JavaSoft

JNDI: Java™ Naming and Directory Interface

The Java Naming and Directory application programming interface (JNDI API).

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Java Naming and Directory *1.1*

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1 Introduction

Directory services play a vital role in Intranets and Internets by providing access to a variety of information about users, machines, networks, services, and applications. By its very nature, a directory service incorporates a naming facility for providing human understandable namespaces that characterize the arrangement and identification of the various entities.

The computing environment of an enterprise typically consists of several naming facilities often representing different parts of a *composite* namespace. For example, the Internet Domain Name System (DNS) may be used as the top-level naming facility for different organizations within an enterprise. The organizations themselves may use a directory service such as LDAP or NDS or NIS. From a user’s perspective, there is one namespace consisting of composite names. URLs are examples of composite names because they span namespaces of multiple naming facilities. Applications which use directory services must support this user perspective.

Many Java^{TM} application developers can benefit from a directory service API that is not only independent of the particular directory or naming service implementation, but also enables seamless access to directory objects through multiple naming facilities. In fact, any application can attach its own objects to the namespace. Such a facility enables any Java application to discover and retrieve objects of any type.

End users can benefit from logical namespaces that allow easier discovery and identification of the objects in the network.

Directory service developers can benefit from a service-provider capability that enables them to incorporate their respective implementations without requiring changes to the client.

JNDI is an API specified in the Java programming language that provides directory and naming functionality to Java applications. It is defined to be independent of any specific directory service implementation. Thus, a variety of directories can be accessed in a common way.

Here are two examples to briefly illustrate some of the more commonly used features of **JNDI**.

An application that wants to access a printer needs the corresponding printer object. This is simply done as follows:

```
prt = (Printer) building7.lookup("puffin");
prt.print(document);
```

JNDI does all the work of locating the information needed to construct the printer object.

An application that wants to find a person’s phone numbers, which are stored in the organization’s directory, can simply do:

```
String[] attrs = {"workPhone", "cellPhone", "faxNumber"};
bobsPhones = directory.getAttributes("cn=Bob, o=Widget, c=US", attrs);
```

If there may be several Bobs in the Widget organization, the application can search the organization’s directory to find the right Bob as follows:

```
bob = directory.search("o=Widget, c=US", "cn=Bob", searchctls);
```

This document describes the architecture and interfaces of **JNDI**.

2 Goals and Design Principles

We followed several principles and maxims in designing the API.

2.1 Keep it Consistent and Intuitive

Wherever possible, we have used existing components from the rest of the Java development environment.

Adhering to this principle not only makes JNDI consistent with existing core classes in the Java platform but also reduces needless proliferation of classes.

The object-oriented nature of the Java programming language allows for an intuitive and simple API design, in which the directory service functionality is expressed as a natural extension to the more fundamental naming service functionality.

2.2 Pay for What you Use

The API is structured in a tiered manner so that the application programmer interested in a certain directory service capability need not necessarily know about a more advanced capability. We have strived to keep the lower tiers simple and also make them represent the common case capability, relegating the more complex ones to the upper tiers.

2.3 JNDI must be implementable over common Directory and Naming service interface and protocols

This goal is important for two reasons. First, it enables Java applications to take advantage of information in a variety of existing naming and directory services — existing ones such as DNS, NDS, NIS (YP), and X.500, and emerging ones such as LDAP servers. Second, it helps prevent the appearance of any implementation specific artifacts in the API.

Providing a unified interface to multiple naming and directory services does not imply that access of unique features of a particular service is precluded. The unified API which is designed to cover the common case is still beneficial to applications that have explicit knowledge of the underlying naming or directory service. Such applications still benefit from sharing the common portions that use the API. This is analogous to applications sharing commonly used classes and yet adding needed specificity via subclassing.

2.4 Enable Directory services to be seamlessly plugged in behind JNDI

This is important not only because of the diversity of directory service and naming services in the installed base that need to be supported, but also because new Java application and service programmers can export their own namespaces and directory objects in a uniform way.

We also wanted to make a variety of implementation choices possible without having the application pay for this freedom. For example, a “thin-client” may be better served by a proxy-style protocol in which the access to specific naming and directory services is relegated to a server. Whereas, a performance sensitive, resource rich client, may choose to use an implementation which directly allows it to access the various servers. However, the application should be insulated from these implementation choices. It should be possible to defer such choices even until run-time.

3 Fundamentals

A directory service provides access to diverse kinds of information about users and resources in a network environment. It uses a *naming system* for purpose of identifying and organizing *directory objects* to represent this information. A directory object provides an association between *attributes* and *values*. Thus, a directory service enables information to be organized in a hierarchical manner to provide a mapping between human understandable names and directory objects.

3.1 Naming — The Foundation

A fundamental facility in any computing system is the naming service – the means by which names are associated with objects, and by which objects are found given their names. In traditional systems, the naming service is seldom a separate service. It is usually integrated with another service, such as a file system, directory service, database, desktop, mail system, spreadsheet, or calendar. For example, a file system includes a naming service for files and directories; a spreadsheet has a naming service for cells and macros.

The computing environment of an enterprise typically consists of several naming services. There are naming services that provide contexts for naming common entities in an enterprise such as organizations, physical sites, human users and computers. Naming services are also incorporated in applications offering services such as file service, mail service, printer service, and so on. From a user's perspective, there exist several natural and logical relationships between these naming services. For example, it is natural to think of naming a variety of services such as files, mail, appointment calendar, and so on, in the context of a user. It is also natural to think of a user in the context of a department, within a division of an enterprise. Meaningful names can be composed using useful arrangements of naming services reflecting these relationships.

Every *name* is generated by a set of syntactic rules called a *naming convention*. An *atomic name* is an indivisible component of a name, as defined by the naming convention.

A *compound name* represents a sequence of zero or more atomic names composed according to the naming convention.

For example, in UNIX pathnames, atomic names are ordered from left to right, and are delimited by slash ('/') characters. The UNIX pathname `usr/local/bin` is a compound name representing the sequence of atomic names, `usr, local,` and `bin`. In names from the Internet Domain Name System (DNS), atomic names are ordered from right to left, and are delimited by dot ('.') characters. Thus, the DNS name `sales.Wiz.COM` is a compound name representing the sequence of atomic names, `COM, Wiz, sales`.

The association of an atomic name with an object is called *binding*.

A *context* is an object whose state is a set of bindings with distinct atomic names. Every context has an associated naming convention. A context provides a lookup (resolution) operation that returns the object, and may provide operations such as for binding names, unbinding names, listing bound names. An atomic name in one context object can be bound to another context object of the same type, called a *subcontext*, giving rise to compound names.

Resolution of compound names proceeds by looking up each successive atomic component in each successive context. The reader will find a familiar model in UNIX file naming, where directories serve as contexts, and pathnames may be compound names.

A *naming system* is a connected set of contexts of the same type (having the same naming convention) and providing the same set of operations with identical semantics.

A *namespace* is the set of all names in a naming system.

A *composite name* is a name that spans multiple naming systems. It consists of an ordered list of zero or more components. Each component is a name from the namespace of a single naming system.

For example, the name `jurassic.eng:/export/home/jdoe/.signature` is a composite name representation made up of a host name `jurassic.eng` from a host namespace, and the file name `/export/home/jdoe/.signature` from a UNIX file namespace. Another example is the Internet URL `http://www.moon.org/public/index.html`, which is a composite name representation made up of the scheme-id `http` from the "URL scheme-id" namespace, `www.moon.org` which is the DNS name of the machine on which the web server is running, and `public/index.html` which is a file name from a file namespace.

Every name is interpreted relative to some context, and every naming operation is performed on a context object. A client can obtain an *initial context* object that provides a starting point for resolution of names.

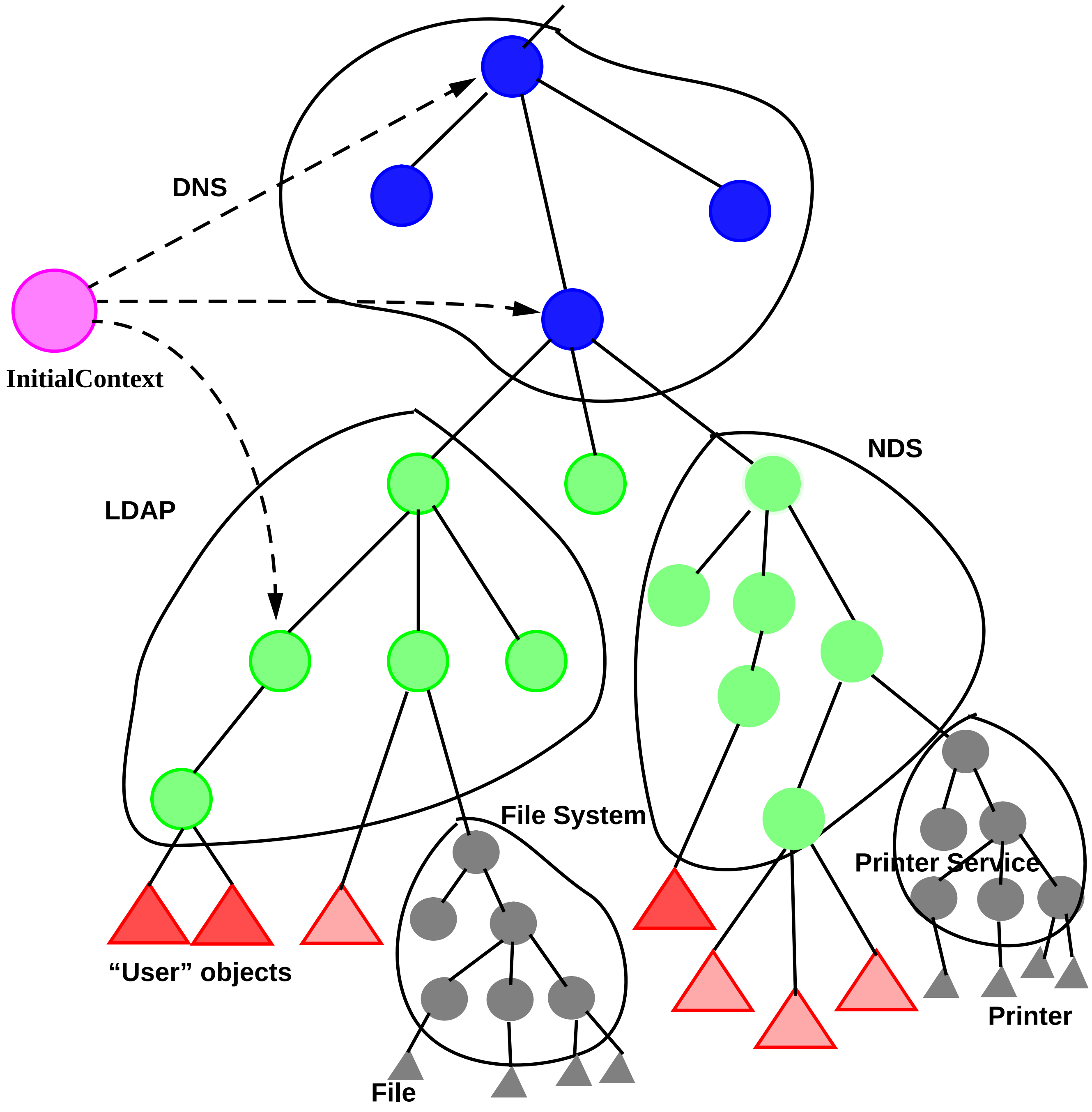
3.2 Directory Objects

The primary function of a naming system is to map names to objects. The objects can be of any type. A *directory* is a particular type of object that is used to represent the variety of information in a computing environment. A directory object can have associated with it *attributes*. An attribute has an identifier and a set of values.

A directory object provides operations for creating attributes, adding, removing, and modifying attributes associated with the directory object. If we make a directory object also be a naming context, we can represent trees of directory information where the interior nodes not only behave like naming contexts but also contain attributes.

Figure 1 is an example used for illustrating several things.

Figure 1: Example of a Composite Namespace



- ‘There can be multiple naming systems that can be represented by a composite namespace. In this case, DNS is the used as the global naming system; one division uses NDS, while a second division uses LDAP.
- Each namespace has interior nodes that represent naming contexts, which may be directory objects as well. Leaf nodes can be objects of any type.
- The *InitialContext* is configured to have bindings to useful starting contexts in different naming and directory systems.
- Applications just see a composite namespace. They can access any type of object bound in any naming system in this arrangement.
- Services can incorporate their own namespaces which appear as first-class citizens in JNDI.
- Arbitrary directory services can be added and accessed without requiring client applications to be changed.

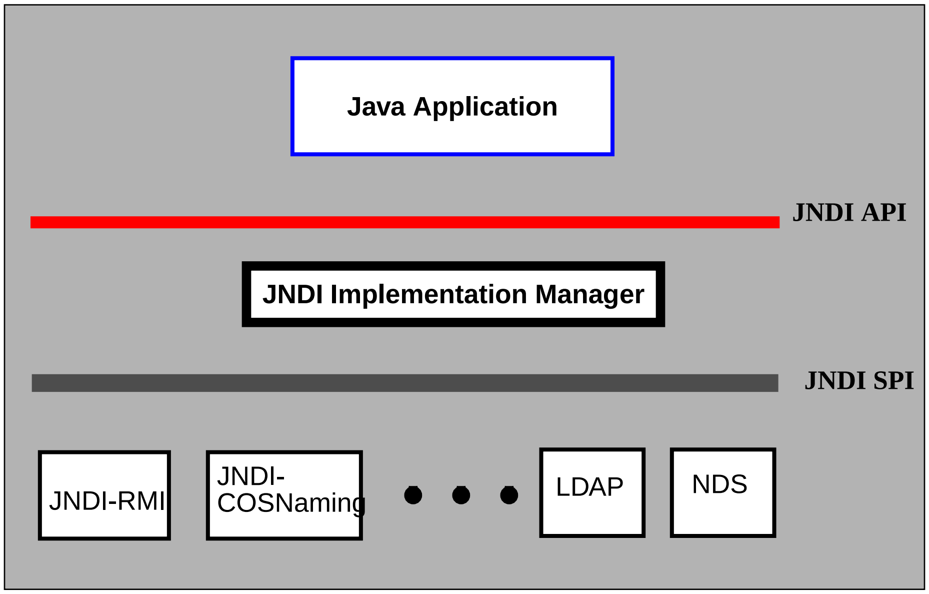
3.3 URLs and Composite Names

Universal Resource Locators (URLs) are composite names. Clients of JNDI can use URLs to refer to arbitrary types of objects. For example, a client can use `nfs://nfs.sun.com/export/jndi/src/README` to refer to a file object that is being accessed using the Network File System (NFS) protocol. Similarly, a client can perform directory operations on a directory object in an LDAP server using the URL `ldap://ldap.widget.com/cn=Jonathan,ou=marketing`.

4 Overview of the Architecture

The JNDI architecture consists of the JNDI API and the JNDI SPI. The JNDI API allows Java applications to access a variety of naming and directory services. The JNDI SPI is designed to be used by arbitrary service providers including directory service providers. This enables a variety of directory and naming services to be plugged in transparently to the Java application (which uses only the JNDI API). Figure 2 shows the JNDI architecture and includes a few service providers of directory and naming contexts as examples.

Figure 2: JNDI Architecture

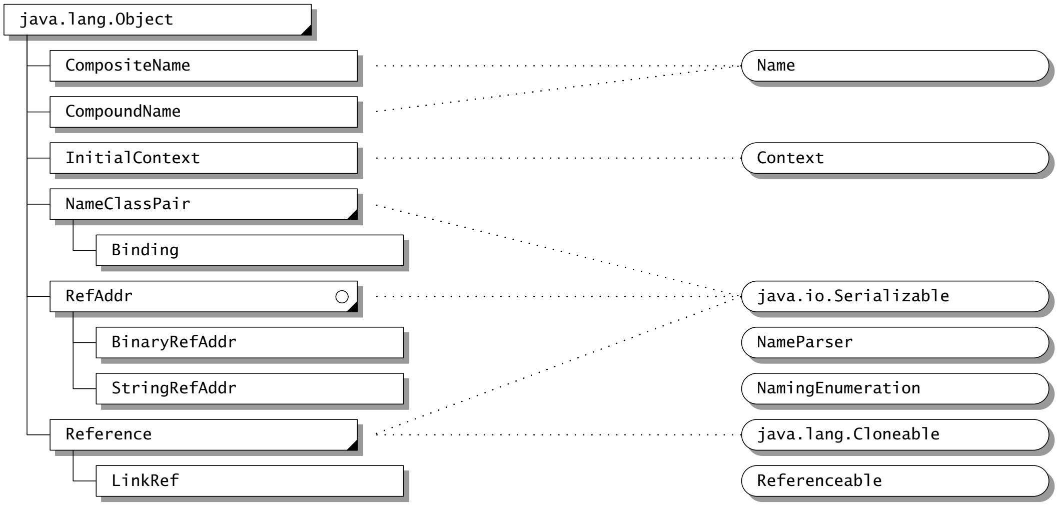


5 Overview of the Interface

The JNDI API is contained in two packages: `javax.naming` for the naming operations, and `javax.naming.directory` for directory operations. The JNDI service provider interface is contained in the package `javax.naming.spi` (see the **JNDI SPI** document for details).

The following sections provide an overview of the JNDI API. For more details on the API, see the corresponding **javadoc**.

5.1 The Naming Interface — javax.naming [1]



(exception classes are not shown)

5.1.1 Contexts and Names

`Context` is the core interface that specifies a naming context. It defines basic operations such as adding a name-to-object binding, looking up the object bound to a specified name, listing the bindings, removing a name-to-object binding, creating and destroying subcontexts of the same type, *etc.*

[1] See Appendix C for legend of class diagram.

```
public interface Context {
    public Object lookup(Name name) throws NamingException;
    public void bind(Name name, Object obj) throws NamingException;
    public void rebind(Name name, Object obj) throws NamingException;
    public void unbind(Name name) throws NamingException;
    public void rename(Name old, Name new) throws NamingException;
    public NamingEnumeration listBindings() throws NamingException;
    ...
    public Context createSubcontext(Name name) throws NamingException;
    public void destroySubcontext(Name name) throws NamingException;
    ...
};
```

Every naming method in `Context` takes a name as an argument. The operation defined by the method is performed on the `Context` object that is obtained by implicitly resolving the name. If the name is empty (“”) the operation is performed directly on the context itself. The name of an object can be a composite name reflecting the arrangement of the namespaces used to refer to the object. Of course, the client is not exposed to any naming service implementation. In fact, a new type of naming service can be introduced without requiring the application to be modified or even disrupted if it is running.

In JNDI, every name is relative to a context. There is no notion of “absolute names.” An application can bootstrap by obtaining its first context of class `InitialContext`:

```
public class InitialContext implements Context {
    public InitialContext() throws NamingException;
    ...
}
```

The initial context contains a variety of bindings that hook up the client to useful and shared contexts from one or more naming systems, such as the namespace of URLs or the root of DNS.

The `Name` interface represents a generic name — an ordered sequence of components. Each `Context` method that takes a `Name` argument has a counterpart that takes the name as a `String` instead. The versions using `Name` are useful for applications that need to manipulate names: composing them, comparing components, and so on. The versions using `String` are likely to be more useful for simple applications, such as those that simply read in a name and look up the corresponding object.

The `CompositeName` class represents a sequence of names (atomic or compound) from multiple namespaces. The `Name` parameter supplied to a method of the `Context` class will typically be a composite name.

The `CompoundName` class represents hierarchical names from a single namespace. A context’s name parser can be used to manipulate compound names in the syntax associated with that particular context:

```
public interface Context {
    ...
    public NameParser getNameParser(Name name) throws NamingException;
    ...
}
```

A namespace browser is an example of the kind of application that may need to manipulate names syntactically at this level. Most other applications will work with strings or composite names.

5.1.2 Bindings

`Context.lookup()` is the most commonly used operation. The context implementation can return an object of whatever class is required by the Java application. For example, a client might use the name of a printer to look up the corresponding `Printer` object, and then print to it directly:

```
Printer printer = (Printer) ctx.lookup(“treekiller”);
printer.print(report);
```

`Context.listBindings()` returns an enumeration of name-to-object bindings, each binding represented by an object of class `Binding`. A binding is a tuple containing the name of the bound object, the name of the object’s class, and the object itself.

The `Context.list()` method is similar to `listBindings()`, except that it returns an enumeration of `NameClassPair` objects. Each `NameClassPair` contains an object’s name and the name of the object’s class. The `list()` method is useful for applications such as browsers that wish to discover information about the objects bound within a context, but don’t need all of the actual objects. Although `listBindings()` provides all of the same information, it is potentially a much more expensive operation.

```
public class NameClassPair {
    public String getName() ...;
    public String getClassName() ...;
    ...
}

public class Binding extends NameClassPair {
    public Object getObject() ...;
    ...
}
```

5.1.3 References

Different `Context` implementations are able to bind different kinds of objects natively. A particularly useful object that should be supported by any general-purpose context implementation is the `Reference` class. A reference represents an object that exists outside of the directory. References are used to give JNDI clients the illusion that objects of arbitrary classes are able to be bound in naming or directory services—such as X.500—that do not have native support for objects in the Java programming language.

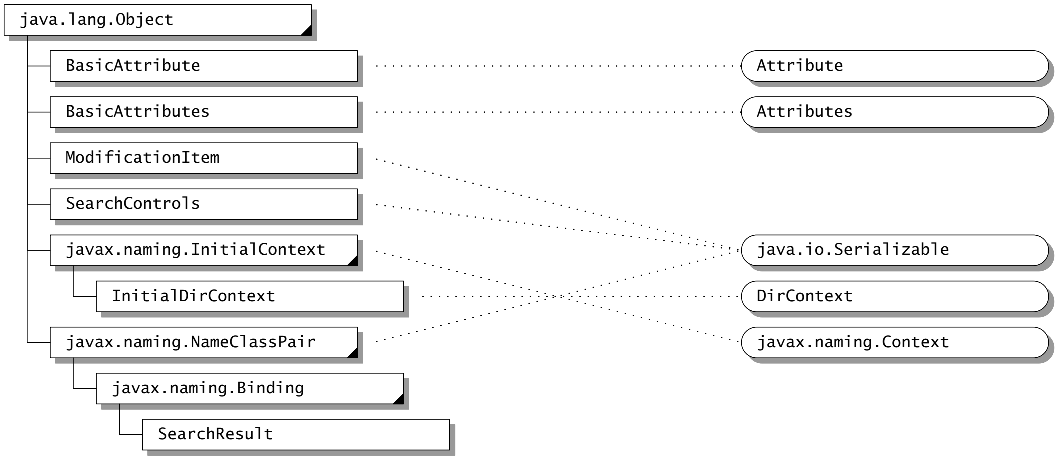
When the result of an operation such as `Context.lookup()` or `Binding.getObject()` is a `Reference` object, JNDI attempts to convert the reference into the object that it represents before returning it to the client. A particularly significant instance of this occurs when a reference representing a `Context` of one naming system is bound to a name in a different naming system. This is how multiple independent naming systems are joined together into the JNDI composite namespace. Details of how this mechanism operates are provided in the **JNDI SPI** document.

Objects that are able to be represented by a reference should implement the `Referenceable` interface. Its single method — `getReference()` — returns the object's reference. When such an object is bound to a name in any context, the context implementation may store the reference in the underlying system if the object itself cannot be stored natively.

Each reference may contain the name of the class of the object that it represents, and may also contain the location (typically a URL) where the class file for that object can be found. In addition, a reference contains a sequence of objects of class `RefAddr`. Each `RefAddr` in turn contains a "type" string and some addressing data, generally a string or a byte array.

A specialization of `Reference` called a `LinkRef` is used to add "symbolic" links into the JNDI namespace. It contains the name of a JNDI object. By default, these links are followed whenever JNDI names are resolved.

5.2 The Directory Interface — javax.naming.directory[1]



(exception classes are not shown)

[1] See Appendix C for legend of class diagram.

5.2.1 Directory Objects and Attributes

The `DirContext` interface enables the directory capability by defining methods for examining and updating attributes associated with a directory object. Each directory object contains a set of zero or more objects of class `Attribute`. Each attribute is denoted by a string identifier and can have zero or more values of any type.

```
public interface DirContext extends Context {
    public Attributes getAttributes(Name name)
            throws NamingException;

    public Attributes getAttributes(Name name,
                                    String[] attrIds)
            throws NamingException;
    ...
    public void modifyAttributes(Name name,
                                 int modOp,
                                 Attributes attrs)
            throws NamingException;

    public void modifyAttributes(Name name,
                                  ModificationItem[] mods)
            throws NamingException;
    ...
}

public class Attribute ... {
    ...
    public String getID();
    public Object get() throws NamingException;
    public NamingEnumerationEnumeration getAll()
            throws NamingException;
    ...
}
```

The `getAttributes()` operations on a directory return some or all of its attributes. Attributes are modified using two forms of `modifyAttributes()`. Both forms make use a “modification operation”, one of:

```
ADD_ATTRIBUTE
REPLACE_ATTRIBUTE
REMOVE_ATTRIBUTE
```

The `ADD_ATTRIBUTE` operation adds values to an attribute if that attribute already exists, while the `REPLACE_ATTRIBUTE` operation discards any pre-existing values. The first form of `modifyAttributes()` performs the specified operation on each element of a set of attributes. The second form of takes an array of objects of class `ModificationItem`:

```
public class ModificationItem {
    public ModificationItem(int modOp, Attribute attr) ...;
    ...
}
```

Each operation is performed on its corresponding attribute in the order specified. When possible, a context implementation should perform each call to `modifyAttributes()` as an atomic operation.

5.2.2 Directory Objects as Naming Contexts

The `DirContext` interface also behaves as a naming context by extending the `Context` interface. This means that any directory object can also provide a naming context. In addition to a directory object keeping a variety of information about a person, for example, it is also a natural naming context for resources associated with that person: a person's printers, file system, calendar, *etc.* An application that is performing directory operations can use `InitialDirContext` instead of `javax.naming.InitialContext` to create its initial context:

```
public class InitialDirContext
                extends InitialContext implements DirContext {
    public InitialDirContext() throws NamingException;
    ...
}
```

Hybrid operations perform certain naming and directory operations in a single atomic operation:

```
public interface DirContext extends Context {
    ...
    public void bind(Name name, Object obj, Attributes attrs)
            throws NamingException;
    ...
}
```

Other hybrid operations that are provided are `rebind()` and `createSubcontext()` that accept an additional `Attributes` argument.

5.2.3 Searches

The `DirContext` interface supports content-based searching of directories. In the simplest and most common form of usage, the application specifies a set of attributes — possibly with specific values — to match. It then invokes the `DirContext.search()` method on the directory object, which returns the matching directory objects along with the requested attributes.

```
public interface DirContext extends Context {
    ...
    public NamingEnumeration search(Name name,
                                    Attributes matchingAttributes)
            throws NamingException;

    public NamingEnumeration search(Name name,
                                 Attributes matchingAttributes,
                                 String[] attributesToReturn)
            throws NamingException;
    ...
}
```

The results of the search are returned as a `NamingEnumeration` containing an enumeration of objects of class `SearchResult`:

```
public class SearchResult extends Binding {
    ...
    public Attributes getAttributes() ...;
}
```

In the more sophisticated case, it is possible to specify a search filter and to provide controlling information such as the scope of the search and the maximum size of the results. The search filter specifies a syntax that follows Internet RFC 2254 for LDAP. The `SearchControls` argument specify such things as the scope of the search: this can include a single directory object, all of its children, or all of its descendants in the directory hierarchy.

```
public interface DirContext extends Context {
    ...
    public NamingEnumeration search(Name name,
                                    String filter,
                                    SearchControls ctls)
            throws NamingException;

    public NamingEnumeration search(Name name,
                                    String filter,
                                    Object[] filterArgs,
                                    SearchControls ctls)
            throws NamingException;
    ...
}
```

5.2.4 Schema

A schema describes the rules that define the structure of a namespace and the attributes stored within it. The granularity in the use of the schema can range from a single schema that is associated with the entire namespace, to a per-attribute, fine-grained schema description.

Because schemas can be expressed as an information tree, it is natural to use for this purpose the naming and directory interfaces already defined in JNDI. This is powerful because the schema part of a namespace is accessible to applications in a uniform way. A browser, for example, can access information in the schema tree just as though it were accessing any other directory objects.

Applications can retrieve the schema associated with a directory object when the underlying context implementation provides the appropriate support.

`DirContext.getSchema()` is used to retrieve the root of the schema tree associated with a directory object. The root has children such as "ClassDefinition", "AttributeDefinition", "SyntaxDefinition", and "MatchingRules", each denoting the kind of definition being described. The schema root and its descendents are objects of type `DirContext`. The `DirContext.getSchemaClassDefinition()` method returns a node under "ClassDefinition" that contains information about a particular directory object.

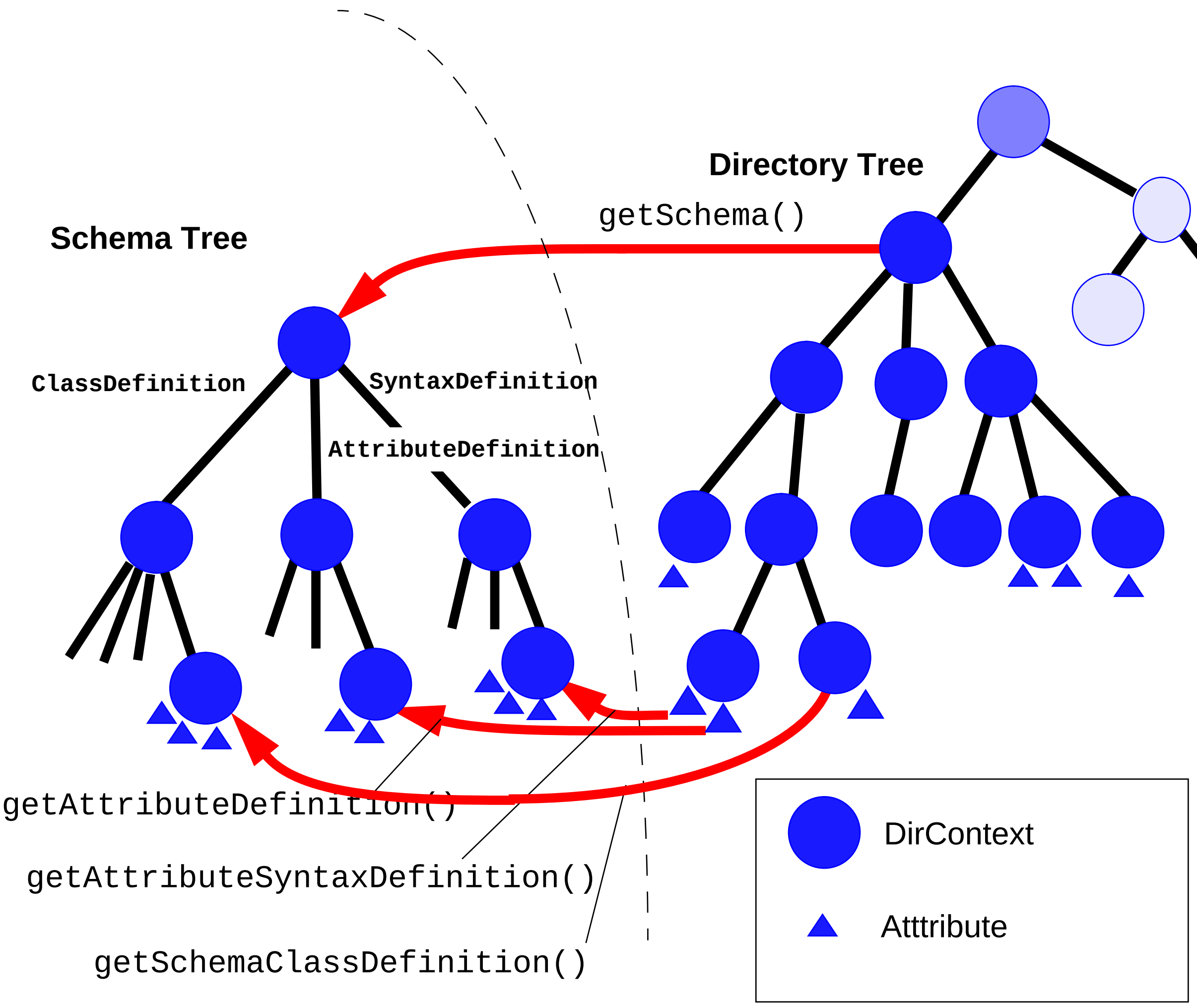
```
public interface DirContext extends Context {
    ...
    public DirContext getSchema(Name name)
        throws NamingException;

    public DirContext getSchemaClassDefinition(Name name)
        throws NamingException;
    ...
}
```

In addition, the schema associated with any attribute can be accessed using the `Attribute.getAttributeDefinition()` and `getAttributeSyntaxDefinition()`methods.

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

Figure 3 is an example showing the different associations for accessing schema information.

Figure 3: Example mapping Directory to Schema



5.3 Context Environment

JNDI applications need a way to communicate various preferences and information that define the environment in which naming and directory services are accessed. For example, an application that wants to specify the level of security for accessing a directory service can do so by setting the `java.naming.security.*` environment properties.

As another example, when directory and naming services are distributed, the source of information is in more than one place—replicas, master, caches, *etc*. An application may need to access information from the authoritative source. It can do so by using the `java.naming.authoritative` environment property.

Environment properties are defined in relatively generic terms. For example, an application can state a preference for the strength of authentication by setting the environment property `java.naming.security.authentication` to `none`, `simple`, or `strong`. Individual directory service providers implement the mapping of the environment properties appropriate to their service.

A context's environment is represented as a `Hashtable` or any of its subclasses (e.g. `Properties`[1]). It is typically specified using an argument to the `InitialContext` and `InitialDirContext` constructors. They are inherited from the parent context as context methods proceed from one context to the next. For example, the following code creates an environment consisting of two security-related properties and creates an initial context using that environment.

```
Hashtable env = new Hashtable(5, 0.75);
env.put(Context.SECURITY_PRINCIPAL, "jsmith");
env.put(Context.SECURITY_CREDENTIALS, "xxxxxxx");
Context ctx = new InitialContext(env);
```

You can also do the same thing using `Properties`.

```
Properties env = new Properties();
env.put(Context.SECURITY_PRINCIPAL, "jsmith");
env.put(Context.SECURITY_CREDENTIALS, "xxxxxxx");
Context ctx = new InitialContext(env);
```

There are three environment-related methods in the `Context` interface.

```
Object addToEnvironment(String propName, Object propValue)
    throws NamingException;
Object removeFromEnvironment(String propName)
    throws NamingException;
Hashtable getEnvironment() throws NamingException;
```

The first two methods update the environment of this context by adding or deleting individual entries. The last method returns the context's environment.

Appendix A specifies a preliminary list of environment properties. The `Context` interface defines constants for these environment property names.

See Section 7.5 for security-related considerations when using environment properties.

5.4 Referrals

Some directory services support the notion of *referrals* for redirecting a client's request to another server. If the `java.naming.referral` environment property is set to "`follow`", the service provider implementation will automatically attempt to follow each referral that it encounters. It the value is "`ignore`", referrals are ignored. If the value is "`throw`", the option of whether or not to follow a referral—and thereby complete the context operation—is left up to the application through the use of a *referral exception.*

The abstract class `ReferralException` is used to represent a referral:

[1] Note that if you use `Properties`, only the top-level properties are consulted—its defaults are not consulted—because `Hashtable.get()` is used when retrieving entries from the environment. See `java.util.Properties` for details.

```
public abstract class ReferralException extends NamingException {
    public abstract Context getReferralContext()
        throws NamingException;

    public abstract Object getReferralInfo();
    public abstract boolean skipReferral();
}
```

When a referral is encountered and the client has requested that referrals not be ignored or automatically followed, a `ReferralException` is thrown. The `getReferralInfo()` method provides information—in a format appropriate to the service provider—about where the referral leads. The application is not required to examine this information; however, it might choose to present it to a human user to help him determine whether to follow the referral or not. `skipReferral()` allows the application to discard a referral and continue to the next referral (if any).

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:

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

6 Scenarios

This section outlines a few application scenarios to help illustrate the capabilities enabled by JNDI.

- *The examples below are not meant to be prescriptive. There are often several ways to solve a problem, and JNDI is designed with flexibility in mind.*

6.1 User authentication

In secure systems, a user must authenticate himself to the computer, network, or service that he wishes to access. For example, logging into Unix requires the user to supply a password. Similarly, use of SSL requires that the user supply his X.509 certificate. Such authentication information can be stored as attributes associated with each user in the directory. The system performing the authentication would look up the attribute (for example, “password”) of the user and verify the authenticity using the information supplied by the user.

```
DirContext ctx = new InitialDirContext();
Attribute attr = ctx.getAttributes(userName).get("password");
String password = (String)attr.get();
```

6.2 Electronic Mail

A useful feature of an electronic mail system is a directory service that provides a mapping between users and email addresses. This allows mail users to search for the email address of a particular user. This is analogous to searching for an individual’s telephone number in the phone book in order to dial his phone number. For example, when I want to send mail to John Smith in my department, I search for “John Smith” in the directory using a “search” widget in the mail application. The widget returns to me five entries of John Smith, from which I select the one that is in a building on my site and use the email address attribute associated with that entry.

```
NamingEnumeration matches =
    deptCtx.search("user", new BasicAttributes("name", "John Smith"));
// use matches to construct a selectable list for end-user
while (matches.hasMore()) {
    SearchResult item = (SearchResult) matches.next();
    Attributes info = item.getAttributes();
    /* display attributes */
    ...
}
```

The directory could also be used by users to set up personalized address books. For example, once I have located John Smith’s email address, I may not want to search the directory again each time I send him mail. Instead, I can create a personal subtree in the directory in which I maintain entries that I frequently use, possibly by creating links to the existing entries.

6.3 Databases

Database applications can use the directory to locate database servers. For example, a financial application needs to get the stock quotes from a stock quote server using JDBC. This application can enable the user to select the stock quote server based on specification of some attributes (such as coverage of which markets and frequency of quote updates). The application searches the directory for quote servers that meet these attributes, and then retrieves the "location" attribute (a JDBC URL) of the selected quote server and connects to it.

```
NamingEnumeration matches =
    ctx.search("service/stockQuotes",
        "(&(market=NASDAQ)(updateFreqency<=300))",
        searchctls);
while (matches.hasMore()) {
    SearchResult item = (SearchResult)matches.next();
    Attribute location = item.getAttributes().get("location");
    ...
}
```

6.4 Browsing

When using almost any kind of interactive application that asks a user to input names, the user's job is made easier if a namespace browser is available to him. The browser can either be built into the application and tailored to suit that application in particular, or it can be more general-purpose such as a typical web browser.

A very simple example of a JNDI browser allows a user to "walk" through a namespace, viewing the atomic names at each step along the way. The browser prints a "*" to highlight the name of each `Context`, thus telling the user where he can go next.[1]

[1] The `isContext()` method used in the example is not part of JNDI. It is a method that must be provided by the application.

```
// Start at the top -- the initial context.
Context ctx = new InitialContext();
while (ctx != null) { // display one level
    NamingEnumeration items = ctx.list();
    while (items.hasMoreElements()) {
        NameClassPair item = (NameClassPair)items.next();
        if (isContext(item.getClassName())) {
            System.out.print("*");
        }
        else {
            System.out.print(" ");
        }
        System.out.println(" " + item.getName());
    }
    // Take the next step down into the namespace.
    String target = input.readLine();
    try {
        ctx = (Context)ctx.lookup(target);
    } catch (NamingException e) {
        ...
    } catch (ClassCastException e) {
        // not a context; cannot traverse
        ...
    }
}
```

6.5 Network Printing

An important function of a printing service is to provide a means for its human users to easily discover and select printers in the network. An application that needs to print, or the machine on which it runs, should not have to be configured each time a new printer is added to the network. The scope of network access to printers may range from a workgroup to global. The printing service can use the directory to provide this capability.

Assume that printers are represented by a `Printer` interface. One of the methods in it could be `print()` which, when given an `InputStream`, will read data from `InputStream` and print it on the printer represented by this instance of `Printer`.

```
interface Printer {
    void print(InputStream data) throws PrinterException;
    ...
}
```

A user selects a printer using a logical printer name, either explicitly or through default settings. For example, the user may have specified a default printer to use for all his applications, which is overridden only when he explicitly specifies another printer to use. The application that is accepting the print request takes the printer name and looks it up in the directory service. The application expects to receive as the result an object that implements the `Printer` interface.

```
void myAppPrint(String printerName, String fileName)
    throws IOException {
    try {
        DirContext ctx = new InitialDirContext();
        Printer prt = (Printer) ctx.lookup(printerName);
        prt.print(new FileInputStream(fileName));
    } catch (NamingException e){
        System.err.println("Could not locate printer: " + e);
    } catch (ClassCastException e) {
        System.err.println(printerName + "does not name a printer");
    }
}
```

6.5.1 Browsing and searching for printers

Selecting a printer by explicitly giving its name is but one way of identifying a printer. The user can also use the directory to see the different printers available (browsing), or to search for printers with particular attributes. For example the user can ask the directory to list all the printers on the second floor of building 5 in the Mountain View campus, or search for all color laser printers with 600dpi resolution. From the application's perspective, just as `lookup()` returned a `Printer` object, the list and search operations also provide the same capability of returning `Printer` objects that the application could use to submit print requests.

7 Security Considerations

There are two main settings in which JNDI is used: in Java applications and applets.

In the case of Java applications, the code is trusted and the application can access service providers from the local classpath. Furthermore, there is no restriction if the service providers access local files, or make network connections to naming or directory servers anywhere on the network.

In the case of applets, there can be trusted applets and untrusted applets. Within an applet, there can be portions that are trusted and portions that are not trusted. The *Sharing Context Handles* and *Context Environment* sections below are especially applicable to applets containing both trusted and untrusted code.

An applet's access to service providers, especially service providers that require the use of restricted resources (like the file system or network connections) may be severely limited.

7.1 JNDI Classes

The classes in the `javax.naming`, `javax.naming.directory` and `javax.naming.spi` packages contain no native methods. They do not require any special installation in order to run inside an applet or an application.

JNDI uses several system properties (see Appendix A). This allows applets and applications to be configured easily without much programming. However, an applet may have restricted access to some or all system properties as a result of the security manager installed on the platform on which the applet is running. Consequently, JNDI also allows these same properties to be specified as environment properties of a context.

In JDK1.2, the JNDI classes will only use `begin privileged/end privileged` sections when accessing the system properties listed in the *Program Configuration* and *Access Configuration* sections in Appendix A.

7.2 Security Model

JNDI does not define a security model or a common security interface for accessing naming and directory servers. Security-related operations, such as those required for authentication or access control to the directory service, are dealt with by individual service providers. JNDI provides the means by which an application or applet can pass such security-related information to service providers in order to establish a connection with the service, but does not itself take part in such security-related activities.

JNDI also provides the means by which security-related problems can be indicated to the client in the form of security-related exceptions.

JNDI service providers are controlled by the security manager in place when they try to gain access to protected resources such as the file system or network. Some service providers may control directory access by making use of the new JDK1.2 security architecture (for example, allowing access to special ports for administration-related applets).

7.3 Access To Servers

Naming and directory services typically have their own security system in place to protect information stored therein. For example, one directory might require that its users first “login” to the directory before reading or updating information in the directory. Some services might allow anonymous access to part of its namespace/directory.

Once a user has logged to a service, it is imperative for security reasons not to share that privilege with untrusted code.

7.4 Sharing Context Handles

In the following discussion, we refer to a *context handle* as a reference to a `Context` instance. This is analogous to how a reference to a `Reader`/`Writer`/`InputStream`/`OutputStream` instance is often referred to as a *file handle*.

A context handle should be treated like any other protected resource. If a piece of trusted code obtains a context handle (possibly by authenticating its access with the directory server), it should protect the use of that context against unauthorized or untrusted code. This is analogous to how application and/or applet code should protect file handles. For example, if a piece of trusted code opens a file for writing (and it was granted such privilege because of its trusted nature), it should be careful about passing that file handle to any other pieces of code, trusted or otherwise.

Similarly, giving access of a context handle to untrusted code may lead to its misuse in accessing or updating information in the directory, or accessing security-sensitive environment properties associated with the context.

7.5 Context Environment

JNDI allows the application/applet to pass preferences and information to a context in the form of an environment. The application/applet can also get the current environment from a context. See Section 5.3 and Appendix A for more information on a context’s environment.

The nature of the information contained in a context’s environment might be sensitive and need protection from untrusted access. Specifically, the environment properties `java.naming.security.principal` and `java.naming.security.credentials` contain information that should not be given out to untrusted code. Service providers might take precaution to protect against accessing these properties (see *Responsibilities of Service Providers* below). Client applications and applets should take care not to pass context handles with such sensitive environment properties to untrusted code.

7.6 Class Loading

JNDI allows the class files of object factories to be loaded dynamically. The current implementation uses the RMI class loader. The classes can only be loaded if there is a security manager installed, and if that security manager permits the class to be loaded. When such classes are loaded, they run in the security context dictated by the security manager.

7.7 Serializable Objects

Several of the JNDI classes are serializable. This allows the objects to be accessed in the form of a byte stream, possibly outside of the environment in which they were created. See the document at the following URL regarding security issues related to serialized objects.

http://java.sun.com/products/jdk/1.1/docs/guide/serialization/spec/security.doc.html

7.8 Responsibilities of Service Providers

7.8.1 Context Environment

When a context handle is created (either by getting the initial context or by looking it up or by creating it from the directory), some environment properties may be specified for it. Sometimes security-related properties are required for the creation of the context handle (such as user information that “logs” the user in with the directory). The service provider should take care to protect this security-sensitive information from untrusted code.

The service provider needs to protect the context’s environment from being tampered or otherwise modified by untrusted code. The service provider needs to protect the security-sensitive environment properties from being read by untrusted code. It might do this by disallowing any thread whose execution context and/or trust level is different than that originally held by the thread that created the context handle to use the context handle. Or it might disallow certain operations (such as accessing security-sensitive environment properties). Or it might simply not return security-sensitive environment properties, or only return them to trusted code.

7.8.2 Network Security

Untrusted code (such as those found in untrusted applets) have limited access to the network. Untrusted applets, for example, can only create a network connection to the host from which they were downloaded. With finer-grain security models, it will be possible for the service provider itself be trusted code, and hence be allowed to connect to hosts not allowed for untrusted applets. In such a scenario, the service provider should be careful not to compromise the security intended by the security manager. If the service provider is sure that access by an untrusted applet to the directory will cause no security problems, then it may proceed to offer such a service to untrusted code. For example, allowing untrusted code to access a directory “anonymously” would post no security problems because the directory already allows any anonymous client (written in the Java programming language or otherwise) to access the same data.

Most naming and directory services are accessed over the network. Although the data requested is protected by the server’s authentication and access control mechanisms, some protocols do not protect (encrypt) the data being sent as replies. Again, this is not a problem particular to a client using JNDI but a problem for any client accessing the directory. The service provider should document the security implications associated with using the associated directory over a network.

7.8.3 Accessing Local Files

Similar to network access, untrusted code has limited access to the local file system. If the service provider has special privileges for accessing local files, it should do so with utmost precaution so as not to compromise the security policies intended by the runtime/platform.

7.8.4 Privileged Code, Native Methods

A service provider that is written completely in the Java programming language with no privileged sections is controlled by the same security policies afforded other code written in the Java programming language. All protected resources that it attempts to access go through the same security manager and access controller.

If a service provider contains privileged code sections, or if it contains native methods, then it needs to be especially careful to preserve the security policies intended by the runtime/platform.

8 Design Choices

8.1 Separation of Interfaces into Context and DirContext

There are two core interfaces in JNDI: `Context`, and `DirContext`, with `DirContext` extending the base naming operations in `Context` with directory service operations. They have been separated into separate interfaces both for modularity and also in keeping with the “pay for what you use” goal of JNDI.

Naming is a basic component found in many computing services such as file systems, spreadsheets, calendar services, and directory services. By having a base `Context` interface for the naming operations, we enable its use by all these other services, not just for directory services.

`DirContext` extends `Context` to provide basic directory service operations, which include manipulation of attributes associated with named objects, attribute-based searches, and schema-related operations of those attributes and named objects.

8.2 Separation of JNDI into Different Functional Packages

JNDI is separated into two client packages (`javax.naming`, `javax.naming.directory`) and a service provider package (`javax.naming.spi`). The idea is that each package contains the interfaces and classes required for a particular category of applications, again in keeping with the “pay for what you use” goal. For example, an application that just wants to perform name-lookups only needs to use the `javax.naming` package. An application that wants to examine/modify attributes associated with an object uses the `javax.naming` and `javax.naming.directory` packages. There is a step-by-step progression of what classes and interfaces each category of application writer needs to learn and use.

8.3 Separation of Client APIs and Service Provider Interfaces

JNDI separates interfaces and classes that a client application needs to use from those that are only of interest to service providers into different packages. For example, a client would use interfaces and classes from `javax.naming`, while a service provider that is hooking up a naming service would use both `javax.naming` and `javax.naming.spi`. The package delineation minimizes confusion for the application developer and makes clear which packages he needs to examine when writing his program.

8.4 Multiple methods for listing Context

There are two common types of applications that list contexts: browser-style applications, and applications that need to perform operations on the objects in a context en-masse. Browser-style applications typically want to display the names of the contents of a context. In addition to the names, many browsers often require type information of the objects bound to the names, so that it can display appropriate pictorial representations of the objects. The browser is usually interactive. Once a user has used a browser to display the contents of a context, he would then select one or a few of the entries displayed and request more information on it.

Some applications need to perform operations on objects within a context en-masse. For example, a backup program might want to perform “file stats” operations on all the objects in a file directory. A printer administration program might want to restart all the printers in a building. To perform such operations, these programs need to obtain all the objects bound in a context.

With these two common styles of usage in mind, the `Context` interface has two types of list methods: `list()` and `listBindings()`. `list()` returns a list of name/class-name pairs while `listBindings()` returns a list of name/class-name/object tuples. `list()` is designed for browser-style applications that want mostly just the names and types of objects bound in a context. `listBindings()` is for applications that want to potentially get all the objects in the context, as well as its name and type. `listBindings()` returns an enumeration of `Binding`. Both the `listBindings()` operation itself and invocation of methods in the `Binding` class (e.g. `getObject()`) could be implemented lazily or eagerly. Using `listBindings()` simply indicates the potential that the caller might be wanting all or many of the objects in the context so that implementations that are able can optimize for it. Using `list()` indicates that the caller is unlikely to want all, if any, objects in the context so implementations can optimize for that if possible.

An alternative is to have a single list operation and have the lazy or eager behavior as part of the implementation of `Binding`. The advantage of this is that there is a single list operation to learn. The disadvantage is that the caller has no way of indicating which piece of information he wants back from list, and subsequently, implementations cannot optimize for the eventual behavior of the program.

8.5 Support for Federation

Federation is a first-class concept in JNDI. In the client interfaces, it is supported by of the use of the `Name` interface for specifying names that can span one or more namespaces. The caller of the methods in the client interface need not know anything else regarding federation. Resolution of names across multiple systems is handled by the SPI and does not involve any intervention on the part of the caller.

Although federation is a first-class concept, that does not mean that all callers and service providers must make use of it. If an application or service does not want to take advantage of federation, there is no requirement that `Name` always span multiple namespaces. `Name` can just name objects within a single namespace, and the SPI can handle name resolution within a single namespace as well (as a degenerate case of multiple namespace support).

8.6 DirContext versus DirObject

Instead of having `DirContext` extend `Context`, an alternative would be to not extend `Context` at all but to have a separate interface called `DirObject` that encapsulates all the directory-related methods. In that case, an object can implement both `Context` and `DirObject` if it supports both the naming and directory operations; another object might implement just `DirObject`.

The problem with eliminating `DirContext` is that `DirContext` contains some hybrid operations that involve both naming and directories (`bind()`, `createSubcontext()` methods that accept attributes as arguments). To keep these operations *and* have `DirObject` at the same time would produce the need for a third interface (perhaps called `DirContext`) to contain just these hybrids.

Furthermore, having `DirContext` instead of `DirObject` is somewhat more convenient in that you can perform some operations in one step instead of two. For example `DirContext.getAttributes()` could be used to get the attributes associated with a named object, whereas with `DirObject`, you would need first to resolve to the object (`Context.lookup()`) and then use `DirObject.getAttributes()` to get the attributes from it.

8.7 Support for Schemas

The `DirContext` interface contains support for schemas. For example, from a `DirContext` object you can obtain its schema object, which points to the directory space where the schema for this particular `DirContext` instance is defined. From a `DirContext` object, you can also obtain its schema class definition (i.e. information about what type of object this represents in the directory). There is further support for schemas in the `Attribute` class, which contains methods for obtaining an attribute's syntax information (i.e. what is the type of the attribute's value) and the attribute's definition (e.g. is it multivalue, syntax, constraints on its syntax). There is no requirement that any of this schema information be dynamically accessible (i.e. points to live directory spaces). Support for such schema information could be generated statically by the service provider. For example, a particular directory service might only support string attribute values, so it can hard-wire the syntax of the attributes that it returns. Another directory might support only static schemas (where information in the schema are not modifiable). Yet another directory might support fully dynamic schemas. The interfaces and classes in `DirContext` are flexible enough that these different levels of support for schemas can be accommodated.

8.8 Overloaded Methods in Context and DirContext

For each method in the `Context` and `DirContext` interfaces that accepts a `Name` argument, there is a corresponding overloaded form that accepts a `String` argument for specifying a name.

The motivation for having the `String`-based methods is that there are many applications that simply accepts a string name from the end-user and perform context methods on the object named by that string name. For those applications, it is useful to have the context methods accepts a string for the name directly, instead of requiring the applications to first construct a `Name` object using the string name.

The motivation for having the `Name`-based methods is that there are also many applications that manipulate names and do not want to worry about syntactic details of the names' string forms when composing and modifying names. These applications deal with the parsed form of names and hence would prefer to deal with `Name` objects rather than string names. For these applications, we provide the `Name`-based methods in the context interfaces. Not providing these methods would probably cause proliferation of `Name`-like interfaces/classes to support manipulation of names in their structural form in applications developed on top of JNDI.

8.9 Reference and Referenceable

There are different ways in which applications and services can use the directory to locate objects. JNDI is general enough that it accommodates several different models. For some applications, the object bound in the directory is the object itself. An application may build up a dynamic directory while the application is active, and delete the directory when the application exits. Another application might store URLs as attributes for locating objects in its namespace. Other systems might bind some reference information in the directory, which can subsequently be used to locate or access the actual object. This last case is quite common, especially for making Java applications take advantage of services in the installed base. The reference in the directory acts as a "pointer" to the real object.

JNDI defines a `Reference` class to provide a uniform way of representing reference information. A `Reference` contains information on how to access an object. It consists of a list of addresses and class information about the object to which this reference refers. When binding a name to an object that is to be represented in the directory as a reference, the desired effect is that the object's reference be extracted and bound. To allow for this behavior, the object's class must implement the `Referenceable` interface, which contains the method `getReference()`.

There is some similarity between the interfaces `Serializable` and `Referenceable` and a natural question is "why not just use `Serializable` instead?" The answer is that a serialized object is really a frozen version of the object, whereas the reference contains just the information needed to construct it. The serialized version may have a lot more state which may not be appropriate for storage in the directory.

8.10 Automatically Turning References into Objects

For an object that is bound as a `Reference` in the directory, JNDI SPI framework automatically creates and instantiates the object identified by the reference. In this way, the program can simply narrow the result of `lookup()` to the expected class, instead of calling a separate operation to transform the result of `lookup()` into an object of the expected class.

For example, if you are looking up a printer object, a successful lookup would return to you a printer object that you can directly use.

```
Printer prt = (Printer) ctx.lookup(somePrinterName);
prt.print(someFileName);
```

JNDI does this automatically, instead of requiring an explicit conversion step, because this is expected to be the common usage pattern. By having the `Reference` class, and a common mechanism for converting a `Reference` into the object identified by the `Reference`, JNDI encourages different applications and system providers to utilize this mechanism, rather than inventing separate mechanisms on their own.

Appendix A: JNDI Context Environment

Table 1: JNDI Environment Properties[a]

Program Configuration	

`java.naming.factory.initial`
`(Context.INITIAL_CONTEXT_FACTORY)`
	Class name of initial context factory to use.
	When unspecified, determined by the `java.naming.factory.initial` system property.
	See `InitialContext`.

`java.naming.factory.object`
`(Context.OBJECT_FACTORIES)`
	Colon-separated list of class names of object factory classes to use.
	When unspecified, determined by the `java.naming.factory.object` system property.
	See `NamingManager.getObjectInstance()`.

`java.naming.factory.url.pkgs`
`(Context.URL_PKG_PREFIXES)`
	Colon-separated list of package prefixes to use when loading in URL context factories.
	When unspecified, determined by the `java.naming.factory.url.pkgs` system property.
	See `NamingManager.getURLContext()`.

Access Configuration	

`java.naming.provider.url`
`(Context.PROVIDER_URL)`
	Specifies configuration information for provider to use.
	When unspecified, determined by the `java.naming.provider.url` system property.
	When unspecified as system property or in environment, determined by provider using its own configuration or discovery protocols.

`java.naming.dns.url`
`(Context.DNS_URL)`
	Specifies the DNS host and domain names to use for the JNDI URL context.
	When unspecified, determined by the `java.naming.dns.url` system property.

Service-Related	

`java.naming.authoritative`
`(Context.AUTHORITATIVE)`
	Specifies the authoritativeness of the service requested. If "true", specifies most authoritative source is to be used (e.g. bypass any caches, or bypass replicas in some systems). Otherwise, source need not be (but can be) authoritative.
	When unspecified, defaults to false.

`java.naming.batchsize`
`(Context.BATCHSIZE)`
	Specifies the preferred batch size to use when returning data via the service's protocol. This is a hint to the provider to return the results of operations in batches of the specified size, so that the provider can optimize its performance and usage of resources.
	When unspecified, determined by provider.

`java.naming.referral`
`(Context.REFERRAL)`
	Specifies that referrals encountered by the service provider are to be followed automatically. If "follow", follow referrals automatically. If "ignore", ignore referrals encountered. If "throw", throw `ReferralException` when a referral is encountered.
	When unspecified, determined by provider.

Security	

`java.naming.security.protocol`
`(Context.SECURITY_PROTOCOL)`
	Security protocol to use for service.
	When unspecified, determined by provider.

Table 1: JNDI Environment Properties[a]

`java.naming.security.authentication`
`(Context.SECURITY_AUTHENTICATION)`
	Takes values “none″, “simple″, “strong″, or a provider-specific string (e.g. “CRAM-MD5″).
	When unspecified, determined by provider.

`java.naming.security.principal`
`(Context.SECURITY_PRINCIPAL)`
	Identity of principal (e.g. user) for the authentication scheme.
	When unspecified, defaults to the identity (specific to the authentication scheme selected) of user running the application.

`java.naming.security.credentials`
`(Context.SECURITY_CREDENTIALS)`
	Principal’s credentials for the authentication scheme.
	When unspecified, obtained by the provider on behalf of the user, using the security infrastructure available to the provider.
	Examples of different types of credentials are passwords, keys, and certificates. The particular type of credentials is determined by the authentication scheme chosen.

Internationalization	

`java.naming.language`
`(Context.LANGUAGE)`
	Specifies a colon-separated list of preferred language to use with this service (e.g. “en-US”, “fr”, “fr-CH”, “ja-JP-kanji”).
	Languages are specified using tags defined in RFC 1766.
	When unspecified, the language preference—if any—is determined by the provider.

[a] The `Context` interface defines constants for these property names. The names of the constants are shown in parentheses below the property’s string names.

Appendix B: Examples for LDAP Programmers

This appendix contains sample JNDI programs intended to help a developer familiar with the LDAP C API. Starting with sample programs from the Netscape Directory SDK for accessing and updating the directory using the LDAP C API, we show the equivalent way of doing the same thing for Java applications using JNDI.

B.1 Search the Directory

B.1.1 Search Using LDAP C API

```
/*
 * Copyright (c) 1996.  Netscape Communications Corporation.  All
 * rights reserved.
 *
 * Search the directory for all people whose surname (last name) is
 * “Jensen”.  Since the “sn” attribute is a caseignorestring (cis), case
 * is not significant when searching.
 *
 */

#include “examples.h”

int
main( int argc, char **argv )
{
        LDAP                *ld;
        LDAPMessage         *result, *e;
        BerElement          *ber;
        char                *a, *dn;
        char                **vals;
        int                 i;

        /* get a handle to an LDAP connection */
        if ( (ld = ldap_init( MY_HOST, MY_PORT )) == NULL ) {
                perror( “ldap_init” );
                return( 1 );
        }
        /* authenticate to the directory as nobody */
        if ( ldap_simple_bind_s( ld, NULL, NULL ) != LDAP_SUCCESS ) {
                ldap_perror( ld, “ldap_simple_bind_s” );
                return( 1 );
        }
        /* search for all entries with surname of Jensen */
        if ( ldap_search_s( ld, MY_SEARCHBASE, LDAP_SCOPE_SUBTREE,
                MY_FILTER, NULL, 0, &result ) != LDAP_SUCCESS ) {
                ldap_perror( ld, “ldap_search_s” );
                return( 1 );
        }
        /* for each entry print out name + all attrs and values */
        for ( e = ldap_first_entry( ld, result ); e != NULL;
            e = ldap_next_entry( ld, e ) ) {
                if ( (dn = ldap_get_dn( ld, e )) != NULL ) {
                    printf( “dn: %s\n”, dn );
                    ldap_memfree( dn );
                }
                for ( a = ldap_first_attribute( ld, e, &ber );
                    a != NULL; a = ldap_next_attribute( ld, e, ber ) ) {
                        if ((vals = ldap_get_values( ld, e, a)) != NULL ) {
                                for ( i = 0; vals[i] != NULL; i++ ) {
                                    printf( “%s: %s\n”, a, vals[i] );
                                }
                                ldap_value_free( vals );
                        }
                        ldap_memfree( a );
                }
                if ( ber != NULL ) {
                        ber_free( ber, 0 );
                }
                printf( “\n” );
        }
        ldap_msgfree( result );
        ldap_unbind( ld );
        return( 0 );
}
```

B.1.2 Search Using JNDI

```
/*
 * Copyright (c) 1997.  Sun Microsystems. All rights reserved.
 *
 * Search the directory for all people whose surname (last name) is
 * "Jensen".  Since the "sn" attribute is a caseignorestring (cis), case
 * is not significant when searching.
 *
 * [equivalent to search.c in Netscape's SDK.]
 *
 */

import java.util.Hashtable;
import java.util.Enumeration;

import javax.naming.*;
import javax.naming.directory.*;

class Search {

public static void main(String[] args) {

    Hashtable env = new Hashtable(5, 0.75f);
    /*
     * Specify the initial context implementation to use.
     * This could also be set by using the -D option to the java program.
     * For example,
     *   java -Djava.naming.factory.initial=com.sun.jndi.ldap.LdapCtxFactory \
     *     Search
     */
    env.put(Context.INITIAL_CONTEXT_FACTORY, Env.INITCTX);

    /* Specify host and port to use for directory service */
    env.put(Context.PROVIDER_URL, Env.MY_SERVICE);

    try {
        /* get a handle to an Initial DirContext */
        DirContext ctx = new InitialDirContext(env);

        /* specify search constraints to search subtree */
        SearchControls constraints = new SearchControls();
        constraints.setSearchScope(SearchControls.SUBTREE_SCOPE);

        /* search for all entries with surname of Jensen */
        NamingEnumeration results
            = ctx.search(Env.MY_SEARCHBASE, Env.MY_FILTER, constraints);
        /* for each entry print out name + all attrs and values */
        while (results != null && results.hasMore()) {
            SearchResult si = (SearchResult)results.next();

            /* print its name */
            System.out.println("name: " + si.getName());

            Attributes attrs = si.getAttributes();
            if (attrs == null) {
                System.out.println("No attributes");
            } else {
                /* print each attribute */
                for (NamingEnumeration ae = attrs.getAll();
                     ae.hasMoreElements();) {
                    Attribute attr = (Attribute)ae.next();
                    String attrId = attr.getID();

                    /* print each value */
                    for (Enumeration vals = attr.getAll();
                         vals.hasMoreElements();
                       System.out.println(attrId + ": " + vals.nextElement()))
                            ;
                }
            }
            System.out.println();
        }
    } catch (NamingException e) {
        System.err.println("Search example failed.");
        e.printStackTrace();
    }
}
}
```

B.2 Read An Entry

B.2.1 Read Using LDAP C-API

```
/*
 * Copyright (c) 1996.  Netscape Communications Corporation.  All
 * rights reserved.
 *
 * Search the directory for the specific entry
 * “cn=Barbara Jensen, ou=Product Development, o=Ace Industry, c=US”.
 * Retrieve all attributes from the entry.
 *
 */

#include “examples.h”

int
main( int argc, char **argv )
{
    LDAP        *ld;
    LDAPMessage *result, *e;
    BerElement  *ber;
    char        *a, *dn;
    char        **vals;
    int         i;

    /* get a handle to an LDAP connection */
    if ( (ld = ldap_init( MY_HOST, MY_PORT )) == NULL ) {
        perror( “ldap_init” );
        return( 1 );
    }
    /* authenticate to the directory as nobody */
    if ( ldap_simple_bind_s( ld, NULL, NULL ) != LDAP_SUCCESS ) {
        ldap_perror( ld, “ldap_simple_bind_s” );
        return( 1 );
    }
    /* search for Babs’ entry */
    if ( ldap_search_s( ld, ENTRYDN, LDAP_SCOPE_SUBTREE,
            “(objectclass=*)”, NULL, 0, &result ) != LDAP_SUCCESS ) {
        ldap_perror( ld, “ldap_search_s” );
        return( 1 );
    }
    /* for each entry print out name + all attrs and values */
    for ( e = ldap_first_entry( ld, result ); e != NULL;
            e = ldap_next_entry( ld, e ) ) {
        if ( (dn = ldap_get_dn( ld, e )) != NULL ) {
            printf( “dn: %s\n”, dn );
            ldap_memfree( dn );
        }
        for ( a = ldap_first_attribute( ld, e, &ber );
                a != NULL; a = ldap_next_attribute( ld, e, ber ) ) {
            if ((vals = ldap_get_values( ld, e, a)) != NULL ) {
                for ( i = 0; vals[i] != NULL; i++ ) {
                    printf( “%s: %s\n”, a, vals[i] );
                }
                ldap_value_free( vals );
            }
            ldap_memfree( a );
        }
        if ( ber != NULL ) {
            ber_free( ber, 0 );
        }
        printf( “\n” );
    }
    ldap_msgfree( result );
    ldap_unbind( ld );
    return( 0 );
}
```

B.2.2 Read Using JNDI

```
/*
 * Copyright (c) 1997.  Sun Microsystems.  All rights reserved.
 *
 * Search the directory for the specific entry
 * "cn=Barbara Jensen, ou=Product Development, o=Ace Industry, c=US".
 * Retrieve all attributes from the entry.
 *
 * [Equivalent to rdentry.c in Netscape SDK]
 */

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


class Rdentry {
public static void main(String[] args) {

    Hashtable env = new Hashtable(5, 0.75f);
    /*
     * Specify the initial context implementation to use.
     * This could also be set by using the -D option to the java program.
     * For example,
     *   java -Djava.naming.factory.initial=com.sun.jndi.ldap.LdapCtxFactory \
     *       Rdentry
     */
    env.put(Context.INITIAL_CONTEXT_FACTORY, Env.INITCTX);

    /* Specify host and port to use for directory service */
    env.put(Context.PROVIDER_URL, Env.MY_SERVICE);

    try {
        /* get a handle to an Initial DirContext */
        DirContext ctx = new InitialDirContext(env);

        /* Read Babs' entry */
        Attributes attrs = ctx.getAttributes(Env.ENTRYDN);

        if (attrs == null) {
            System.out.println(Env.ENTRYDN + "has no attributes");
        } else {
            /* print each attribute */
            for (NamingEnumeration ae = attrs.getAll();
                 ae.hasMoreElements();) {
                Attribute attr = (Attribute)ae.next();
                String attrId = attr.getID();

                /* print each value */
                for (NamingEnumeration vals = attr.getAll();
                     vals.hasMoreElements();
                     System.out.println(attrId + ": " + vals.nextElement()))
                    ;
            }
        }
    } catch (NamingException e) {
        System.err.println("Rdentry example failed.");
        e.printStackTrace();
    }
}
}
```

B.3 Get Attributes

B.3.1 Get Attributes Using LDAP C API

```
/*
 * Copyright (c) 1996.  Netscape Communications Corporation.  All
 * rights reserved.
 *
 * Retrieve several attributes of a particular entry.
 */

#include “examples.h”


int
main( int argc, char **argv )
{
    LDAP                    *ld;
    LDAPMessage             *result, *e;
    char                    **vals, *attrs[ 5 ];
    int                     i;

    /* get a handle to an LDAP connection */
    if ( (ld = ldap_init( MY_HOST, MY_PORT )) == NULL ) {
        perror( “ldap_init” );
        return( 1 );
    }

    attrs[ 0 ] = “cn”;         /* Get canonical name(s) (full name) */
    attrs[ 1 ] = “sn”;         /* Get surname(s) (last name) */
    attrs[ 2 ] = “mail”;       /* Get email address(es) */
    attrs[ 3 ] = “telephonenumber”;      /* Get telephone number(s) */
    attrs[ 4 ] = NULL;

    if ( ldap_search_s( ld, ENTRYDN, LDAP_SCOPE_BASE,
            “(objectclass=*)”, attrs, 0, &result ) != LDAP_SUCCESS ) {
        ldap_perror( ld, “ldap_search_s” );
        return( 1 );
    }

    /* print it out */
    if (( e = ldap_first_entry( ld, result )) != NULL ) {
        if (( vals = ldap_get_values( ld, e, “cn” )) != NULL ) {
            printf( “Full name:\n” );
            for ( i = 0; vals[i] != NULL; i++ ) {
                printf( “\t%s\n”, vals[i] );
            }
            ldap_value_free( vals );
        }
        if (( vals = ldap_get_values( ld, e, “sn” )) != NULL ) {
            printf( “Last name (surname):\n” );
            for ( i = 0; vals[i] != NULL; i++ ) {
                printf( “\t%s\n”, vals[i] );
            }
            ldap_value_free( vals );
        }
        if (( vals = ldap_get_values( ld, e, “mail” )) != NULL ) {
            printf( “Email address:\n” );
            for ( i = 0; vals[i] != NULL; i++ ) {
                printf( “\t%s\n”, vals[i] );
            }
            ldap_value_free( vals );
        }
        if (( vals = ldap_get_values( ld, e, “telephonenumber” )) != NULL ) {
            printf( “Telephone number:\n” );
            for ( i = 0; vals[i] != NULL; i++ ) {
                printf( “\t%s\n”, vals[i] );
            }
            ldap_value_free( vals );
        }
    }
    ldap_msgfree( result );
    ldap_unbind( ld );
    return( 0 );
}
```

B.3.2 Get Attributes Using JNDI

```
/*
 * Copyright (c) 1997.  Sun Microsystems.  All rights reserved.
 *
 * Retrieve several attributes of a particular entry.
 *
 * [equivalent to getattrs.c in Netscape SDK]
 */

import java.util.Hashtable;
import java.util.Enumeration;

import javax.naming.*;
import javax.naming.directory.*;

class Getattrs {

public static void main(String[] args) {

    Hashtable env = new Hashtable(5, 0.75f);
    /*
     * Specify the initial context implementation to use.
     * For example,
     * This could also be set by using the -D option to the java program.
     *   java -Djava.naming.factory.initial=com.sun.jndi.ldap.LdapCtxFactory \
     *       Getattrs
     */
    env.put(Context.INITIAL_CONTEXT_FACTORY, Env.INITCTX);

    /* Specify host and port to use for directory service */
    env.put(Context.PROVIDER_URL, Env.MY_SERVICE);

    try {
        /* get a handle to an Initial DirContext */
        DirContext ctx = new InitialDirContext(env);

        String[] attrs = new String[4];
        attrs[ 0 ] = "cn";             /* Get canonical name(s) (full name) */
        attrs[ 1 ] = "sn";              /* Get surname(s) (last name) */
        attrs[ 2 ] = "mail";            /* Get email address(es) */
        attrs[ 3 ] = "telephonenumber"; /* Get telephone number(s) */

        Attributes result = ctx.getAttributes(Env.ENTRYDN, attrs);

        if (result == null) {
            System.out.println(Env.ENTRYDN +
                               "has none of the specified attributes.");
        } else {
            /* print it out */
            Attribute attr = result.get("cn");
            if (attr != null) {
                System.out.println("Full name:" );
                for (NamingEnumeration vals = attr.getAll();
                     vals.hasMoreElements();
                     System.out.println("\t" + vals.nextElement()))
                    ;
            }

            attr = result.get("sn");
            if (attr != null) {
                System.out.println("Last name (surname):" );
                for (NamingEnumeration vals = attr.getAll();
                     vals.hasMoreElements();
                     System.out.println("\t" + vals.nextElement()))
                    ;
            }

            attr = result.get("mail");
            if (attr != null) {
                System.out.println("Email address:" );
                for (NamingEnumeration vals = attr.getAll();
                     vals.hasMoreElements();
                     System.out.println("\t" + vals.nextElement()))
                    ;
            }
            attr = result.get("telephonenumber");
            if (attr != null) {
                System.out.println("Telephone number:" );
                for (NamingEnumeration vals = attr.getAll();
                     vals.hasMoreElements();
                     System.out.println("\t" + vals.nextElement()))
                    ;
            }
        }
    } catch (NamingException e) {
        System.err.println("Getattrs example failed.");
        e.printStackTrace();
    }
}
}
```

B.4 Compare An Attribute

B.4.1 Compare Using LDAP C API

```
/*
 * Copyright (c) 1996.  Netscape Communications Corporation.  All
 * rights reserved.
 *
 * Use ldap_compare() to compare values agains values contained in entry
 * “cn=Barbara Jensen, ou=Product Development, o=Ace Industry, c=US”.
 * We test to see if (1) the value “person” is one of the values in the
 * objectclass attribute (it is), and if (2) the value “xyzzy” is in the
 * objectlass attribute (it isn’t, or at least, it shouldn’t be).
 *
 */

#include “examples.h”

int
main( int main, char **argv )
{
    LDAP        *ld;
    int         rc;

    /* get a handle to an LDAP connection */
    if ( (ld = ldap_init( MY_HOST, MY_PORT )) == NULL ) {
        perror( “ldap_init” );
        return( 1 );
    }

    /* authenticate to the directory as nobody */
    if ( ldap_simple_bind_s( ld, NULL, NULL ) != LDAP_SUCCESS ) {
        ldap_perror( ld, “ldap_simple_bind_s” );
        return( 1 );
    }

    /* compare the value “person” against the objectclass attribute */
    rc = ldap_compare_s( ld, ENTRYDN, “objectclass”, “person” );
    switch ( rc ) {
    case LDAP_COMPARE_TRUE:
        printf( “The value \”person\” is contained in the objectclass “
                “attribute.\n” );
        break;
    case LDAP_COMPARE_FALSE:
        printf( “The value \”person\” is not contained in the objectclass “
                “attribute.\n” );
        break;
    default:
        ldap_perror( ld, “ldap_compare_s” );
    }

    /* compare the value “xyzzy” against the objectclass attribute */
    rc = ldap_compare_s( ld, ENTRYDN, “objectclass”, “xyzzy” );
    switch ( rc ) {
    case LDAP_COMPARE_TRUE:
        printf( “The value \”xyzzy\” is contained in the objectclass “
                “attribute.\n” );
        break;
    case LDAP_COMPARE_FALSE:
        printf( “The value \”xyzzy\” is not contained in the objectclass “
                “attribute.\n” );
        break;
    default:
        ldap_perror( ld, “ldap_compare_s” );
    }

    ldap_unbind( ld );
    return( 0 );
}
```

B.4.2 Compare Using JNDI

```
/*
 * Copyright (c) 1997.  Sun Microsystems.  All rights reserved.
 *
 * Use search() to compare values against values contained in entry
 * "cn=Barbara Jensen, ou=Product Development, o=Ace Industry, c=US".
 * We test to see if (1) the value "person" is one of the values in the
 * objectclass attribute (it is), and if (2) the value "xyzzy" is in the
 * objectlass attribute (it isn't, or at least, it shouldn't be).
 *
 * [equivalent to compare.c in Netscape SDK]
 *
 */

import java.util.Hashtable;

import javax.naming.*;
import javax.naming.directory.*;

class Compare {

public static void main(String[] args) {

    Hashtable env = new Hashtable(5, 0.75f);
    /*
     * Specify the initial context implementation to use.
     * This could also be set by using the -D option to the java program.
     * For example,
    *    java -Djava.naming.factory.initial=com.sun.jndi.ldap.LdapCtxFactory \
     *       Compare
     */
    env.put(Context.INITIAL_CONTEXT_FACTORY, Env.INITCTX);

    /* Specify host and port to use for directory service */
    env.put(Context.PROVIDER_URL, Env.MY_SERVICE);

    DirContext ctx = null;
    SearchControls ctls = new SearchControls();
    ctls.setSearchScope(SearchControls.OBJECT_SCOPE);
    ctls.setReturningAttributes(new String[0]);  // do not return any attrs

    try {
        /* get a handle to an Initial DirContext */
        ctx = new InitialDirContext(env);
    } catch (NamingException e) {
        System.err.println("Cannot get initial context.");
        return;
    }

    try {
        NamingEnumeration results =
            ctx.search(Env.ENTRYDN, "objectclass=person", ctls);

        if (results != null && results.hasMoreElements()) {
            System.out.println(
            "The value \"person\" is contained in the objectclass attribute.");
        } else {
            System.out.println(
       "The value \"person\" is not contained in the objectclass attribute." );
        }
    } catch (NamingException e) {
        System.err.println("Comparison of value person failed.");
    }

    try {
        NamingEnumeration results =
            ctx.search(Env.ENTRYDN, "objectclass=xyzzy", ctls);

        if (results != null && results.hasMoreElements()) {
            System.out.println(
             "The value \"xyzzy\" is contained in the objectclass attribute.");
        } else {
            System.out.println(
        "The value \"xyzzy\" is not contained in the objectclass attribute." );
        }
    } catch (NamingException e) {
        System.err.println("Comparison of value xyzzy failed.");
    }
}
}
```

B.5 Modify Attributes

B.5.1 Modify Attributes Using LDAP C API

```
/*
 * Copyright (c) 1996.  Netscape Communications Corporation.  All
 * rights reserved.
 *
 * Modify an entry:
 *  - replace any existing values in the “mail” attribute with “babs@ace.com”
 *  - add a new value to the “description” attribute
 */

#include “examples.h”

int
main( int argc, char **argv )
{
    LDAP        *ld;
    LDAPMod     mod0;
    LDAPMod     mod1;
    LDAPMod     *mods[ 3 ];
    char        *vals0[ 2 ];
    char        *vals1[ 2 ];
    time_t      now;
    char        buf[ 128 ];

    /* get a handle to an LDAP connection */
    if ( (ld = ldap_init( MY_HOST, MY_PORT )) == NULL ) {
        perror( “ldap_init” );
        return( 1 );
    }
    /* authenticate */
    if ( ldap_simple_bind_s( ld, ENTRYDN, ENTRYPW ) != LDAP_SUCCESS ) {
        ldap_perror( ld, “ldap_simple_bind_s” );
        return( 1 );
    }
    /* construct the list of modifications to make */
    mod0.mod_op = LDAP_MOD_REPLACE;
    mod0.mod_type = “mail”;
    vals0[0] = “babs@ace.com”;
    vals0[1] = NULL;
    mod0.mod_values = vals0;

    mod1.mod_op = LDAP_MOD_ADD;
    mod1.mod_type = “description”;
    time( &now );
    sprintf( buf, “This entry was modified with the modattrs program on %s”,
            ctime( &now ));
    /* Get rid of \n which ctime put on the end of the time string */
    if ( buf[ strlen( buf ) - 1 ] == ‘\n’ ) {
        buf[ strlen( buf ) - 1 ] = ‘\0’;
    }
    vals1[ 0 ] = buf;
    vals1[ 1 ] = NULL;
    mod1.mod_values = vals1;

    mods[ 0 ] = &mod0;
    mods[ 1 ] = &mod1;
    mods[ 2 ] = NULL;

    /* make the change */
    if ( ldap_modify_s( ld, ENTRYDN, mods )
            != LDAP_SUCCESS ) {
        ldap_perror( ld, “ldap_modify_s” );
        return( 1 );
    }
    ldap_unbind( ld );
    printf( “modification was successful\n” );
    return( 0 );
}
```

B.5.2 Modify Attributes Using JNDI

```
/*
 * Copyright (c) 1997.  Sun Microsystems.  All rights reserved.
 *
 * Modify an entry:
 *  - replace any existing values in the "mail" attribute with "babs@ace.com"
 *  - add a new value to the "description" attribute
 *
 * [equivalent to modattrs.c in Netscape SDK]
 */

import java.util.Hashtable;
import java.util.Date;

import javax.naming.*;
import javax.naming.directory.*;

class Modattrs {
```

```
public static void main(String[] args) {

    Hashtable env = new Hashtable(5, 0.75f);
    /*
     * Specify the initial context implementation to use.
     * This could also be set by using the -D option to the java program.
     * For example,
     *   java -Djava.naming.factory.initial=com.sun.jndi.ldap.LdapCtxFactory \
     *       Modattrs
     */
    env.put(Context.INITIAL_CONTEXT_FACTORY, Env.INITCTX);

    /* Specify host and port to use for directory service */
    env.put(Context.PROVIDER_URL, Env.MY_SERVICE);

    /* specify authentication information */
    env.put(Context.SECURITY_AUTHENTICATION, "simple");
    env.put(Context.SECURITY_PRINCIPAL, Env.MGR_DN);
    env.put(Context.SECURITY_CREDENTIALS, Env.MGR_PW);

    try {
        /* get a handle to an Initial DirContext */
        DirContext ctx = new InitialDirContext(env);

        /* construct the list of modifications to make */
        ModificationItem[] mods = new ModificationItem[2];

        Attribute mod0 = new BasicAttribute("mail", "babs@eng");
        // Update mail attribute
        mods[0] = new ModificationItem(DirContext.REPLACE_ATTRIBUTE, mod0);

        // Add another value to description attribute
        Attribute mod1 =
            new BasicAttribute("description",
                      "This entry was modified with the Modattrs program on " +
                          (new Date()).toString());
        mods[1] = new ModificationItem(DirContext.ADD_ATTRIBUTE, mod1);

         /* Delete the description attribute altogether */
        /*
        Attribute mod1 =  new BasicAttribute("description");
        mods[2] = new ModificationItem(DirContext.REMOVE_ATTRIBUTE, mod1);
     */

        /* make the change */
        ctx.modifyAttributes(Env.ENTRYDN, mods);
        System.out.println( "modification was successful." );

    } catch (NamingException e) {
        System.err.println("modification failed. " + e);
    }
}
}
```

B.6 Rename An Entry

B.6.1 Rename Using LDAP C API

```
/*
 * Copyright (c) 1996.  Netscape Communications Corporation.  All
 * rights reserved.
 *
 * Modify the RDN (relative distinguished name) of an entry.  In this
 * example, we change the dn “cn=Jacques Smith, o=Ace Industry, c=US”
 * to “cn=Jacques M Smith, o=Ace Industry, c=US”.
 *
 * Since it is an error to either (1) attempt to modrdn an entry which
 * does not exist, or (2) modrdn an entry where the destination name
 * already exists, we take some steps, for this example, to make sure
 * we’ll succeed.  We (1) add “cn=Jacques Smith” (if the entry exists,
 * we just ignore the error, and (2) delete “cn=Jacques M Smith” (if the
 * entry doesn’t exist, we ignore the error).
 *
 * We pass 0 for the “deleteoldrdn” argument to ldap_modrdn2_s().  This
 * means that after we change the RDN, the server will put the value
 * “Jacques Smith” into the cn attribute of the new entry, in addition to
 * “Jacques M Smith”.
 */

#include “examples.h”

#define        NMODS        4

unsigned long        global_counter = 0;

static void free_mods( LDAPMod **mods );

int
main( int argc, char **argv )
{
    LDAP                    *ld;
    char                    *dn, *ndn, *nrdn;
    int                     i;
    int                     rc;
    LDAPMod                 **mods;

    /* Values we’ll use in creating the entry */
    char *objectclass_values[] = { “top”, “person”, “organizationalPerson”,
                                   “inetOrgPerson”, NULL };
    char *cn_values[] = { “Jacques Smith”, NULL };
    char *sn_values[] = { “Smith”, NULL };
    char *givenname_values[] = { “Jacques”, NULL };

    /* Specify the DN we’re adding */
    dn = “cn=Jacques Smith, o=Ace Industry, c=US”;
    /* the destination DN */
    ndn = “cn=Jacques M Smith, o=Ace Industry, c=US”;
    /* the new RDN */
    nrdn = “cn=Jacques M Smith”;

    /* get a handle to an LDAP connection */
    if ( (ld = ldap_init( MY_HOST, MY_PORT )) == NULL ) {
        perror( “ldap_init” );
        return( 1 );
    }
```

```
/* authenticate to the directory as the Directory Manager */
if ( ldap_simple_bind_s( ld, MGR_DN, MGR_PW ) != LDAP_SUCCESS ) {
    ldap_perror( ld, “ldap_simple_bind_s” );
    return( 1 );
}

if (( mods = ( LDAPMod ** ) malloc(( NMODS + 1 ) * sizeof( LDAPMod *)))
        == NULL ) {
    fprintf( stderr, “Cannot allocate memory for mods array\n” );
    return( 1 );
}
/* Construct the array of values to add */
for ( i = 0; i < NMODS; i++ ) {
    if (( mods[ i ] = ( LDAPMod * ) malloc( sizeof( LDAPMod ))) == NULL ) {
        fprintf( stderr, “Cannot allocate memory for mods element\n” );
        return( 1 );
    }
}
mods[ 0 ]->mod_op = 0;
mods[ 0 ]->mod_type = “objectclass”;
mods[ 0 ]->mod_values = objectclass_values;
mods[ 1 ]->mod_op = 0;
mods[ 1 ]->mod_type = “cn”;
mods[ 1 ]->mod_values = cn_values;
mods[ 2 ]->mod_op = 0;
mods[ 2 ]->mod_type = “sn”;
mods[ 2 ]->mod_values = sn_values;
mods[ 3 ]->mod_op = 0;
mods[ 3 ]->mod_type = “givenname”;
mods[ 3 ]->mod_values = givenname_values;
mods[ 4 ] = NULL;


/* Add the entry */
if (( rc = ldap_add_s( ld, dn, mods )) != LDAP_SUCCESS ) {
    /* If entry exists already, fine.  Ignore this error. */
    if ( rc == LDAP_ALREADY_EXISTS ) {
        printf( “Entry \”%s is already in the directory.\n”, dn );
    } else {
        ldap_perror( ld, “ldap_add_s” );
        free_mods( mods );
        return( 1 );
    }
} else {
    printf( “Added entry \”%s\”.\n”, dn );
}
free_mods( mods );

/* Delete the destination entry, for this example */
if (( rc = ldap_delete_s( ld, ndn )) != LDAP_SUCCESS ) {
    /* If entry does not exist, fine.  Ignore this error. */
    if ( rc == LDAP_NO_SUCH_OBJECT ) {
        printf( “Entry \”%s\” is not in the directory.  “
                “No need to delete.\n”, ndn );
    } else {
        ldap_perror( ld, “ldap_delete_s” );
        return( 1 );
    }
} else {
        printf( “Deleted entry \”%s\”.\n”, ndn );
    }

    /* Do the modrdn operation */
    if ( ldap_modrdn2_s( ld, dn, nrdn, 0 ) != LDAP_SUCCESS ) {
        ldap_perror( ld, “ldap_modrdn2_s” );
        return( 1 );
    }

    printf( “The modrdn operation was successful.  Entry\n”
            “\”%s\” has been changed to\n”
            “\”%s\”.\n”, dn, ndn );

    ldap_unbind( ld );
    return 0;
}



/*
 * Free a mods array.
 */
static void
free_mods( LDAPMod **mods )
{
    int i;

    for ( i = 0; i < NMODS; i++ ) {
        free( mods[ i ] );
    }
    free( mods );
}
```

B.6.2 Rename Using JNDI

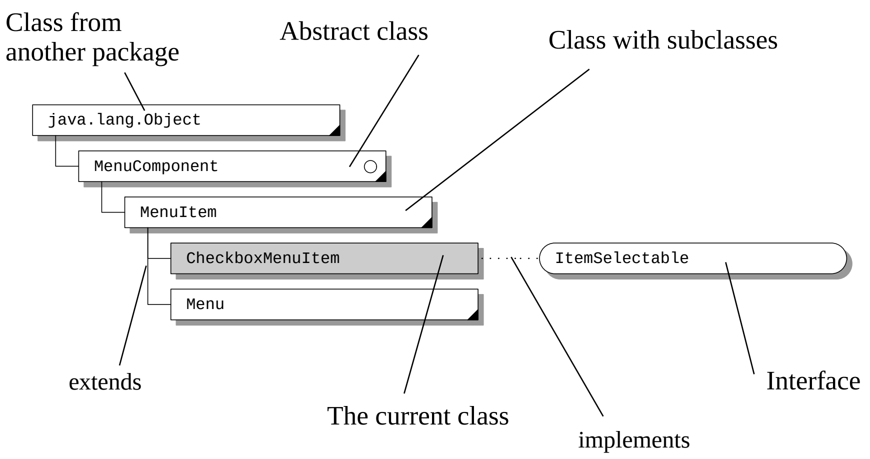
```
/*
 * Copyright (c) 1997.  Sun Microsystems.  All rights reserved.
 *
 * Modify the RDN (relative distinguished name) of an entry.  In this
 * example, we change the dn "cn=Jacques Smith, o=Ace Industry, c=US"
 * to "cn=Jacques M Smith, o=Ace Industry, c=US".
 *
 * Since it is an error to either (1) attempt to modrdn an entry which
 * does not exist, or (2) modrdn an entry where the destination name
 * already exists, we take some steps, for this example, to make sure
 * we'll succeed.  We (1) add "cn=Jacques Smith" (if the entry exists,
 * we just ignore the error, and (2) delete "cn=Jacques M Smith" (if the
 * entry doesn't exist, we ignore the error).
 *
 * After renaming, we add back the attribute "Jacques Smith" into the cn
 * attribute.
 *
 * [based on modrdn.c of Netscape  SDK]
 */

import java.util.Hashtable;
import java.util.Date;
import javax.naming.*;
import javax.naming.directory.*;

class Modrdn {

public static void main(String[] args) {

    /* Values we'll use in creating the entry */
    Attribute objClasses = new BasicAttribute("objectclass");
    objClasses.add("top");
    objClasses.add("person");
    objClasses.add("organizationalPerson");
    objClasses.add("inetOrgPerson");

    Attribute cn = new BasicAttribute("cn", "Jacques Smith");
    Attribute sn = new BasicAttribute("sn", "Smith");
    Attribute givenNames = new BasicAttribute("givenname", "Jacques");

    /* Specify the DN we're adding */
    String dn = "cn=Jacques Smith, " + Env.MY_MODBASE;
    /* the destination DN */
    String ndn = "cn=Jacques M Smith, " + Env.MY_MODBASE;
    /* the new RDN */
    String nrdn = "cn=Jacques M Smith";

    Hashtable env = new Hashtable(5, 0.75f);
    /*
     * Specify the initial context implementation to use.
     * This could also be set by using the -D option to the java program.
     * For example,
     *   java -Djava.naming.factory.initial=com.sun.jndi.ldap.LdapCtxFactory \
     *       Modrdn
     */
    env.put(Context.INITIAL_CONTEXT_FACTORY, Env.INITCTX);

    /* Specify host and port to use for directory service */
    env.put(Context.PROVIDER_URL, Env.MY_SERVICE);

    /* specify authentication information */
    env.put(Context.SECURITY_AUTHENTICATION, "simple");
    env.put(Context.SECURITY_PRINCIPAL, Env.MGR_DN);
    env.put(Context.SECURITY_CREDENTIALS, Env.MGR_PW);

    DirContext ctx = null;

    try {
        /* get a handle to an Initial DirContext */
        ctx = new InitialDirContext(env);
        Attributes orig = new BasicAttributes();
        orig.put(objClasses);
        orig.put(cn);
        orig.put(sn);
        orig.put(givenNames);

        /* Add the entry */
        ctx.createSubcontext(dn, orig);
        System.out.println( "Added entry " + dn + ".");

    } catch (NameAlreadyBoundException e) {
        /* If entry exists already, fine.  Ignore this error. */
        System.out.println("Entry " + dn + " already exists, no need to add");
    } catch (NamingException e) {
        System.err.println("Modrdn: problem adding entry." + e);
        System.exit(1);
    }

    try {
        /* Delete the destination entry, for this example */
        ctx.destroySubcontext(ndn);
        System.out.println( "Deleted entry " + ndn + "." );

    } catch (NameNotFoundException e) {
        /* If entry does not exist, fine.  Ignore this error. */
        System.out.println( "Entry " + ndn + " is not in the directory.  " +
                    "No need to delete.");
    } catch (NamingException e) {
        System.err.println("Modrdn: problem deleting entry." + e);
        System.exit(1);
    }


    /* Do the modrdn operation */
    try {
        ctx.rename(dn, ndn);
        System.out.println("The modrdn operation was successful.  Entry " +
                           dn + " has been changed to " + ndn + ".");
    } catch (NamingException e) {
        System.err.println("Modify operation failed." + e);
    }
}
}
```

Appendix C: 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 D: JNDI Change History

1.1: JNDI Changes Since 1.1Beta1

API-related Changes

- `DirContext.search()` accepts RFC 2254 filters instead of RFC 1960 filters.
- Added constants for environment properties to `Context` interface.
- Changed `Attributes.remove()` and `Attributes.put()` to return `Attribute` instead of `Object`.
- `Name.add()` and `Name.addAll()` (and related methods in `CompositeName` and `CompoundName`) are changed so that they return the updated instance of `Name`. This allows constructs such as `new CompositeName("a").add("b").add("c")` to be supported.
- Moved `implements Cloneable` from `CompositeName` and `CompoundName` to `Name`, where the `clone()` method is declared.
- Turned `Attribute` and `Attributes` into interfaces and renamed the original classes `BasicAttribute` and `BasicAttributes`, respectively.
- Allow class name to be specified in `Binding` and `SearchResult` constructors, and added `NameClassPair.setClassName()`.
- `DirContext.REMOVE_ATTRIBUTE` does not require nonexistent attributes or their values to be ignored.
- Added `throws NamingException` clause to `InitialContext` and `InitialDirContext` constructors so that connection problems can be reported and thrown at construction time.

SPI-related Changes

- `InitialContextFactory.getInitialContext()` must return a non-null initial context (instead of possibly null).
- `InitialContextFactoryBuilder.createInitialConetxtFactory()` and `ObjectFactoryBuilder.createObjectFactory()` now have a `throws NamingException` clause and must return non-null.
- `NamingManager.getObjectInstance()` and `getURLContext()` pass up exceptions thrown for operational errors (e.g. problem instantiating a factory class).

1.1Beta1: JNDI Changes Since 1.0Licensee Release

Package Name Change

JNDI is being packaged as a Java 1.1-compatible Standard Extension. The JNDI packages have been renamed to use the “javax” prefix, following the convention for Java Standard Extensions. The new package names are: `javax.naming`, `javax.naming.directory`, and `javax.naming.spi`.

General Changes

- Property names have been renamed following the convention used by the JDK. They have a “java.naming” prefix. See Appendix A of **JNDI API** document for details on the new names.
- Make `java.naming.provider.url` a system property in addition to being available as an environment property.
- Replaced use of `Properties` with `Hashtable` (`Properties`’ superclass) for the environment properties/settings so that service providers and applications can completely enumerate its contents. `Properties` can still be passed as arguments and returned as values when `Hashtable` is called for. But declaring the methods to use `Hashtable` makes clear the fact that nested `Properties` are not examined for the operation at hand.

API-related Changes

As most of these changes are renames, the 1.1Beta1 release of the code includes a Java ClassRenamer[1] program that assists you with the renames. See the instructions for the release for details.

[1] Thanks to the Swing team for use and distribution of this program.

- Added Context.close() to allow applications to release resources immediately.
- Added InterruptedNamingException to indicate a naming operation has been interrupted.
- Class renames: DSContext->DirContext, InitialDSContext->InitialDirContext, AttributeSet->Attributes, InvalidAttributeSetException->InvalidAttributesException, SearchConstraints->SearchControls, InvalidSearchConstraintsException->InvalidSearchControlsException.
- Make Attributes' methods look like Map's[1], Attribute's methods look like Set's, and Name, CompoundName, CompositeName, and Reference's methods look like List's.
- Added protected Attribute.Attribute() constructor so that subclasses can avoid allocating Vector.
- Added constructors to Attributes that accept an attribute.
- Added throws NamingException clause to Attribute's schema methods.
- Renamed DirContext.DELETE_ATTRIBUTE->DirContext.REMOVE_ATTRIBUTE.
- Replaced ModificationEnumeration with ModificationItem[].
- Replaced RefAddrEnumeration and StringEnumeration with Enumeration.
- Replaced AttributeEnumeration, NameClassEnumeration, BindingEnumeration, aand SearchEnumeration with NamingEnumeration to allow generic means of doing JNDI enumerations.
- Attribute.getAll() returns NamingEnumeration instead of Enumeration.
- Link.getLinkName() returns String instead of Name.
- BinaryRefAddr.buf and StringRefAddr.contents made private. Deleted Binary.getAddressBytes(), StringRefAddr.getAddressString(), BinaryRefAddr.size().
- Renamed RefAddr.getAddressContents()->getContent().
- Removed DSException, re-parented exceptions to be subclass of NamingException
- Removed most constructors from NamingException and its subclasses. Each has two constructors: one that accepts an explanation and a public constructor that takes no parameters.
- Removed Name.toString(), equals(), hashCode() as these are already defined by Object.
- Constructors for abstract classes RefAddr and ReferralException are now protected.

SPI-related Changes

- NamingManager.getObjectInstance() and ObjectFactory.getObjectInstance() allow the caller to supply two optional parameters: a name and a context. The name is the name of the object resolved relative to the context supplied. An object factory can make use of this information to gather further information about the object to create. See the corresponding javadoc for these methods for details. Corresponding fields and accessor methods were added to CannotProceedException so that this information, if supplied, can be propagated.
- Constants used in NamingManager for property names removed: ObjectFactoryProperty, InitialContextFactoryProperty, PkgPathProperty. These were used for internal development. Programs should use the appropriate strings instead.
- NamingManager.getObjectInstance() returns original input if it cannot create a factory using the reference of the object (it used to return null).
- InitialContext constructor that takes no parameters calls NamingManager.getInitialContext() with a null environment instead of empty environment.

1.0Licensee Release: JNDI Changes Since 1.0Beta1

Package Name Change

To allow this release to work in all Java 1.1 systems, the JNDI classes have been temporarily renamed from thejava.naming hierarchy to com.sun.java.naming.

API-related Changes

- SearchConstraints now implements java.io.Serializable.
- Added ReferralException.skipReferrals() to allow application to skip individual referrals.

[1] See http://java.sun.com/products/jdk/preview/docs/guide/collections/ for information on Map, Set and List.

- Added constructor to `NoInitialContextException` that accepts an explanation string.
- Added `SchemaViolationException` for reporting schema-related problems.
- Renamed `java.naming.directory.SearchTimeLimitExceededException` to `java.naming.TimeLimitExceededException` so that it can be used by the `java.naming` package. Added `java.naming.LimitExceededException`, which is the super class of `TimeLimitExceededException` and `SizeLimitExceededException` (new as well).
- To assist in debugging and displaying classes, added `AttributeSet.toString()`, `Binding.toString()`, `SearchResult.toString()`.
- Clarified semantics of the overloaded form of `search()` that accepts a matching attribute set (`AttributeSet`). If the matching attribute set is `null` or empty, return all the objects in the target context.
- `AttributeSet` now implements `Cloneable`, and has a `clone()` method.

SPI-related Changes

- Added "set" methods to `NameClassPair`, `Binding`, and `SearchResult` classes and made the protected fields private. This enables service providers to update the fields in these classes without subclassing.
- Added a constructor to `NameClassPair`, `Binding`, and `SearchResult` that accepts a "relative" parameter, and `isRelative()` and `setRelative()` methods. This allows service providers to return names that are not relative to the target context of the search. Non-relative names are named using URL strings.
- Contract between `NamingManager.getObjectInstance()` and `ObjectFactory` is clarified. An object factory returns `null` if it cannot create the object; it only throws an exception (which is passed up to the caller of `NamingManager.getObjectInstance()`) if no other object factories should be tried.
- Replaced `Resolver.resolvePenultimate()` with `Resolver.resolveToClass()`. This allows more efficient implementation of service providers by allowing the resolution to stop at the first context that exports a target class, rather than requiring resolution to proceed to the penultimate context. The final service provider in a chain of federated naming systems no longer needs to implement `Resolver`; only the intermediate providers.must do so.
- Removed `NotDSContextException`. Service providers should use `NotContextException` with the target class name in the explanation to indicate that a particular subclass of `Context` is required but not found.
- The default package prefix for loading URL context factories has changed from "sun.jndi.url" to "com.sun.jndi.url" because of package renaming.

Document Version Numbers Reset

The earlier versions of the JNDI documents were labeled as versions 1.0, 1.1. and 1.2. They should have been "Early Access", "Beta1" and so on, to match the code releases.

1.0Beta1: JNDI Changes Since 1.0Early Access

API-related Changes

- Added `java.naming.ReferralException` to support client-side referrals. This abstract class is used to represent a referral exception, such as that available in LDAP v3. A service provider defines a subclass of `ReferralException` to handle its own style of referrals.

- Added `compareTo()` to `Name` (and related classes `CompositeName`, `CompoundName`).

  ```
  public int compareTo(Object obj);
  ```

  This method compares this `Name` with the specified `Object` for order. It returns a negative integer, zero, or a positive integer as this `Name` is less than, equal to, or greater than the given `Object`. This method is useful for sorting a list of names.

- Added '`throws NamingException`' to `Referenceable.getReference()` so that the implementor of `getReference()` can throw an exception if it encounters one.

  ```
  public Reference getReference() throws NamingException;
  ```

- `AttributeSet` was originally case-sensitive. That is, the case of an attribute identifier was considered when retrieving or adding an attribute to the set. To better support service providers that support case-insensitive attribute identifiers, an `AttributeSet` may now be made case-insensitive. This change involved adding a new constructor to `AttributeSet` and a new method for interrogating an attribute set about its handling of case.

    public AttributeSet(boolean caseIgnore);

    ```
    public boolean isCaseIgnored();
    ```

- `Context.setEnvironment()` was insufficient to allow both addition and removal of environment properties. The change is to replace `setEnvironment()` with `addToEnvironment()` and `removeFromEnvironment()`.

    public Properties addToEnvironment(Properties additions) throws NamingException;

    ```
    public Properties removeFromEnvironment(Properties deletions) throws
    NamingException;
    ```

- Added `hasMore()` to `BindingEnumeration`, `NameClassEnumeration` and `SearchEnumeration` so that a service provider can throw an exception when this query fails for some unexpected reason. `Enumeration.hasMoreElements()` cannot throw exceptions. The workaround is for `hasMoreElements()` to return `true` and save the exception until the program calls `next()`. `hasMore()` allows a provider to indicate to the caller that it has encountered an exception while determining whether there are more elements. The caller that wants to be notified of exceptions can use `hasMore()` instead of `hasMoreElements()`.

    public boolean hasMore() throws NamingException;

- Added a new constructor to `OperationNotSupportedException` that accepts an explanation message as argument. This avoids the provider having to use the two steps of creating an empty `OperationNotSupportedException` and then setting the explanation.

- Added `composeName()` methods to `Context` class. These may be used to keep track of the full name of an object as name resolution proceeds from context to context.

- Removed extraneous parameter in `NamingException.getRootCause()`.

SPI-related Changes

- Clarified how URL context factories and contexts are located and created. Eliminated the ‘`String url`’ argument from `NamingManager.getURLContext()` and clarified its semantics.
  `getURLContext(String scheme, Properties env)` now returns a context for resolving URLs with scheme id `scheme`. It is not tied to any specific URLs, only the scheme id. See **JNDI SPI** document and `NamingManager.getURLContext()` for details.

- Clarified how `NamingManager.getObjectInstance()` treats URLs. Formerly, it only treated `References` and `Referenceables` specially. It now treats URLs specially as well. You can now call `getObjectInstance()` with a URL string or an array of URL strings and get back an object identified by the URL. See **JNDI SPI** document and `NamingManager.getObjectInstance()` for details.

- Placed additional requirements on URL context factories on how to treat its arguments so that all URL context factories behave consistently. See **JNDI SPI** document and `ObjectFactory.getObjectInstance()` for details.

- `NamingManager.getContinuationContext()` and `DirectoryManager.getContinuationDSContext()` accept as an argument `CannotProceedException` instead of a resolved object. This allows information required to create a continuation context to be passed using one argument and accommodates a common programming scenario of service providers using `CannotProceedException` to indicate the state of the operation.

- Added a ‘remaining newname’ part to `CannotProceedException` so that information required to continue a `rename()` can be represented, and an environment part for storing and retrieving the environment to use when resolution continues..

System Properties

- Two new system properties are introduced.
  - `jndi.urlfactory.pkgs`: Specifies package prefixes to use when loading URL context factories. See `NamingManager.getURLContext()`.
  - `jndi.dns.url`: Specifies DNS service location when using DNS names in "jndi" URLs (e.g "`jndi://dnsname/...`").

These can also be passed as environment properties to the `InitialContext` constructor.

Environment Properties

- `jndi.service.host` and `jndi.service.port` have been replaced by the more general `jndi.service.url`. `jndi.service.url` specifies the location information for configuring a context.
  Context service provider are encouraged to use this new environment property. They are still free to use additional environment properties as needed for their provider.
- Added `jndi.service.followReferrals`: Specifies that referrals encountered by the service provider are to be followed automatically.

1.0Early Access: JNDI Changes Since Initial Documentation Release

General Changes

- Renamed packages

```
jndi.ns -> java.naming

jndi.ds -> java.naming.directory

jndi.spi -> java.naming.spi
```

- Added implements `java.io.Serializable` to the following classes and interfaces:

```
Name
NameClassPair
RefAddr
Reference
Attribute
AttributeSet
ModificationItem
ModificationEnumeration
SearchConstraints
```

- Renamed the "count" methods to be more descriptive.

```
Reference.count() -> Reference.getAddressCount()
Name.count() -> Name.getComponentCount()
    [same for CompoundName and CompositeName]
Attribute.count() -> Attribute.getValueCount()
AttributeSet.count() -> AttributeSet.getAttributeCount()
ModificationEnumeration.count() ->
    ModificationEnumeration.getModificationItemCount()
```

- Renamed methods with '`SubContext`' to '`Subcontext`'. The new method names are now `Context.createSubcontext()`, `Context.destroySubcontext()`, and `DSContext.createSubcontext()`.

Name-related Changes

- `NameParser` is now an interface instead of abstract class. None of its methods contain any implementation so it is more flexible for it to be an interface. Removed the `getNamingConvention()` method from `NameParser`.

- Added class hierarchy to `NamingException` for security-related exceptions.

```
NamingException

      NamingSecurityException

            NoPermissionException

            AuthenticationException

            AuthenticationNotSupportedException
```

- Added `throws IllegalNameException` to name-manipulation methods so that they have a way of indicating error. This applies to the `Name` interface, the `CompositeName` and `CompoundName` classes.

```
prependName()
appendName()
insertName()
prependComponent()
appendComponent()
insertComponent()
deleteComponent()
```

- The following constructors throw `IllegalNameException` instead of `NamingException`

```
CompositeName()
CompoundName()
```

DSContext-related Changes:

- Dropped '`WithAttributes`' suffix from `bindWithAttributes(), rebindWithAttributes(),` and `createSubContextWithAttributes()`. They are now simply `DSContext.bind(), DSContext.rebind(),` and `DSContext.createSubcontext(),` respectively.
- Removed `DSContext.SearchFilter` class and replaced two existing `DSContext.Search()` methods:

```
public SearchEnumeration search(String name, String filterExpr,

      Object[] filterArgs, SearchConstraints constraints);

public SearchEnumeration search(Name name, String filterExpr,

      Object[] filterArgs, SearchConstraints constraints);
```

where `filterExpr` contains '`{n}`', `n` is an integer and denotes the n'th element in `filterArgs` to substitute in the expression. The reason for this change is that `SearchFilter` had limited capabilities and a full class for it was not justified. These changes make the syntax for substitution of variables within an expression consistent with the formatting methods in `java.text`.

- Renamed `AttributeSet.modify()` to `AttributeSet.replace()` for consistent usage of 'replace' with `Attribute.replaceValue()` and `DSContext.REPLACE_ATTRIBUTE`.
- Changes to `Attribute` class:
    - Added `Attribute.contains()` for testing whether an attribute contains a specified value.
    - `Attribute.add()` throws `AttributeInUseException` instead of the more general `NamingException`.
    - Schema methods return `null` by default. Removed protected variables `syntax` and `attr_defn`.
- Added `InvalidAttributeSetException` to deal with the case of incorrectly or insufficiently specified attribute

sets.

SPI-related Changes

- Renamed some class and interface names in `java.naming.spi` for consistency

```
        InitialContextImpl -> InitialContextFactory

        InitialContextImplFactory -> InitialContextFactoryBuilder

        setInitialContextImplFactory() -> setInitialContextFactoryBuilder()

        hasInitialContextImplFactory() -> hasInitialContextFactoryBuilder()

        InitialContextImplFactory.createInitialContextImpl() ->

                    InitialContextFactoryBuilder.createInitialContextFactory()

        JNDIManager -> NamingManager

        JNDIDSManager -> DirectoryManager
```

- Renamed `createObject()` to `getObjectInstance()` so that it is consistent with similar usage in other Java packages.

```
        JNDIManager.createObject() -> NamingManager.getObjectInstance()

        ObjectFactory.createObject() -> ObjectFactory.getObjectInstance().
```

- Renamed property `jndi.initialContext` to `jndi.initialContextFactory` for consistency with method names.
- The `jndi.initialContextFactory` property now contains a single class name instead of a colon-separated list because it does not make sense to have more than one class.
- To provide more flexibility and to avoid `SecurityManager`-related problems in some configurations, the system properties `jndi.initialContextFactory` and `jndi.objectFactories` can be passed as part of the environment properties passed to the constructors for `InitialContext` and `InitialDSContext`, and `ObjectFactory.getObjectInstance()`.
- Some protected methods in `NamingManager` and `DirectoryManager` are now private. This provides more flexibility in subsequent changes to these classes without exposing details of the implementation