CHAPTER 9

# A Simple Example

This chapter looks at a simple problem to give a complete example of a Jini service and client.

Before a Jini service can be built, common knowledge must be defined about the type of service that will be offered. This involves designing a set of "well-known" classes and interfaces. Based on a well-known interface, a client can be written to search for and use services implementing the interface.

The client can use either a unicast or multicast search to find services, but it will be uninterested in how any particular service is implemented. This chapter looks at building clients using both methods, and these clients will be heavily reused throughout the rest of the book.

The service, on the other hand, is implemented by each vendor in a different way. This chapter discusses a simple choice, with alternatives being dealt with in the next chapter. It is difficult to get a Jini service and client functioning correctly, as there are many configuration issues to be dealt with. These are discussed in some detail.

By the end of this chapter you should be able to build a client and a service, and configure your system so that they are able to run and communicate with each other.

## Problem Description

Applications often need to work out the type of a file, to see if it is a text file, an HTML document, an executable, and so forth. This can be done in two ways:

- By examining the file's name
- By examining the file's contents

Utilities such as the Unix `file` command use the second method and have a complex description file (such as `/etc/magic` or `/usr/share/magic`) to aid in this. Many other applications, such as web browsers, mail readers, and even some operating systems, use the first method and work out a file's type based on its name.

A common way of classifying files is into MIME types, such as `text/plain` and `image/gif`. There are tables of "official" MIME types (unofficial ones can be added on an ad hoc basis), and there are also tables of mappings from file name endings to corresponding MIME types. These tables have entries such as these:

```
application/postscript          ai eps ps
application/rtf                 rtf
application/zip                 zip
image/gif                       gif
```

```
image/jpeg                        jpeg jpg jpe
text/html                         html htm
text/plain                         txt
```

These tables are stored in files for applications to access.

Storing these tables separately from the applications that would use them is considered bad from the object-oriented point of view, since each application would need to have code to interpret the tables. Also, the multiplicity of these tables and the ability of users to modify them makes this a maintenance problem. It would be better to encapsulate at least the file name to MIME type mapping table in an object.

We could define a MIME class as follows:

```
package common;
import java.io.Serializable;
/**
 * MIMEType.java
 */
public class MIMEType implements Serializable {
    /**
     * A MIME type is made up of 2 parts
     * contentType/subtype
     */
    private String contentType;
    private String subType;
    public MIMEType() {
        // empty constructor required just in case
        // we want to use this as a Java Bean
    }
    public MIMEType(String type) {
        int slash = type.indexOf('/');
        contentType = type.substring(0, slash-1);
        subType = type.substring(slash+1, type.length());
    }

    public MIMEType(String contentType, String subType) {
        this.contentType = contentType;
        this.subType = subType;
    }
    public String toString() {
        return contentType + "/" + subType;
    }
    /**
     * Accessors/setters
     */
    public String getContentType() {
        return contentType;
    }
    public void setContentType(String type) {
        contentType = type;
    }
    public String getSubType() {
        return subType;
    }
    public void setSubType(String type) {
        subType = type;
    }
} // MIMEType
```

We could then define a mapping class like this:

```
package common;
/**
 * FileClassifier.java
 */
public interface FileClassifier {

    public MIMEType getMIMEType(String fileName)
        throws java.rmi.RemoteException;

} // FileClasssifier
```

This mapping class has no constructors, because it justs acts as a lookup table via its static method `getMIMEType()`.

Applications can make use of these classes as they stand, by simply compiling them and having the class files available at runtime. This would still result in duplication throughout JVMs, possible multiple copies of the class files, and potentially severe maintenance problems if applications need to be recompiled, so it may be better to have the `FileClassifier` as a network service. Let's consider what would be involved in this.

## Service Specification

If we wish to make a version of `FileClassifier` available across the network, there are a number of possibilities. The client will be asking for an instance of a class, and generally will not care too much about the details of this instance. For example, it will want an instance of a `DiskDrive` or a `Calendar`. Usually it will not care which drive it gets or which calendar. If it requires further specification, it can either ask for a subclass instance (such as a `SeagateDiskDrive`) or use an `Entry` object for this additional information.

Services will have particular implementations and will upload these to the service locators. The uploaded service will be of a specific class and may have associated entries.

The client can use several options when trying to locate a suitable service:

- This is the silly option: push the entire implementation up to the lookup service and make the client ask for it by its class. Then the client might just as well create the classifier as a local object, because it has all the information needed! This doesn't lend itself to flexibility with new unknown services coming along, because the client already has to know the details. So this option is not feasible.

- Let the client ask for a superclass of the service. This option is better than the previous one, as it allows new implementations of a service to just be implemented as new subclasses. It is not ideal, however, as classes have implementation code, and if this changes over time, there is a maintenance issue with the possibility of version "skew." This option can be used for Jini; it just isn't the best way.
- Separate the interface completely from the implementation. Make the interface available to the client, and upload the implementation to the lookup service. Then, when the client asks for an instance object that implements the interface, it will get *any* object for this interface. This will reduce maintenance: if the client is coded just in terms of the interface, then it will not need recompilation even if the implementation changes. Note that these words will translate straight into Java terms; the client knows about a Java `interface`, whereas the service provider deals in terms of a Java class that `implements` the `interface`.

The ideal mechanism in the Jini world is to specify services by Java interfaces and have all clients know this interface. Then each service can be an implementation of this interface. This is simple in Java terms, simple in specification terms, and simple for maintenance. This is not the complete set of choices for the service, but it is enough to allow a service to be specified and to get on with building the client. One possibility for service implementation is looked at later in this chapter, and the next chapter is devoted to the full range of possibilities.

Although I do not wish to get involved in discussions about which middleware is "best," I would like to note that consistent use of Java throughout Jini, and in particular its use for both specification and implementation, avoids many of the "mismatch" problems that can occur when specification and implementation occur in different languages. For example, Web Services use XML data types, and this is a very rich system distinct from the Java type system. It is not possible to represent all XML types in Java, nor all Java types in XML. This leads to either compromises with a "least common denominator" approach or to services that cannot be written or specified properly.

## Common Classes

The client and any implementations of a service must share some common classes. For a file classification service, the common classes are the classifier itself (which can be implemented as many different services) and the return value, the `MIMEType`. These have to change very slightly from their stand-alone form.

### MIMEType

The `MIMEType` class is known to the client and to any file classifier service. The `MIMEType` class files can be expected to be known to the JVMs of all clients and services. That is, these class files need to be in the `CLASSPATH` of every file classifier service and of every client that wants to use a file classifier service.

The `getMIMEType()` method will return an object from the file classifer service. Implementation possibilities that can affect this object are as follows:

- If the service runs in the client's JVM, then nothing special needs to be done.
- If the service is implemented remotely and runs in a separate JVM, then the MIMEType object must be serialized for transport to the client JVM. For this to be possible, it must implement the Serializable interface. Note that while the class files are accessible to both client and service, the instance data of the MIMEType object needs to be serializable to move the object from one machine to the other.

There can be differences in the object depending on possible implementations. If it implements Serializable, it can be used in both the remote and local cases, but if it doesn't, then it can only be used in the local case.

Making decisions about interfaces based on future implementation concerns is traditionally considered to be poor design. In particular, the philosophy behind remote procedure calls is that they hide the network as much as possible and make the calls behave as though they were local calls. With this philosophy, there is no need to make a distinction between local and remote calls at design time. However, a document from Sun, "A Note on Distributed Computing," by Jim Waldo and others, argues that this is wrong, particularly in the case of distributed objects. The basis of their argument is that the network brings in a host of other factors, in particular that of *partial failure*. That is, part of the network itself may fail, or a component on the network may fail without all of the network or all of the components failing. If other components do not make allowance for this possible (or maybe even likely) behavior, then the system as a whole will not be robust and could be brought down by the failure of a single component.

According to this document, it is important to determine whether the objects could be running remotely and to adjust interfaces and classes accordingly at the design stage. Doing so enables you to take into account possible extra failure modes of methods, and in this case, an extra requirement on the object. This important paper is reprinted in *The Jini Specifications, Second Edition*, edited by Ken Arnold (Addison-Wesley Professional, 2000), and is also at http://www.sun.com/research/techrep/1994/abstract_29.html.

These considerations lead to an interface that adds the Serializable interface to the original version of the MIMEType class, as objects of this class could be sent across the network. The objects sent are copies of the one on the server, not references to one that remains on the server.

```
package common;
import java.io.Serializable;
/**
 * MIMEType.java
 */
public class MIMEType implements Serializable {
    /**
     * A MIME type is made up of 2 parts
     * contentType/subtype
     */
    private String contentType;
    private String subType;
    public MIMEType() {
        // empty constructor required just in case
        // we want to use this as a Java Bean
    }
    public MIMEType(String type) {
        int slash = type.indexOf('/');
        contentType = type.substring(0, slash-1);
        subType = type.substring(slash+1, type.length());
    }

    public MIMEType(String contentType, String subType) {
        this.contentType = contentType;
        this.subType = subType;
    }
    public String toString() {
        return contentType + "/" + subType;
    }
    /**
     * Accessors/setters
     */
    public String getContentType() {
        return contentType;
    }
    public void setContentType(String type) {
        contentType = type;
    }
    public String getSubType() {
        return subType;
    }
    public void setSubType(String type) {
        subType = type;
    }
} // MIMEType
```

## FileClassifier Interface

Changes have to be made to the file classifier interface as well. First, interfaces cannot have static methods, so we will have to turn the `getMIMEType()` method into a public instance method.

In addition, all methods are defined to throw a `java.rmi.RemoteException`. This type of exception is used throughout Java (not just the RMI component) to mean "a network error has occurred." This error could be a lost connection, a missing server, a class not downloadable, and so on. There is a little subtlety here, related to the `java.rmi.Remote` class: the methods of `Remote` must all throw a `RemoteException`, but a class is not required to be `Remote` if its methods throw `RemoteException`. If all the methods of a class throw `RemoteException`, it does not mean the class implements or extends `Remote`; it only means that an implementation *may* be implemented as a remote (distributed) object, and this implementation may also use the RMI `Remote` interface.

There are some very fine points to this, which you can skip if you like. Basically, though, you can't go wrong if every method of a Jini interface throws `RemoteException` and the interface does not extend `Remote`. In fact, prior to JDK 1.2.2, making the interface extend `Remote` would force each implementation of the interface to actually be a remote object. At JDK 1.2.2, however, the semantics of Remote were changed a little, and this requirement was relaxed. From JDK 1.2.2 onward, an interface can extend Remote without implementation consequences. At least, that is almost the case: "unusual" ways of implementing RMI, such as over IIOP (IIOP is the transport protocol for CORBA, and RMI can use this), have not yet caught up to this. So for maximum flexibility, just throw RemoteException from each method and don't extend Remote.

Doing so gives the following interface:

```
package common;
/**
 * FileClassifier.java
 */
public interface FileClassifier {

    public MIMEType getMIMEType(String fileName)
        throws java.rmi.RemoteException;

} // FileClasssifier
```

Why does this interface throw a java.rmi.RemoteException in the getMIMEType() method? Well, an interface is supposed to be above all possible implementations and should never change. The implementation discussed later in this chapter does not throw such an exception. However, other implementations in other sections use a Remote implementation, and this will require that the method throws an java.rmi.RemoteException. Since it is not possible to just add a new exception in a subclass or interface implementation, the possibility must be added in the interface specification.

There is nothing Jini-specific about these classes. They can be compiled using any Java compiler with no special flags. For example, the following code shows a compilation using the JDK compiler:

```
javac common/MIMEType.java common/FileClassifier.java
```

## The Client

The client is the same for all of the possible server implementations discussed throughout this book. The client does not care how the service implementation is done, just as long as it gets a service that it wants, and it specifies this by asking for a FileClassifier interface.

### Unicast Client

If there is a known service locator that will know about the service, then there is no need to search for the service locator. This doesn't mean that the location of the service is known, only the location of the locator. For example, there might be a (fictitious) organization "All About Files" at http://www.all_about_files.com that would know about various file services, keeping track of them as they come online, move, disappear, and so on. A client would ask the service locator running on this site for the service, wherever it is. This client uses the unicast lookup techniques:

```
package client;
import common.FileClassifier;
import common.MIMEType;
import net.jini.core.discovery.LookupLocator;
import net.jini.core.lookup.ServiceRegistrar;
import net.jini.core.lookup.ServiceItem;
import net.jini.core.lookup.ServiceRegistration;
import java.rmi.RMISecurityManager;
import net.jini.core.lookup.ServiceTemplate;
/**
 * TestUnicastFileClassifier.java
 */
public class TestUnicastFileClassifier {
    public static void main(String argv[]) {
        new TestUnicastFileClassifier();
    }
    public TestUnicastFileClassifier() {
        LookupLocator lookup = null;
        ServiceRegistrar registrar = null;
        FileClassifier classifier = null;
        try {
            // lookup = new LookupLocator("jini://www.all_about_files.com");
            lookup = new LookupLocator("jini://192.168.1.13");
        } catch(java.net.MalformedURLException e) {
            System.err.println("Lookup failed: " + e.toString());
            System.exit(1);
        }
        System.setSecurityManager(new RMISecurityManager());
        try {
            registrar = lookup.getRegistrar();
        } catch (java.io.IOException e) {
            System.err.println("Registrar search failed: " + e.toString());
            System.exit(1);
        } catch (java.lang.ClassNotFoundException e) {
            System.err.println("Registrar search failed: " + e.toString());
            System.exit(1);
        }
        Class[] classes = new Class[] {FileClassifier.class};
        ServiceTemplate template = new ServiceTemplate(null, classes, null);
        try {
            classifier = (FileClassifier) registrar.lookup(template);
        } catch(java.rmi.RemoteException e) {
            e.printStackTrace();
            System.exit(1);
        }
        if (classifier == null) {
            System.out.println("Classifier null");
            System.exit(2);
        }
        MIMEType type;
        try {
            type = classifier.getMIMEType("file1.txt");
            System.out.println("Type is " + type.toString());
        } catch(java.rmi.RemoteException e) {
            System.err.println(e.toString());
        }
        System.exit(0);
    }
} // TestUnicastFileClassifier
```

The client's JVM looks like Figure 9-1. Figure 9-1 shows a UML class diagram, surrounded by the JVM in which the objects exist.

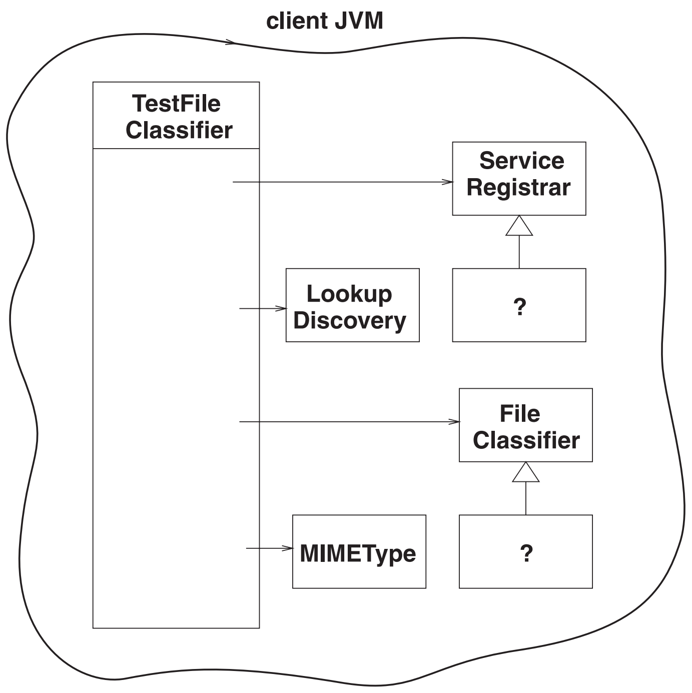
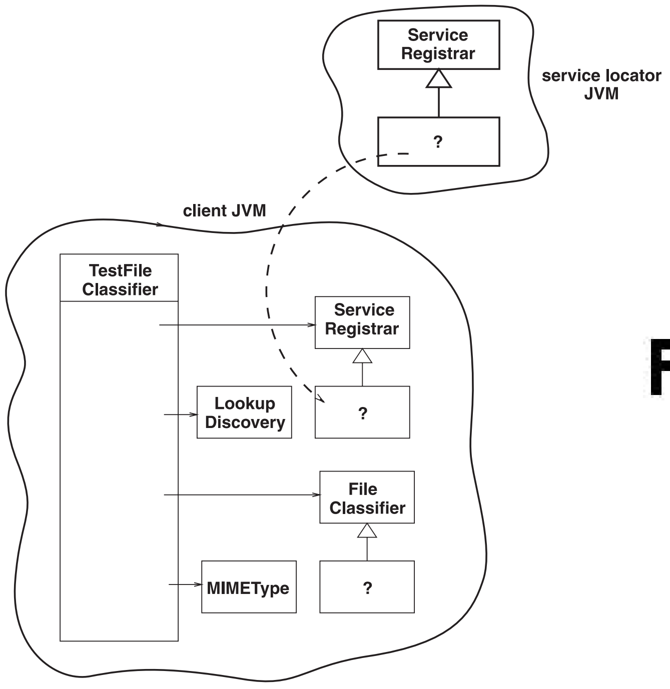


**Figure 9-1.** *Objects in the client JVM*

The client has a main `TestFileClassifier` class, which has two objects of types `LookupDiscovery` and `MIMEType`. It also has objects that implement the interfaces `ServiceRegistrar` and `FileClassifier`, but it doesn't know (or need to know) what classes they are. These objects have come across the network as implementation objects of the two interfaces.

Figure 9-2 shows the situation when the lookup service's JVM is added in. The lookup service has an object implementing `ServiceRegistrar`, and this is the object exported to the client.



FPO

**Figure 9-2.** *Objects in the client and service locator JVMs*

Figure 9-2 shows that the client gets its `registrar` from the JVM of the service locator. This `registrar` object is not specified in detail. Sun supplies a service locator known as `reggie`, which implements the `ServiceRegistrar` using an implementation that neither clients nor services are expected to know. The classes that implement the `ServiceRegistrar` object are contained in the `reggie-dl.jar` file and are downloaded to the clients and services using (typically) an HTTP server.

The figure also shows a question mark for the object in the client implementing `FileClassifier`. The source of this object is not yet shown; it will get the object from a service, but we haven't yet discussed any of the possible implementations of a `FileClassifier` service.

The unicast client uses a number of Jini classes. These classes must be in the `CLASSPATH` of the compiler. The classes are in the Jini `lib` directory in the `jsk-platform.jar` and `jsk-lib.jar` files. These files need to be in the `CLASSPATH` for any compiler, for example:

```
javac -classpath .../jsk-platform.jar:.../jsk-lib.jar client/
TestUnicastFileClassifier.java
```

An Ant file to build this client is `client.TestUnicastFileClassifier.xml`:

```
<!--
     Project name must be the same as the filename which must
     be the same as the main.class. Builds jar files with the
     same name
  -->

<project name="client.TestUnicastFileClassifier">
    <!-- Inherits properties from ../build.xml:
         jini.home
         jini.jars
         src
         dist
         build
         httpd.classes
      -->
    <!-- files for this project -->
    <!-- Source files for the client -->
    <property name="src.files"
              value="
                     common/MIMEType.java,
                     common/FileClassifier.java,
                     client/TestUnicastFileClassifier.java
                    "/>
    <!-- Class files to run the client -->
    <property name="class.files"
              value="
                     common/MIMEType.class,
                     common/FileClassifier.class,
                     client/TestUnicastFileClassifier.class
                    "/>
    <!-- Class files for the client to download -->
    <property name="class.files.dl"
              value="
                    "/>
    <!-- Uncomment if no class files downloaded to the client -->
    <property name="no-dl" value="true"/>
    <!-- derived names - may be changed -->
    <property name="jar.file"
              value="${ant.project.name}.jar"/>
    <property name="jar.file.dl"
              value="${ant.project.name}-dl.jar"/>
    <property name="main.class"
              value="${ant.project.name}"/>
    <!-- targets -->
    <target name="all" depends="compile"/>
    <target name="compile">
        <javac destdir="${build}" srcdir="${src}"
               classpath="${jini.jars}"
               includes="${src.files}">
        </javac>
    </target>
    <target name="dist" depends="compile"
            description="generate the distribution">
        <jar jarfile="${dist}/${jar.file}"
             basedir="${build}"
             includes="${class.files}"/>
        <antcall target="dist-jar-dl"/>
    </target>
    <target name="dist-jar-dl" unless="no-dl">
        <jar jarfile="${dist}/${jar.file.dl}"
             basedir="${build}"
             includes="${class.files.dl}"/>
    </target>
    <target name="build" depends="dist,compile"/>
    <target name="run" depends="build">
        <java classname="${main.class}"
              fork="true"
              classpath="${jini.jars}:${dist}/${jar.file}">
             <jvmarg value="-Djava.security.policy=${res}/policy.all"/>
        </java>
    </target>
    <target name="deploy" depends="dist" unless="no-dl">
        <copy file="${dist}/${jar.file.dl}"
              todir="${httpd.classes}"/>
    </target>
</project>
```

## Multicast Client

We have looked at the unicast client, where the location of the service locator is already known. However, it is more likely that a client will need to search through all of the service locators until it finds one holding a service it is looking for. It would need to use a multicast search for this. If it needs only one occurrence of the service, then it can exit after using the service. More complex behavior will be illustrated in later examples.

In this situation, the client does not need to have long-term persistence, but it does need a user thread to remain in existence for long enough to find service locators and find a suitable service. Therefore, in `main()` a user thread sleeps for a short period (ten seconds).

```
package client;
import common.FileClassifier;
import common.MIMEType;
import java.rmi.RMISecurityManager;
import net.jini.discovery.LookupDiscovery;
import net.jini.discovery.DiscoveryListener;
import net.jini.discovery.DiscoveryEvent;
import net.jini.core.lookup.ServiceRegistrar;
import net.jini.core.lookup.ServiceTemplate;
/**
 * TestFileClassifier.java
 */
public class TestFileClassifier implements DiscoveryListener {
    public static void main(String argv[]) {
        new TestFileClassifier();
        // stay around long enough to receive replies
        try {
            Thread.currentThread().sleep(100000L);
        } catch(java.lang.InterruptedException e) {
            // do nothing
        }
    }
    public TestFileClassifier() {
        System.setSecurityManager(new RMISecurityManager());
        LookupDiscovery discover = null;
        try {
            discover = new LookupDiscovery(LookupDiscovery.ALL_GROUPS);
        } catch(Exception e) {
            System.err.println(e.toString());
            System.exit(1);
        }
        discover.addDiscoveryListener(this);
    }

    public void discovered(DiscoveryEvent evt) {
        ServiceRegistrar[] registrars = evt.getRegistrars();
        Class [] classes = new Class[] {FileClassifier.class};
        FileClassifier classifier = null;
        ServiceTemplate template = new ServiceTemplate(null, classes,
                                                       null);

        for (int n = 0; n < registrars.length; n++) {
            System.out.println("Lookup service found");
            ServiceRegistrar registrar = registrars[n];
            try {
                classifier = (FileClassifier) registrar.lookup(template);
            } catch(java.rmi.RemoteException e) {
                e.printStackTrace();
                continue;
            }
            if (classifier == null) {
                System.out.println("Classifier null");
                continue;
            }
            // Use the service to classify a few file types
            MIMEType type;
            try {
                String fileName;
                fileName = "file1.txt";
                type = classifier.getMIMEType(fileName);
                printType(fileName, type);
                fileName = "file2.rtf";
                type = classifier.getMIMEType(fileName);
                printType(fileName, type);
                fileName = "file3.abc";
                type = classifier.getMIMEType(fileName);
                printType(fileName, type);
            } catch(java.rmi.RemoteException e) {
                System.err.println(e.toString());
                continue;
            }
            // success
            System.exit(0);
        }
    }
    private void printType(String fileName, MIMEType type) {
        System.out.print("Type of " + fileName + " is ");
        if (type == null) {
            System.out.println("null");
        } else {
            System.out.println(type.toString());
        }
    }
    public void discarded(DiscoveryEvent evt) {
        // empty
    }
} // TestFileClassifier
```

The multicast client uses a number of Jini classes. These classes must be in the `CLASSPATH` of the compiler. The classes are in the Jini `lib` directory in the `jsk-platform.jar` and `jsk-lib.jar` files. These need to be in the `CLASSPATH` for any compiler, for example:

```
javac -classpath .../jsk-platform.jar:.../jsk-lib.jar client/TestFileClassifier.java
```

An Ant file to build this client is `client.TestFileClassifier.xml`:

```
<!--
     Project name must be the same as the filename which must
     be the same as the main.class. Builds jar files with the
     same name
  -->

<project name="client.TestFileClassifier">
    <!-- Inherits properties from ../build.xml:
         jini.home
         jini.jars
         src
         dist
         build
         httpd.classes
      -->
    <!-- files for this project -->
    <!-- Source files for the client -->
    <property name="src.files"
              value="
                     common/MIMEType.java,
                     common/FileClassifier.java,
                     client/TestFileClassifier.java
                    "/>
    <!-- Class files to run the client -->
    <property name="class.files"
              value="
                     common/MIMEType.class,
                     common/FileClassifier.class,
                     client/TestFileClassifier.class
                    "/>
    <!-- Class files for the client to download -->
    <property name="class.files.dl"
              value="
                    "/>
    <!-- Uncomment if no class files downloaded to the client -->
    <property name="no-dl" value="true"/>
    <!-- derived names - may be changed -->
    <property name="jar.file"
              value="${ant.project.name}.jar"/>
    <property name="jar.file.dl"
              value="${ant.project.name}-dl.jar"/>
    <property name="main.class"
              value="${ant.project.name}"/>
    <!-- targets -->
    <target name="all" depends="compile"/>
    <target name="compile">
        <javac destdir="${build}" srcdir="${src}"
               classpath="${jini.jars}"
               includes="${src.files}">
        </javac>
    </target>
    <target name="dist" depends="compile"
            description="generate the distribution">
        <jar jarfile="${dist}/${jar.file}"
             basedir="${build}"
             includes="${class.files}"/>
        <antcall target="dist-jar-dl"/>
    </target>
    <target name="dist-jar-dl" unless="no-dl">
        <jar jarfile="${dist}/${jar.file.dl}"
             basedir="${build}"
             includes="${class.files.dl}"/>
    </target>
    <target name="build" depends="dist,compile"/>
    <target name="run" depends="build">
        <java classname="${main.class}"
              fork="true"
              classpath="${jini.jars}:${dist}/${jar.file}">
             <jvmarg value="-Djava.security.policy=${res}/policy.all"/>
        </java>
    </target>
    <target name="deploy" depends="dist" unless="no-dl">
        <copy file="${dist}/${jar.file.dl}"
              todir="${httpd.classes}"/>
    </target>
</project>
```

## Exception Handling

A Jini program can generate a huge number of exceptions, often related to the network nature of Jini. This is not accidental, but lies at the heart of the Jini approach to network programming. Services can disappear because the link to them has vanished, the server machine has crashed, or the service provider has died. Class files can disappear for similar problems with the HTTP server that delivers them. Timeouts can occur due to unpredictable network delays. Many of these exceptions have their own exception types, such as `LookupUnmarshalException`, which can occur when unmarshalling objects. Many others are simply wrapped in a `RemoteException`, which has a `detail` field for the wrapped exception.

Since many Jini calls can generate exceptions, these must be handled somehow. Many Java programs (or rather, their programmers!) adopt a somewhat cavalier attitude to exceptions: catch them, maybe put out an error message, and continue—Java makes it easy to handle errors! More seriously, whenever an exception occurs, the following questions have to be asked: Can the program can continue, or has its state been corrupted but not so badly that it cannot recover? Or has the program state been damaged so much that the program must exit?

The multicast `TestFileClassifier` of the last section can throw exceptions at a number of places:

- The `LookupDiscovery` constructor can fail. This is indicative of some serious network error. The created `discover` object is needed to add a listener, and if this cannot be done, then the program really can't do anything. So it is appropriate to exit with an error value.
- The `ServiceRegistrar.lookup()` method can fail. This is indicative of some network error in the connection with a particular service locator. While this connection may have failed, it is possible that other network connections may succeed. The application can restore a consistent state by skipping the rest of the code in this iteration of the `for()` loop by using a `continue` statement.
- The `FileClassifier.getMIMEType()` method can fail. This can be caused by a network error, or perhaps the service has simply gone away. Regardless, consistent state can again be restored by skipping the rest of this loop iteration.

Finally, if one part of a program can exit with an abnormal (nonzero) error value, then a successful exit should signal its success with an exit value of `0`. If this is not done, then the exit value becomes indeterminate and is of no value to other processes that may wish to know whether or not the program exited successfully.

## The Service Proxy

A service will be delivered from out of a service provider. That is, a server will be started to act as a service provider. It will create one or more objects, which between them will implement the service. Among these objects will be a distinguished object: the service object. The service provider will register the service object with service locators and then wait for network requests to come in for the service. What the service provider will actually export as service object is usually a proxy for the service. The *proxy* is an object that will eventually run in a client, and it will usually make calls back across the network to *service back-end* objects. These back-end objects running within the server actually complete the implementation of the service.

The proxy and the service back-end objects are tightly integrated; they must communicate using a protocol known to them both, and they must exchange information in an agreed-upon manner. However, the relative *size* of each is up to the designer of a service and its proxy. For example, the proxy may be "fat" (or "smart"), which means it does a lot of processing on the client side. Back-end object(s) within the service provider itself are then typically "thin," not doing much at all. Alternatively, the proxy may be "thin," doing little more (or nothing more) than passing requests between the client and "fat" back-end objects, and most processing will be done by these back-end objects running in the service provider.

As well as this choice of size, there is also a choice of communication mechanisms between the client and service provider objects. Client/server systems often have the choice of message-based or remote procedure call (RPC) communications. These choices are also available between a Jini proxy and its service. Since they are both in Java, there is a standard RPC-like mechanism called Remote Method Invocation (RMI), and this can be used if wanted. There is no need to use RMI, but many implementations of Jini proxies will do so because it is easy. RMI does force a particular choice of thin proxy to fat service back-end, though, and this may not be ideal for all situations.

This chapter looks at one possibility only, where the proxy is fat and is the whole of the service implementation (the service back-end is an empty set of objects). Chapter 10 covers the other possibilities in more detail.

## Uploading a Complete Service

The file classifier service does not rely on any particular properties of its host—it is not hardware or operating system dependent, and it does not make use of any files on the host side. In this case, it is possible to upload the entire service to the client and let it run there. The proxy is the service, and no processing elements need to be left on the server.

### FileClassifier Implementation

The implementation of the `FileClassifier` is straightforward:

```java
package complete;
import common.MIMEType;
import common.FileClassifier;
/**
 * FileClassifierImpl.java
 */
public class FileClassifierImpl implements FileClassifier, java.io.Serializable {
    public MIMEType getMIMEType(String fileName) {
        if (fileName.endsWith(".gif")) {
            return new MIMEType("image", "gif");
        } else if (fileName.endsWith(".jpeg")) {
            return new MIMEType("image", "jpeg");
        } else if (fileName.endsWith(".mpg")) {
            return new MIMEType("video", "mpeg");
        } else if (fileName.endsWith(".txt")) {
            return new MIMEType("text", "plain");
        } else if (fileName.endsWith(".html")) {
            return new MIMEType("text", "html");
        } else
            // fill in lots of other types,
            // but eventually give up and
            return null;
    }
    public FileClassifierImpl() {
        // empty
    }
} // FileClassifierImpl
```

This implementation consists of ordinary Java code and does not require any special libraries. It does need the FileClassifier and MIMEType in its classpath. The implementation can be compiled by a simple command:

```
javac complete/FileClassifierImpl.java
```

Other implementations may require other packages to be included, of course.

## FileClassifierServer Implementation

The service provider for the file classifier service needs to create an instance of the exportable service object, register this, and keep the lease alive. In the discovered() method, it not only registers the service but also adds it to a LeaseRenewalManager, to keep the lease alive "forever." This manager runs its own threads to keep reregistering the leases, but these are daemon threads. So in the main() method, the user thread goes to sleep for as long as you want the server to stay around.

The following code uses an "unsatisfied wait" condition that will sleep forever until interrupted. Note that if the server does terminate, then the lease will fail to be renewed and the exported service object will be discarded from lookup locators even though the server is not required for delivery of the service.

The serviceID is initially set to null. This may be the first time this service is ever run, or at least the first time it is ever run with this particular implementation. Since a service ID is issued by lookup services, it must remain null until at least the first registration. Then the service ID can be extracted from the registration and reused for all further lookup services. In addition, the service ID can be saved in some permanent form so that if the server crashes and restarts, the service ID can be retrieved from permanent storage and used. The following server code saves and retrieves this value in a FileClassifier.id file. Note that we get the service ID from the registration, not the registrar.

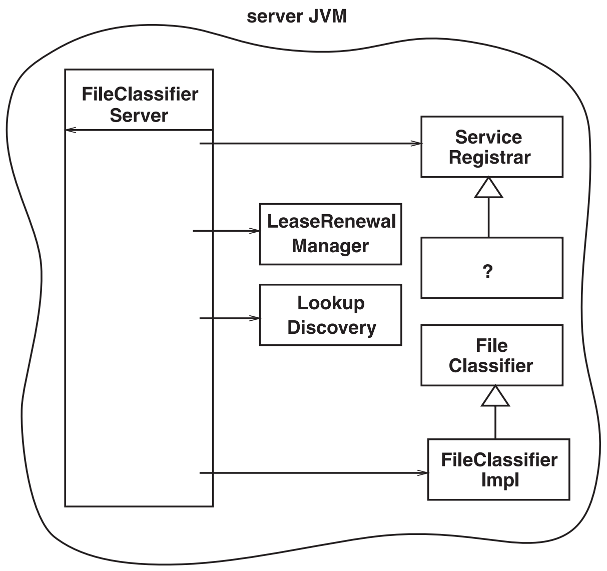
```
package complete;
import java.rmi.RMISecurityManager;
import net.jini.discovery.LookupDiscovery;
import net.jini.discovery.DiscoveryListener;
import net.jini.discovery.DiscoveryEvent;
import net.jini.core.lookup.ServiceRegistrar;
import net.jini.core.lookup.ServiceItem;
import net.jini.core.lookup.ServiceRegistration;
import net.jini.core.lease.Lease;
import net.jini.core.lookup.ServiceID ;
import net.jini.lease.LeaseListener;
import net.jini.lease.LeaseRenewalEvent;
import net.jini.lease.LeaseRenewalManager;
import java.io.*;
/**
 * FileClassifierServer.java
 */
public class FileClassifierServer implements DiscoveryListener,
                                              LeaseListener {
```

```
protected LeaseRenewalManager leaseManager = new LeaseRenewalManager();
protected ServiceID serviceID = null;
protected         FileClassifierImpl impl;
public static void main(String argv[]) {
    FileClassifierServer s = new FileClassifierServer();

    // keep server running forever to
    // - allow time for locator discovery and
    // - keep re-registering the lease
    Object keepAlive = new Object();
    synchronized(keepAlive) {
        try {
            keepAlive.wait();
        } catch(java.lang.InterruptedException e) {
            // do nothing
        }
    }
}
public FileClassifierServer() {
    // Create the service
    impl = new FileClassifierImpl();
    // Try to load the service ID from file.
    // It isn't an error if we can't load it, because
    // maybe this is the first time this service has run
    DataInputStream din = null;
    try {
        din = new DataInputStream(new FileInputStream("FileClassifier.id"));
        serviceID = new ServiceID(din);
    } catch(Exception e) {
        // ignore
    }
    System.setSecurityManager(new RMISecurityManager());
    LookupDiscovery discover = null;
    try {
        discover = new LookupDiscovery(LookupDiscovery.ALL_GROUPS);
    } catch(Exception e) {
        System.err.println("Discovery failed " + e.toString());
        System.exit(1);
    }
    discover.addDiscoveryListener(this);
}
```

```
    public void discovered(DiscoveryEvent evt) {
        ServiceRegistrar[] registrars = evt.getRegistrars();
        for (int n = 0; n < registrars.length; n++) {
            ServiceRegistrar registrar = registrars[n];
            ServiceItem item = new ServiceItem(serviceID,
                                               impl,
                                               null);
            ServiceRegistration reg = null;
            try {
                reg = registrar.register(item, Lease.FOREVER);
            } catch(java.rmi.RemoteException e) {
                System.err.println("Register exception: " + e.toString());
                continue;
            }
            System.out.println("Service registered with id " + reg.getServiceID());
            // set lease renewal in place
            leaseManager.renewUntil(reg.getLease(), Lease.FOREVER, this);
            // set the serviceID if necessary
            if (serviceID == null) {
                serviceID = reg.getServiceID();
                // try to save the service ID in a file
                DataOutputStream dout = null;
                try {
                    dout = new DataOutputStream(
                               new FileOutputStream("FileClassifier.id"));
                    serviceID.writeBytes(dout);
                    dout.flush();
                } catch(Exception e) {
                    // ignore
                }
            }
        }
    }
    public void discarded(DiscoveryEvent evt) {
    }
    public void notify(LeaseRenewalEvent evt) {
        System.out.println("Lease expired " + evt.toString());
    }
} // FileClassifierServer
```

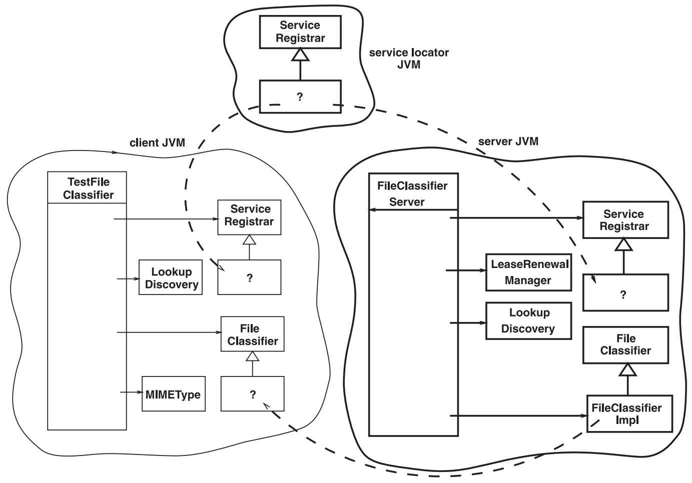
Figure 9-3 shows the server by itself running in its JVM.



FPO

**Figure 9-3.** *Objects in the server JVM*

The server receives an object implementing `ServiceRegistrar` from the service locator (such as `reggie`). Adding in the service locator and the client in their JVMs is shown in Figure 9-4.



FPO

**Figure 9-4.** *Objects in all the JVMs*

The unknown `FileClassifier` object in the client is here supplied by the service object `FileClassifierImpl` (via the lookup service, where it is stored in passive form).

The server uses a number of Jini classes. These classes must be in the `CLASSPATH` of the compiler. The classes are in the Jini `lib` directory in the `jsk-platform.jar` and `jsk-lib.jar` files. These files need to be in the `CLASSPATH` for any compiler, for example:

```
javac -classpath .../jsk-platform.jar:.../jsk-lib.jar complete/
FileClassifierServer.java
```

An Ant file to build this server is `complete.FileClassifierServer.xml`:

```
<!--
     Project name must be the same as the filename which must
     be the same as the main.class. Builds jar files with the
     same name
  -->

<project name="complete.FileClassifierServer">
    <!-- Inherits properties from ../build.xml:
         jini.home
         jini.jars
         src
         dist
         build
         httpd.classes
         localhost
      -->
    <!-- files for this project -->
    <!-- Source files for the server -->
    <property name="src.files"
              value="
                     common/MIMEType.java,
                     common/FileClassifier.java,
                     complete/FileClassifierImpl.java,
                     complete/FileClassifierServer.java
                    "/>
    <!-- Class files to run the server -->
    <property name="class.files"
              value="
                     common/MIMEType.class,
                     common/FileClassifier.class,
                     complete/FileClassifierImpl.class,
                     complete/FileClassifierServer.class
                    "/>
    <!-- Class files for the client to download -->
    <property name="class.files.dl"
              value="
                     common/MIMEType.class,
                     common/FileClassifier.class,
                      complete/FileClassifierImpl.class
                     "/>
    <!-- Uncomment if no class files downloaded to the client -->
    <!-- <property name="no-dl" value="true"/> -->
    <!-- derived names - may be changed -->
    <property name="jar.file"
              value="${ant.project.name}.jar"/>
    <property name="jar.file.dl"
              value="${ant.project.name}-dl.jar"/>
    <property name="main.class"
              value="${ant.project.name}"/>
    <property name="codebase"
              value="http://${localhost}/classes/${jar.file.dl}"/>
    <!-- targets -->
    <target name="all" depends="compile"/>
    <target name="compile">
        <javac destdir="${build}" srcdir="${src}"
               classpath="${jini.jars}"
               includes="${src.files}">
        </javac>
    </target>
    <target name="dist" depends="compile"
            description="generate the distribution">
        <jar jarfile="${dist}/${jar.file}"
             basedir="${build}"
             includes="${class.files}"/>
        <antcall target="dist-jar-dl"/>
    </target>
    <target name="dist-jar-dl" unless="no-dl">
        <jar jarfile="${dist}/${jar.file.dl}"
             basedir="${build}"
             includes="${class.files.dl}"/>
    </target>
    <target name="build" depends="dist,compile"/>
    <target name="run" depends="build,deploy">
        <java classname="${main.class}"
              fork="true"
              classpath="${jini.jars}:${dist}/${jar.file}">
             <jvmarg value="-Djava.security.policy=${res}/policy.all"/>
             <jvmarg value="-Djava.rmi.server.codebase=${codebase}"/>
        </java>
    </target>
    <target name="deploy" depends="dist" unless="no-dl">
        <copy file="${dist}/${jar.file.dl}"
              todir="${httpd.classes}"/>
    </target>
</project>
```

## Client Implementation

The client for this service was discussed earlier in the section "The Client." The client does not need any special information about this implementation of the service and so can remain quite generic.

### What Classes Need to Be Where?

In this chapter, we have defined the following classes:

- `common.MIMEType`
- `common.FileClassifier`
- `complete.FileClassifierImpl`
- `complete.FileClassifierServer`
- `client.TestFileClassifier`

Instance objects of these classes could be running on up to four different machines:

- The server machine for `FileClassifier`.
- The machine for the lookup service.
- The machine running the client `TestFileClassifier`.
- An HTTP server will need to run somewhere to deliver the class file definition of `FileClassifierImpl` to clients.

What classes need to be known to which machines? The term "known" can refer to different things:

- The class may be in the `CLASSPATH` of a JVM.
- The class may be loadable across the network.
- The class may be accessible by an HTTP server.

### Service Provider

The server running `FileClassifierServer` needs to know the following classes and interfaces:

- The `common.FileClassifier` interface
- The `common.MIMEType` class
- The `complete.FileClassifierServer` class
- The `complete.FileClassifierImpl` class

These classes all need to be in the `CLASSPATH` of the server.

### HTTP Server

The complete.FileClassifierImpl class will need to be accessible to an HTTP server, as discussed in the next section.

### Lookup Service

The lookup service does not need to know any of these classes. It just deals with them in the form of a java.rmi.MarshalledObject.

### Client

The client needs to know the following:

- The common.FileClassifier interface
- The common.MIMEType class
- The client.TestFileClassifier class

These all need to be in the CLASSPATH of the client. In addition, the client will need to know the class files for complete.FileClassifierImpl. However, these will come across the network as part of the discovery process, and this will be invisible to the client's programmer.

## Running the FileClassifier

We now have a FileClassifierServer service and a TestFleClassifier client to run. There should also be at least one lookup locator already running. The CLASSPATH should be set for each to include the classes discussed in the last section, in addition to the standard ones.

A serialized instance of complete.FileClassifierImpl will be passed from the server to the locator and then to the client. Once on the client, it will need to be able to run the class file for this service object, and so will need to load its class file from an HTTP server. The location of this class file relative to the server's DocumentRoot will need to be specified by the service invocation. For example, if it is stored in /DocumentRoot/classes/complete/FileClassifierImpl.class, then the server will also be downloading a registrar object from the lookup service, so it will need a security policy. The service will be started as follows:

```
java -Djava.rmi.server.codebase=http://hostname/classes \
     -Djava.security.policy=policy.all \
     complete.FileClassifierServer
```

In this command, hostname is the name of the host the server is running on. Note that this hostname cannot be localhost, because the localhost for the server will not be the localhost for the client!

In this case, we only need to put one file, FileClassifierImpl.class, on the HTTP server. Although the implementation relies on the MIMEType and the FileClassifier interface, the client has copies of these. In more complex situations, the implementation may consist of more classes, some which will not be known to the client. All of these class files may be put individually on the HTTP server, but it has become common practice to put them all into a .jar file with a name including -dl (for *download*), such as FileClassifierImpl-dl.jar. I should also point out that service browsers will not know about the classes used by the implementation, so for them to be able to examine the service, the `.jar` file should include all classes that the service depends on--that is, the `.jar` file should be created as follows:

```
jar cf FileClassifierImpl-dl.jar \
       common/MIMEType.class \
       common/FileClassifier.class \
       complete/FileClassifierImpl.class
```

and the server would then be run as follows:

```
java -Djava.rmi.server.codebase=http://hostname/classes/FileClassifierImpl-dl.jar \
     -Djava.security.policy=policy.all \
     complete.FileClassifierServer
```

The client will be loading a class definition across the network. It will need to allow this in a security policy file with the following statement:

```
java -Djava.security.policy=policy.all client.TestFileClassifier
```

The client does *not* need to know anything about the implementation classes. It just needs to know the `FileClassifier` interface, the `MIMEType` class, and the standard Jini classes. All other classes are downloaded as needed from the HTTP server specified by the service.

## Summary

In this chapter, the material presented in the previous chapters was put together in a simple example. We discussed the requirements of class structures for a Jini system, and we also covered the classes that need to be available to each component of a Jini system.