuration makes use of the `SRPLoginModule` with a `srpServerJndiName` option value that corresponds to the JBoss server component `SRPService` JndiName attribute value(`srp-test/SRPServerInterface`). Also needed is the `ClientLoginModule` configured with the `password-stacking="useFirstPass"` value to propagate the user authentication credentials generated by the `SRPLoginModule` to the EJB invocation layer.

There are two issues to note about the server side login module configuration. First, note the `cacheJndiName=srp-test/AuthenticationCache` configuration option tells the `SRPCacheLoginModule` the location of the `CachePolicy` that contains the `SRPServerSession` for users who have authenticated against the `SRPService`. This value corresponds to the `SRPService` `AuthenticationCacheJndiName` attribute value. Second, the configuration includes a `UsersRolesLoginModule` with the `password-stacking=useFirstPass` configuration option. It is required to use a second login module with the `SRPCacheLoginModule` because SRP is only an authentication technology. A second login module needs to be configured that accepts the authentication credentials validated by the `SRPCacheLoginModule` to set the principal's roles that determines the principal's permissions. The `UsersRolesLoginModule` is augmenting the SRP authentication with properties file based authorization. The user's roles are coming the `roles.properties` file included in the EJB JAR.

Now, run the example 3 client by executing the following command from the book examples directory:

```
[examples]$ ant -Dchap=security -Dex=3 run-example
...
run-example3:
     [echo] Waiting for 5 seconds for deploy...
     [java] Logging in using the 'srp' configuration
     [java] Created Echo
     [java] Echo.echo()#1 = This is call 1
     [java] Echo.echo()#2 = This is call 2
```

In the `examples/logs` directory you will find a file called `ex3-trace.log`. This is a detailed trace of the client side of the SRP algorithm. The traces show step-by-step the construction of the public keys, challenges, session key and verification.

Note that the client has taken a long time to run relative to the other simple examples. The reason for this is the construction of the client's public key. This involves the creation of a cryptographically strong random number, and this process takes quite a bit of time the first time it occurs. If you were to log out and log in again within the same VM, the process would be much faster. Also note that `Echo.echo()#2` fails with an authentication exception. The client code sleeps for 15 seconds after making the first call to demonstrate the behavior of the `SRPService` cache expiration. The `SRPService` cache policy timeout has been set to a mere 10 seconds to force this issue. As stated earlier, you need to make the cache timeout very long, or handle re-authentication on failure.

7.7. Running JBoss with a Java 2 security manager

By default the JBoss server does not start with a Java 2 security manager. If you want to restrict privileges of code using Java 2 permissions you need to configure the JBoss server to run under a security manager. This is done by configuring the Java VM options in the `run.bat` or `run.sh` scripts in the JBoss server distribution bin directory. The two required VM options are as follows:

- **java.security.manager**: This is used without any value to specify that the default security manager should be used. This is the preferred security manager. You can also pass a value to the `java.security.manager` option to specify a custom security manager implementation. The value must be the fully qualified class name of a subclass of `java.lang.SecurityManager`. This form specifies that the policy file should augment the default security policy as configured by the VM installation.
- **java.security.policy**: This is used to specify the policy file that will augment the default security policy information for the VM. This option takes two forms: `java.security.policy=policyFileURL` and `java.security.policy==policyFileURL`. The first form specifies that the policy file should augment the default security policy as configured by the VM installation. The second form specifies that only the indicated policy file should be used. The `policyFileURL` value can be any URL for which a protocol handler exists, or a file path specification.

Both the `run.bat` and `run.sh` start scripts reference an JAVA_OPTS variable which you can use to set the security manager properties.

Enabling Java 2 security is the easy part. The difficult part of Java 2 security is establishing the allowed permissions. If you look at the `server.policy` file that is contained in the default configuration file set, you'll see that it contains the following permission grant statement:

```
grant {
    // Allow everything for now
    permission java.security.AllPermission;
};
```

This effectively disables security permission checking for all code as it says any code can do anything, which is not a reasonable default. What is a reasonable set of permissions is entirely up to you.

The current set of JBoss specific `java.lang.RuntimePermissions` that are required include:

TargetName	What the permission allows	Risks
org.jboss.security.SecurityAssociation.getPrincipalInfo	Access to the org.jboss.security.SecurityAssociation getPrincipal() and getCredentials() methods.	The ability to see the current thread caller and credentials.
org.jboss.security.SecurityAssociation.setPrincipalInfo	Access to the org.jboss.security.SecurityAssociat	The ability to set the current thread caller and credentials.

TargetName	What the permission allows	Risks
	ion setPrincipal() and setCredentials() methods.	
org.jboss.security.SecurityAssociation.setServer	Access to the org.jboss.security.SecurityAssociation setServer method.	The ability to enable or disable multithread storage of the caller principal and credential.
org.jboss.security.SecurityAssociation.setRunAsRole	Access to the org.jboss.security.SecurityAssociation pushRunAsRole and popRunAsRole methods.	The ability to change the current caller run-as role principal.

To conclude this discussion, here is a little-known tidbit on debugging security policy settings. There are various debugging flag that you can set to determine how the security manager is using your security policy file as well as what policy files are contributing permissions. Running the VM as follows shows the possible debugging flag settings:

```
[bin]$ java -Djava.security.debug=help

all           turn on all debugging
access        print all checkPermission results
combiner      SubjectDomainCombiner debugging
jar           jar verification
logincontext  login context results
policy        loading and granting
provider      security provider debugging
scl           permissions SecureClassLoader assigns

The following can be used with access:

stack     include stack trace
domain    dumps all domains in context
failure   before throwing exception, dump stack
          and domain that didn't have permission

Note: Separate multiple options with a comma
```

Running with `-Djava.security.debug=all` provides the most output, but the output volume is torrential. This might be a good place to start if you don't understand a given security failure at all. A less verbose setting that helps debug permission failures is to use `-Djava.security.debug=access,failure`. This is still relatively verbose, but not nearly as bad as the all mode as the security domain information is only displayed on access failures.

7.8. Using SSL with JBoss using JSSE

JBoss uses JSEE, the Java Secure Socket Extension (JSSE), for SSL. JSSE is bundled with JDK 1.4. To get started with JSSE you need a public key/private key pair in the form of an X509 certificate for use by the SSL server sockets. For the purpose of this example we have created a self-signed certificate using the JDK keytool and included the resulting keystore file, `example.keystore`. It was created using the following command and input:

```
 keytool -genkey -keystore example.keystore -storepass rmi+ssl -keypass rmi+ssl -keyalg RSA -alias exampl
```

This produces a keystore file called `example.keystore`. A keystore is a database of security keys. There are two different types of entries in a keystore:

- **key entries**: each entry holds very sensitive cryptographic key information, which is stored in a protected format to prevent unauthorized access. Typically, a key stored in this type of entry is a secret key, or a private key accompanied by the certificate chain for the corresponding public key. The `keytool` and `jarsigner` tools only handle the later type of entry, that is private keys and their associated certificate chains.
- **trusted certificate entries**: each entry contains a single public key certificate belonging to another party. It is called a trusted certificate because the keystore owner trusts that the public key in the certificate indeed belongs to the identity identified by the subject (owner) of the certificate. The issuer of the certificate vouches for this, by signing the certificate.

Listing the `src/main/org/jboss/book/security/example.keystore` examples file contents using the keytool shows one self-signed certificate:

```
[examples]$ keytool -list -v -keystore src/main/org/jboss/book/security/example.keystore
Enter keystore password:  rmi+ssl

Keystore type: jks
Keystore provider: SUN

Your keystore contains 1 entry

Alias name: example
Creation date: Oct 31, 2006
Entry type: keyEntry
Certificate chain length: 1
Certificate[1]:
Owner: CN=example, OU=admin book, DC=jboss, DC=org
Issuer: CN=example, OU=admin book, DC=jboss, DC=org
Serial number: 45481c1b
Valid from: Tue Oct 31 22:01:31 CST 2006 until: Fri Oct 28 23:01:31 CDT 2016
Certificate fingerprints:
         MD5:  C2:CA:CA:D3:00:71:3E:32:CB:B3:C8:A8:4E:68:9A:BB
         SHA1: A6:44:EF:66:2A:49:14:B0:A4:14:74:8B:64:61:E4:E6:AF:E3:70:41


*******************************************
*******************************************
```

With JSSE working and a keystore with the certificate you will use for the JBoss server, your are ready to configure JBoss to use SSL for EJB access. This is done by configuring the EJB invoker RMI socket factories. The JBossSX framework includes implementations of the `java.rmi.server.RMIServerSocketFactory` and `java.rmi.server.RMIClientSocketFactory` interfaces that enable the use of RMI over SSL encrypted sockets. The implementation classes are `org.jboss.security.ssl.RMISSLServerSocketFactory` and `org.jboss.security.ssl.RMISSLClientSocketFactory` respectively. There are two steps to enable the use of SSL for RMI access to EJBs. The first is to enable the use of a keystore as the database for the SSL server certificate, which is done by configuring an `org.jboss.security.plugins.JaasSecurityDomain` MBean. The `jboss-service.xml` descriptor in the `book/security/ex4` directory includes the `JaasSecurityDomain` definition shown in Example 7.14.

Example 7.14. A sample JaasSecurityDomain config for RMI/SSL

```
<!-- The SSL domain setup -->
<mbean code="org.jboss.security.plugins.JaasSecurityDomain"
       name="jboss.security:service=JaasSecurityDomain,domain=RMI+SSL">
    <constructor>
        <arg type="java.lang.String" value="RMI+SSL"/>
    </constructor>
    <attribute name="KeyStoreURL">example.keystore</attribute>
    <attribute name="KeyStorePass">rmi+ssl</attribute>
</mbean>
```

The `JaasSecurityDomain` is a subclass of the standard `JaasSecurityManager` class that adds the notions of a keystore as well JSSE `KeyManagerFactory` and `TrustManagerFactory` access. It extends the basic security manager to allow support for SSL and other cryptographic operations that require security keys. This configuration simply loads the example.keystore from the example 4 MBean SAR using the indicated password.

The second step is to define an EJB invoker configuration that uses the JBossSX RMI socket factories that support SSL. To do this you need to define a custom configuration for the `JRMPInvoker` we saw in Chapter 4 as well as an EJB setup that makes use of this invoker. The top of the listing shows the `jboss-service.xml` descriptor that defines the custom `JRMPInovker`

```
<mbean code="org.jboss.invocation.jrmp.server.JRMPInvoker"
       name="jboss:service=invoker,type=jrmp,socketType=SSL">
    <attribute name="RMIObjectPort">14445</attribute>
    <attribute name="RMIClientSocketFactory">
        org.jboss.security.ssl.RMISSLClientSocketFactory
    </attribute>
    <attribute name="RMIServerSocketFactory">
        org.jboss.security.ssl.RMISSLServerSocketFactory
    </attribute>
    <attribute name="SecurityDomain">java:/jaas/RMI+SSL</attribute>
    <depends>jboss.security:service=JaasSecurityDomain,domain=RMI+SSL</depends>
</mbean>
```

To set up an SSL invoker, we will create an invoker binding named `stateless-ssl-invoker` that uses our custom JRMPInvoker. We can declare the invoker binding and connect it to `EchoBean4` as shown in the following `jboss.xml` file.

```
<?xml version="1.0"?>
<jboss>
    <enterprise-beans>
        <session>
            <ejb-name>EchoBean4</ejb-name>
            <configuration-name>Standard Stateless SessionBean</configuration-name>
            <invoker-bindings>
                <invoker>
                    <invoker-proxy-binding-name>
                        stateless-ssl-invoker
                    </invoker-proxy-binding-name>
                </invoker>
            </invoker-bindings>
        </session>
    </enterprise-beans>

    <invoker-proxy-bindings>
        <invoker-proxy-binding>
            <name>stateless-ssl-invoker</name>
            <invoker-mbean>jboss:service=invoker,type=jrmp,socketType=SSL</invoker-mbean>
            <proxy-factory>org.jboss.proxy.ejb.ProxyFactory</proxy-factory>
            <proxy-factory-config>
            <client-interceptors>
                <home>
                    <interceptor>org.jboss.proxy.ejb.HomeInterceptor</interceptor>
                    <interceptor>org.jboss.proxy.SecurityInterceptor</interceptor>
                    <interceptor>org.jboss.proxy.TransactionInterceptor</interceptor>
                    <interceptor>org.jboss.invocation.InvokerInterceptor</interceptor>
                </home>
                <bean>
                    <interceptor>org.jboss.proxy.ejb.StatelessSessionInterceptor</interceptor>
                    <interceptor>org.jboss.proxy.SecurityInterceptor</interceptor>
                    <interceptor>org.jboss.proxy.TransactionInterceptor</interceptor>
                    <interceptor>org.jboss.invocation.InvokerInterceptor</interceptor>
                </bean>
            </client-interceptors>
            </proxy-factory-config>
        </invoker-proxy-binding>
    </invoker-proxy-bindings>
</jboss>
```

The example 4 code is located under the `src/main/org/jboss/book/security/ex4` directory of the book examples. This is another simple stateless session bean with an echo method that returns its input argument. It is hard to tell when SSL is in use unless it fails, so we'll run the example 4 client in two different ways to demonstrate that the EJB deployment is in fact using SSL. Start the JBoss server using the default configuration and then run example 4b as follows:

```
[examples]$ ant -Dchap=security -Dex=4b run-example
...
run-example4b:
...
     [java] Exception in thread "main" java.rmi.ConnectIOException: error during JRMP connect
ion establishment; nested exception is:
     [java]     javax.net.ssl.SSLHandshakeException: sun.security.validator.ValidatorExceptio
n: No trusted certificate found
...
```

The resulting exception is expected, and is the purpose of the 4b version of the example. Note that the exception stack trace has been edited to fit into the book format, so expect some difference. The key item to notice about the exception is it clearly shows you are using the Sun JSSE classes to communicate with the JBoss EJB container. The exception is saying that the self-signed certificate you are using as the JBoss server certificate cannot be validated as signed by any of the default certificate authorities. This is expected because the default certificate authority keystore that ships with the JSSE package only includes well known certificate authorities such as VeriSign, Thawte, and RSA Data Security. To get the EJB client to accept your self-signed certificate as valid, you need to tell the JSSE classes to use your `example.keystore` as its truststore. A truststore is just a keystore that contains public key certificates used to sign other certificates. To do this, run example 4 using `-Dex=4` rather than `-Dex=4b` to pass the location of the correct truststore using the `javax.net.ssl.trustStore` system property:

```
[examples]$ ant -Dchap=security -Dex=4 run-example
...
run-example4:
     [copy] Copying 1 file to /tmp/jboss-4.0.1/server/default/deploy
     [echo] Waiting for 5 seconds for deploy...
...
     [java] Created Echo
     [java] Echo.echo()#1 = This is call 1
```

This time the only indication that an SSL socket is involved is because of the `SSL handshakeCompleted` message. This is coming from the `RMISSLClientSocketFactory` class as a debug level log message. If you did not have the client configured to print out log4j debug level messages, there would be no direct indication that SSL was involved. If you note the run times and the load on your system CPU, there definitely is a difference. SSL, like SRP, involves the use of cryptographically strong random numbers that take time to seed the first time they are used. This shows up as high CPU utilization and start up times.

One consequence of this is that if you are running on a system that is slower than the one used to run the examples for the book, such as when running example 4b, you may seen an exception similar to the following:

```
javax.naming.NameNotFoundException: EchoBean4 not bound
   at sun.rmi.transport.StreamRemoteCall.exceptionReceivedFromServer
...
```

The problem is that the JBoss server has not finished deploying the example EJB in the time the client allowed. This is due to the initial setup time of the secure random number generator used by the SSL server socket. If you see this issue, simply rerun the example again or increase the deployment wait time in the `build-security.xml` Ant script.

7.9. Configuring JBoss for use Behind a Firewall

JBoss comes with many socket based services that open listening ports. In this section we list the services that open ports that might need to be configured to work when accessing JBoss behind a firewall. The following table shows the ports, socket type, associated service for the services in the default configuration file set. Table 7.2 shows the same information for the additional ports that exist in the all configuration file set.

Table 7.1. The ports found in the default configuration

Port	Type	Service
1098	TCP	`org.jboss.naming.NamingService`
1099	TCP	`org.jboss.naming.NamingService`
4444	TCP	`org.jboss.invocation.jrmp.server.JRMPInvoker`
4445	TCP	`org.jboss.invocation.pooled.server.PooledInvoker`
8009	TCP	`org.jboss.web.tomcat.tc4.EmbeddedTomcatService`
8080	TCP	`org.jboss.web.tomcat.tc4.EmbeddedTomcatService`
8083	TCP	`org.jboss.web.WebService`
8093	TCP	`org.jboss.mq.il.uil2.UILServerILService`

Table 7.2. Additional ports in the all configuration

Port	Type	Service
1100	TCP	`org.jboss.ha.jndi.HANamingService`
1101	TCP	`org.jboss.ha.jndi.HANamingService`

Port	Type	Service
1102	UDP	`org.jboss.ha.jndi.HANamingService`
1161	UDP	`org.jboss.jmx.adaptor.snmp.agent.SnmpAgentService`
1162	UDP	`org.jboss.jmx.adaptor.snmp.trapd.TrapdService`
3528	TCP	`org.jboss.invocation.iiop.IIOPInvoker`
4447	TCP	`org.jboss.invocation.jrmp.server.JRMPInvokerHA`
45566[a]	UDP	`org.jboss.ha.framework.server.ClusterPartition`

[a]Plus two additional anonymous UDP ports, one can be set using the `rcv_port`, and the other cannot be set.

7.10. How to Secure the JBoss Server

JBoss comes with several admin access points that need to be secured or removed to prevent unauthorized access to administrative functions in a deployment. This section describes the various admin services and how to secure them.

7.10.1. The JMX Console

The `jmx-console.war` found in the deploy directory provides an html view into the JMX microkernel. As such, it provides access to arbitrary admin type access like shutting down the server, stopping services, deploying new services, etc. It should either be secured like any other web application, or removed.

7.10.2. The Web Console

The `web-console.war` found in the `deploy/management` directory is another web application view into the JMX microkernel. This uses a combination of an applet and a HTML view and provides the same level of access to admin functionality as the `jmx-console.war`. As such, it should either be secured or removed. The `web-console.war` contains commented out templates for basic security in its `WEB-INF/web.xml` as well as commented out setup for a security domain in `WEB-INF/jboss-web.xml`.

7.10.3. The HTTP Invokers

The `http-invoker.sar` found in the deploy directory is a service that provides RMI/HTTP access for EJBs and the JNDI `Naming` service. This includes a servlet that processes posts of marshalled `org.jboss.invocation.Invocation` objects that represent invocations that should be dispatched onto the `MBeanServer`. Effectively this allows access to MBeans that support the detached invoker operation via HTTP since one could figure out how to format an appropriate HTTP post. To security this access point you would need to secure the `JMXInvokerServlet` servlet found in the `http-invoker.sar/invoker.war/WEB-INF/web.xml` descriptor. There is a secure mapping defined for the `/restricted/JMXInvokerServlet` path by default, one would simply have to remove the other paths and configure the `http-invoker` security domain setup in the `http-invoker.sar/invoker.war/WEB-INF/jboss-web.xml` descriptor.

7.10.4. The JMX Invoker

The `jmx-invoker-adaptor-server.sar` is a service that exposes the JMX MBeanServer interface via an RMI compatible interface using the RMI/JRMP detached invoker service. The only way for this service to be secured currently would be to switch the protocol to RMI/HTTP and secure the `http-invoker.sar` as described in the previous section. In the future this service will be deployed as an XMBean with a security interceptor that supports role based access checks.

8

Additional Services

This chapter discusses useful MBean services that are not discussed elsewhere either because they are utility services not necessary for running JBoss, or they don't fit into a current section of the book.

8.1. Memory and Thread Monitoring

The `jboss.system:type=ServerInfo` MBean provides several attributes that can be used to monitor the thread and memory usage in a JBoss instance. These attributes can be monitored in many ways: through the JMX Console, from a third-party JMX management tool, from shell scripts using the twiddle command, etc... The most interesting attributes are shown below.

FreeMemory
: This is the current free memory available in the JVM.

ActiveThreadCount
: This is the number of active threads in the JVM.

ActiveThreadGroupCount
: This is the number of active thread groups in the JVM.

These are useful metrics for monitoring and alerting, but developers and administrators need a little more insite than this. The Java 5 JVMs from Sun provide more detailed information about the current state of the JVM. Some of these details are exposed by JBoss through operations on the SystemInfo MBean.

listMemoryPools
: This operations shows the size and current usage of all JVM memory pools. This operation is only available when using Java 5.

listThreadDump
: This operations shows all threads currently running in the JVM. When using Java 5, JBoss will display a complete stack trace for each thread, showing you exactly what code each thread is executing.

listThreadCpuUtilization
: This operations shows all threads currently running in the JVM along with the total CPU time each thread has used. The operation is only available in Java 5.

8.2. The Log4j Service

The `Log4jService` MBean configures the Apache log4j system. JBoss uses the log4j framework as its internal logging API.

- **ConfigurationURL**: The URL for the log4j configuration file. This can refer to either a XML document parsed by the `org.apache.log4j.xml.DOMConfigurator` or a Java properties file parsed by the `org.apache.log4j.PropertyConfigurator`. The type of the file is determined by the URL content type, or if this is null, the file extension. The default setting of `resource:log4j.xml` refers to the `conf/log4j.xml` file of the active server configuration file set.
- **RefreshPeriod**: The time in seconds between checks for changes in the log4 configuration specified by the `ConfigurationURL` attribute. The default value is 60 seconds.
- **CatchSystemErr**: This boolean flag if true, indicates if the `System.err` stream should be redirected onto a log4j category called `STDERR`. The default is true.
- **CatchSystemOut**: This boolean flag if true, indicates if the `System.out` stream should be redirected onto a log4j category called `STDOUT`. The default is true.
- **Log4jQuietMode**: This boolean flag if true, sets the `org.apache.log4j.helpers.LogLog.setQuiteMode`. As of log4j1.2.8 this needs to be set to avoid a possible deadlock on exception at the appender level. See bug#696819.

8.3. System Properties Management

The management of system properties can be done using the system properties service. It supports setting of the VM global property values just as `java.lang.System.setProperty` method and the VM command line arguments do.

Its configurable attributes include:

- **Properties**: a specification of multiple property `name=value` pairs using the `java.util.Properites.load(java.io.InputStream)` method format. Each `property=value` statement is given on a separate line within the body of the `Properties` attribute element.
- **URLList**: a comma separated list of URL strings from which to load properties file formatted content. If a component in the list is a relative path rather than a URL it will be treated as a file path relative to the `<jboss-dist>/server/<config>` directory. For example, a component of `conf/local.properties` would be treated as a file URL that points to the `<jboss-dist>/server/default/conf/local.properties` file when running with the `default` configuration file set.

The following illustrates the usage of the system properties service with an external properties file.

```
<mbean code="org.jboss.varia.property.SystemPropertiesService"
        name="jboss.util:type=Service,name=SystemProperties">

    <!-- Load properties from each of the given comma separated URLs -->
    <attribute name="URLList">
        http://somehost/some-location.properties,
        ./conf/somelocal.properties
    </attribute>
</mbean>
```

The following illustrates the usage of the system properties service with an embedded properties list.

```
<mbean code="org.jboss.varia.property.SystemPropertiesService"
        name="jboss.util:type=Service,name=SystemProperties">
    <!-- Set properties using the properties file style. -->
    <attribute name="Properties">
       property1=This is the value of my property
       property2=This is the value of my other property
    </attribute>

</mbean>
```

8.4. Property Editor Management

In JBoss, JavaBean property editors are used for reading data types from service files and for editing values in the JMX console. The `java.bean.PropertyEditorManager` class controls the `java.bean.PropertyEditor` instances in the system. The property editor manager can be managed in JBoss using the `org.jboss.varia.property.PropertyEditorManagerService` MBean. The property editor manager service is configured in `deploy/properties-service.xml` and supports the following attributes:

- **BootstrapEditors:** This is a listing of `property_editor_class=editor_value_type_class` pairs defining the property editor to type mappings that should be preloaded into the property editor manager. The value type of this attribute is a string so that it may be set from a string without requiring a custom property editor.
- **Editors**: This serves the same function as the `BootstrapEditors` attribute, but its type is `java.util.Properties`. Setting it from a string value in a service file requires a custom property editor for properties objects already be loaded. JBoss provides a suitable property editor.
- **EditorSearchPath**: This attribute allows one to set the editor packages search path on the `PropertyEditor-Manager` editor packages search path. Since there can be only one search path, setting this value overrides the default search path established by JBoss. If you set this, make sure to add the JBoss search path, `org.jboss.util.propertyeditor` and `org.jboss.mx.util.propertyeditor`, to the front of the new search path.

8.5. Services Binding Management

With all of the independently deployed services available in JBoss, running multiple instances on a given machine can be a tedious exercise in configuration file editing to resolve port conflicts. The binding service allows you centrally configure the ports for multiple JBoss instances. After the service is normally loaded by JBoss, the `Service-Configurator` queries the service binding manager to apply any overrides that may exist for the service. The service binding manager is configured in `conf/jboss-service.xml`. The set of configurable attributes it supports include:

- **ServerName**: This is the name of the server configuration this JBoss instance is associated with. The binding manager will apply the overrides defined for the named configuration.
- **StoreFactoryClassName**: This is the name of the class that implements the `ServicesStoreFactory` interface. You may provide your own implementation, or use the default XML based store

`org.jboss.services.binding.XMLServicesStoreFactory`. The factory provides a `ServicesStore` instance responsible for providing the names configuration sets.

- **StoreURL**: This is the URL of the configuration store contents, which is passed to the `ServicesStore` instance to load the server configuration sets from. For the XML store, this is a simple service binding file.

The following is a sample service binding manager configuration that uses the `ports-01` configuration from the `sample-bindings.xml` file provided in the JBoss examples directory.

```
<mbean code="org.jboss.services.binding.ServiceBindingManager"
      name="jboss.system:service=ServiceBindingManager">
    <attribute name="ServerName">ports-01</attribute>
    <attribute name="StoreURL">
        ../docs/examples/binding-manager/sample-bindings.xml
    </attribute>
    <attribute name="StoreFactoryClassName">
        org.jboss.services.binding.XMLServicesStoreFactory
    </attribute>
</mbean>
```

The structure of the binding file is shown in Figure 8.1.

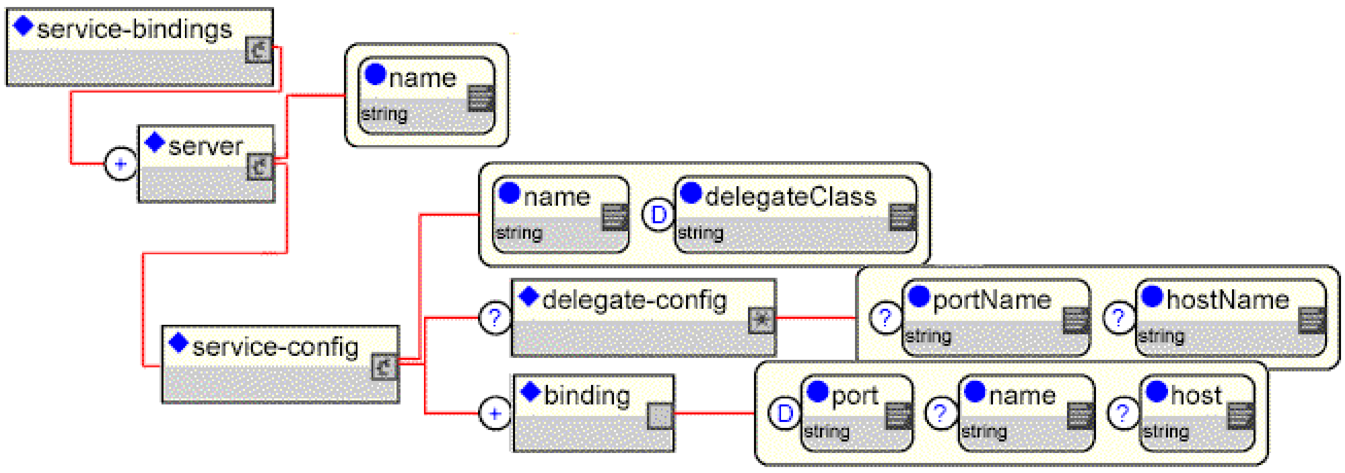


Figure 8.1. The binding service file structure

The elements are:

- **service-bindings**: The root element of the configuration file. It contains one or more server elements.

- **server**: This is the base of a JBoss server instance configuration. It has a required `name` attribute that defines the JBoss instance name to which it applies. This is the name that correlates with the `ServiceBindingManager` `ServerName` attribute value. The server element content consists of one or more `service-config` elements.

- **service-config**: This element represents a configuration override for an MBean service. It has a required name attribute that is the JMX `ObjectName` string of the MBean service the configuration applies to. It also has a required `delegateClass` name attribute that specifies the class name of the `ServicesConfigDelegate` implementation that knows how to handle bindings for the target service. Its contents consists of an optional `delegate-config` element and one or more binding elements.

- **binding**: A `binding` element specifies a named port and address pair. It has an optional `name` that can be used to provide multiple binding for a service. An example would be multiple virtual hosts for a web container. The port and address are specified via the optional `port` and `host` attributes respectively. If the port is not specified it defaults to 0 meaning choose an anonymous port. If the host is not specified it defaults to null meaning any address.

- **delegate-config**: The `delegate-config` element is an arbitrary XML fragment for use by the `ServicesConfig-Delegate` implementation. The `hostName` and `portName` attributes only apply to the `AttributeMappingDeleg-ate` of the example and are there to prevent DTD aware editors from complaining about their existence in the `AttributeMappingDelegate` configurations. Generally both the attributes and content of the `delegate-config` are arbitrary, but there is no way to specify and a element can have any number of attributes with a DTD.

The three `ServicesConfigDelegate` implementations are `AttributeMappingDelegate`, `XSLTConfigDelegate`, and `XSLTFileDelegate`.

8.5.1. AttributeMappingDelegate

The `AttributeMappingDelegate` class is an implementation of the `ServicesConfigDelegate` that expects a `deleg-ate-config` element of the form:

```
<delegate-config portName="portAttrName" hostName="hostAttrName">
    <attribute name="someAttrName">someHostPortExpr</attribute>
    <!-- ... -->
</delegate-config>
```

The `portAttrName` is the attribute name of the MBean service to which the binding port value should be applied, and the `hostAttrName` is the attribute name of the MBean service to which the binding host value should be ap-plied. If the `portName` attribute is not specified then the binding port is not applied. Likewise, if the `hostName` at-tribute is not specified then the binding host is not applied. The optional attribute element(s) specify arbitrary MBean attribute names whose values are a function of the host and/or port settings. Any reference to `${host}` in the attribute content is replaced with the host binding and any `${port}` reference is replaced with the port binding. The `portName`, `hostName` attribute values and attribute element content may reference system properties using the `${x}` syntax that is supported by the JBoss services descriptor.

The sample listing illustrates the usage of `AttributeMappingDelegate`.

```
<service-config name="jboss:service=Naming"
                 delegateClass="org.jboss.services.binding.AttributeMappingDelegate">
     <delegate-config portName="Port"/>
     <binding port="1099" />
</service-config>
```

Here the `jboss:service=Naming` MBean service has its `Port` attribute value overridden to 1099. The correspond-ing setting from the jboss1 server configuration overrides the port to 1199.

8.5.2. XSLTConfigDelegate

The `XSLTConfigDelegate` class is an implementation of the `ServicesConfigDelegate` that expects a `delegate-con-fig` element of the form:

```
<delegate-config>
```

```
    <xslt-config configName="ConfigurationElement"><![CDATA[
        Any XSL document contents...
        ]]>
     </xslt-config>
     <xslt-param name="param-name">param-value</xslt-param>
     <!-- ... -->
</delegate-config>
```

The `xslt-config` child element content specifies an arbitrary XSL script fragment that is to be applied to the MBean service attribute named by the `configName` attribute. The named attribute must be of type `org.w3c.dom.Element`. The optional `xslt-param` elements specify XSL script parameter values for parameters used in the script. There are two XSL parameters defined by default called `host` and `port`, and their values are set to the configuration host and port bindings.

The `XSLTConfigDelegate` is used to transform services whose `port/interface` configuration is specified using a nested XML fragment. The following example maps the port number on hypersonic datasource:

```

<service-config name="jboss.jca:service=ManagedConnectionFactory,name=DefaultDS"
                delegateClass="org.jboss.services.binding.XSLTConfigDelegate">
    <delegate-config>
        <xslt-config configName="ManagedConnectionFactoryProperties"><![CDATA[
<xsl:stylesheet
      xmlns:xsl='http://www.w3.org/1999/XSL/Transform' version='1.0'>

  <xsl:output method="xml" />
  <xsl:param name="host"/>
  <xsl:param name="port"/>

  <xsl:template match="/">
    <xsl:apply-templates/>
  </xsl:template>

  <xsl:template match="config-property[@name='ConnectionURL']">
    <config-property type="java.lang.String" name="ConnectionURL">
       jdbc:hsqldb:hsql://<xsl:value-of select='$host'/>:<xsl:value-of select='$port'/>
    </config-property>
  </xsl:template>

  <xsl:template match="*|@*">
    <xsl:copy>
      <xsl:apply-templates select="@*|node()"/>
    </xsl:copy>
  </xsl:template>
</xsl:stylesheet>
]]>
        </xslt-config>
     </delegate-config>
     <binding host="localhost" port="1901"/>
</service-config>
```

8.5.3. XSLTFileDelegate

The `XSLTFileDelegate` class works similarly to the `XSLTConfigDelegate` except that instead of transforming an embedded XML fragment, the XSLT script transforms a file read in from the file system. The `delegate-config` takes exactly the same form:

```
<delegate-config>
    <xslt-config configName="ConfigurationElement"><![CDATA[
        Any XSL document contents...
        ]]>
     </xslt-config>
     <xslt-param name="param-name">param-value</xslt-param>
     <!-- ... -->
</delegate-config>
```

The `xslt-config` child element content specifies an arbitrary XSL script fragment that is to be applied to the MBean service attribute named by the `configName` attribute. The named attribute must be a String value corresponding to an XML file that will be transformed. The optional `xslt-param` elements specify XSL script parameter values for parameters used in the script. There are two XSL parameters defined by default called `host` and `port`, and their values are set to the configuration `host` and `port` bindings.

The following example maps the host and port values for the Tomcat connectors:

```

<service-config name="jboss.web:service=WebServer"
                delegateClass="org.jboss.services.binding.XSLTFileDelegate">
    <delegate-config>
        <xslt-config configName="ConfigFile"><![CDATA[
   <xsl:stylesheet
         xmlns:xsl='http://www.w3.org/1999/XSL/Transform' version='1.0'>

     <xsl:output method="xml" />
     <xsl:param name="port"/>

     <xsl:variable name="portAJP" select="$port - 71"/>
     <xsl:variable name="portHttps" select="$port + 363"/>

     <xsl:template match="/">
       <xsl:apply-templates/>
     </xsl:template>

      <xsl:template match = "Connector">
         <Connector>
            <xsl:for-each select="@*">
            <xsl:choose>
               <xsl:when test="(name() = 'port' and . = '8080')">
                  <xsl:attribute name="port">
                      <xsl:value-of select="$port" />
                  </xsl:attribute>
               </xsl:when>
               <xsl:when test="(name() = 'port' and . = '8009')">
                  <xsl:attribute name="port">
                      <xsl:value-of select="$portAJP" />
                  </xsl:attribute>
               </xsl:when>
               <xsl:when test="(name() = 'redirectPort')">
                  <xsl:attribute name="redirectPort">
                      <xsl:value-of select="$portHttps" />
                  </xsl:attribute>
               </xsl:when>
               <xsl:when test="(name() = 'port' and . = '8443')">
                  <xsl:attribute name="port">
                      <xsl:value-of select="$portHttps" />
                  </xsl:attribute>
               </xsl:when>
               <xsl:otherwise>
                  <xsl:attribute name="{name()}"><xsl:value-of select="." /></xsl:attribute>
               </xsl:otherwise>
            </xsl:choose>
            </xsl:for-each>
            <xsl:apply-templates/>
```

```
          </Connector>
       </xsl:template>

     <xsl:template match="*|@*">
       <xsl:copy>
         <xsl:apply-templates select="@*|node()"/>
       </xsl:copy>
     </xsl:template>
   </xsl:stylesheet>
   ]]>
        </xslt-config>
    </delegate-config>
    <binding port="8280"/>
</service-config>
```

8.5.4. The Sample Bindings File

JBoss ships with service binding configuration file for starting up to three separate JBoss instances on one host. Here we will walk through the steps to bring up the two instances and look at the sample configuration. Start by making two server configuration file sets called `jboss0` and `jboss1` by running the following command from the book examples directory:

```
[examples]$ ant -Dchap=misc -Dex=1 run-example
```

This creates duplicates of the `server/default` configuration file sets as `server/jboss0` and `server/jboss1`, and then replaces the `conf/jboss-service.xml` descriptor with one that has the `ServiceBindingManager` configuration enabled as follows:

```
<mbean code="org.jboss.services.binding.ServiceBindingManager"
       name="jboss.system:service=ServiceBindingManager">
    <attribute name="ServerName">${jboss.server.name}</attribute>
    <attribute name="StoreURL">${jboss.server.base.dir}/misc-ex1-bindings.xml</attribute>
    <attribute name="StoreFactoryClassName">
        org.jboss.services.binding.XMLServicesStoreFactory
    </attribute>
</mbean>
```

Here the configuration name is `${jboss.server.name}`. JBoss will replace that with name of the actual JBoss server configuration that we pass to the run script with the `-c` option. That will be either `jboss0` or `jboss1`, depending on which configuration is being run. The binding manager will find the corresponding server configuration section from the `misc-ex1-bindings.xml` and apply the configured overrides. The `jboss0` configuration uses the default settings for the ports, while the `jboss1` configuration adds 100 to each port number.

To test the sample configuration, start two JBoss instances using the `jboss0` and `jboss1` configuration file sets created previously. You can observe that the port numbers in the console log are different for the `jboss1` server. To test out that both instances work correctly, try accessing the web server of the first JBoss on port 8080 and then try the second JBoss instance on port 8180.

8.6. RMI Dynamic Class Loading

The `WebService` MBean provides dynamic class loading for RMI access to the server EJBs. The configurable attributes for the service are as follows:

- **Port**: the `WebService` listening port number. A port of 0 will use any available port.
- **Host**: Set the name of the public interface to use for the host portion of the RMI codebase URL.
- **BindAddress**: the specific address the `WebService` listens on. This can be used on a multi-homed host for a `java.net.ServerSocket` that will only accept connect requests to one of its addresses.
- **Backlog**: The maximum queue length for incoming connection indications (a request to connect) is set to the `backlog` parameter. If a connection indication arrives when the queue is full, the connection is refused.
- **DownloadServerClasses**: A flag indicating if the server should attempt to download classes from thread context class loader when a request arrives that does not have a class loader key prefix.
- **DownloadResources**: A flag indicating whether the server should attempt to download non-class file resources using the thread context class loader. Note that allowing this is generally a security risk as it allows access to server configuration files which may contain security settings.
- **ThreadPool**: The `org.jboss.util.threadpool.BasicThreadPoolMBean` instance thread pool used for the class loading.

8.7. Scheduling Tasks

Java includes a simple timer based capability through the `java.util.Timer` and `java.util.TimerTask` utility classes. JMX also includes a mechanism for scheduling JMX notifications at a given time with an optional repeat interval as the `javax.management.timer.TimerMBean` agent service.

JBoss includes two variations of the JMX timer service in the `org.jboss.varia.scheduler.Scheduler` and `org.jboss.varia.scheduler.ScheduleManager` MBeans. Both MBeans rely on the JMX timer service for the basic scheduling. They extend the behavior of the timer service as described in the following sections.

8.7.1. org.jboss.varia.scheduler.Scheduler

The Scheduler differs from the `TimerMBean` in that the `Scheduler` directly invokes a callback on an instance of a user defined class, or an operation of a user specified MBean.

- **InitialStartDate**: Date when the initial call is scheduled. It can be either:

  - `NOW`: date will be the current time plus 1 seconds
  - A number representing the milliseconds since 1/1/1970
  - Date as String able to be parsed by `SimpleDateFormat` with default format pattern "`M/d/yy h:mm a`". If the date is in the past the `Scheduler` will search a start date in the future with respect to the initial repetitions and the period between calls. This means that when you restart the MBean (restarting JBoss etc.) it will start at the next scheduled time. When no start date is available in the future the `Scheduler` will not start.

  For example, if you start your `Schedulable` everyday at Noon and you restart your JBoss server then it will start at the next Noon (the same if started before Noon or the next day if start after Noon).

- **InitialRepetitions**: The number of times the scheduler will invoke the target's callback. If -1 then the callback will be repeated until the server is stopped.
- **StartAtStartup**: A flag that determines if the `Scheduler` will start when it receives its startService life cycle notification. If true the `Scheduler` starts on its startup. If false, an explicit `startSchedule` operation must be invoked on the `Scheduler` to begin.
- **SchedulePeriod**: The interval between scheduled calls in milliseconds. This value must be bigger than 0.
- **SchedulableClass**: The fully qualified class name of the `org.jboss.varia.scheduler.Schedulable` interface implementation that is to be used by the `Scheduler` . The `SchedulableArguments` and `SchedulableArgumentTypes` must be populated to correspond to the constructor of the `Schedulable` implementation.
- **SchedulableArguments**: A comma separated list of arguments for the `Schedulable` implementation class constructor. Only primitive data types, `String` and classes with a constructor that accepts a `String` as its sole argument are supported.
- **SchedulableArgumentTypes**: A comma separated list of argument types for the `Schedulable` implementation class constructor. This will be used to find the correct constructor via reflection. Only primitive data types, `String` and classes with a constructor that accepts a `String` as its sole argument are supported.
- **SchedulableMBean**: Specifies the fully qualified JMX `ObjectName` name of the schedulable MBean to be called. If the MBean is not available it will not be called but the remaining repetitions will be decremented. When using `SchedulableMBean` the `SchedulableMBeanMethod` must also be specified.
- **SchedulableMBeanMethod**: Specifies the operation name to be called on the schedulable MBean. It can optionally be followed by an opening bracket, a comma separated list of parameter keywords, and a closing bracket. The supported parameter keywords include:

  - `NOTIFICATION` which will be replaced by the timers notification instance (javax.management.Notification)
  - `DATE` which will be replaced by the date of the notification call (java.util.Date)
  - `REPETITIONS` which will be replaced by the number of remaining repetitions (long)
  - `SCHEDULER_NAME` which will be replaced by the `ObjectName` of the `Scheduler`
  - Any fully qualified class name which the `Scheduler` will set to null.

A given Scheduler instance only support a single schedulable instance. If you need to configure multiple scheduled events you would use multiple `Scheduler` instances, each with a unique `ObjectName`. The following is an example of configuring a `Scheduler` to call a `Schedulable` implementation as well as a configuration for calling a MBean.

```
<server>

    <mbean code="org.jboss.varia.scheduler.Scheduler"
           name="jboss.docs:service=Scheduler">
        <attribute name="StartAtStartup">true</attribute>
        <attribute name="SchedulableClass">org.jboss.book.misc.ex2.ExSchedulable</attribute>
        <attribute name="SchedulableArguments">TheName,123456789</attribute>
        <attribute name="SchedulableArgumentTypes">java.lang.String,long</attribute>

        <attribute name="InitialStartDate">NOW</attribute>
        <attribute name="SchedulePeriod">60000</attribute>
        <attribute name="InitialRepetitions">-1</attribute>
    </mbean>

</server>
```

The `SchedulableClass` `org.jboss.book.misc.ex2.ExSchedulable` example class is given below.

```
package org.jboss.book.misc.ex2;

import java.util.Date;
import org.jboss.varia.scheduler.Schedulable;

import org.apache.log4j.Logger;

/**
 * A simple Schedulable example.
 * @author Scott.Stark@jboss.org
 * @version $Revision: 1.2 $
 */
public class ExSchedulable implements Schedulable
{
    private static final Logger log = Logger.getLogger(ExSchedulable.class);

    private String name;
    private long value;

    public ExSchedulable(String name, long value)
    {
        this.name = name;
        this.value = value;
        log.info("ctor, name: " + name + ", value: " + value);
    }

    public void perform(Date now, long remainingRepetitions)
    {
        log.info("perform, now: " + now +
                 ", remainingRepetitions: " + remainingRepetitions +
                 ", name: " + name + ", value: " + value);
    }
}
```

Deploy the timer SAR by running:

```
[examples]$ ant -Dchap=misc -Dex=2 run-example
```

The server console shows the following which includes the first two timer invocations, separated by 60 seconds:

```
21:09:27,716 INFO  [ExSchedulable] ctor, name: TheName, value: 123456789
21:09:28,925 INFO  [ExSchedulable] perform, now: Mon Dec 20 21:09:28 CST 2004,
  remainingRepetitions: -1, name: TheName, value: 123456789
21:10:28,899 INFO  [ExSchedulable] perform, now: Mon Dec 20 21:10:28 CST 2004,
  remainingRepetitions: -1, name: TheName, value: 123456789
21:11:28,897 INFO  [ExSchedulable] perform, now: Mon Dec 20 21:11:28 CST 2004,
  remainingRepetitions: -1, name: TheName, value: 123456789
```

8.8. The Timer Service

The JMX standard defines a timer MBean (`javax.management.timer.Timer`) which can send notifications at pre-determined times. The a timer MBean can be instantiated within JBoss as any other MBean.

```
<mbean code="javax.management.timer.Timer" name="jboss.monitor:name=Heartbeat,type=Timer"/>
```

A standard JMX timer doesn't produce any timer events unless it is asked to. To aid in the configuration of the timer MBean, JBoss provides a complementary `TimerService` MBean. It interacts with the timer MBean to configure timer events at regular intervals and to transform them into JMX notifications more suitable for other services. The `TimerService` MBean takes the following attributes:

- **NotificationType**: This is the type of the notification to be generated.
- **NotificationMessage**: This is the message that should be associated with the generated notification.
- **TimerPeriod**: This is the time period between notification. The time period is in milliseconds, unless otherwise specified with a unit like "30min" or "4h". Valid time suffixes are `msec`, `sec`, `min` and `h`.
- **Repeatitions**: This is the number of times the alert should be generated. A value of 0 indicates the alert should repeat indefinitely.
- **TimerMbean**: This is the `ObjectName` of the time MBean that this `TimerService` instance should configure notifications for.

The following sample illustrates the the use of the `TimerService` MBean.

```
<mbean code="org.jboss.monitor.services.TimerService"
       name="jboss.monitor:name=Heartbeat,type=TimerService">
    <attribute name="NotificationType">jboss.monitor.heartbeat</attribute>
    <attribute name="NotificationMessage">JBoss is alive!</attribute>
    <attribute name="TimerPeriod">60sec</attribute>
    <depends optional-attribute-name="TimerMBean">
        jboss.monitor:name=Heartbeat,type=Timer
    </depends>
</mbean>
```

This MBean configuration configures the `jboss.monitor:name=Heartbeat,type=Timer` timer to generate a `jboss.monitor.heartbeat` notification every 60 seconds. Any service that that wants to receive this periodic notifications can subscribe to the notification.

As an example, JBoss provides a simple `NotificationListener` MBean that can listen for a particular notifcation and log a log message when an event is generated. This MBean is very useful for debugging or manually observing notifications. The following MBean definition listens for any events generated by the heartbeat timer used in the previous examples.

```
<mbean code="org.jboss.monitor.services.NotificationListener"
       name="jboss.monitor:service=NotificationListener">
    <attribute name="SubscriptionList">
        <subscription-list>
            <mbean name="jboss.monitor:name=Heartbeat,type=Timer" />
        </subscription-list>
    </attribute>
</mbean>
```

The `subscription-list` element lists which MBeans the listener should listen to. Notice that the MBean we are listening to is the name of the actual timer MBean and not the `TimerService` MBean. Because the timer might generate multiple events, configured by multiple `TimerService` instances, you may need to filter by notification type. The `filter` element can be used to create notification filters that select only the notification types desired. The following listing shows how we can limit notifications to only the `jboss.monitor.heartbeat` type the timer service configured.

```
<mbean code="org.jboss.monitor.services.NotificationListener"
      name="jboss.monitor:service=NotificationListener">
    <attribute name="SubscriptionList">
        <subscription-list>
            <mbean name="jboss.monitor:name=Heartbeat,type=Timer">
                <filter factory="NotificationFilterSupportFactory">
                    <enable type="jboss.monitor.heartbeat"/>
                </filter>
            </mbean>
        </subscription-list>
    </attribute>
</mbean>
```

As an example of a slightly more interesting listener, we'll look at the ScriptingListener. This listener listens for particular events and then executes a specified script when events are received. The script can be writen in any bean shell scripting language. The ScriptingListener accepts has the following parameters.

- **ScriptLanguage**: This is the language the script is written in. This should be `beanshell`, unless you have loaded libraries for another beanshell compatible language.
- **Script**: This is the text of the script to evaluate. It is good practice to enclose the script in a CDATA section to minimize conflicts between scripting language syntax and XML syntax.
- **SubscriptionList**: This is the list of MBeans that this MBean will listen to for events that will trigger the script.

The following example illustrates the use of the `ScriptingListener`. When the previously configured timer generates a heartbeat notification, the beanshell script will execute, printing the current memory values to STDOUT. (This output will be redirected to the log files) Notice that the beanshell script has a reference to the MBean server and can execute operations against other MBeans.

```
<mbean code="org.jboss.monitor.services.ScriptingListener"
       name="jboss.monitor:service=ScriptingListener">
    <attribute name="SubscriptionList">
        <subscription-list>
            <mbean name="jboss.monitor:name=Heartbeat,type=Timer"/>
        </subscription-list>
    </attribute>
    <attribute name="ScriptLanguage">beanshell</attribute>
    <attribute name="Script">
                <![CDATA[
   import javax.management.ObjectName;

   /* poll free memory and thread count */
   ObjectName target = new ObjectName("jboss.system:type=ServerInfo");

   long freeMemory = server.getAttribute(target, "FreeMemory");
   long threadCount = server.getAttribute(target, "ActiveThreadCount");

   log.info("freeMemory" + freeMemory + ", threadCount" + threadCount);
]]>
    </attribute>
</mbean>
```

Of course, you are not limited to these JBoss-provided notification listeners. Other services such as the barrier service (see Section 8.9) receive and act on notifications that could be generated from a timer. Additionally, any MBean can be coded to listen for timer-generated notifications.

8.9. The BarrierController Service

Expressing dependencies between services using the <depends> tag is a convenient way to make the lifecycle of one service depend on the lifecycle of another. For example, when `serviceA` depends on `serviceB` JBoss will ensure the `serviceB.create()` is called before `serviceA.create()` and `serviceB.start()` is called before `serviceA.start()`.

However, there are cases where services do not conform to the JBoss lifecycle model, i.e. they don't expose create/start/stop/destroy lifesycle methods). This is the case for `jboss.system:type=Server MBean`, which represents the JBoss server itself. No lifecycle operations are exposed so you cannot simply express a dependcy like: if JBoss is fully started then start my own service.

Or, even if they do conform to the JBoss lifecycle model, the completion of a lifecycle method (e.g. the `start` method) may not be sufficient to describe a dependency. For example the `jboss.web:service=WebServer` MBean that wraps the embedded Tomcat server in JBoss does not start the Tomcat connectors until after the server is fully started. So putting a dependency on this MBean, if we want to hit a webpage through Tomcat, will do no good.

Resolving such non-trivial dependencies is currently performed using JMX notifications. For example the `jboss.system:type=Server` MBean emits a notification of type `org.jboss.system.server.started` when it has completed startup, and a notification of type `org.jboss.system.server.stopped` when it shuts down. Similarly, `jboss.web:service=WebServer` emits a notification of type `jboss.tomcat.connectors.started` when it starts up. Services can subscribe to those notifications in order to implement more complex dependencies. This technique has been generalized with the barrier controller service.

The barrier controller is a relatively simple MBean service that extends `ListenerServiceMBeanSupport` and thus can subscribe to any notification in the system. It uses the received notifications to control the lifecycle of a dynamically created MBean called the barrier.

The barrier is instantiated, registered and brought to the create state when the barrier controller is deployed. After that, the barrier is started and stopped when matching notifications are received. Thus, other services need only depend on the barrier MBean using the usual `<depends>` tag, without having to worry about complex lifecycle issues. They will be started and stopped in tandem with the Barrier. When the barrier controller is undeployed the barrier is destroyed.

The notifications of interest are configured in the barrier controller using the `SubscriptionList` attribute. In order to identify the starting and stopping notifications we associate with each subscription a handback string object. Handback objects, if specified, are passed back along with the delivered notifications at reception time (i.e. when `handleNotification()` is called) to qualify the received notifications, so that you can identify quickly from which subscription a notification is originating (because your listener can have many active subscriptions).

So we tag the subscriptions that produce the starting/stopping notifications of interest using any handback strings, and we configure this same string to the `StartBarrierHandback` (and `StopBarrierHandback` correspondingly) attribute of the barrier controller. Thus we can have more than one notifications triggering the starting or stopping of the barrier.

The following example shows a service that depends on the Tomcat connectors. In fact, this is a very common pattern for services that want to hit a servlet inside tomcat. The service that depends on the Barrier in the example, is a simple memory monitor that creates a background thread and monitors the memory usage, emitting notifications when thresholds get crossed, but it could be anything. We've used this because it prints out to the console starting and stopping messages, so we know when the service gets activated/deactivated.

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- $Id: master.xml,v 1.2 2006/11/01 18:14:13 nrichards Exp $ -->

<server>
  <!--
    In this example we have the BarrierController controlling a Barrier
    that is started when we receive the "jboss.tomcat.connectors.started"
    notification from the Tomcat mbean, and stopped when we receive the
    "org.jboss.system.server.stopped" notification from the server mbean.

    The dependent services need only define a dependency on the Barrier mbean!
  -->
  <mbean code="org.jboss.system.BarrierController"
         name="jboss:service=BarrierController">

    <!-- Whether to have the Barrier initially started or not -->
    <attribute name="BarrierEnabledOnStartup">false</attribute>

    <!-- Whether to subscribe for notifications after startup -->
    <attribute name="DynamicSubscriptions">true</attribute>

    <!-- Dependent services will depend on this mbean -->
    <attribute name="BarrierObjectName">jboss:name=TomcatConnector,type=Barrier</attribute>

    <!-- The notification subscription handback that starts the barrier -->
    <attribute name="StartBarrierHandback">start</attribute>

    <!-- The notification subscription handback that stops the barrier -->
    <attribute name="StopBarrierHandback">stop</attribute>

    <!-- The notifications to subscribe for, along with their handbacks -->
    <attribute name="SubscriptionList">
      <subscription-list>
        <mbean name="jboss.web:service=WebServer" handback="start">
          <filter factory="NotificationFilterSupportFactory">
            <enable type="jboss.tomcat.connectors.started"/>
          </filter>
        </mbean>
        <mbean name="jboss.system:type=Server" handback="stop">
          <filter factory="NotificationFilterSupportFactory">
            <enable type="org.jboss.system.server.stopped"/>
          </filter>
        </mbean>
      </subscription-list>
    </attribute>
  </mbean>

  <!--
    An example service that depends on the Barrier we declared above.
    This services creates a background thread and monitors the memory
    usage. When it exceeds the defined thresholds it emits notifications
  -->
  <mbean code="org.jboss.monitor.services.MemoryMonitor"
         name="jboss.monitor:service=MemoryMonitor">

    <attribute name="FreeMemoryWarningThreshold">20m</attribute>
    <attribute name="FreeMemoryCriticalThreshold">15m</attribute>
    <!-- The BarrierObjectName configured in the BarrierController -->
    <depends>jboss:name=TomcatConnector,type=Barrier</depends>
  </mbean>

</server>
```

If you hot-deploy this on a running server the Barrier will be stopped because by the time the barrier controller is deployed the starting notification is already seen. (There are ways to overcome this.) However, if you re-start the server, the barrier will be started just after the Tomcat connectors get activated. You can also manually start or stop the barrier by using the `startBarrier()` and `stopBarrier()` operations on the barrier controller. The attribute `BarrierStateString` indicates the status of the barrier.

8.10. Exposing MBean Events via SNMP

JBoss has an SNMP adaptor service that can be used to intercept JMX notifications emitted by MBeans, convert them to traps and send them to SNMP managers. In this respect the snmp-adaptor acts as a SNMP agent. Future versions may offer support for full agent get/set functionality that maps onto MBean attributes or operations.

This service can be used to integrate JBoss with higher order system/network management platforms (HP OpenView, for example), making the MBeans visible to those systems. The MBean developer can instrument the MBeans by producing notifications for any significant event (e.g. server coldstart), and adaptor can then be configured to intercept the notification and map it onto an SNMP traps. The adaptor uses the JoeSNMP package from OpenNMS as the SNMP engine.

The SNMP service is configured in `snmp-adaptor.sar`. This service is only available in the `all` configuration, so you'll need to copy it to your configuration if you want to use it. Inside the snmp-adaptor.sar directory, there are two configuration files that control the SNMP service.

- **managers.xml**: configures where to send traps. The content model for this file is shown in Figure 8.2.
- **notifications.xml**: specifies the exact mapping of each notification type to a corresponding SNMP trap. The content model for this file is shown in Figure 8.3.

The `SNMPAgentService` MBean is configured in `snmp-adaptor.sar/META-INF/jboss-service.xml`. The configurable parameters are:

- **HeartBeatPeriod**: The period in seconds at which heartbeat notifications are generated.
- **ManagersResName**: Specifies the resource name of the `managers.xml` file.
- **NotificationMapResName**: Specifies the resource name of the `notications.xml` file.
- **TrapFactoryClassName**: The `org.jboss.jmx.adaptor.snmp.agent.TrapFactory` implementation class that takes care of translation of JMX Notifications into SNMP V1 and V2 traps.
- **TimerName**: Specifies the JMX ObjectName of the JMX timer service to use for heartbeat notifications.
- **SubscriptionList**: Specifies which MBeans and notifications to listen for.

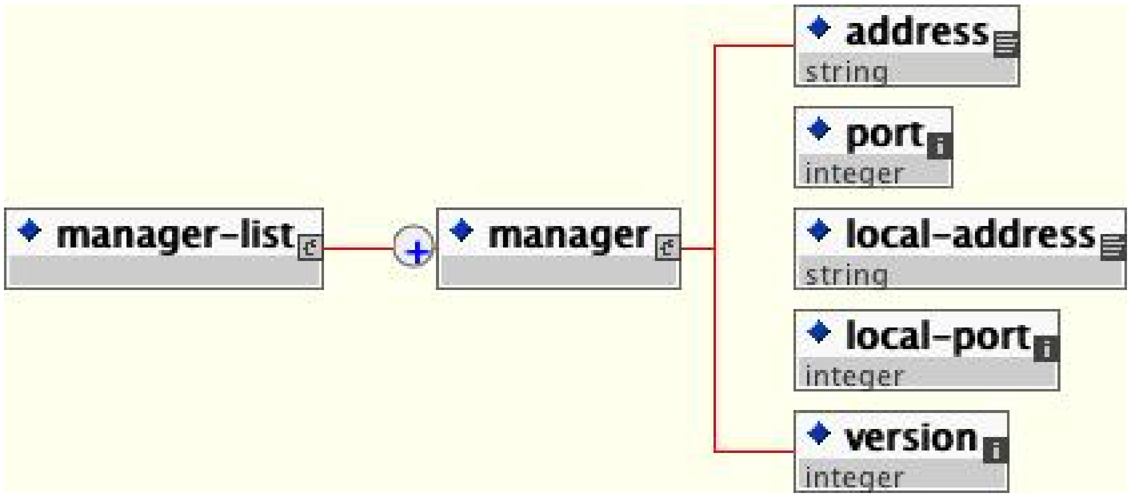


Figure 8.2. The schema for the SNMP managers file

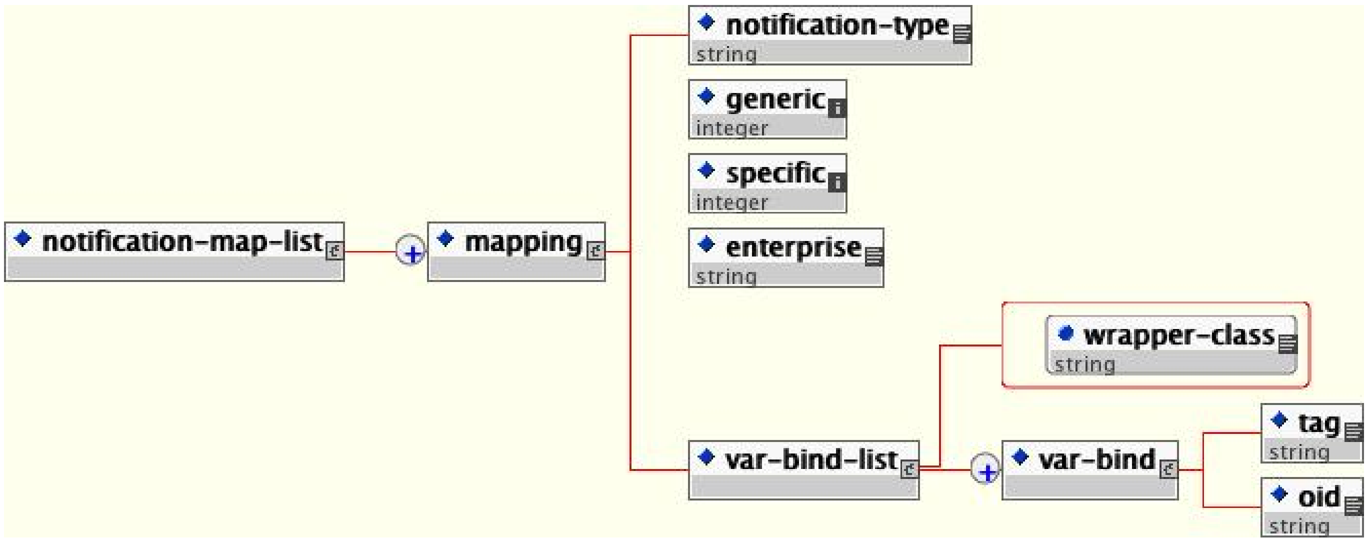


Figure 8.3. The schema for the notification to trap mapping file

`TrapdService` is a simple MBean that acts as an SNMP Manager. It listens to a configurable port for incoming traps and logs them as DEBUG messages using the system logger. You can modify the log4j configuration to redirect the log output to a file. `SnmpAgentService` and `TrapdService` are not dependent on each other.

A

Book Example Installation

The book comes with the source code for the examples discussed in the book. The examples are included with the book archive. Unzipping the example code archive creates a JBoss `jboss4guide` directory that contains an `examples` subdirectory. This is the `examples` directory referred to by the book.

The only customization needed before the examples may be used is to set the location of the JBoss server distribution. This may be done by editing the `examples/build.xml` file and changing the `jboss.dist` property value. This is shown in bold below:

```
<project name="JBoss book examples" default="build-all" basedir=".">
    <!-- Allow override from local properties file -->
    <property file="ant.properties"/>

    <!-- Override with your JBoss server bundle dist location -->
    <property name="jboss.dist"        value="/tmp/jboss-4.0.3"/>
    <property name="jboss.deploy.conf" value="default"/>
    ...
```

or by creating an `.ant.properties` file in the examples directory that contains a definition for the `jboss.dist` property. For example:

```
jboss.dist=/usr/local/jboss/jboss-4.0.1
```

Part of the verification process validates that the version you are running the examples against matches what the book examples were tested against. If you have a problem running the examples first look for the output of the validate target such as the following:

```
validate:
     [java] ImplementationTitle: JBoss [Zion]
     [java] ImplementationVendor: JBoss Inc.
     [java] ImplementationVersion: 4.0.1 (build: CVSTag=JBoss_4_0_1 date=200412230944)
     [java] SpecificationTitle: JBoss
     [java] SpecificationVendor: JBoss (http://www.jboss.org/)
     [java] SpecificationVersion: 4.0.1
     [java] JBoss version is: 4.0.1
```