Sun Microsystems, Inc.

Java™ Naming and Directory Interface™ Service Provider Interface (JNDI SPI)

Please send technical comments to jndi@java.sun.com.

Please send product and business questions to jndi-business@java.sun.com.

JNDI 1.2

July 14, 1999

Contents

1 Introduction

The JNDI SPI provides the means by which developers can write different naming and directory *service providers* and make them available so that the corresponding services are accessible from applications that use the JNDI API. A service provider is a set of modules that together satisfy JNDI API requests. In addition, because JNDI allows the use of names that span multiple namespaces, one service provider implementation may need to interact with another in order to complete an operation. The SPI provides methods that allow different provider implementations to cooperate to complete client JNDI operations.

This document describes the components of the SPI and explains how developers can build service providers for JNDI. It is assumed that the reader is familiar with the contents of the **JNDI API** document.

All service provider developers should read the “Security Considerations” section of the **JNDI API** document. It contains important issues that all developers using JNDI, especially those writing service providers, should consider.

1.1 Document Overview

There are several types of implementations that sit beneath the JNDI API. A service provider contains at a minimum a c*ontext implementation*. A context implementation implements the `Context` interface or any of its subinterfaces, such as `DirContext`, `EventContext`, or `LdapContext`. The complexity of the implementation depends primarily on the complexity of the underlying service, and secondarily on the number of JNDI features that the implementation supports. Chapter 2 describes the details of building a context implementation.

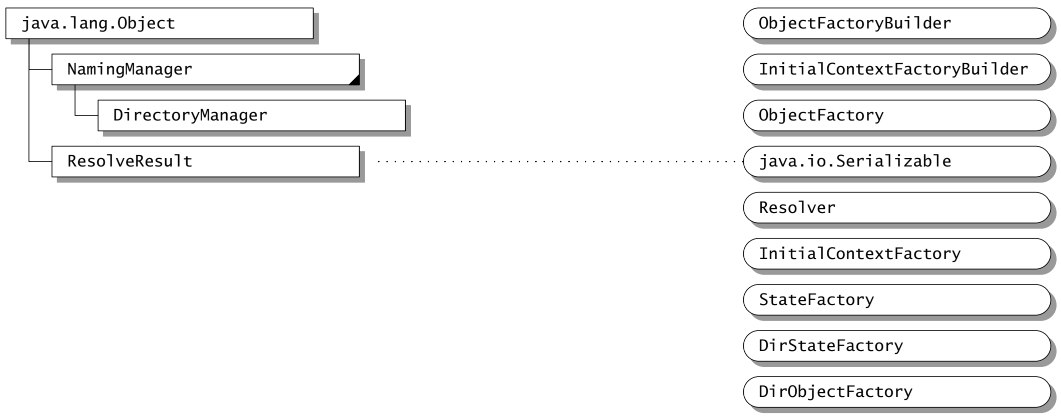
A context implementation can be accessed in different ways. The most common way is to access it from the initial context. Chapter 3 describes two ways that a context implementation can be accessed from the initial context: via an initial context factory and a URL context factory.

The JNDI architecture defines components/implementations that can be used to augment the behavior of context implementations. This allows users and applications to customize the implementation. These components are supported through *factories*. JNDI defines three types of factories and provides SPI methods that make use of them. These factories are described in Chapter 4.

- *Object factories*—For transforming data stored in naming/directory services into Java types more natural to the Java application.
- *State factories*—For transforming objects of Java types natural to the program into formats suitable for storage into naming/directory services.
- *Response control factories*—For narrowing LDAP v3 response controls received from LDAP servers into more user-friendly types.

1.2 Interface[1] Overview

The JNDI SPI is contained in the package `javax.naming.spi`. The following sections provide an overview of the SPI. For more details on the SPI, see the corresponding **javadoc**.



1.2.1 NamingManager and DirectoryManager

The `NamingManager` class contains static methods that perform provider-related operations. For example, it contains methods to create instances of objects using `Reference`, to obtain an instance of the initial context using the `java.naming.factory.initial` property, and to install `ObjectFactoryBuilder` and `InitialContextFactoryBuilder`. The `DirectoryManager` class provides similar static methods for `DirContext` related operations.

1.2.2 Initial Contexts

`InitialContextFactory` is the interface for creating an initial context instance. See Section 3.1 for more details.

`InitialContextFactoryBuilder` is the interface for creating `InitialContextFactory` instances. See Section 3.3 for more details.

1.2.3 Object Factories

`ObjectFactory` is the interface for supporting creation of objects using information stored in the namespace. `DirObjectFactory` is a subinterface of `ObjectFactory` for use by context implementations that implement the `DirContext` interface. See Section 4.1 for more details.

`ObjectFactoryBuilder` is the interface for creating object factories. See Section 4.1.4 for more details.

1.2.4 State Factories

`StateFactory` is the interface for supporting converting objects into storable formats supported by the naming/directory service. `DirStateFactory` is a subinterface of `StateFactory` for use by context implementations that implement the `DirContext` interface. `DirStateFacto-`

1. See Appendix B for legend of class diagram.

`ry.Result` is a class for holding a pair of `java.lang.Object` and `Attributes` that is returned by `DirStateFactory.getStateToBind()`. See Section 4.2 for more details.

1.2.5 Federation Support

The `Resolver` interface defines a method for providers to implement that allows them to participate in a federation for supporting extended interfaces to `Context`. See “Resolving Through to Subinterfaces of Context” on page 10 for more details.

`ResolveResult` is the return value of calling `Resolver.resolveToClass()`. It contains the object to which resolution succeeded, and the remaining name yet to be resolved.

2 Building a Context Implementation

One of the basic tasks in building a service provider is to define a class that implements the `Context` interface or any of its subinterfaces. This class is called a *context implementation*. The following guidelines should be used for developing a context implementation.

2.1 Ownership of Parameters

In general, any object passed as a parameter to methods in the `Context` interface (or subinterfaces) and `NamingManager`/`DirectoryManager` utility methods is owned by the caller. In many cases, the parameter eventually reaches a context implementation. Because the caller owns the object, the context implementation is prohibited from modifying the object. Furthermore, the context implementation is allowed to maintain a pointer to the object only for the duration of the operation and not beyond. If a context implementation needs to save the information contained in a parameter beyond the duration of the operation, it should maintain its own copy.

For purposes of parameter ownership, an operation on a context instance is not considered to have completed while any referrals generated by that operation are still being followed, or if the operation returns a `NamingEnumeration`, while the enumeration is still in use.

2.2 Reentrancy

A context instance need not be reentrant. Two threads that need to access the same context instance concurrently should synchronize amongst themselves and provide the necessary locking.

However, different context instances must be safe for concurrent multithreaded access. That is, two threads each operating concurrently on their respective context instance should not need to synchronize their access. For example, even though two contexts might share the same resources (such as the same connection), it must be possible (and safe) for two separate threads to operate on each of those contexts without the threads having to do any explicit synchronization.

For purposes of concurrency control, an operation on a context instance is not considered to have completed while any referrals generated by that operation are still being followed, or if the operation returns a `NamingEnumeration`, while the enumeration is still in use.

2.3 Basic Support—Implementing the Context Interface(s)

The context implementation defines implementations for each of the methods in the `Context` interface or subinterfaces that the implementation supports.

If a method is not supported, it should throw `OperationNotSupportedException`.

For methods in the `Context` interface or subinterfaces that accept a name argument (either as a `String` or a `Name`), an empty name denotes the current context. For example, if an empty name is supplied to `lookup()`, that means to return a new instance of the current context. If an empty name is supplied to `list()`, that means to enumerate the names in the current context.

If an empty name is supplied to `getAttributes()`, that means to retrieve the attributes associated with this context.

Appendix A contains an example context implementation that implements a flat, in-memory namespace.

2.4 Object Support

JNDI encourages providers to supply implementations of the `Context` and its subinterfaces that are natural and intuitive for the Java application programmer. For example, when looking up a printer name in the namespace, it is natural for the programmer to expect to get back a printer object on which to operate.

```
Context ctx = new InitialContext();
Printer prt = (Printer)ctx.lookup(somePrinterName);
prt.print(someStreamOfData);
```

Similarly, when storing an application's object into the underlying service, it is most portable and convenient if the application does not have to know about the underlying data representation.

However, what is bound in the underlying directory or naming services typically are not objects in the Java programming language but merely reference information which can be used to locate or access the actual object. This case is quite common, especially for Java applications accessing and sharing services in an existing installed base. The reference in effect acts as a "pointer" to the real object. In the printer example, what is actually bound might be information on how to access the printer (e.g., its protocol type, its server address). To enable this easy-to-use model for the application developer, the context implementation must do the transformation of the data to/from the underlying service into the appropriate objects in the Java programming language.

There are different ways to achieve this goal. One context implementation might have access to all the implementation classes of objects that a directory can return; another context implementation might have a special class loader for locating implementation classes for its objects. JNDI provides the `Reference` class as a standard way of representing references. Applications and context implementations are encouraged to use this class, rather than invent separate mechanisms on their own. However, this does not preclude context implementations from using their own mechanisms for achieving the same goal.

JNDI provides utilities for context implementations to use when reading/storing objects in the Java programming language in a format-independent way to the underlying service. This section describes these utilities. These utilities interact with components called *object* and *state factories* that do the actual transformations. These factories are described in Chapter 4.

2.4.1 Reading an Object

JNDI provides the following methods that context implementations should use to transform data read from the underlying service into objects in the Java programming language:

```
Object NamingManager.getObjectInstance(Object refInfo,
                                       Name name,
                                       Context nameCtx,
                                       Hashtable env)
    throws Exception;
Object DirectoryManager.getObjectInstance(Object refInfo,
                                       Name name,
                                       Context nameCtx,
                                       Hashtable env,
                                       Attributes attrs)
    throws Exception;
```

`refInfo` is the data (representing the object) read from the underlying service. `name` is the name of the object while `nameCtx` is the context in which to resolve `name`. The `name`/`nameCtx` pair can be used to obtain more information about the object than is available from `refInfo`. `env` is the environment of the context from which `getObjectInstance()` is being invoked. `attrs` is the collection of attributes read from the directory about the object, usually in the same request that was used to get `refInfo`. It might not be the complete collection of attributes if such was not requested.

The method in the `NamingManager` class should be used by context implementations that implement the `Context` interface, while the method in the `DirectoryManager` class should be used by context implementations that implement the `DirContext` interface.

When constructing objects to be returned for the following methods, the context implementation should call `getObjectInstance()`, or its own mechanism for generating objects from the bound information, if it wants this feature to be enabled in their contexts. (String overloads not shown.)

```
javax.naming.Context.lookup(Name name)
javax.naming.Context.lookupLink(Name name)
javax.naming.Binding.getObject()
javax.naming.directory.SearchResult.getObject()
```

For `Binding` and `SearchResult`, the context implementation should either pass an object that is the result of calling `getObjectInstance()` or its equivalent to the constructor, or override the default implementation of `Binding` and `SearchResult` so that their `getObject()` implementations call `getObjectInstance()` or its equivalent before returning.

Here is an example. Suppose printers are represented in the namespace using `References`. To turn a printer `Reference` into a live `Printer` object, the context implementation would use the `NamingManager.getObjectInstance()` method. In this way, the underlying service need not know anything specific about printers.

```
Object lookup(Name name) {
    ...
    Reference ref = <some printer reference looked up from naming service>;
    return NamingManager.getObjectInstance(ref, name, this, env);
}
```

In another example, suppose printers are represented in the directory as a collection of attributes. To turn a printer's directory entry into a live `Printer` object, the context implementation would use `DirectoryManager.getObjectInstance()`.

```
Object lookup(Name name) {
    ...
    Attributes attrs = <read attributes from directory>;
    Reference ref = <construct reference from attributes>;
    return DirectoryManager.getObjectInstance(ref, name, this,
        env, attrs);
}
```

2.4.2 Storing an Object

JNDI provides the following methods that context implementations should use to transform an object before storing it in the underlying service:

```
Object NamingManager.getStateToBind(
                                    Object obj,
                                    Name name,
                                    Context nameCtx,
                                    Hashtable env)
    throws NamingException;
DirStateFactory.Result DirectoryManager.getStateToBind(
                                    Object obj,
                                    Name name,
                                    Context nameCtx,
                                    Hashtable env,
                                    Attributes attrs)
    throws NamingException;
```

`obj` is the object to be stored in the underlying service. `name` is the name of the object while `nameCtx` is the context in which to resolve `name`. The `name`/`nameCtx` pair can be used to obtain more information about the object than is available from `obj`. `env` is the environment of the context from which `getStateToBind()` is being invoked. `attrs` is the collection of attributes that is to be bound with the object. `DirStateFactory.Result` is a class that contains an object and a collection of attributes.

The method in the `NamingManager` class should be used by context implementations that implement the `Context` interface, while the method in the `DirectoryManager` class should be used by context implementations that implement the `DirContext` interface.

Before storing an object supplied by the application, the context implementation should call `getStateToBind()`, or its own mechanism for generating information to be bound, if it wants this feature to be enabled in their contexts. (String overloads not shown.)

```
javax.naming.Context.bind(Name name, Object o)
javax.naming.Context.rebind(Name name, Object o)
javax.naming.DirContext.bind(Name name, Object o, Attributes attrs)
javax.naming.DirContext.rebind(Name name, Object o, Attributes attrs)
```

Here's an example of how a `Context` implementation supports `Context.bind`:

```
// First do transformation
obj = NamingManager.getStateToBind(obj, name, ctx, env);

// Check for Referenceable
if (obj instanceof Referenceable) {
    obj = ((Referenceable)obj).getReference();
}

if (obj instanceof Reference) {
    // store as ref
} else if (obj instanceof Serializable) {
    // serialize
} else {
    ...
}
```

Here's an example of how a `DirContext` implementation supports `DirContext.bind`:

```
// First do transformation
DirStateFactory.Result res = DirectoryManager.getStateToBind(
    obj, name, ctx, env, inAttrs);

obj = res.getObject();
Attributes outAttrs = res.getAttributes();

// Check for Referenceable
if (obj instanceof Referenceable) {
    obj = ((Referenceable)obj).getReference();
}
if (obj instanceof Reference) {
    // store as ref and add outAttrs
} else if (obj instanceof Serializable) {
    // serialize and add outAttrs
} else if (obj instanceof DirContext) {
    // grab attributes and merge with outAttrs
} else {
    ...
}
```

As shown in these examples, a context implementation might be able to store different types of objects (`Reference`, `Serializable`, and `DirContext`). If the context implementation cannot store `Referenceable` objects directly and `getStateToBind()` returns such an object, the context implementation should subsequently call `Referenceable.getReference()` and store the resulting `Reference` instead.

If a context implementation can store different types of objects, it should follow this order for the following common types:

- `Reference`
- `Serializable`
- `DirContext`

This order is recommended because it is most likely to capture the intent of the caller of the `bind()`/`rebind()` method. For example, a `Reference` is `Serializable`, so if you performed the `Serializable` check first, no `Reference` objects would ever be stored in the reference format (that is, they would all be serialized).

2.5 Federation Support

2.5.1 Names

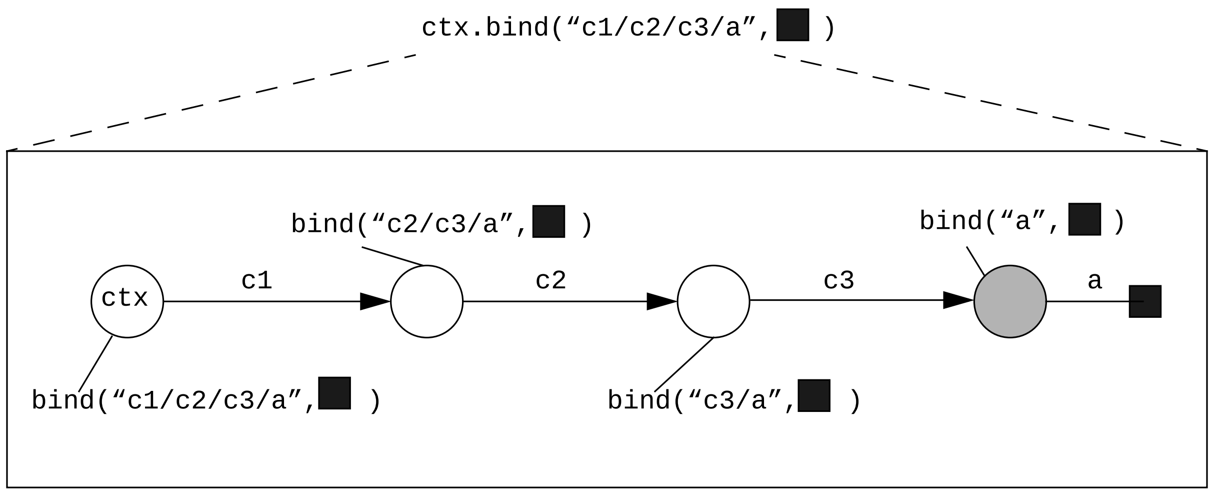
When a context is given a string name argument, the name represents a composite name that may span multiple namespaces, or it may have only a single compound name component (which in turn may be made up of one or several atomic names) that belongs to a single namespace. The context implementation must determine which part of the name is to be resolved/ processed in its context and pass the rest onto the next context. This may be done syntactically by examining the name, or dynamically by resolving the name.

When a context is given a `Name` argument, if it is an instance of `CompositeName`, then it will be treated as a composite name. Otherwise, it will be treated as a compound name that is implemented by the `CompoundName` class or some other compound name implementation.

2.5.2 Resolving Through a Context

A context participates in a federation by performing the resolution phase of all of the context operations. The `lookup()` method must always be supported. Support for other methods is optional, but if the context is to participate in a federation, then the resolution implicit in all operations must be supported.

Figure 1: Example of Resolving through Intermediate Contexts to Perform a bind().



For example, suppose a context does not support the `bind()` operation. When that context is being used as an intermediate context for `bind()`, it must perform the resolution part of that operation to enable the operation to continue to the next context. It should only throw `OperationNotSupportedException` if it is being asked to create a binding in its own context. Figure 1 shows an example of how the `bind()` operation is passed through intermediate contexts to be performed in the target context.

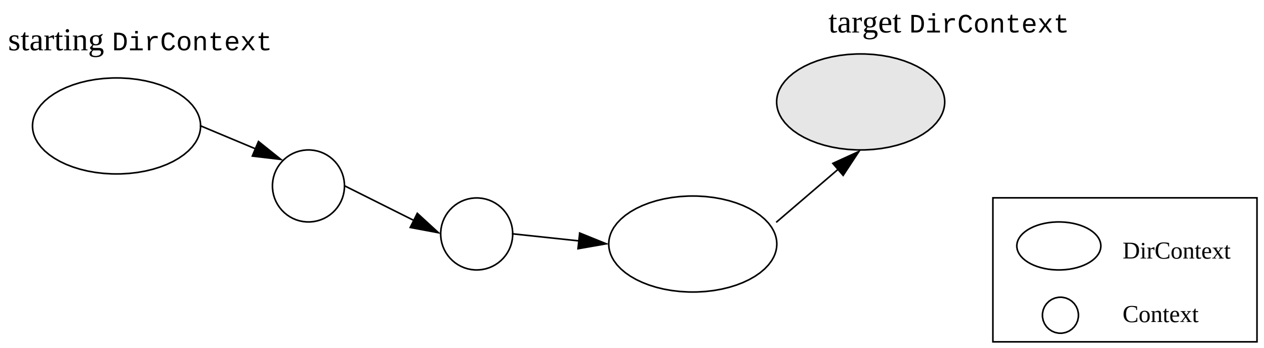
2.5.3 Resolving Through to Subinterfaces of Context

To invoke a `DirContext` method (such as `getAttributes()`), the application first obtains an initial `DirContext`, and then perform the operation on the `DirContext`.

```
DirContext ctx = new InitialDirContext();
Attributes attrs = ctx.getAttributes(someName);
```

From the context implementation's perspective, in order to retrieve the attributes, `getAttributes()` might need to traverse multiple naming systems. Some of these naming systems only support the `Context` interface, not the `DirContext` interface. These naming systems are being used as intermediaries for resolving towards the target context. The target context must support the `DirContext` interface. Figure 2 shows an example of this.

Figure 2: Example of Resolving Through Intermediate non-DirContexts



In order for intermediate naming systems to participate in the federation for extensions of `Context`, they must implement the `Resolver` interface. The `Resolver` interface is used by the JNDI framework to resolve through intermediate contexts that do not support a particular subinterface of `Context`. It consists of two overloaded forms of the method `resolveToClass()`. This method is used to partially resolve a name, stopping at the first context that is an instance of the required subinterface. By providing support for this method and the resolution phase of all methods in the `Context` interface, a context implementation can act as an intermediate context for extensions (subinterfaces) of `Context`.

```
public interface Resolver {
    public ResolveResult resolveToClass(Name name, Class contextType)
        throws NamingException;
    public ResolveResult resolveToClass(String name,
                                        Class contextType)
        throws NamingException;
}
```

2.5.4 Naming System Boundaries

The resolution of a (multicomponent) composite name proceeds from one naming system to the next, with the resolution of the components that span each naming system typically handled by a corresponding context implementation. From a context implementation's point of view, it passes the components for which it is not responsible to the (context implementation of the) *next naming system*.

There are several ways in which the context implementation for the next naming system may be located. It may be done *explicitly* through the use of a *junction*, where a name in one naming system is bound to a context (or a `Reference` to a context) in the next naming system. For example, with the composite name “cn=fs,ou=eng/lib/xyz.zip”, the LDAP name “cn=fs,ou=eng” might resolve to a file system context in which the name “lib/xyz.zip” could then be resolved.

Alternately, the next naming system may be located *implicitly*. For example, a context implementation may choose the next naming system based upon service-specific knowledge of the object that it has resolved. For example, with the composite name “ldap.wiz.com/cn=fs,ou=eng”, the DNS name `ldap.wiz.com` might name a DNS entry. To get the next naming system beyond DNS, the DNS context implementation might construct a context using SRV resource records found in that entry, which in this case, happens to name an LDAP context. When the next naming system is located in this fashion, JNDI composite name separator is used to denote the boundary from one naming system to the next, and is referred to as the *implicit next naming system pointer*.

However the next naming system is located, the context implementation must hand the next naming system the remaining portion of the composite name to resolve.

2.5.5 Continuing an Operation in a Federation

In performing an operation on a name that spans multiple namespaces, a context in an intermediate naming system needs to pass the operation onto the next naming system. The context does this by first constructing a `CannotProceedException` containing information pinpointing how far it has proceeded. In so doing it sets the resolved object, resolved name, remaining name, and environment parts of the exception.[1] (In the case of the `Context.rename()` method, it also sets the “resolved newname” part.)

It then obtains a *continuation context* from JNDI by passing the `CannotProceedException` to static method `NamingManager.getContinuationContext()`

```
public class NamingManager {
    public static Context getContinuationContext(
        CannotProceedException e) throws NamingException;
    ...
}
```

The information in the exception is used by `getContinuationContext()` to create the context instance in which to continue the operation.

To obtain a continuation context for the `DirContext` operations, use `DirectoryManager.getContinuationDirContext()`.

1. The `CannotProceedException` may well have been thrown by one of the context’s internal methods when it discovered that the name being processed is beyond the scope of its naming system. The process by which the exception is produced is dependent on the implementation of the context.

```
public class DirectoryManager {
    public static getContinuationDirContext(
        CannotProceedException e) throws NamingException;
    ...
}
```

Upon receiving the continuation context, the operation should be continued using the remainder of the name that has not been resolved.

For example, when attempting to continue a `bind()` operation, the code in the context implementation might look as follows:

```
public void bind(Name name, Object obj) throws NamingException {
    ...
    try {
        internal_bind(name, obj);
        ...
    } catch (CannotProceedException e) {
        Context cctx = NamingManager.getContinuationContext(e);
        cctx.bind(e.getRemainingName(), obj);
    }
}
```

In this example, `bind()` depends on an internal method, `internal_bind()`, to carry out the actual work of the bind and to throw a `CannotProceedException` when it discovers that it is going beyond this naming system. The exception is then passed to `getContinuationContext()` in order to continue the operation. If the operation cannot be continued, the continuation context will throw the `CannotProceedException` to the caller of the original `bind()` operation.

2.5.6 "Dynamic" Location of Next Naming System

In some federation configurations, the result of resolution in one naming system does not indicate which is the next naming system. The only conclusion that the context implementation can draw is that resolution has terminated in the current naming system and should proceed to the next naming system.

For example, suppose the composite name "lib/xyz.zip/part1/abc" consists of two parts: "lib/xyz.zip", which names a file in ZIP format, and "part1/abc", which names an entry within the ZIP file. Although the resolution of "lib/xyz.zip" results in a file object, the desired result is a context in which to resolve names of ZIP entries. Similarly, another composite name could name an entry within a file in "tar" format, and the desired result of the resolution of the file component of the composite name would be a context in which to resolve tar entries.

In effect, any type of context might be federated beneath the file system namespace depending on the format of the files. Such relationships should be symmetric: it should be possible for the ZIP file context and other similar contexts to federate beneath other, non-file system namespaces. Furthermore, developers writing the file system context implementation and those writing the context implementations for the ZIP file context, the tar file context, or a context for some yet-to-be defined format, should be able to work independently.

To support this type of federation, JNDI defines a special form of `Reference` called an *nns reference* ("nns" stands for "next naming system"). This `Reference` has an address with type `nns`.

The address contents is the resolved object (in the above example, the ZIP file). Continuing with the file system example, the file system context implementation might create the nns reference as follows:

```
 RefAddr addr = new RefAddr("nns") {
    public Object getContent() {
        return theFile;
    }
};
Reference ref = new Reference("java.io.File", addr);
```

Next, the context implementation constructs a `CannotProceedException` (as with the junction case) by using the nns reference as the resolved object, and a resolved name consisting of the resolved file name and an empty component. The empty component is being used as an implicit next naming system pointer and indicates that the resolution has succeeded to the point of resolving the next naming system. (Notice how the values of the resolved object and resolved name are matched.) The context implementation then passes the `CannotProceedException` to `getContinuationContext()`.

As with any resolved object in a `CannotProceedException`, `getContinuationContext()` searches for a context implementation that accepts this nns reference. The ZIP file context implementation, for instance, might accept an nns reference and other information provided, such as the name of the file (relative to a given context). If the context implementation determines that the file is a ZIP file, it would then construct a context for resolving names within that file.

2.5.7 More about CannotProceedException

Central to the JNDI SPI's framework for federation is the `CannotProceedException`. A `CannotProceedException` contains information such as the resolved name/object and remaining name, inherited from the `NamingException` superclass. In addition, a `CannotProceedException` also contains fields for the "alt" name and "alt" name context. While the resolved name from `NamingException` is the full composite name (relative to the starting context of the operation), alt name is the resolved name relative to the alt name context. That is, alt name might not necessarily be the same as the resolved name. Alt name and alt name context are used as arguments to `NamingManager`/`DirectoryManager.getObjectInstance()`. They allow the factories that are called by this method to obtain more information about the resolved object (for example, it could be used to get a special attribute about the object). These factories are described in Chapter 4.

2.5.8 Contextual Information

While the emphasis of the JNDI SPI framework is on "looking forward" and trying to find the next naming system, some context implementations, once located, need to "look back" the resolution chain to obtain contextual information. For example, a particular context implementation that is federated off of a host naming system might be designed such that the only means by which it can find out host information is to ask its (possibly not immediate) superior naming system. To do that, it needs *contextual information*—information about how the resolution proceeded to its current point.

Summarizing earlier discussions on federation, when performing an operation on a name that spans multiple namespaces, the context implementation first constructs a `CannotProceed-`

`Exception` containing information pinpointing how far it has proceeded. It then obtains a continuation context from JNDI by calling `getContinuationContext()`. To support the retrieval of contextual information, `getContinuationContext()` automatically adds the environment property `java.naming.spi.CannotProceedException`, with the value of the `CannotProceedException` argument, to the continuation context's environment. This property is inherited by the continuation context and may be used by that context's implementation to inspect the fields of the exception.

2.6 Referral Support

LDAP-style directory services support the notion of *referrals* for redirecting a client's request to another server. A referral differs from the federation continuation mechanism described earlier in that a referral may be presented to the JNDI client, who then decides whether to follow it, whereas a `CannotProceedException` should be returned to the client only when no further progress is possible. Another difference is that an individual context implementation offers the capability of continuing the operation using the referral (and itself determines the mechanism for doing so). In a federation, the mechanism of continuation is beyond the scope of individual context implementations: individual context implementations benefit from the common federation mechanism provided by the JNDI SPI framework.

A context implementation that supports referrals defines a subclass of `ReferralException` and provides implementations for its abstract methods. `getReferralContext()` returns a context at which to carry on the operation, and `getReferralInfo()` returns information on where the referral leads to, in a format appropriate to the context implementation.

The environment property `java.naming.referral` specifies how the context implementation should treat referrals. If the context implementation is asked to throw an exception when a referral is encountered, or if the context implementation encounters problems following a referral, it throws a `ReferralException` to the application. To continue the operation, the application re-invokes the method on the referral context using the same arguments it supplied to the original method. The following code sample shows how `ReferralException` may be used by an application:[1]

1. Note that this is code in the *application*. In "Continuing an Operation in a Federation", the code sample presented is code in the *context implementation*.

```
while (true) {
    try {
        bindings = ctx.listBindings(name);
        while (bindings.hasMore()) {
            b = (Binding) bindings.next();
            ...
        }
        break;
    } catch (ReferralException e) {
        ctx = e.getReferralContext();
    }
}
```

This convention of re-invoking the method using the original arguments is a simple one for applications to follow. This places the burden on the implementation of the `ReferralException` to supply enough information to the implementation of the referral context for the operation to be continued. Note that this will likely render some of the arguments passed to the re-invoked operation superfluous. The referral context implementation is free to ignore any redundant or unneeded information.

It is possible for an operation to return results in addition to a referral. For example, when searching a context, the server might return several results in addition to a few referrals as to where to obtain further results. These results and referrals might be interleaved at the protocol level. If referrals require user interaction (i.e., not followed automatically), the context implementation should return the results through the search enumeration first. When the results have been returned, the referral exception can then be thrown. This allows a simple programming model to be used when presenting the user with a clear relationship between a referral and its set of results.

2.7 Schema Support

JNDI defines the `Attribute` interface for representing an attribute in a directory. An attribute consists of an attribute identifier (a string) and a set of attribute values, which can be any object in the Java programming language. There are also methods defined in `Attribute` for obtaining the attribute's definition and syntax definition from the directory's schema.

```
public class Attribute {
    public DirContext getAttributeDefinition() throws NamingException;
    public DirContext getAttributeSyntaxDefinition()
        throws NamingException;
    ...
}
```

The utility class, `BasicAttribute`, does not provide useful implementations for these methods. A directory context implementation that has support for such schema information should provide implementations of `Attribute` that implement these two methods based on its schema mechanisms, perhaps by subclassing `BasicAttribute` and overriding these two methods. The context implementation should then return instances of these subclasses when asked to return instances of `Attribute`. The context implementation, when it receives an `Attribute` instance that do not have meaningful implementations of these two methods, should use reasonable defaults to determine the attribute's definition and syntax, using information such as the attribute values' class names or conventions used for the attribute identifier.

The `DirContext` interface contains schema-related methods:

```
public class DirContext {
    ...
    public DirContext getSchema(Name name) throws NamingException;
    public DirContext getSchema(String name) throws NamingException;

    public DirContext getSchemaClassDefinition(Name name)
        throws NamingException;
    public DirContext getSchemaClassDefinition(String name)
        throws NamingException;

}
```

`getSchema()` returns the schema tree for the named object, while `getSchemaClassDefinition()` returns a context containing schema class definitions for the named object. Some systems have just one global schema and, regardless of the value of the `name` argument, will return the same schema tree. Others support finer grained schema definitions, and may return different schema trees depending on which context is being examined.

2.8 Event Support

A context implementation supports event notification by providing implementation for the methods in the `EventContext`/`EventDirContext` interfaces. The event model advocated by these interfaces can be readily supported using a multithreaded model. When an application uses `addNamingListener()` to register a listener with a context, the context records the requests and takes action to collect information required to generate the events. When the context eventually receives information to generate the events, it fires the events to the listener. The thread that does the registration is typically different from the thread that runs the listener. The context implementation typically uses a thread that it has created and manages to run the listener method. When one event is dispatched to multiple listeners, the context implementation may choose to (and is generally encouraged) to execute the listener methods concurrently in separate threads.

The `addNamingListener()` methods accept an instance of `NamingListener`. The instance might implement one or more subinterfaces of `NamingListener`. If the listener implements more than one subinterface, the context implementation should try to conserve resources required to satisfy the registration. For example, an implementation might be able to submit a single request to the server that captures all of the requests of the subinterfaces.

Where possible, the context implementation should fire a `NamingExceptionEvent` to a listener if the context will be unable to fire further events and then automatically deregister the listener. For example, if the connection to the server is broken subsequent to the registration of the listener and no information will be available to fire events, the context should fire a `NamingExceptionEvent` to the listener.

2.9 Context Environment Support

Each instance of `Context` (or its subinterfaces) can have associated with it an *environment* which contains preferences expressed by the application of how it would like to access the services offered by the context. Examples of information found in an environment are security-related information that specify the user's credentials and desired level of security (`none`, `simple`, `strong`), and configuration information, such as the server to use. See Chapter 6 and Appendix A of the **JNDI API** document for more details about environment properties.

Environment properties are defined generically in order to ensure maximum portability. Individual service providers should map these generic properties to characteristics appropriate for their service. Properties that are not relevant to a provider should be recorded and silently ignored. The environment may also be used for storing service provider-specific properties or preferences, in which case their applicability across different providers is limited.

2.9.1 Property Naming Convention

See Section 6.1 in the **JNDI API** document for a description of how environment properties are named. Service provider-specific properties should have a prefix that reflects their uniqueness to the provider. A common practice is to use the package name of the service provider as the prefix. For example, since Sun's LDAP provider is primarily contained in the package `com.sun.jndi.ldap`, properties specific to Sun's LDAP provider have the prefix "com.sun.jndi.ldap.".

2.9.2 Initializing a Context's Environment

When creating an initial context (either using the constructors from `InitialContext` or its subclasses), the application can supply an environment as a parameter. The parameter is represented as a `Hashtable` or any of its subclasses (e.g., `Properties`). The JNDI class library augments the data from this parameter with data from other sources (see Chapter 6 in the **JNDI API** document) and passes this to the context implementation.

Like all other parameters, the environment parameter received by a context implementation is owned by the caller. The context implementation should make a copy of the environment parameter it gets or otherwise take steps to ensure that changes by the caller to the parameter would not affect what the context implementation sees and vice versa. Note also that if the environment parameter is a `Properties` instance, enumeration and `Hashtable.get()` on the parameter only examine the top-level properties (not any nested defaults). This is the expected behavior. The context implementation is not expected to retrieve or enumerate values in the `Properties` instance's nested defaults.

The JNDI library is responsible for merging properties from different sources, such as the environment parameter to the initial context, resource files, and, where appropriate, system properties and applet parameters (see the JNDI API document, Chapter 6). The context implementation typically just reads the property it needs from the environment which it was supplied. There is seldom a need for a context implementation to consult other sources.

2.9.3 Inheritance

The environment is inherited from parent to child as the context methods proceed from one context to the next. The entire environment of a context instance is inherited by the child context instances, regardless of whether certain properties within the environment are ignored by a particular context.

A context implementation must pass on the environment from one context instance to the next in order to implement this "inheritance" trait of environments. Within one context implementation it can do so by passing the environment as an argument to the `Context` constructor, or to the `NamingManager/DirectoryManager.getObjectInstance()` method for creating `Context` instances.

Across context implementations in a federation, this is supported by passing the environment as part of the `CannotProceedException` parameter of `NamingManager.getContinuationContext()/DirectoryManager.getContinuationDirContext()`, which in turn will use this environment when creating an instance of the context in which to continue the operation.

Inheritance can be implemented in any way as long as it preserves the semantics that each context has its own view of its environment. For example, a copy-on-write implementation could be used to defer copying of the environment until it is absolutely necessary.

2.9.4 Updates to the Environment

The environment of a context can be updated via the use of the `addToEnvironment()` and `removeFromEnvironment()` methods in the `Context` interface.

```
public interface Context {
    ...
    public Object addToEnvironment(String propName, Object propVal)
        throws NamingException;

    public Object removeFromEnvironment(String propName)
        throws NamingException;
}
```

These methods update the environment of this instance of `Context`. An environment property that is not relevant to the context implementation is silently ignored but maintained as part of the environment. The updated environment affects this instance of `Context`, and will be inherited by any new child `Context` instances, but does not affect any `Context` instances already in existence. A lookup of the empty name on a `Context` will return a new `Context` instance with an environment inherited as with any other child.

See Section 6.6 in the **JNDI API** document for details.

2.9.5 Provider Resource Files

Each service provider has an optional resource file that contains properties specific to that provider. The name of this resource is:

```
[prefix/]jndiprovider.properties
```

where *prefix* is the package name of the provider's context implementation(s), with each period (".") converted to a slash ("/"). For example, suppose a service provider defines a context implementation with class name `com.sun.jndi.ldap.LdapCtx`. The provider resource for this provider is named `com/sun/jndi/ldap/jndiprovider.properties`.

The JNDI class library will consult this file when it needs to determine the value of a property, as described in Section 6.5.2 in the **JNDI API** document.

When the service provider needs to determine the value of a property, it will generally take that value directly from the environment. The service provider may define provider-specific properties to be placed in its own provider resource file. In that case it needs to read them from its property resource file and merge them in a way consistent with the algorithm described in Section 6.5.2 in the **JNDI API** document.

2.10 Connection Management

For a context implementation that uses a client/server protocol, there is not necessarily a one-to-one mapping between a context and a connection between the client and the server. JNDI is a high-level API that does not deal directly with connections. It is the job of the context implementation to do any necessary connection management. Hence, a single connection may be shared by multiple context instances, and a context implementation is free to use its own algorithms to conserve connection and network usage. Thus, when a method is invoked on the context instance, the context implementation might need to do some connection management in addition to performing the requested operation.

The `Context.close()` and `NamingEnumeration.close()` methods can be used by applications to provide hints to the context implementation as to when to free connection-related resources. A context implementation may choose to (and is generally encouraged to) take other measures to garbage-collect and conserve its connection-related resources.

Some environment properties affect a context's connection. For example, if the application changes the security-related properties, the context implementation might need to modify or create a new connection using those updated properties. If the connection was being shared by other contexts prior to the change, the connection change should not affect contexts whose properties have not been updated.

3 The Initial Context

Since all naming methods are performed relative to a context, an application needs a starting context in order to invoke them. This starting context is referred to as the *initial context*. The bindings in the initial context are determined by policies set forth by the initial context implementation, perhaps using standard policies for naming global and enterprise-wide namespaces. For example, the initial context might contain a binding to the Internet DNS namespace, a binding to the enterprise-wide namespace, and a binding to a personal directory belonging to the user who is running the application.

An application obtains an initial context by making the following call:

```
Context ctx = new InitialContext();
```

An alternate constructor allows an environment to be passed as an argument. This allows the application to pass in preferences or security information to be used in the construction of the initial context.

```
Hashtable env = new Hashtable();[1]
env.put(Context.SECURITY_PRINCIPAL, "jsmith");
env.put(Context.SECURITY_CREDENTIALS, "xxxxxxx");
Context ctx = new InitialContext(env);
```

Subsequent to getting an initial context, the application can invoke `Context` methods.

```
Object obj = ctx.lookup("this/is/a/test");
```

The `InitialContext` class (and subclasses) selects an implementation using a default algorithm that can be overridden by installing an *initial context factory builder* (described below).

The `InitialDirContext` is an extension of `InitialContext`. It is used for performing directory operations using the initial context. The `InitialLdapContext` class is an extension of `InitialDirContext`. It is used for performing special LDAP v3 operations using the initial context. The algorithms and policies described in this section also apply to `InitialDirContext` and `InitialLdapContext`. Places where `DirContext/LdapContext` is required instead of `Context` have been noted.

3.1 The Initial Context Factory

An *initial context factory* is a class that creates an instance of a context that has been implemented following the guidelines outlined in Chapter 2. The factory is used by the `InitialContext` class (or subclass) constructor.

Given an environment, the factory returns an instance of `Context` (or its subinterfaces).

```
public interface InitialContextFactory {
    public Context getInitialContext(Hashtable env)
        throws NamingException;
}
```

Appendix A contains an example of an `InitialContextFactory`.

1. You can also use a subclass of `Hashtable` (e.g. `Properties`) for this.

Once the context instance has been created, when a method is invoked on `InitialContext` by using a non-URL name (see below), the method is forwarded and invoked on that context instance.

JNDI selects the initial context implementation to use by using the property `java.naming.factory.initial`. This property contains the fully-qualified class name of an initial context factory. The class must implement the `InitialContextFactory` interface and have a public constructor that does not take any arguments. JNDI will load the initial context factory class and then invoke `getInitialContext()` on it to obtain a `Context` instance to be used as the initial context.

An application that wants to use a particular initial context must supply the `java.naming.factory.initial` property in the environment passed to the `InitialContext` (or subclass) constructors, or via resource files, system properties, or applet parameters.

3.1.1 Exceptions

When the property `java.naming.factory.initial` is set to a non-`null` value, the `InitialContext` (and subclass) constructors will try to load and instantiate an initial context factory, which will then create a context instance. If the factory or context cannot be created, for example as a result of an authentication problem, the initial context factory can throw an exception to indicate this problem. Note however that it is up to the context implementation *when* it verifies and indicates to users of the initial context any environment property- or connection- related problems. It can do so lazily—delaying until an operation is performed on the context, or eagerly, at the time the context is created.

If the property `java.naming.factory.initial` is not set, no attempt will be made to create an underlying context for the initial context. The initial context is still useful, for instance, for processing URL names, as described next.

3.2 URL Support

If a URL[1] string is passed to the initial context, it will be resolved using the corresponding *URL context implementation*. This feature is supported by the `InitialContext` class (and subclasses) and is independent of the setting of the `java.naming.factory.initial` environment property.

This feature allows applications to use the initial context to reach any namespace for which a URL context implementation has been made available. For example, the following code lists an LDAP namespace from the initial context:

```
new InitialContext().list("ldap://lserver/ou=eng,o=wiz,c=us");
```

3.2.1 URL Context

A URL string has the following format:

1. The mention of “URL” in this document refers to a URL string as defined by RFC 1738 and its related RFCs. It is any string that conforms to the syntax described therein, and may not always have corresponding support in the `java.net.URL` class or Web browsers. The URL string is either passed as the `String` name parameter, or as the first component of the `Name` parameter.

scheme_id:*opaque_string*

For example, an LDAP URL string has the scheme id “ldap”; a file URL has the scheme id “file”.

A URL context implementation is a class that implements the `Context` interface (and possibly some subinterfaces) and accepts name arguments that are URL strings of the scheme that it supports. For example, an LDAP URL context accepts “ldap” URL strings.

When a URL string name is passed to a URL context, the context methods that accept `String` treat the name as a URL with the syntax defined by the URL scheme. When a `Name` object in which the first component is a URL string name is passed to a URL context, the first component is treated as a URL string, and the rest is used for federation (that is, resolution of the first component will indicate which naming system to use to resolve the rest). The `Name` instance should be a `CompositeName`; otherwise, an `InvalidNameException` should be thrown.

Name arguments that are not URL strings, and URL strings with an inappropriate scheme id should be rejected with an `InvalidNameException`.

3.2.2 URL Context Factory

A *URL context factory* is a class (actually a special type *object factory* (see Section 4.1)) that creates an instance of a URL context for URLs of one or more schemes.

When the `InitialContext` class receives a URL string as a name argument, it will look for a URL context factory by using the following algorithm. The environment property `java.naming.factory.url.pkgs` contains a colon-separated list of package prefixes. The factory’s class name is constructed by using the following rule:

package_prefix + “.” + *scheme_id* + “.” + *scheme_id*`URLContextFactory`

for each package prefix listed in the property. The default package prefix `com.sun.jndi.url` is appended to the end of the list.

For example, if the URL is “`ldap://somehost:389`” and `java.naming.factory.url.pkgs` contains “`com.widget:com.wiz.jndi`”, the `InitialContext` class will attempt to locate the corresponding factory class by loading the following classes until one is successfully instantiated:

```
com.widget.ldap.ldapURLContextFactory
com.wiz.jndi.ldap.ldapURLContextFactory
com.sun.jndi.url.ldap.ldapURLContextFactory
```

The factory class implements the `ObjectFactory` interface (see “URL Context Factory” on page 31) and has a public constructor that takes no arguments. The `InitialContext` class passes the scheme id as the resolved object to the factory’s `getObjectInstance()` method, which in turn creates a URL context for the URL scheme. The URL context will then be used to carry out the originally intended `Context` or `DirContext` operation on the URL supplied to `InitialContext`.

3.2.3 Service Provider’s Responsibility

There is no requirement that a service provider supply a URL context factory and URL context implementation. It only does so if it wants to allow URL string names with its URL scheme to be accepted by the `InitialContext` class. A service provider, for instance, might just provide an initial context factory and a context implementation that is accessed through that factory.

3.3 Overriding the Default Behavior

The policy of creating an initial context factory using the `java.naming.factory.initial` environment property and URL support is built into the `InitialContext` class. There are two ways an application can override some or all of this policy.

3.3.1 Removing URL Support

If an application does not want URL strings to be treated specially, it can use the method `NamingManager.getInitialContext()`, which creates a context instance using the factory named in the `java.naming.factory.initial` environment property.

This method is also useful if the application needs to access interfaces implemented by the context created by the initial context factory, but which are not one of `Context`, `DirContext`, or `LdapContext`. Here is a code fragment that gets a context using `NamingManager.getInitialContext()` and then casts it to a subclass:

```
FooContext ctx = (FooContext) NamingManager.getInitialContext(env);
...
Object obj = ctx.lookup(name);
ctx.fooMethod1(...);
```

Note that installing an initial context factory builder (discussed next) affects the result of `NamingManager.getInitialContext()`.

3.3.2 Removing All Policy

An initial context factory *builder* is a class that creates instances of initial context factories.

An application can install an initial context factory builder to define its own policy of how to locate and construct initial context implementations. When a builder has been installed, it is solely responsible for creating the initial context factories. None of the default policies (`java.naming.factory.initial` property or URL support) normally used by JNDI are employed.

An implementation of an initial context factory builder must implement the `InitialContextFactoryBuilder` interface. Its `createInitialContextFactory()` method creates instances of `InitialContextFactory`.

After a builder has been installed. the application can get the initial context by either using the `InitialContext/InitialDirContext/InitialLdapContext` constructors, or by using `NamingManager.getInitialContext()`. When one of the constructors is used, its class is basically a wrapper around the underlying context implementation returned by `NamingManager.getInitialContext()`.

3.4 Implementing a Subclass of InitialContext

When there is a need to provide an initial context that supports an interface that extends from `Context`, `DirContext`, or `LdapContext`, the service provider should supply a subclass of `InitialContext` (or `InitialDirContext/InitialLdapContext`).

3.4.1 URL Support

To add support for URLs in the same way `InitialContext` and `InitialDirContext` do, the subclass should use the protected methods available in `InitialContext` as follows. This only makes sense for interfaces that have methods that accept name argument.

For example, suppose `FooContext` is a subinterface of `DirContext`. Its initial context implementation would define `getURLOrDefaultInitFooCtx()` methods (for both `Name` and `String` parameters) that retrieve the real initial context to use.

```
public class InitialFooContext extends InitialDirContext {
    ...
    protected FooContext getURLOrDefaultInitFooCtx(Name name)
        throws NamingException {
        Context answer = getURLOrDefaultInitCtx(name);
        if (!(answer instanceof FooContext)) {
            throw new NoInitialContextException(“Not a FooContext”);
        }
        return (FooContext)answer;
    }
    // similar code for getURLOrDefaultInitFooCtx(String name)
}
```

When providing implementations for the new methods in the `FooContext` interface that accept a name argument, `getURLOrDefaultInitFooCtx()` is used in the following way.

```
public Object FooMethod1(Name name, ...) throws NamingException {
    return getURLOrDefaultInitFooCtx(name).FooMethod1(name, ...);
}
```

3.4.2 New Method Support

When providing implementations for the new methods in the `FooContext` interface that do not have a name argument, or for which URL support is not required, use `InitialContext.getDefaultInitCtx()`.

```
protected FooContext getDefaultInitFooCtx() throws NamingException {
    Context answer = getDefaultInitCtx();
    if (!(answer instanceof FooContext)) {
        throw new NoInitialContextException(“Not an FooContext”);
    }
    return (FooContext)answer;
}
public Object FooMethod2(Args args) throws NamingException {
    return getDefaultInitFooCtx().FooMethod2(args);
}
```

3.4.3 Constructors

The implementation should provide appropriate constructors for the class. The constructor should call the appropriate constructor of the superclass. If the environment needs to be modified or examined prior to the superclass’s constructor being called, it should use the protected constructor that accepts a boolean flag to control the initialization of the initial context, and then use the `init()` method to initialize the context. Here is an example:

```
public InitialFooContext(Hashtable environment, Object otherArg)
        throws NamingException {
    super(true); // don’t initialize yet

    // Clone environment and adjust
    Hashtable env = (environment == null) ? new Hashtable(11) :
        (Hashtable)environment.clone();
    ...
    init(env);
}
```

Client programs that use this new initial context would look as follows.

```
import com.widget.jndi.InitialFooContext;
...
FooContext ctx = new InitialFooContext(env);
Object obj = ctx.lookup(name);
ctx.FooMethod1(name, ...);
```

4 Customizing A Context Implementation

JNDI allows a context implementation to be customized—by the application, the application's deployer or user, or the service provider—in how it reads and stores objects in the naming/directory service. A similar facility is also available for narrowing LDAP v3 control classes.

You can think of these facilities as modules that plug into a context implementation.

4.1 Reading Objects: Object Factories

JNDI provides a generic way of creating objects (including instances of `Context`) using information stored in the namespace. That information may be of arbitrary type (`java.lang.Object`). For example, it may be a `Reference`, or a URL, or any other data required to create the object. Turning such information stored in the namespace into an object is supported through the use of *object factories*. An object factory is a class that implements the `ObjectFactory` interface (or the `DirObjectFactory` subinterface):

```
public interface ObjectFactory {
    public Object getObjectInstance(Object refObj,
                                    Name name,
                                    Context nameCtx,
                                    Hashtable env)
        throws Exception;
}
public interface DirObjectFactory extends ObjectFactory {
    public Object getObjectInstance(Object refObj,
                                    Name name,
                                    Context nameCtx,
                                    Hashtable env,
                                    Attributes attrs)
        throws Exception;
}
```

Given some reference information (`refObj`) about an object, optional information about the name of the object and where it is bound, and optionally some additional environment information (for example, some identity or authentication information about the user creating the object), the factory attempts to create an object represented by the reference information. For example, given reference information about a printer, a printer object factory might return an instance of `Printer`. In the case of an object factory that is to be used with a `DirContext` implementation, the factory is also given some attributes about the object. If the factory requires more attributes or information, it can obtain them directly from the naming/directory service by using the `name`/`nameCtx` arguments.

If the factory cannot created an object using the arguments supplied, it should return `null`. For example, when a printer object factory is given data about a disk drive, it should return `null`. The factory should only thrown an exception if no other object factories should be tried. Therefore, the factory should be careful about runtime exceptions that might be thrown from its implementation. For example, if a printer object factory is given data about a printer but the data is malformed in some way, it should throw an exception.

Object factories are used in several places in JNDI, basically to turn any reference information into an object. They are used in federation, URL processing in the initial context, and, as illustrated by the printer example, turning data into a form expected by the application.

4.1.1 Handling Structured References

A `Reference` contains methods for returning the class name and location of the object factory. The following methods are found in `Reference`.

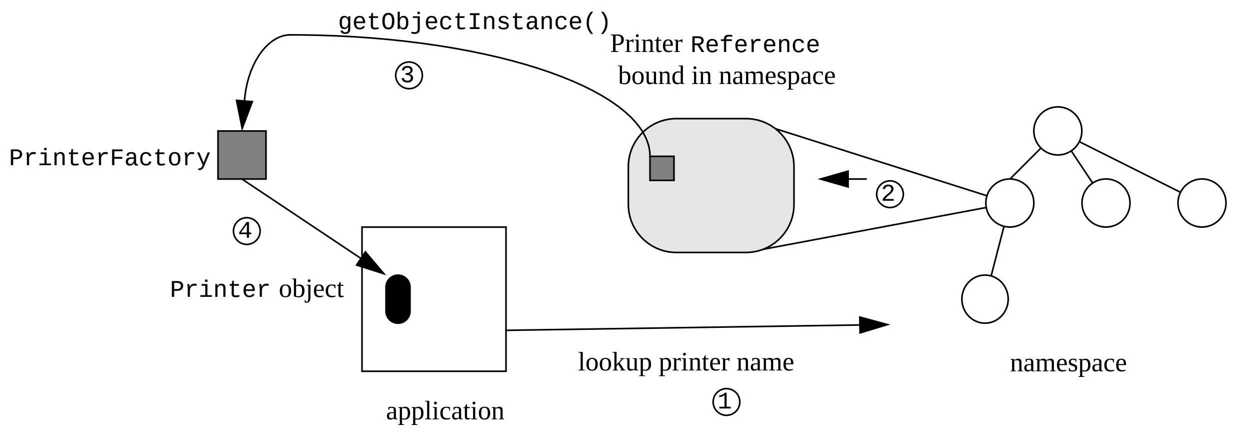
```
public class Reference {
    ...
    public String getClassName();
    public String getFactoryClassName();
    public String getFactoryClassLocation();
}
```

If the object read from the directory/naming service is an instance of `Reference` or `Referenceable`, its corresponding object factory can be located using information in `Reference`. The `getFactoryClassName()` method retrieves the name of the factory class that implements the `ObjectFactory` interface. This factory must implement the `ObjectFactory` interface and have a public constructor that takes no arguments. `getFactoryClassLocation()` retrieves the codebase of the class implementation for the factory, which is a list of space-separated URLs.

JNDI creates the object by invoking `getObjectInstance()` on the `ObjectFactory` instance, by using the `Reference` and environment as arguments. The result is an instance of a class identified by `getClassName()`.

Note that all the classes necessary to instantiate the object returned to the application are made available using mechanisms provided by JNDI. The application doesn't have to install the classes locally.

Figure 3: Example Using Reference to Get Back An Object From the Namespace



Returning to the printer example, suppose `Printer` is an interface for representing a printer and the `BSDPrinter` class is an implementation of that interface. `BSDPrinter` implements the `Referenceable` interface and uses the `Reference` class to store information on how to construct instances of `BSDPrinter` and address information for communicating with the print server. The `Reference` contains the class name of the object ("`Printer`"), the class name of the printer object factory ("`PrinterFactory`") and a URL for loading the factory's class implementation. Using the factory class name and implementation location, JNDI first loads the implementation of `PrinterFactory` and creates an instance of `PrinterFactory`. It then invokes `getObjectInstance()` on the factory to create an instance of `Printer` using the reference. For example, one address in the reference may have an address of type "`bsd`", and contains the print server's host name ("`lobby-printserver`"). The `PrinterFactory` instance uses the address type ("`bsd`") to decide to create a `BSDPrinter` instance and passes the address contents ("`lobby-printserver`") to its constructor. The resulting `BSDPrinter` object is returned as the result of `lookup()`.

From the context implementation's point of view, all of this is done automatically by its invocation of `NamingManager/DirectoryManager.getObjectInstance()`.

When the application invokes `print()` on the `BSDPrinter` instance returned by `lookup()`, the data is sent to the print server on the machine "`lobby-printserver`" for printing. The application need not know the details of the `Reference` stored in the namespace, the protocol used to perform the job, or whether the `BSDPrinter` class was defined locally or loaded over the network. The transformation of the information stored in the underlying service into an object that implements the `Printer` interface is done transparently through the cooperation of the service provider (which stores bindings of printer names to printer address information), the printer service provider (which provides the `PrinterFactory` and `BSDPrinter` classes), and the JNDI SPI framework (which ties the two together to return an object that the application can use directly).

A service provider for such an object must do the following:

1. Define the class for the object (e.g., `BSDPrinter`) that implements `Referenceable` or is a subclass of `Reference`.
2. Define the `Reference` and its reference addresses for the object.
3. Define a factory class that implements `ObjectFactory` (e.g., `PrinterFactory`). This class's `getObjectInstance()` method will create an instance of the class from step 1 (e.g., `BSDPrinter`) when given the `Reference` from step 2.

4.1.2 Handling URL References

If a `Reference` contains an address of type "URL" but not the factory class name and location, or if the reference is an array of strings containing URLs, JNDI will use the URL context factory support described in Section 3.2 to locate the factory, and then pass the URL string in the address to the factory's `getObjectInstance()` method. See Section 4.1.6 for a description of how JNDI expects a URL context factory implementation to behave.

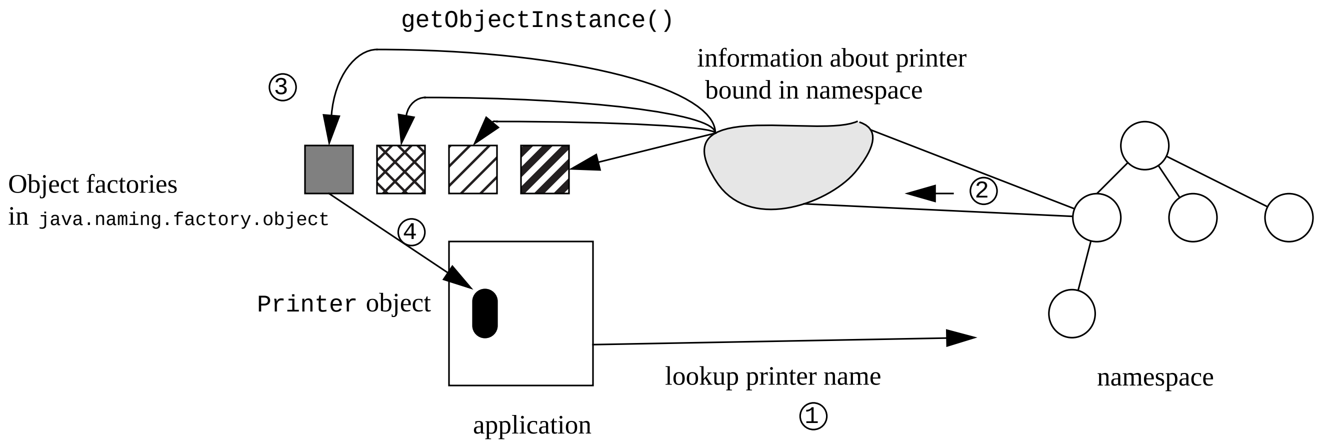
A service provider for such an object must do the following:

1. Define the class for the object (e.g., `BSDPrinter`).
2. Define the URL scheme for the object.
3. Define a URL context factory class that implements `ObjectFactory`. This class's `getObjectInstance()` method will create an instance of the class from step 1 (e.g., `BSDPrinter`) when given the URL from step 2.

4.1.3 Handling Arbitrary References: The java.naming.factory.object Property

In addition to extracting factory information from `References`, or using URLs, JNDI also looks for object factories specified in the `java.naming.factory.object` property, which can be in the environment or the provider resource file (see Section 2.9.5). The property contains a colon-separated list of fully-qualified class names of object factories. Each class must implement the `ObjectFactory` interface and have a public constructor that takes no arguments. For each class in the list, JNDI attempts to load and instantiate the factory class, and to invoke the `ObjectFactory/DirObjectFactory.getObjectInstance()` method on it using the object and environment arguments supplied. If the creation is successful, the resulting object is returned; otherwise, JNDI uses the same procedure on the next class in the list until the list is exhausted or a factory returns a non-`null` result.

Figure 4: Example using java.naming.factory.object to Get Back an Object from the Namespace


getObjectInstance()
③
information about printer bound in namespace
Object factories in java.naming.factory.object
②
④
Printer object
lookup printer name
①
namespace
application

For the printer example, instead of using a `Reference` to represent a printer in the namespace, some other information is stored. When that information is later retrieved, the object factories specified `java.naming.factory.object` are tried in turn to attempt to turn that information into a `Printer` instance.

A service provider for such an object must do the following:

1. Define the class for the object (e.g., `BSDPrinter`).
2. Define the class for reference information for the object. This is the object that will be bound in the namespace. This need not be `Reference`. It can be anything that will be understood by its corresponding object factory (e.g., some string containing the server name "`printer type=bsd; host=lobby-printserver`").
3. Define a factory class that implements `ObjectFactory` (e.g., `PrinterFactory`). This class's `getObjectInstance()` method will create an instance of the class from step 1 (e.g., `BSDPrinter`) when given an instance of the class from step 2 (e.g., "`printer type=bsd; host=lobby-printserver`").

The service provider should automatically convert between the actual object (e.g., `BSDPrinter`) and the reference information (step 2, e.g., "`printer type=bsd; host=lobby-print-server`") when binding or looking up the object.

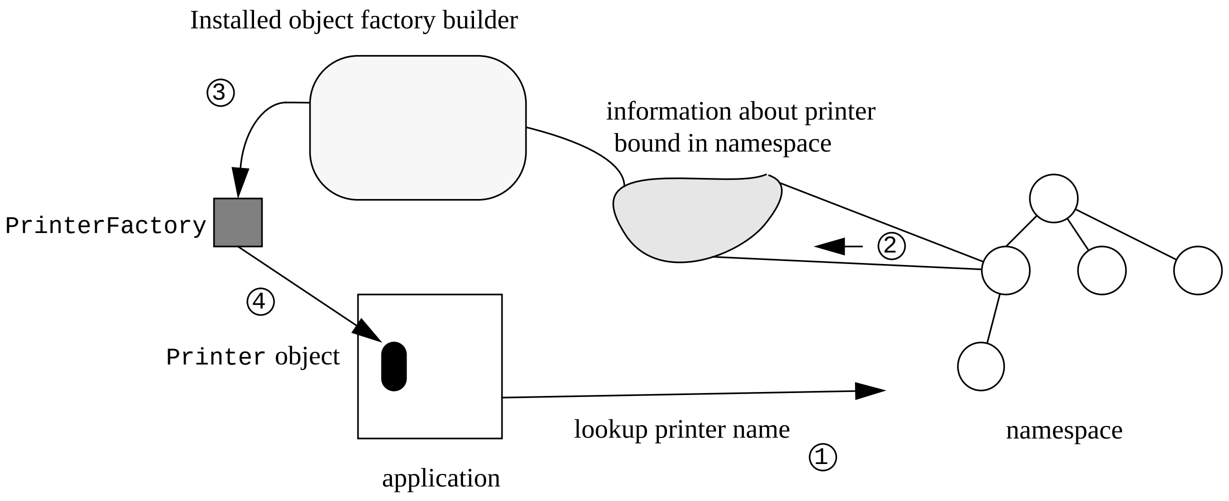
An application that wants to use a particular factory for generating objects must include the factory's class name in its `java.naming.factory.object` environment property and make the factory's classes and object classes available.

4.1.4 Overriding the Default Behavior

An object factory *builder* is a class that creates instances of object factories.

An application can install an object factory builder to defining its own policy of how to locate and construct object factory implementations. When a builder has been installed, it is solely responsible for creating the object factories. None of the default policies (`Reference`, URL string, or `java.naming.factory.object` property) normally used by JNDI are employed.

Figure 5: Example using an Object Factory Builder to Get Back an Object from the Namespace


Installed object factory builder
③
information about printer bound in namespace
PrinterFactory
②
④
Printer object
lookup printer name
namespace
①
application

A service provider for an object factory builder must do the following:

1. Define object factories that implement `ObjectFactory`.
2. Define a class that implements `ObjectFactoryBuilder`. This class's `createObjectFactory()` method will use the constructors for the `ObjectFactory` classes in step 1.

An application that wants to use this factory builder must first install it.

```
NamingManager.setObjectFactoryBuilder(builder);
```

4.1.5 Context Factory

A *context factory* is an object factory that creates instances of `Context`. The implementation of these contexts for a particular naming or directory service is referred to as a *context implementation*. Context implementations are described in Chapter 2. Like any other object factory, a context factory can be obtained by using any of the three mechanisms described above: from a `Reference`, a URL scheme id, or listed in the `java.naming.factory.object` property.

4.1.6 URL Context Factory

A URL context factory is a special kind of context factory. It follows these rules when implementing `ObjectFactory.getObjectInstance()`.

- If `refObj` is `null`, create a context for resolving URLs of the scheme associated with this factory. The resulting context is not tied to a specific URL. For example, invoking

  ```
  getObjectInstance(null, null, null, env)
  ```

  on an "ldap" URL context factory returns a context that can resolve LDAP URLs (e.g., "`ldap://ldap.wiz.com/o=wiz,c=us`" or "`ldap://ldap.umich.edu/`", ...).
- If `refObj` is a URL string, create the object identified by the URL. For example, invoking

  ```
  getObjectInstance("ldap://ldap.wiz.com/o=wiz,c=us", null, null, env);
  ```

  on an "ldap" URL context factory would return the object named by "`o=wiz,c=us`" on the LDAP server `ldap.wiz.com`. If this happens to name a context, it can then be used for resolving (relative) LDAP names (e.g., "`cn=Jane Smith`").
- If `refObj` is an array of URL strings, the assumption is that the URLs are equivalent in terms of the context to which they refer. Verification of whether the URLs are, or need to be, equivalent is up to the context factory. The order of the URLs in the array is not significant. The object returned by `getObjectInstance()` is the same as that for the single URL case—it is an object (perhaps a context) named by the URLs.
- If `refObj` is any other type, the behavior of `getObjectInstance()` is determined by the implementation.

URL context factories are used by the `InitialContext` class when it is passed a URL to resolve. URL context factories are also used for creating objects in the Java programming language from URLs stored in the namespace (see Section 4.1.2).

4.2 Storing Objects: State Factories

JNDI provides a mechanism to transform an object into a form storable by the underlying context implementation. That form may be any arbitrary type acceptable to the underlying context implementation. For example, it may be a `Reference`, a URL, a `Serializable` object, or a set of attributes, or any other data acceptable by the underlying context implementation. Turning an arbitrary object into data that can be stored in the namespace is supported through the use of *state factories*. A state factory is a class that implements the `StateFactory` interface (or the `DirStateFactory` subinterface):

```
public interface StateFactory {
    public Object getStateToBind(Object obj,
                                Name name,
                                Context nameCtx,
                                Hashtable env)
        throws NamingException;
}
public interface DirStateFactory {
    public DirStateFactory.Result getStateToBind(Object obj,
                                Name name,
                                Context nameCtx,
                                Hashtable env,
                                Attributes attrs)
        throws NamingException;
}
```

Given an object (`obj`), optional information about the name of the object and where it is bound, and optionally some additional environment information (for example, some identity or authentication information about the user accessing the namespace), the factory attempts to create an object suitable for binding. Typically, the state factory is knowledgeable about the target naming/directory service and/or context implementation, and knows which data formats are acceptable. In the case of a state factory that is to be used with a `DirContext` implementation, the factory is also given some attributes that are to be stored with the object. If the factory require more information about the object, it can obtain them directly from the naming/directory service by using the `name`/`nameCtx` arguments. For example, a printer state factory for an LDAP directory might return a set of attributes that represent the printer.

If the factory cannot return any data using the arguments supplied, it should return `null`. For example, when a printer state factory is given a disk object, it should return `null`. The factory should only thrown an exception if no other state factories should be tried. Therefore, the factory should be careful about exceptions that might be thrown from its implementation. For example, if a printer state factory is given a printer object but perhaps contradictory attributes, it might throw an exception.

4.2.1 Input/Output Options

Ultimately, a factory's output formats are determined by the underlying naming/directory service. A context implementation for the CORBA Object Services (COS) naming service, for example, can only store CORBA object references into the service; a context implementation for LDAP can only store attributes, although there is a lot of flexibility in how to encode information within those attributes.

A service provider typically supplies a factory for each (common) type of input that it expects, and the application can augment that set with state factories of its own. For example, a service provider for COS naming might have a state factory for converting a Java Remote Method Invocation (RMI) object into a CORBA object reference. A user of that provider might add a state factory for converting a Microsoft COM object reference into a CORBA object reference.

4.2.2 Locating State Factories: The java.naming.factory.state Property

JNDI looks for state factories specified in the `java.naming.factory.state` property, which can be in the environment or the provider resource file (see Section 2.9.5). The property contains a colon-separated list of fully-qualified class names of state factories. Each class must implement the `StateFactory` interface and have a public constructor that takes no arguments. For each class in the list, JNDI attempts to load and instantiate the factory class, and to invoke the `StateFactory/DirStateFactory.getStateToBind()` method on it using the object, name, context, environment, and attributes arguments supplied. If the factory produces a non-`null` result, the result is returned; otherwise, JNDI uses the same procedure on the next class in the list until the list is exhausted or a factory returns a non-`null` result.

4.3 Narrowing LDAP v3 Controls: Response Control Factories

The LDAP v3 protocol allows response controls to accompany any response sent by the server. The control consists of an OID string identifier and a sequence of ASN.1 BER encoded bytes. In the absence of any external information or assistance, the context implementation can only return a plain implementation of the `Control` interface that returns the OID and bytes.

JNDI provides the following abstract class for dealing with response controls:

```
public abstract javax.naming.ldap.ControlFactory {
    ...
    public static Control getControlInstance(Control ctl,
                                             Context ctx,
                                             Hashtable env)
        throws NamingException;
    public abstract Control getControlInstance(Control ctl)
        throws NamingException;
}
```

When a context implementation receives a response control, it invokes the static `getControlInstance()` method to find a control factory that can narrow the control to one that has more user-friendly access methods. Such a control, for instance, can decode the ASN.1 BER bytes and provide access methods that return the information as Java types. If no such control factory can be found, the original response control is returned. Here is an example of a hypothetical `TimeResponseControl` which decodes the time of day.

```
public class TimeResponseControl implements Control {
    long time;
    // Constructor used by ControlFactory
    public TimeResponseControl(String OID, byte[] berVal)
        throws NamingException {
        // check validity of OID
        time = // extract time from berVal
    };

    // Type-safe and User-friendly method
    public long getTime() {
        return time;
    }
    // Low-level methods
    public String getID() {
        return TIME_OID;
    }
    public byte[] getEncodedValue() {
        return // original berVal
    }
     ...
}
```

A control factory may be responsible for one or more controls. If the factory cannot return a control using the arguments supplied, it should return `null`. Typically, this involves just matching the control's OID against the list of OIDs supported by the factory. The factory should only thrown an exception if no other control factories should be tried. Therefore, the factory should be careful about exceptions that might be thrown from its implementation. For example, if a control factory is given a control with an OID that it supports, but the byte array has an encoding error, it should throw an exception.

Here is an example of a control factory:

```
public class VendorXControlFactory extends ControlFactory {
    public VendorXControlFactory () {
    }
    public Control getControlInstance(Control orig)
        throws NamingException {
        if (isOneOfMyControls(orig.getID())) {
             ...
            // determine which of ours it is and call its constructor
            return new TimeResponseControl(orig.getID(),
                                    orig.getEncodedValue());
        }
        return null;  // not one of ours
    }
}
```

4.3.1 Locating Response Control Factories: The java.naming.factory.control Property

JNDI looks for response control factories specified in the `java.naming.factory.control` property, which can be in the environment or the provider resource file (see Section 2.9.5). The property contains a colon-separated list of fully-qualified class names of control factories. Each class must implement the `ControlFactory` interface and have a public constructor that takes no arguments. For each class in the list, JNDI attempts to load and instantiate the factory class, and to invoke the `ControlFactory.getControlInstance()` instance method on it using the control, context, and environment arguments supplied. If the factory produces a non-`null` result, the result is returned; otherwise, JNDI uses the same procedure on the next class in the list until the list is exhausted or a factory returns a non-`null` result.

4.4 Ownership of Parameters

Any object passed as a parameter to a method in a factory is owned by the caller. Therefore, the factory is prohibited from maintaining a pointer to the object beyond the duration of the operation or modifying the object. If the factory needs to save the information contained in a parameter beyond the duration of the operation, it should maintain its own copy.

4.5 Reentrancy

A factory instance should be reentrant. That is, it should be possible for multiple threads to invoke methods on a single instance of a factory concurrently.

Appendix A: Service Provider Example

This appendix contains a simple service provider. It implements a flat namespace (with no federation support). It shows how to produce a context implementation by providing all the methods in the `Context` interface.

An instance of this context is bound directly as the initial context. This example provides the corresponding `InitialContextFactory` definition.

A.1 Simple Flat Context

A.1.1 Context Implementation

```
/*
 * Copyright (c) 1998.  Sun Microsystems. All rights reserved.
 */
package examples.spi.flat;

import javax.naming.*;
import java.util.*;

/**
 * A sample service provider that implements a flat namespace in memory.
 */

class FlatCtx implements Context {
    Hashtable myEnv;
    private Hashtable bindings = new Hashtable(11);
    static NameParser myParser = new FlatNameParser();

    FlatCtx(Hashtable environment) {
        myEnv = (environment != null)
            ? (Hashtable)(environment.clone())
            : null;
    }

    public Object lookup(String name) throws NamingException {
        if (name.equals(““)) {
           // Asking to look up this context itself.  Create and return
            // a new instance with its own independent environment.
            return (new FlatCtx(myEnv));
        }
        Object answer = bindings.get(name);
        if (answer == null) {
            throw new NameNotFoundException(name + “ not found”);
        }
        return answer;
    }

    public Object lookup(Name name) throws NamingException {
        // Flat namespace; no federation; just call string version
        return lookup(name.toString());
    }

    public void bind(String name, Object obj) throws NamingException {
        if (name.equals(““)) {
            throw new InvalidNameException(“Cannot bind empty name”);
        }
        if (bindings.get(name) != null) {
            throw new NameAlreadyBoundException(
                    “Use rebind to override”);
        }
        bindings.put(name, obj);
    }

    public void bind(Name name, Object obj) throws NamingException {
        // Flat namespace; no federation; just call string version
        bind(name.toString(), obj);
    }

   public void rebind(String name, Object obj) throws NamingException {
        if (name.equals(“”)) {
            throw new InvalidNameException(“Cannot bind empty name”);
        }
        bindings.put(name, obj);
    }

    public void rebind(Name name, Object obj) throws NamingException {
        // Flat namespace; no federation; just call string version
        rebind(name.toString(), obj);
    }

    public void unbind(String name) throws NamingException {
        if (name.equals(“”)) {
           throw new InvalidNameException(“Cannot unbind empty name”);
        }
        bindings.remove(name);
    }

    public void unbind(Name name) throws NamingException {
        // Flat namespace; no federation; just call string version
        unbind(name.toString());
    }

    public void rename(String oldname, String newname)
            throws NamingException {
        if (oldname.equals(“”) || newname.equals(“”)) {
           throw new InvalidNameException(“Cannot rename empty name”);
        }

        // Check if new name exists
        if (bindings.get(newname) != null) {
            throw new NameAlreadyBoundException(newname +
                                                “ is already bound”);
        }

        // Check if old name is bound
        Object oldBinding = bindings.remove(oldname);
        if (oldBinding == null) {
            throw new NameNotFoundException(oldname + “ not bound”);
        }

        bindings.put(newname, oldBinding);
    }

    public void rename(Name oldname, Name newname)
```

```
            throws NamingException {
        // Flat namespace; no federation; just call string version
        rename(oldname.toString(), newname.toString());
    }

    public NamingEnumeration list(String name)
            throws NamingException {
        if (name.equals(““)) {
            // listing this context
            return new FlatNames(bindings.keys());
        }

        // Perhaps ‘name’ names a context
        Object target = lookup(name);
        if (target instanceof Context) {
            return ((Context)target).list(““);
        }
        throw new NotContextException(name + “ cannot be listed”);
    }

    public NamingEnumeration list(Name name)
            throws NamingException {
        // Flat namespace; no federation; just call string version
        return list(name.toString());
    }

    public NamingEnumeration listBindings(String name)
            throws NamingException {
        if (name.equals(““)) {
            // listing this context
            return new FlatBindings(bindings.keys());
        }

        // Perhaps ‘name’ names a context
        Object target = lookup(name);
        if (target instanceof Context) {
            return ((Context)target).listBindings(““);
        }
        throw new NotContextException(name + “ cannot be listed”);
    }

    public NamingEnumeration listBindings(Name name)
            throws NamingException {
        // Flat namespace; no federation; just call string version
        return listBindings(name.toString());
    }

   public void destroySubcontext(String name) throws NamingException {
        throw new OperationNotSupportedException(
                “FlatCtx does not support subcontexts”);
    }

    public void destroySubcontext(Name name) throws NamingException {
        // Flat namespace; no federation; just call string version
        destroySubcontext(name.toString());
    }

    public Context createSubcontext(String name)
            throws NamingException {
        throw new OperationNotSupportedException(
                "FlatCtx does not support subcontexts");
    }

   public Context createSubcontext(Name name) throws NamingException {
        // Flat namespace; no federation; just call string version
        return createSubcontext(name.toString());
    }

    public Object lookupLink(String name) throws NamingException {
        // This flat context does not treat links specially
        return lookup(name);
    }

    public Object lookupLink(Name name) throws NamingException {
        // Flat namespace; no federation; just call string version
        return lookupLink(name.toString());
    }

    public NameParser getNameParser(String name)
            throws NamingException {
        return myParser;
    }

   public NameParser getNameParser(Name name) throws NamingException {
        // Flat namespace; no federation; just call string version
        return getNameParser(name.toString());
    }

    public String composeName(String name, String prefix)
            throws NamingException {
        Name result = composeName(new CompositeName(name),
                                  new CompositeName(prefix));
        return result.toString();
    }

    public Name composeName(Name name, Name prefix)
            throws NamingException {
        Name result = (Name)(prefix.clone());
        result.addAll(name);
        return result;
    }

    public Object addToEnvironment(String propName, Object propVal)
            throws NamingException {
        if (myEnv == null) {
            myEnv = new Hashtable(5, 0.75f);
        }
        return myEnv.put(propName, propVal);
    }

    public Object removeFromEnvironment(String propName)
            throws NamingException {
        if (myEnv == null)
            return null;

        return myEnv.remove(propName);
    }

    public Hashtable getEnvironment() throws NamingException {
        if (myEnv == null) {
            // Must return non-null
            myEnv = new Hashtable(3, 0.75f);
        }
        return myEnv;
    }

    public String getNameInNamespace() throws NamingException {
        return ““;
    }

    public void close() throws NamingException {
        myEnv = null;
        bindings = null;
    }

    // Class for enumerating name/class pairs
    class FlatNames implements NamingEnumeration {
        Enumeration names;

        FlatNames (Enumeration names) {
            this.names = names;
        }

        public boolean hasMoreElements() {
            return names.hasMoreElements();
        }

        public boolean hasMore() throws NamingException {
            return hasMoreElements();
        }

        public Object nextElement() {
            String name = (String)names.nextElement();
           String className = bindings.get(name).getClass().getName();
            return new NameClassPair(name, className);
        }

        public Object next() throws NamingException {
            return nextElement();
        }
        public void close() {
        }
    }

    // Class for enumerating bindings
    class FlatBindings implements NamingEnumeration {
        Enumeration names;

        FlatBindings (Enumeration names) {
            this.names = names;
        }

        public boolean hasMoreElements() {
            return names.hasMoreElements();
        }

        public boolean hasMore() throws NamingException {
            return hasMoreElements();
        }

        public Object nextElement() {
            String name = (String)names.nextElement();
            return new Binding(name, bindings.get(name));
        }

        public Object next() throws NamingException {
            return nextElement();
        }
        public void close() {
        }
    }
};
```

A.1.2 Name Parser

```
/*
 * Copyright (c) 1998.  Sun Microsystems. All rights reserved.
 */
package examples.spi.flat;

import javax.naming.NameParser;
import javax.naming.Name;
import javax.naming.CompoundName;
import javax.naming.NamingException;
import java.util.Properties;

class FlatNameParser implements NameParser {

    static Properties syntax = new Properties();
    static {
        syntax.put(“jndi.syntax.direction”, “flat”);
        syntax.put(“jndi.syntax.ignorecase”, “false”);
    }
    public Name parse(String name) throws NamingException {
        return new CompoundName(name, syntax);
    }
}
```

A.1.3 Initial Context Factory

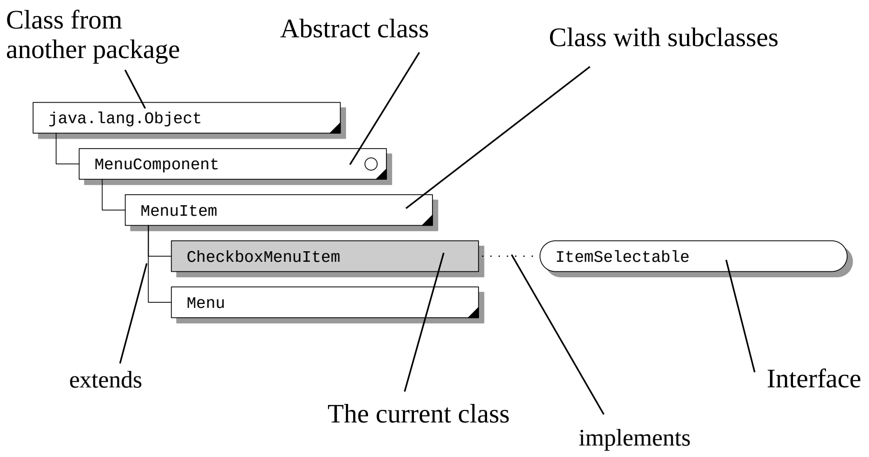
```
/*
 * Copyright (c) 1998.  Sun Microsystems. All rights reserved.
 */
package examples.spi.flat;

import java.util.Hashtable;
import javax.naming.Context;
import javax.naming.spi.InitialContextFactory;

public class FlatInitCtxFactory implements InitialContextFactory {

    public Context getInitialContext(Hashtable env) {
        return new FlatCtx(env);
    }
}
```

Appendix B: Legend for Class Diagram

In a class diagram, we visually distinguish the different kinds of Java entities, as follows:

1. The interface: A rounded rectangle
2. The class: A rectangle
3. The abstract class: A rectangle with an empty dot
4. The final class: A rectangle with a black dot
5. Classes with subclasses: A rectangle with a small black triangle on the lower right corner

Most of these elements are shown below. The class or interface being described in the current chapter is shaded grey (this is not applicable for package class diagrams). A solid line represents extends, while a dotted line represents implements.



Appendix C: JNDI Change History

1.2: JNDI Changes Since 1.1

- Added `javax.naming.event` package.
- Added `javax.naming.ldap` package.
- Added support for configuration using resource files. See Chapter 6 of the **JNDI API** document.

API-related Changes

- Added `NamingEnumeration.close()` for cancelling or terminating enumerations.
- Added `ReferralException.getReferralContext(Hashtable env)` and `ReferralException.retryReferral()` to allow creation and retry of referral context with different environment properties.
- Clarified how context methods that accept `Name` argument should deal with `CompositeName` and non`CompositeName` arguments. Specifically, instances of `CompositeName` are treated as composite name, while all others are treated as compound name.
- Added `Context.getNameInNamespace()` for retrieving the full name of a context within its own namespace.
- Clarified definition of the class factory location of a `Reference` object. Specifically, the location is a codebase, which consists of a list space-separated URLs.
- Added support for ordered multivalued attributes to `Attribute` and `BasicAttribute`.
- Added `BasicAttributes.equals()` and `BasicAttributes.hashCode()`.
- Redefined semantics of `DirContext.getSchemaClassDefinition()` so that it returns a context that contains the `DirContext` objects of class definitions, rather than returning one (arbitrary) class definition.
- Added protected `InitialContext`/`InitialDirContext` constructors to allow lazy initialization. Useful for subclass implementations.

SPI-related Changes

- Added `StateFactory`/`NamingManager.getStateToBind()`, analogous to `ObjectFactory`/`NamingManager.getObjectInstance()`, for transforming an object's state before the object is bound in the naming/directory service.
- Added interfaces `DirObjectFactory` and `DirStateFactory` to better support service providers that implement the `DirContext` interface. Added `DirectoryManager.getObjectInstance()` and `DirectoryManager.getStateToStore()` to use these interfaces.
- Refined definition of `NamingManager.getObjectInstance()` to not treat URL strings specially. Instead, the URL should be wrapped inside a `Reference` whose `RefAddr` type is "URL".
- Made `ResolveResult` implement `Serializable`.
- Defined a special form of `Reference` called a next naming system (nns) reference for supporting "dynamic federation". This reference has a `RefAddr` type of "nns" and a content consisting of the resolved object.
- Added the string constant `NamingManager.CPE` which names a property set by `NamingManager.getContinuationContext()`/`DirectoryManager.getContinuationContext()`. The value of this property is an instance of `CannotProceedException`. This is useful to service providers that implement federation by chaining the CPEs.
- Defined a convention for service providers to use when naming environment properties. See Section 6.1.