A tutorial on Jini

Jan Newmarch
jan@ise.canberra.edu.au
University of Canberra
DSTC (Distributed Systems Technology CRC)

OVERVIEW

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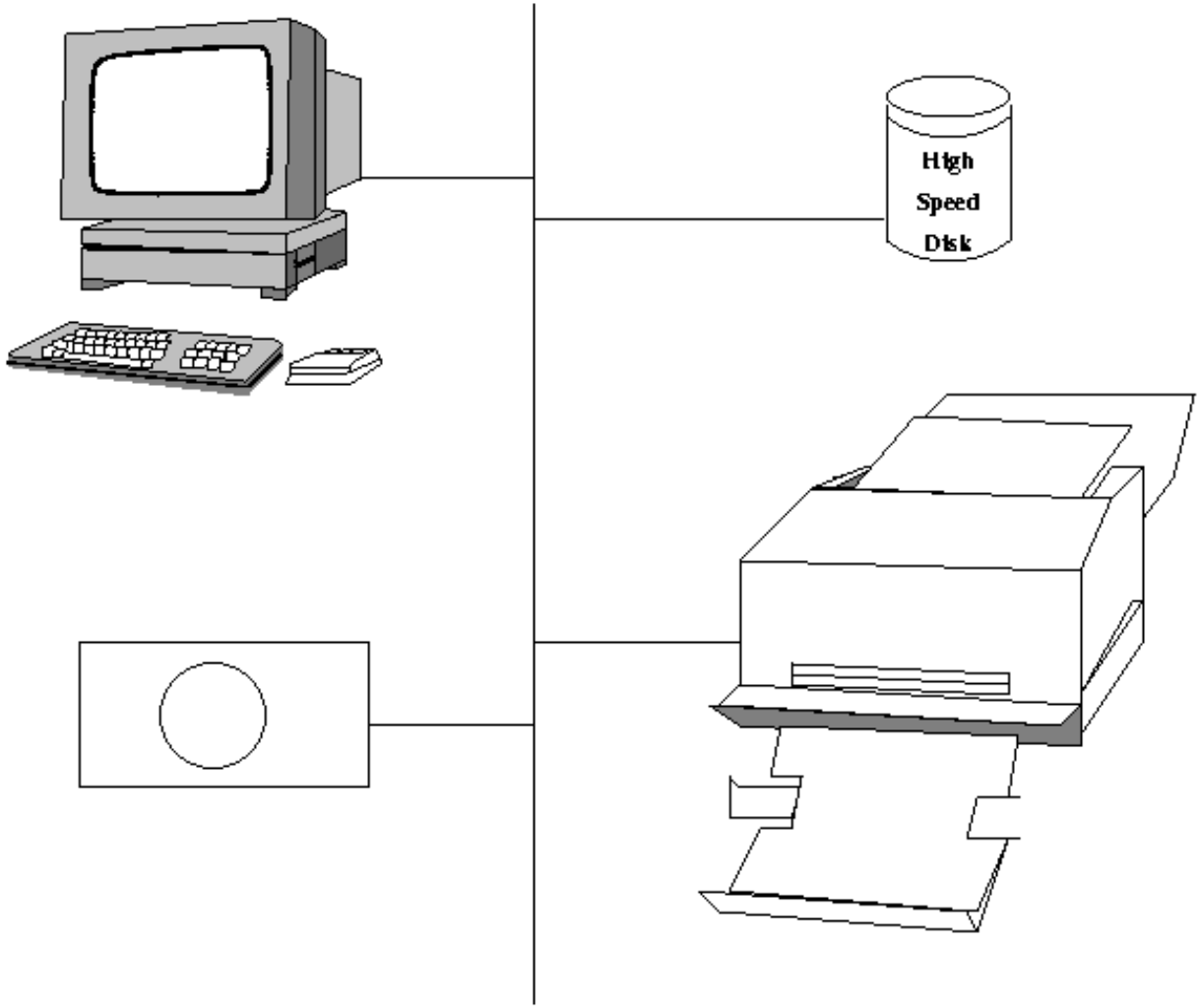
What is Jini?

- Jini brings ‘‘network plug and play’’ to hardware devices and software services
- Jini is in pure Java
- It makes hardware and software available as Java networked services
- ‘‘Legacy’’ systems can be wrapped in a Java proxy
- Jini has competitors including CORBA Trader, DCOM, HP’s Chai, Enterprise Java Beans, JNDI, etc



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Jini Federation

- A Jini federation or ‘‘djinn’’ consists of a number of clients, services and service locators
- Typically connected by TCP/IP
- Code is moved around from service to locator to client using Java 1.2 extensions to RMI

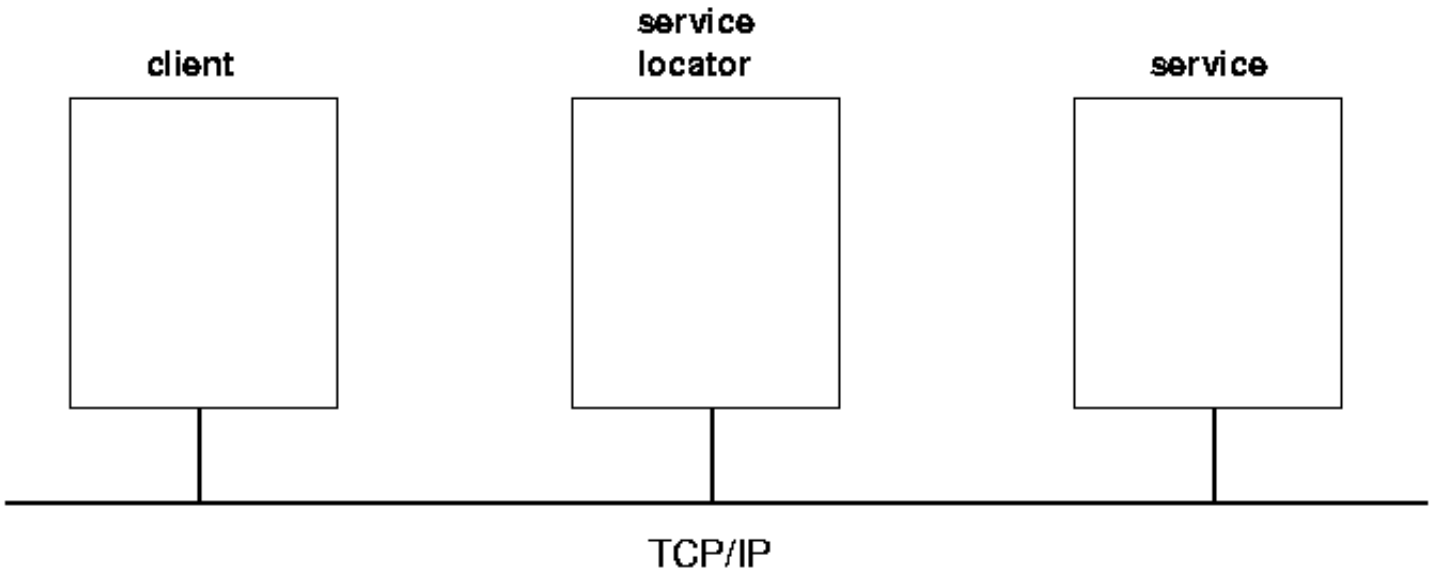

Figure 1: Components of a Jini federation

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Service Registration

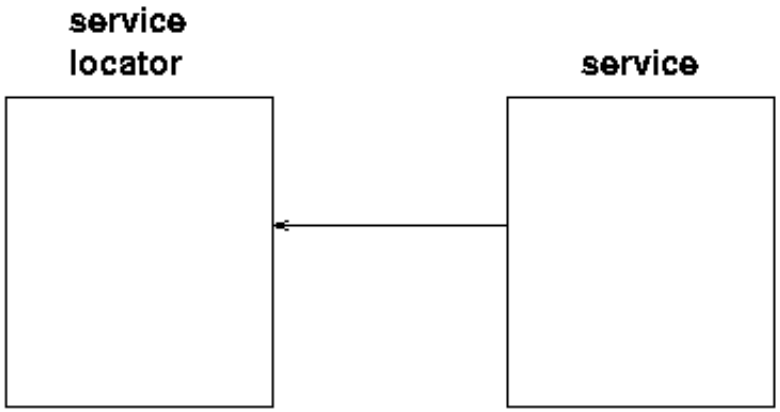

Figure 2: Querying for a service locator

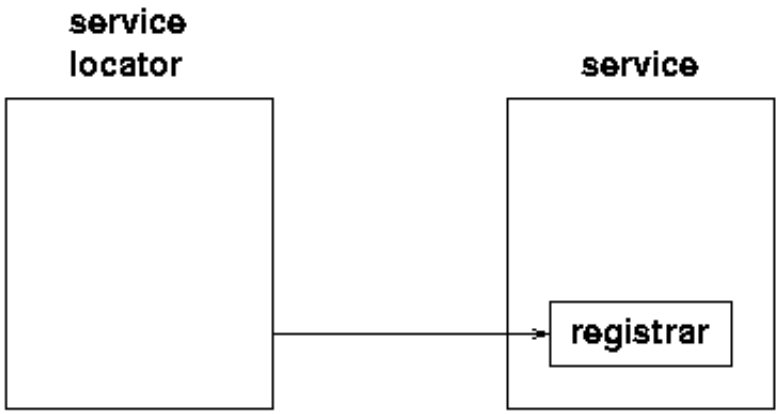

Figure 3: Registrar returned

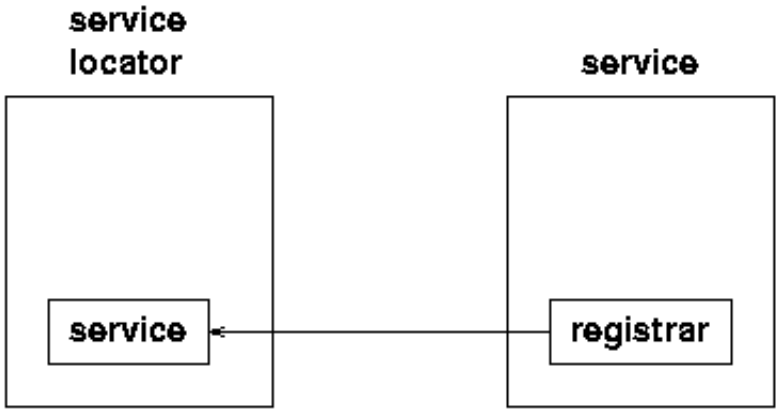

Figure 4: Service uploaded

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Client Lookup

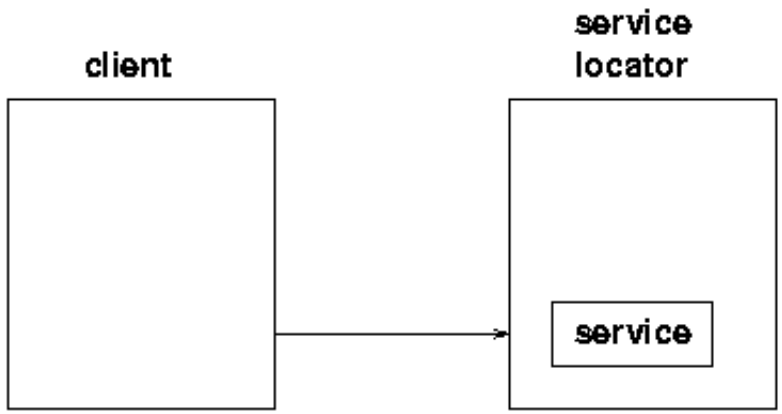

Figure 5: Querying for a service locator

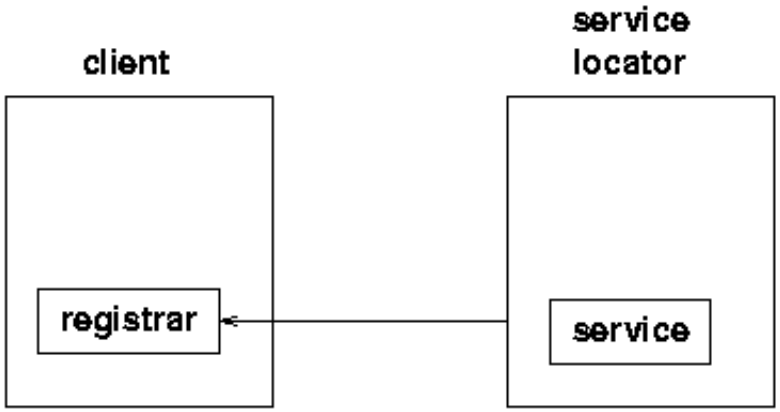

Figure 6: Registrar returned

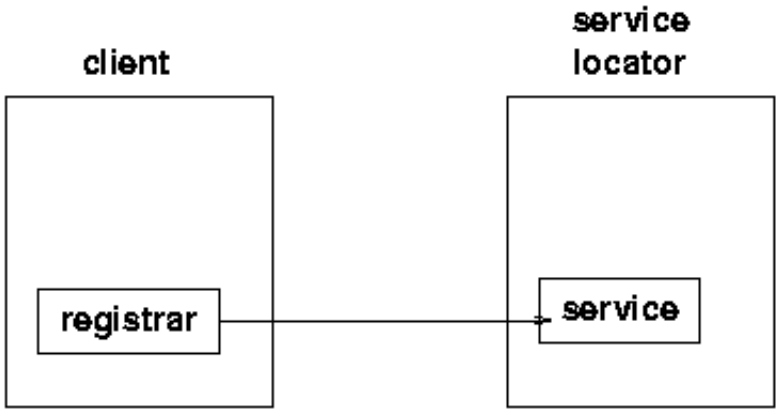

Figure 7: Asking for a service

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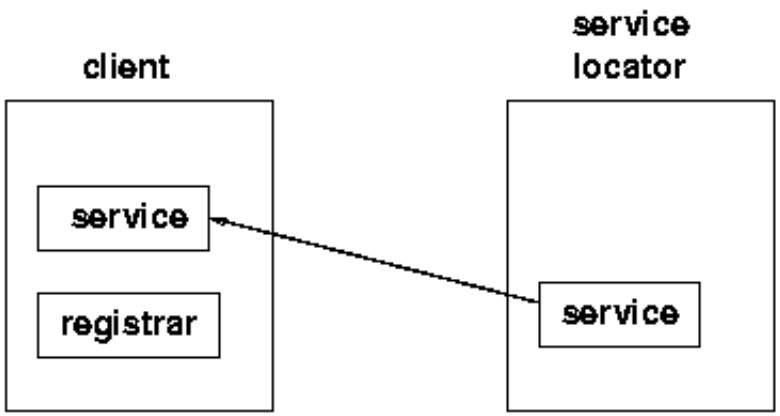

Figure 8: Service returned

Support Services

- Jini objects are moved in ‘‘marshalled’’ form
- Class files may need to follow these for proper activation
- The class files may need to be available from HTTP servers
- RMI Naming can be used to locate remote objects
- RMI Naming may need an rmiregistry or rmid running
- Security permissions will need to be set using JDK 1.2 security model

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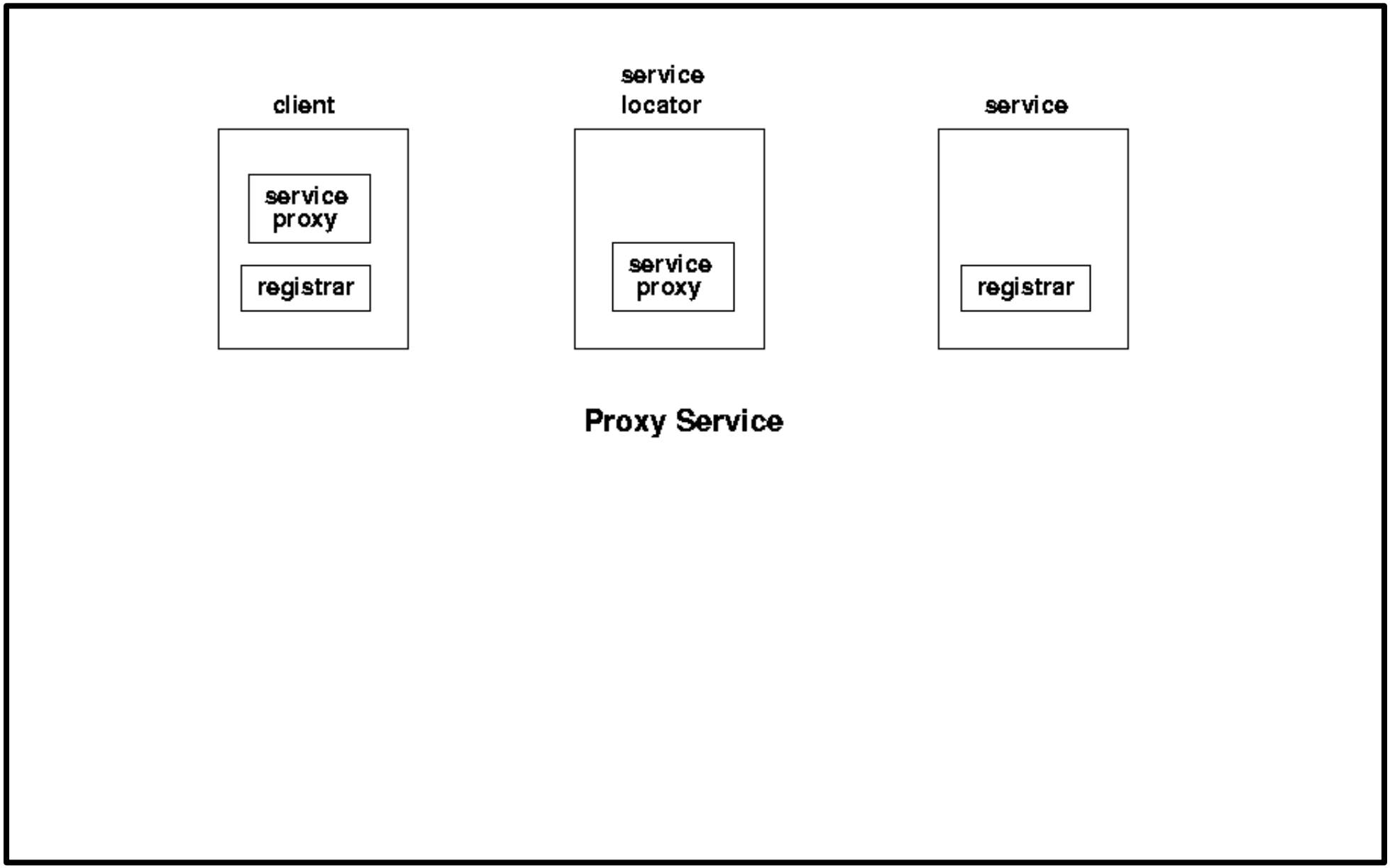
Proxies

- A toaster will be controlled by some service software
- The service software will be moved across the network to the client
- The mobile code must be a proxy for the real service code
- The proxy may be explicitly written or be an RMI proxy stub
- Remote calls from the proxy may be RMI Remote calls, or by some other mechanism such as private TCP connection



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Attribute Registration

- A service is uploaded to a locator as an instance of a class
- Additional information such as address may also be uploaded as instances of Entry classes
- Service registration is done using a leasing system

Service Location

- A client asks for a service as an instance of a class, typically of an interface
- A client may ask for additional Entry attributes
- Matching on fields is *exact*
- You can ask for a printer with a certain speed, but not for one *greater than* a certain speed
- Additional services may be used if complex boolean expressions are needed

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Leasing

- Because services can come and go, network connections can be lost, etc, a distributed garbage collection mechanism is needed
- Services which register are granted a lease
- Registration lasts for as long as the lease
- When the lease expires, the service is removed
- Leases can be renewed

Non-distributed Application

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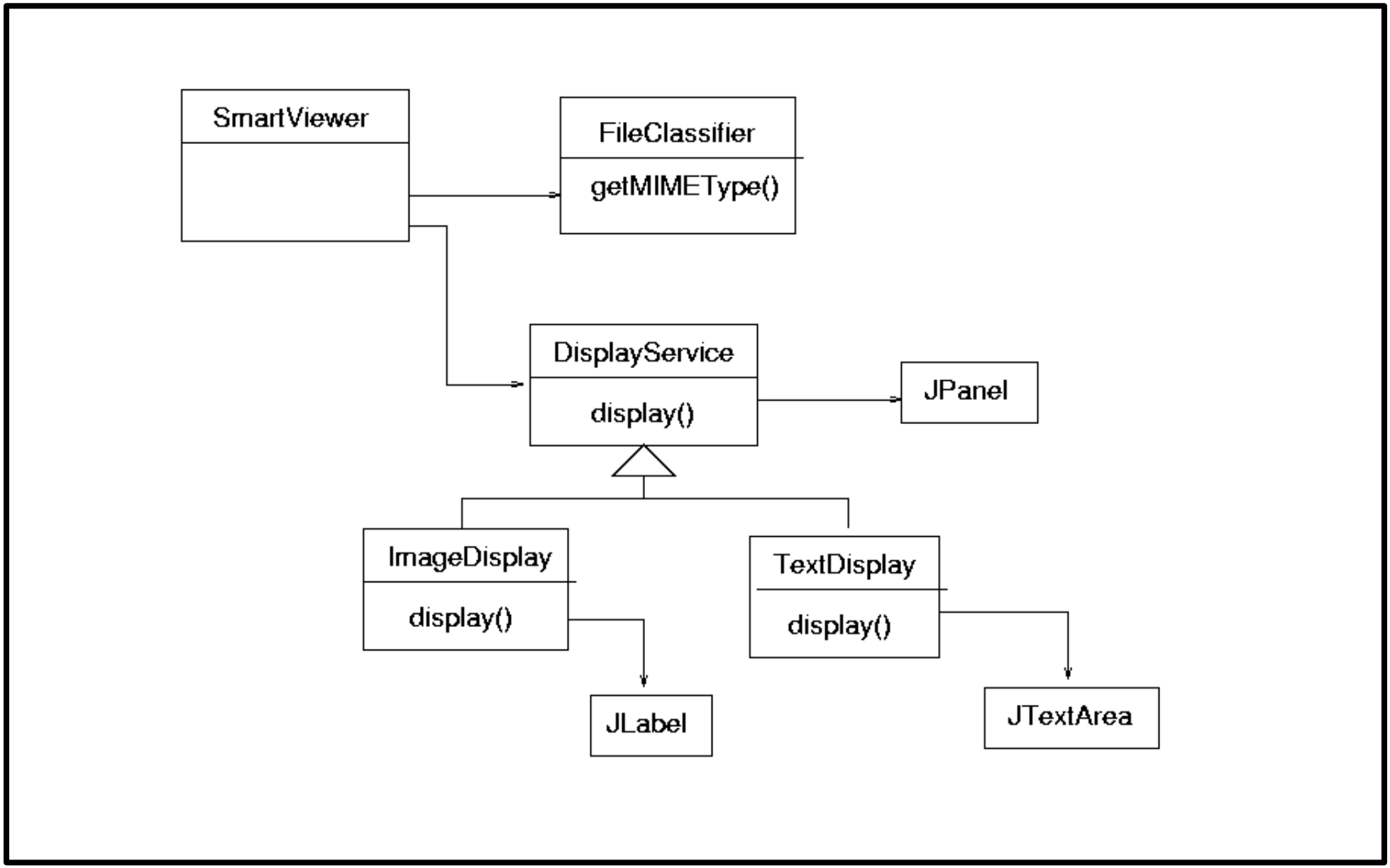
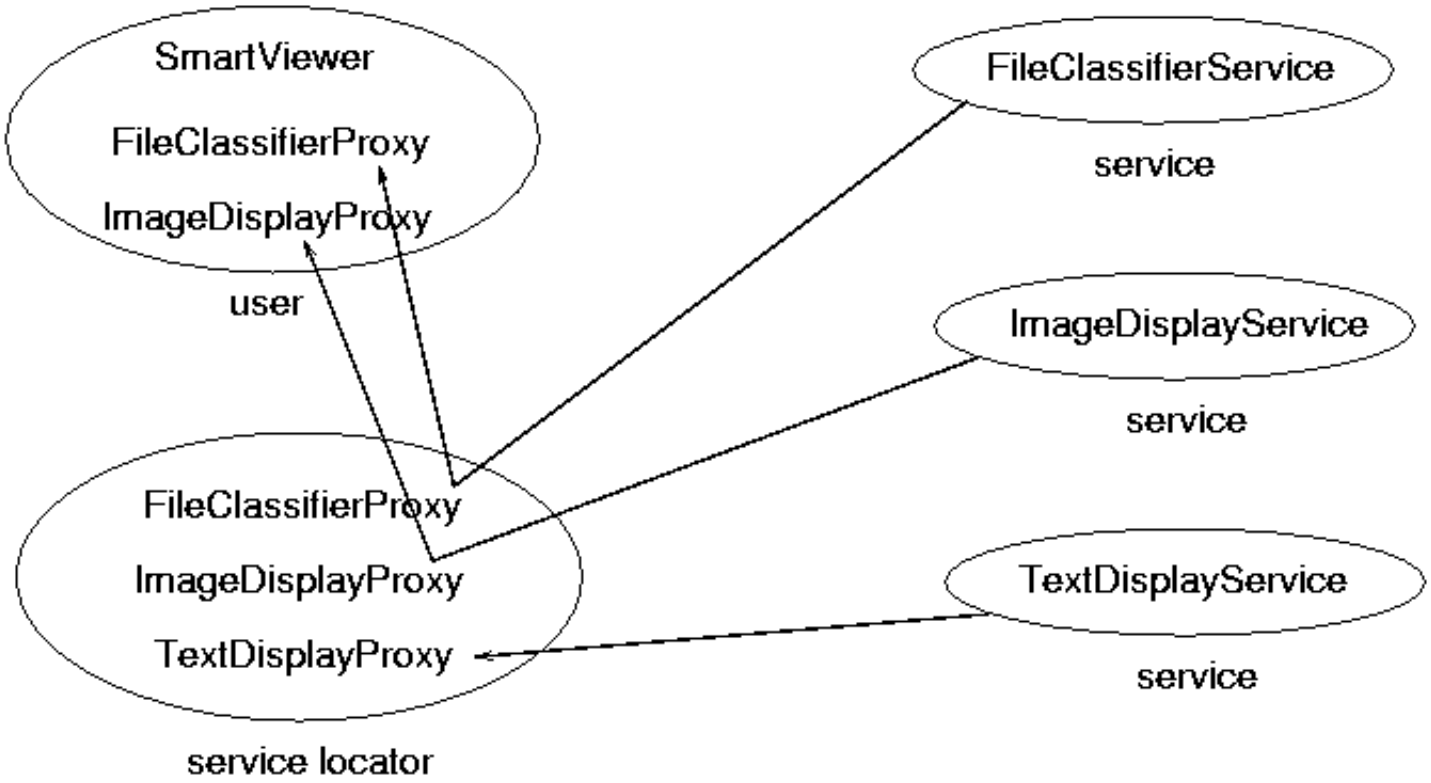

SmartViewer
FileClassifier
getMIMEType()
DisplayService
display()
JPanel
ImageDisplay
display()
TextDisplay
display()
JLabel
JTextArea

Distributed Version



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Client Structure

Internally a client will look like

```
prepare for discovery
discover a lookup service
prepare a template for lookup search
lookup a service
call the service
```

The following code is simplified from the real case. It attempts to find a `FileClassifier` service, calling the method `getMIMEType()` on this service.

```
public class TestUnicastFileClassifier {

    public static void main(String argv[]) {
        new TestUnicastFileClassifier();
    }

    public TestUnicastFileClassifier() {
        LookupLocator lookup = null;
        ServiceRegistrar registrar = null;
        FileClassifier classifier = null;

        // Prepare for discovery
        lookup = new LookupLocator("jini://www.all_about_files.com");

        // Discover a lookup service
        // This uses the synchronous unicast protocol
        registrar = lookup.getRegistrar();

        // Prepare a template for lookup search
        Class[] classes = new Class[] {FileClassifier.class};
        ServiceTemplate template = new ServiceTemplate(null, classes, null);

        // Lookup a service
```

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```
        classifier = (FileClassifier) registrar.lookup(template);

        // Call the service
        MIMEType type;
        type = classifier.getMIMEType("file1.txt");
        System.out.println("Type is " + type.toString());
    }
} // TestUnicastFileClassifier
```

Server Structure

```
prepare for discovery
discover a lookup service
create information about a service
export a service
renew leasing periodically
```

The following code is simplified from the real case. It exports an implementation of a file classifier service, as a `FileClassifierImpl` object.

```
public class FileClassifierServer implements DiscoveryListener {

    protected LeaseRenewalManager leaseManager = new LeaseRenewalManager();

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

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```
        new FileClassifierServer();

        // keep server running forever to
        // - allow time for locator discovery and
        // - keep re-registering the lease
        Thread.currentThread().sleep(Lease.FOREVER);
    }

    public FileClassifierServer() {
        LookupDiscovery discover = null;

        // Prepare for discovery - empty here

        // Discover a lookup service
        // This uses the asynchronous multicast protocol,
        // which calls back into the discovered() method
        discover = new LookupDiscovery(LookupDiscovery.ALL_GROUPS);

        discover.addDiscoveryListener(this);
    }

    public void discovered(DiscoveryEvent evt) {
```

```
        ServiceRegistrar registrar = evt.getRegistrars()[0];
        // At this point we have discovered a lookup service

        // Create information about a service
        ServiceItem item = new ServiceItem(null,
                                           new FileClassifierImpl(),
                                           null);

        // Export a service
        ServiceRegistration reg = registrar.register(item, Lease.FOREVER);

        // Renew leasing
        leaseManager.renewUntil(reg.getLease(), Lease.FOREVER, this);
    }
} // FileClassifierServer
```

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DISCOVERING A LOOKUP SERVICE

Lookup Service

- Before a client or service can do anything, they find a lookup service
- Unicast lookup can be made to known locations
- Multicast search can be made for unknown locations
- Sun supply a lookup service called `reggie`

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Unicast discovery

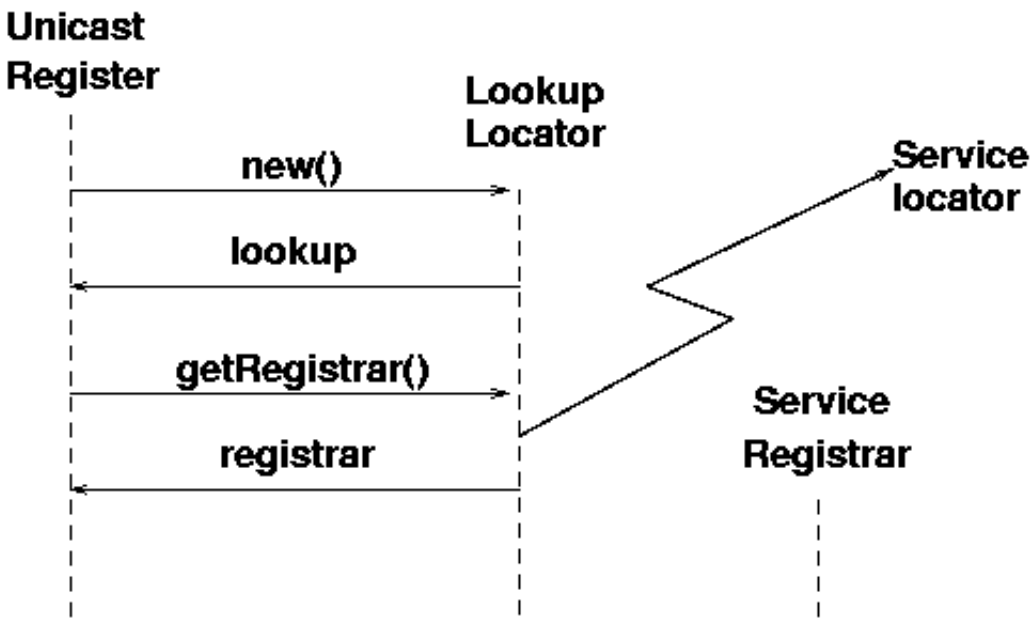
- The class `LookupLocator` handles unicast discovery

```
public class LookupLocator {
    public LookupLocator(String url);
    public LookupLocator(String host, int port);

    String getHost();
    int getPort();

    ServiceRegistrar getRegistrar() throws ...;
}
```

- `LookupDiscovery` specifies the url. Its `getRegistrar()` method returns a proxy for the lookup service



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Unicast discovery program

```
import net.jini.core.discovery.LookupLocator;
import net.jini.core.lookup.ServiceRegistrar;

public class UnicastRegister  {

    static public void main(String argv[]) {
        new UnicastRegister();
    }

    public UnicastRegister() {
        LookupLocator lookup = null;
        ServiceRegistrar registrar = null;

        try {
            lookup = new LookupLocator("jini://localhost");
        } catch(java.net.MalformedURLException e) {
            System.err.println("Lookup failed: " + e.toString());
            System.exit(1);
        }
```

```
        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);
        }
        System.out.println("Registrar found");

        // the code takes separate routes from here for client or service
    }

} // UnicastRegister
```

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Multicast discovery

- Broadcast discovery is done using the class `LookupDiscovery`

```
public class LookupDiscovery {
    public LookupDiscovery(String[] groups);

    addDiscoveryListener(LookupDiscoveryListener l);
}
```

- Replies are handled asynchronously by a listener

```
interface LookupDiscoveryListener {
    public void discovered(DiscoveryEvent e);
    public void discarded(DiscoveryEvent e);
}
```

- The event contains registrar information

```
public class DiscoveryEvent {
    Registrar[] getRegistrars();
}
```

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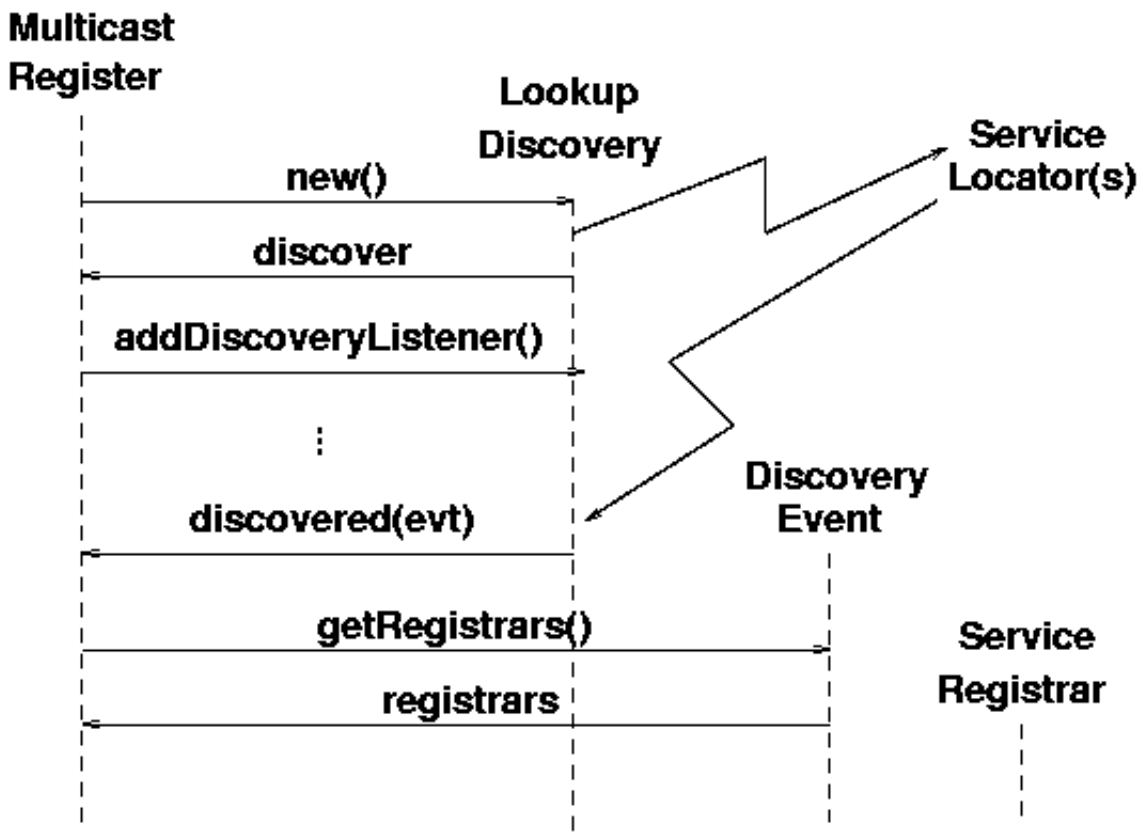
Multicast
Register
Lookup
Discovery
Service
Locator(s)
new()
discover
addDiscoveryListener()
discovered(evt)
Discovery
Event
getRegistrars()
registrars
Service
Registrar

Multicast discovery program

```
import net.jini.discovery.LookupDiscovery;
import net.jini.discovery.DiscoveryListener;
import net.jini.discovery.DiscoveryEvent;
import net.jini.core.lookup.ServiceRegistrar;

public class MulticastRegister implements DiscoveryListener {

    static public void main(String argv[]) {
        new MulticastRegister();

        // stay around long enough to receive replies
        try {
            Thread.currentThread().sleep(10000L);
        } catch(java.lang.InterruptedException e) {
            // do nothing
        }
    }

    public MulticastRegister() {
        LookupDiscovery discover = null;
```

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```
        try {
            discover = new LookupDiscovery(LookupDiscovery.ALL_GROUPS);
        } catch(Exception e) {
            System.err.println(e.toString());
            e.printStackTrace();
            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];

            // the code takes separate routes from here for client or service
            System.out.println("found a service locator");
        }
    }
```

```
    public void discarded(DiscoveryEvent evt) {

    }
} // MulticastRegister
```

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ServiceRegistrar

- Both lookup methods return a `ServiceRegistrar`. This is a proxy for the lookup service

```
public interface ServiceRegistrar {
    public ServiceRegistration register(ServiceItem i,
                                        long leaseDuration);

    public Object lookup(ServiceTemplate tmpl);
    public ServiceMatches lookup(ServiceTemplate tmpl, int maxMatches);

    LookupLocator getLocator();
}
```

- The `register()` method is used by a *service*
- The `lookup()` methods are used by a *client*. The first returns a single service, the second a set of services
- The `getLocator()` method can say where the lookup service is

ENTRIES

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Entry class

- Entries are additional information about a service, such as location, name, cost
- This information is not part of the service object itself
- The additional information can be used to select between otherwise identical services e.g. a *colour* printer, a *four-slice* toaster
- Entries implement `Entry`

```
public interface Entry {}
```

- There are a bunch of convenience implementations such as
  - `Address`
  - `Comment`
  - `Name`
  - `ServiceInfo`

Creating entries

- You can create your own classes, or use the given ones
- Typical code

```
Entry[] entries = new Entry[] {new Comment("best toaster made"),
                               new Name("Classy Toaster")};
```

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Interfaces, implementations and entries

- A client looks for an instance of an interface
- It may qualify the search with entries
- A service exports an implementation of this interface
- A service will also export additional entry information, as much as it can

CLIENT

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Problem domain

- Files have a type, that can be described by a MIME type

```
public class MIMEType implements java.io.Serializable {
    protected String contentType;
    protected String subType;

    public MIMEType(String contentTpe, String subType) {...}

    public String toString() {...}
}
```

  (It may need to be serialized, to move it from one machine to another)
- A file classifier can take a filename and use this to work out the MIME type, using an internal table

```
public interface FileClassifier {
    MIMEType getMIMEType(String fileName)
        throws java.rmi.RemoteException;
}
```

(The method may be executing remotely, so can throw a remote exception)

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Unicast client

Use this pattern when you do know where the lookup locator is:

```
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;

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");
    } 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);
```

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```
}

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
```

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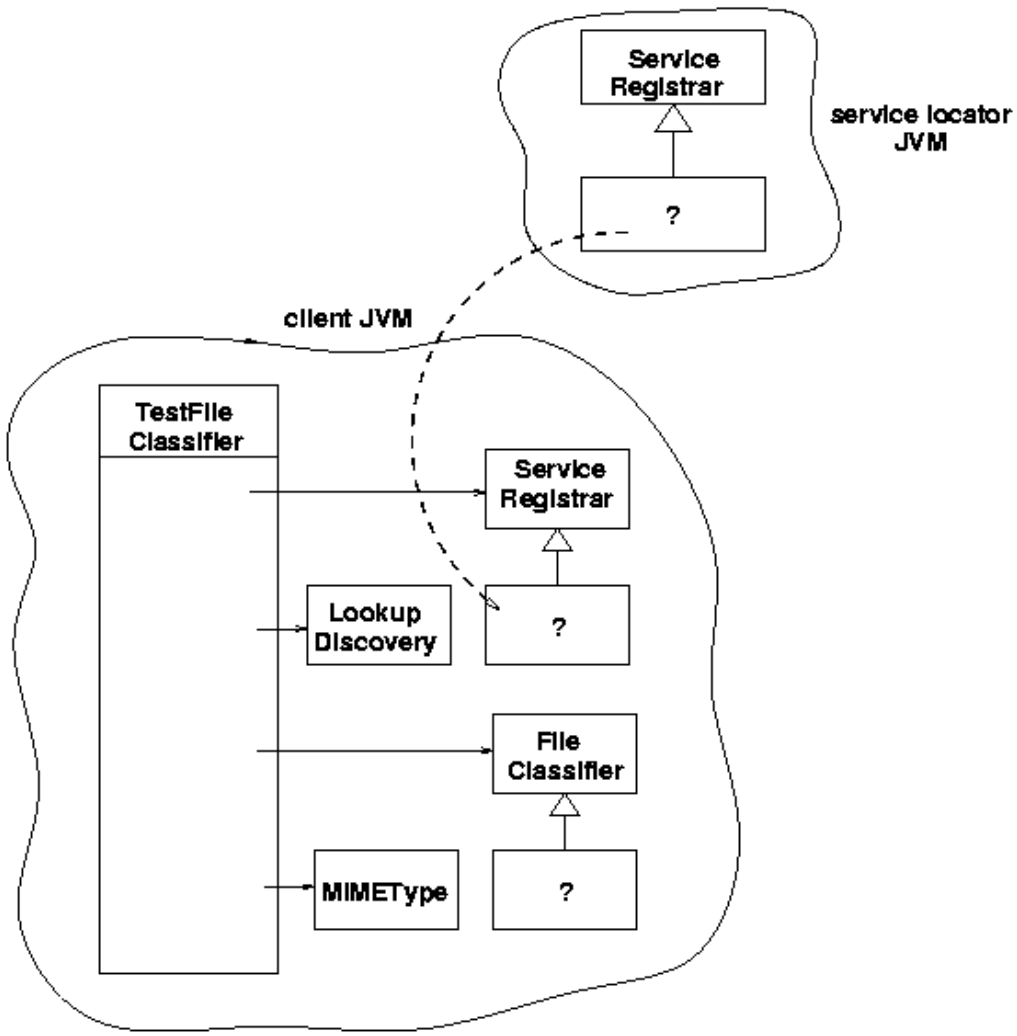
Client and service locator JVM's

The two JVM's look like



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Multicast client

Use this pattern when you don't know where the lookup locator(s) are:

```
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;

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);
```

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```
}

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("Service found");
        ServiceRegistrar registrar = registrars[n];
        try {
            classifier = (FileClassifier) registrar.lookup(template);
        } catch(java.rmi.RemoteException e) {
            e.printStackTrace();
            System.exit(2);
        }
        if (classifier == null) {
            System.out.println("Classifier null");
            continue;
```

```
            }
            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);
        }
    }

    public void discarded(DiscoveryEvent evt) {
        // empty
    }
} // TestFileClassifier
```

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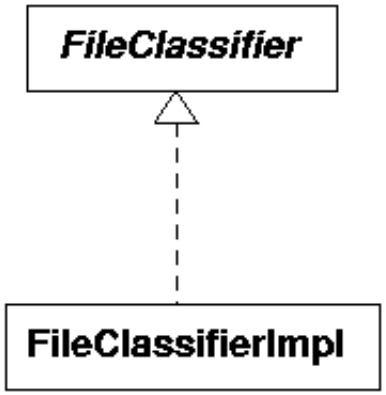
PROXY IMPLEMENTATION CHOICES

Proxy is the Service

- The complete service may be uploaded, so there is no separate proxy



- The client uses `FileClassifier`
- The server creates a `FileClassifierImpl`
- The server exports the `FileClassifierImpl`
- This is a “fat” proxy model, with no processing being done on the server side
- This is suitable for software services that do not need to maintain state on

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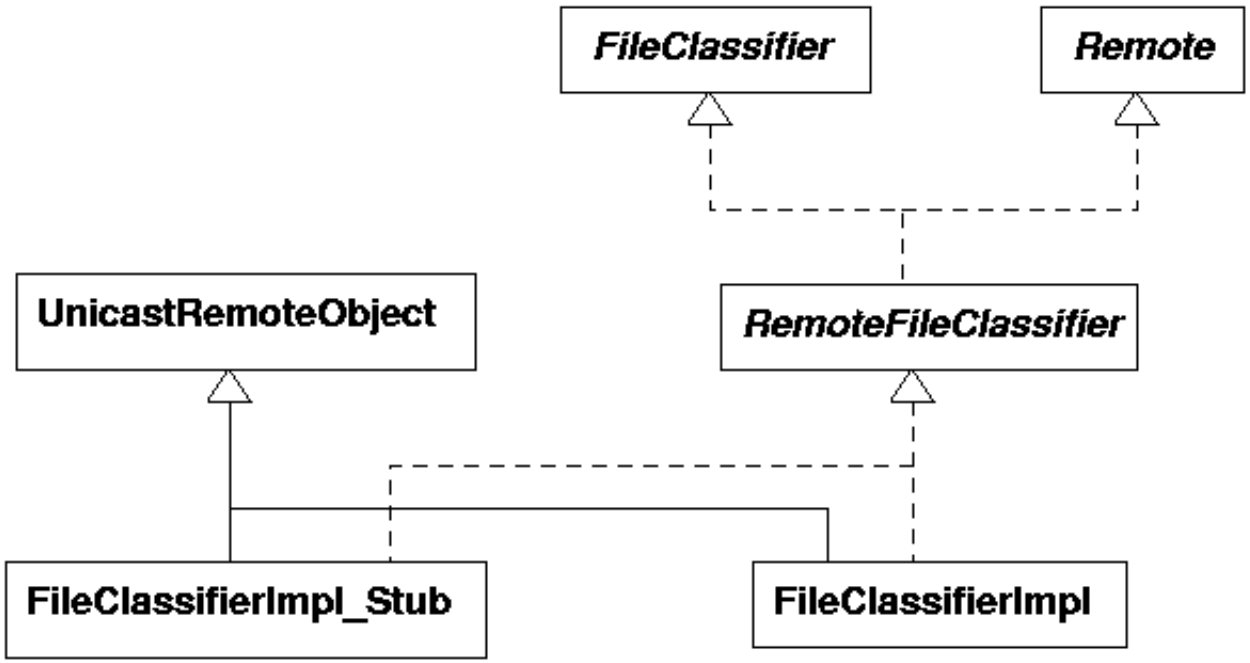
the server side

RMI Proxies

- If RMI stubs are used to implement the proxy, it looks like



- The client uses `FileClassifier`
- The server creates a `FileClassifierImpl`

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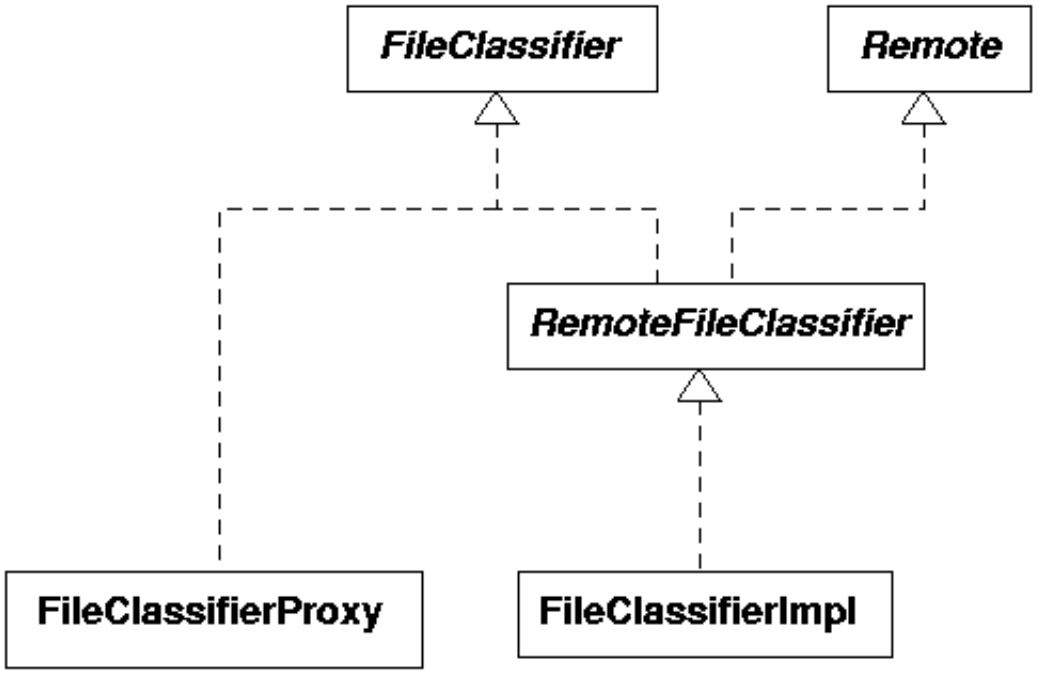
- The RMI runtime ensures that a `FileClassifierimpl_Stub` is exported to the service locator
- This is a “thin” proxy, with no processing being done on the client side
- This is closest to the standard RPC model between client and service

Non-RMI Proxy

- If RMI is not used, the proxy must be explicitly created



- The client uses `FileClassifier` (like before - it doesn't care what the proxy is)

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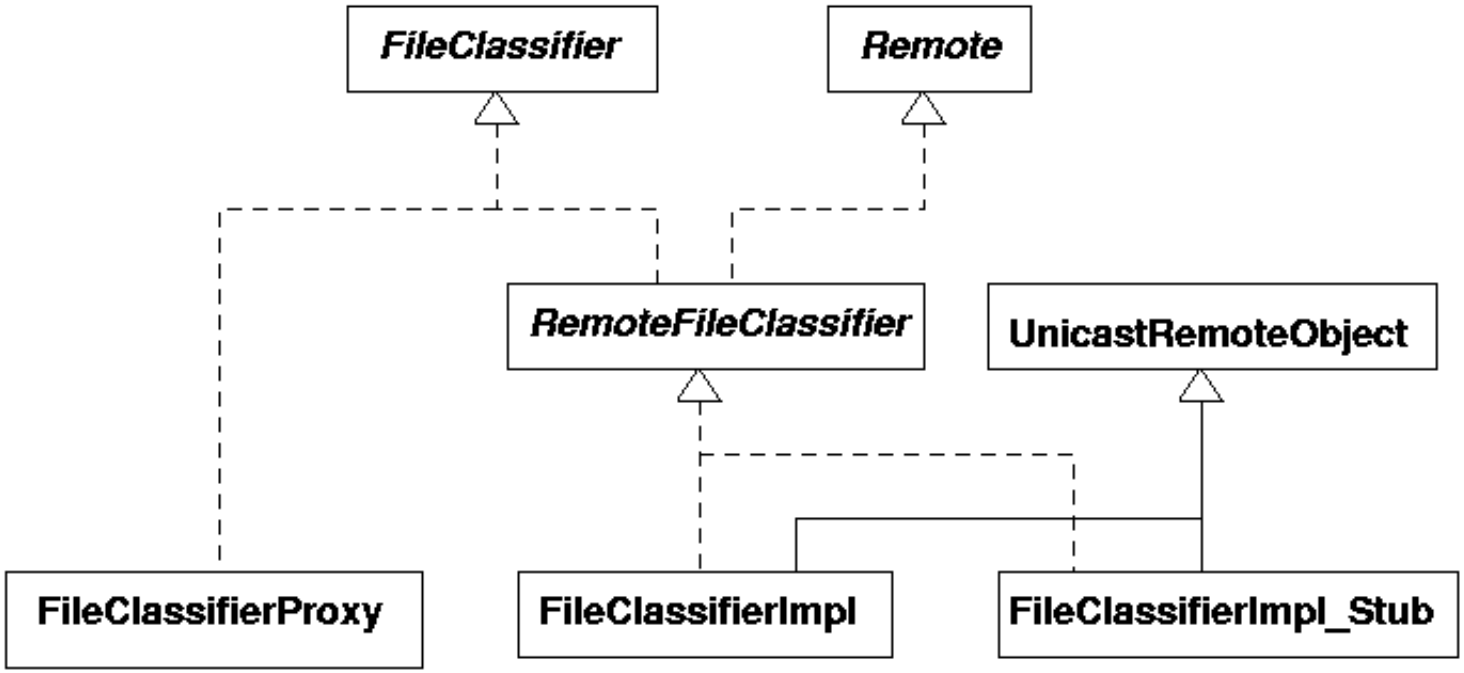
- The server creates a `FileClassifierImpl` and a `FileClassifierProxy`
- The server exports a `FileClassifierProxy`
- The proxy and service communicate using some protocol
- This can have processing done on both sides
- This is good for client-server problems communicating on their own ports with their own protocol. The proxy is the heart of the client

RMI and Non-RMI Proxies

- You can use both RMI and a non-RMI proxy



- The client uses `FileClassifier`
- The server creates a `FileClassifierImpl` and a

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`FileClassifierProxy`

- The server exports a `FileClassifierProxy` and a `FileClassifierImpl_Stub`
- The proxy uses the stub locally (on the client), which uses RMI to talk back to the service
- This can have processing done on both sides, using an RPC-like model for communication

PROXY IS THE SERVICE

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Service implementation

```
package option2;

import common.MIMEType;
import common.FileClassifier;

public class FileClassifierImpl implements FileClassifier {

    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
```

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File classifier server

```
package option2;

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 com.sun.jini.lease.LeaseRenewalManager;
import com.sun.jini.lease.LeaseListener;
import com.sun.jini.lease.LeaseRenewalEvent;

public class FileClassifierServer implements DiscoveryListener,
                                              LeaseListener {

    protected LeaseRenewalManager leaseManager = new LeaseRenewalManager();
```

```
public static void main(String argv[]) {
    new FileClassifierServer();

    // keep server running forever to
    // - allow time for locator discovery and
    // - keep re-registering the lease
            try {
        Thread.currentThread().sleep(Lease.FOREVER);
    } catch(java.lang.InterruptedException e) {
        // do nothing
    }
}

public FileClassifierServer() {

    LookupDiscovery discover = null;
    try {
        discover = new LookupDiscovery(LookupDiscovery.ALL_GROUPS);
    } catch(Exception e) {
        System.err.println(e.toString());
        System.exit(1);
    }
```

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```
        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(null,
                                               new FileClassifierImpl(),
                                               null);
            ServiceRegistration reg = null;
            try {
                reg = registrar.register(item, Lease.FOREVER);
            } catch(java.rmi.RemoteException e) {
                System.err.println("Register exception: " + e.toString());
            }
            System.out.println("service registered");
```

```
            // set lease renewal in place
            leaseManager.renewUntil(reg.getLease(), Lease.FOREVER, this);
        }
    }

    public void discarded(DiscoveryEvent evt) {

    }

    public void notify(LeaseRenewalEvent evt) {
        System.out.println("Lease expired " + evt.toString());
    }

} // FileClassifierServer
```

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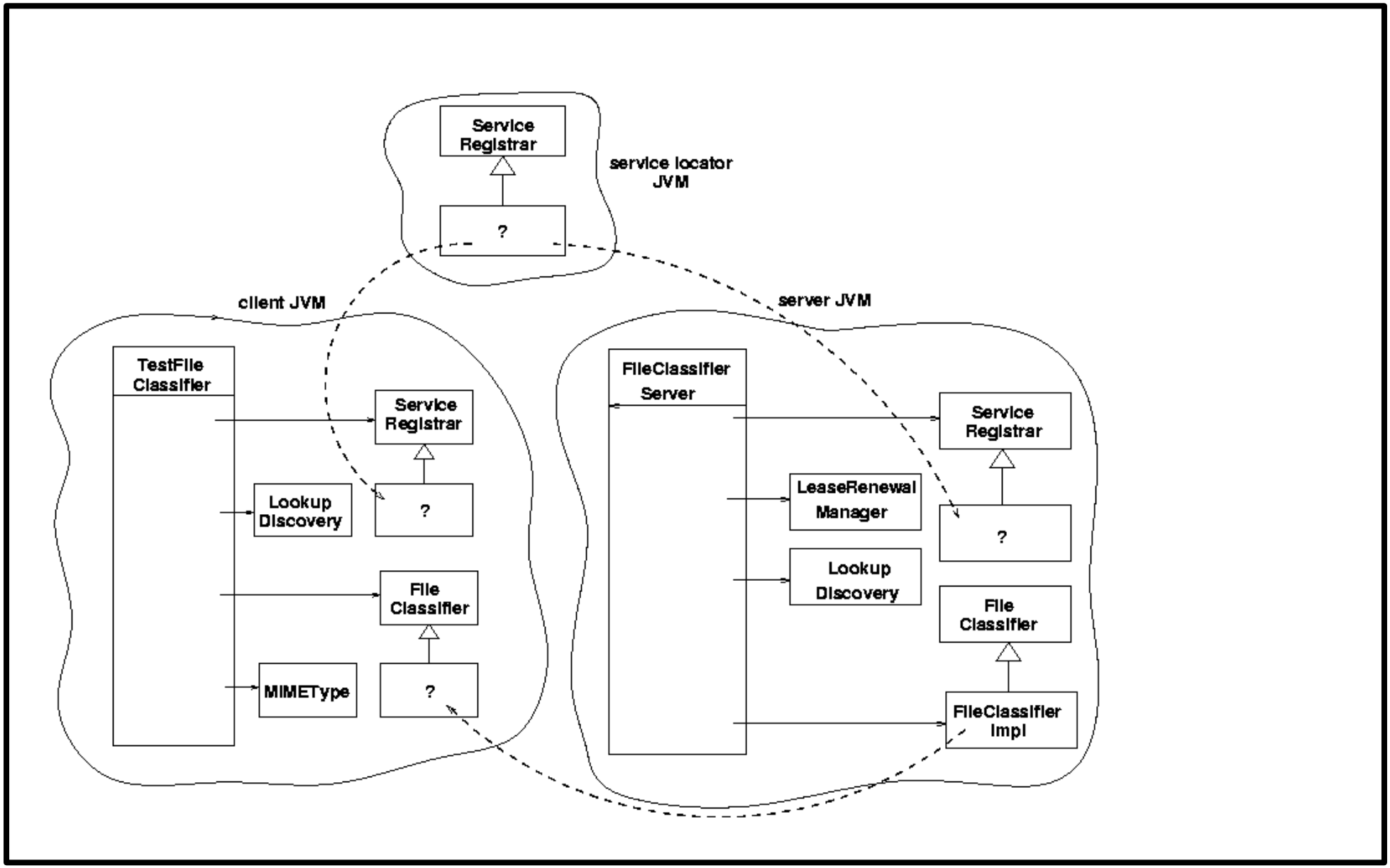
All the JVM's



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JOIN MANAGER

Join Manager

- There are common steps in any server:
  - contact all known service locators by unicast
  - search for unknown locators by multicast
  - register the service with all of these
  - install a lease manager to keep the service alive
- These are encapsulated in `JoinManager` (which will change in later versions of Jini)

```
public class JoinManager {
    public JoinManager(java.lang.Object obj,
                       Entry[] attrSets,
                       java.lang.String[] groups,
                       LookupLocator[] locators,
                       ServiceIDListener callback,
```

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```
                                LeaseRenewalManager leaseMgr);
        ...
    }
```

Service using Join Manager

```
package joinmgr;

import option2.FileClassifierImpl;

import com.sun.jini.lookup.JoinManager;
import net.jini.core.lookup.ServiceID;
import com.sun.jini.lookup.ServiceIDListener;
import com.sun.jini.lease.LeaseRenewalManager;
import net.jini.discovery.LookupDiscovery;

public class FileClassifierServer implements ServiceIDListener {

    public static void main(String argv[]) {
        new FileClassifierServer();

        // stay around long enough to receive replies
        try {
```

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```
            Thread.currentThread().sleep(1000000L);
        } catch(java.lang.InterruptedException e) {
            // do nothing
        }

    }

    public FileClassifierServer() {

        JoinManager joinMgr = null;
        try {
            joinMgr = new JoinManager(new FileClassifierImpl(),
                                      null,
                                      LookupDiscovery.ALL_GROUPS,
                                      null,
                                      this,
                                      new LeaseRenewalManager());
        } catch(Exception e) {
            e.printStackTrace();
            System.exit(1);
```

```
        }
    }

    public void serviceIDNotify(ServiceID serviceID) {
        System.out.println("got service ID " + serviceID.toString());
    }

} // FileClassifierServer
```

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SECURITY

JDK 1.2 Security

- Jini security uses the security model of JDK 1.2, with no changes or extensions
- Security is based on granting permissions (access rights), in security files
- Debug the application with a slack policy

```
grant {
    permission java.security.AllPermission "", "";
};
```

- Leave it like this of production only at your peril

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Service requirements

```
grant {
    permission net.jini.discovery.DiscoveryPermission "*";
    // multicast request address
    permission java.net.SocketPermission "224.0.1.85", "connect,accept";
    // multicast announcement address
    permission java.net.SocketPermission "224.0.1.84", "connect,accept";

    // RMI connections
    permission java.net.SocketPermission "*.dstc.edu.au:1024-", "connect,accept";
    permission java.net.SocketPermission "130.102.176.249:1024-", "connect,accept";
    permission java.net.SocketPermission "127.0.0.1:1024-", "connect,accept";

    // reading parameters
    // like net.jini.discovery.debug!
    permission java.util.PropertyPermission "net.jini.discovery.*", "read";
};
```

Client requirements

The client is most at risk as it imports remote objects into its address space

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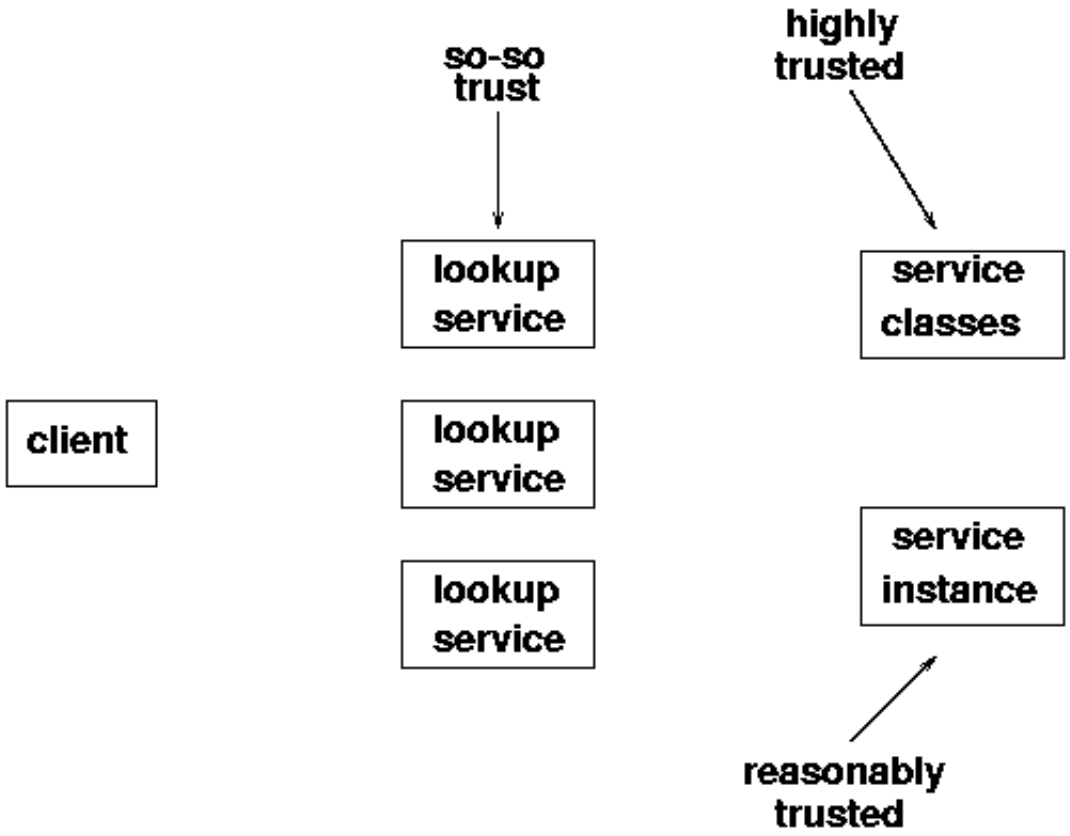
so-so
trust
highly
trusted
lookup
service
service
classes
client
lookup
service
service
instance
lookup
service
reasonably
trusted

Client policy

```
grant {
    permission net.jini.discovery.DiscoveryPermission "*";

    // multicast request address
    permission java.net.SocketPermission "224.0.1.85", "connect,accept";
    // multicast announcement address
    permission java.net.SocketPermission "224.0.1.84", "connect,accept";

    // RMI connections
    permission java.net.SocketPermission "127.0.0.1:1024-", "connect,accept";
    permission java.net.SocketPermission "*.dstc.edu.au:1024-", "connect,accept";
    permission java.net.SocketPermission "130.102.176.249:1024-", "connect,accept";

    // DANGER
    // HTTP connections - this is where external code may come in - careful!!!
    permission java.net.SocketPermission "127.0.0.1:80", "connect,accept";
    permission java.net.SocketPermission "*.dstc.edu.au:80", "connect,accept";

    // reading parameters
```

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```
    // like net.jini.discovery.debug!
    permission java.util.PropertyPermission "net.jini.discovery.*", "read";

};
```

REMOTE EVENTS

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Event models

- Java has several event models
- Input events are generated by user actions such as key press, mouse click. These are placed into an event queue by one thread, removed by another
- Semantic events are generated by GUI components, such as mouse click in a `Button` generates an `ActionEvent`
- Property changes in objects generate `PropertyChange` events for Java beans
- Jini events are designed to work in a network environment
  - Events may be lost
  - Event delivery may have time delays, and state information may be out of date when it arrives
  - A listener may have disappeared or be unreachable, so listeners need to be on leases
  - Multiple event types (such as AWT events) require class availability while

simple types don’t

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Remote events

- Event listeners must implement

```
public interface RemoteEventListener {
    public void notify(RemoteEvent evt) throws ...:
}
```

- Where

```
public class RemoteEvent {
    public long getID();                  // distinguish event types
    public long getSequenceNumber(); // like a timestamp
    public MarshalledObject getRegistrationObject(); // handback
```

- There is no equivalent within Jini to `addActionListener()`, `addPropertyChangeListener()`, etc. Each object must look after its own

listener list and decide when and how to call it. But...

- Registration of a remote event listener must return

```
public class EventRegistration {
    public EventRegistration(long eventID, Object source,
                             Lease lease, long seqNum);
    public long getID();
    public Object getSource();
    public Lease getLease();
    public long getSequenceNumber();
}
```

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A single listener list

A list with only one listener on it can be done by

```
protected RemoteEventListener listener = null;

public EventRegistration addRemoteListener(RemoteEventListener listener)
       throws java.util.TooManyListenersException {
    if (this.listener == null {
        this.listener = listener;
    } else {
        throw new java.util.TooManyListenersException();
    }
    return new EventRegistration(0L, this, null, 0L);
}
```

Single listener event notification

The source object can send an event to its listener by

```
protected void fireNotify(long eventID,
                          long seqNum) {
    if (listener == null) {
        return;
    }

    RemoteEvent remoteEvent = new RemoteEvent(this, eventID,
                                              seqNum, null);
    listener.notify(remoteEvent);
}
```

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Mutable file classifier

Allow the file classifier to change its list of MIME type mappings, and notify listeners when it does so

```
package mutable;

import java.rmi.server.UnicastRemoteObject;
import java.rmi.MarshalledObject;
import net.jini.core.event.RemoteEventListener;
import net.jini.core.event.RemoteEvent;
import net.jini.core.event.EventRegistration;
import java.rmi.RemoteException;
import net.jini.core.event.UnknownEventException ;

import javax.swing.event.EventListenerList;

import common.MIMEType;
import common.MutableFileClassifier;
import java.util.Map;
import java.util.HashMap;
```

```
public class FileClassifierImpl extends  UnicastRemoteObject
                                implements RemoteFileClassifier {

    /**
     * Map of String extensions to MIME types
     */
    protected Map map = new HashMap();

    /**
     * Listeners for change events
     */
    protected EventListenerList listenerList = new EventListenerList();

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

        MIMEType type;
        String fileExtension;
        int dotIndex = fileName.lastIndexOf('.');

        if (dotIndex == -1 || dotIndex + 1 == fileName.length()) {
            // can't find suitable suffix
            return null;
        }
```

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```
        fileExtension= fileName.substring(dotIndex + 1);
        type = (MIMEType) map.get(fileExtension);
        return type;
    }

    public void addType(String suffix, MIMEType type)
        throws java.rmi.RemoteException {
        map.put(suffix, type);
        fireNotify(ADD_TYPE);
    }

    public void removeMIMEType(String suffix, MIMEType type)
        throws java.rmi.RemoteException {
        if (map.remove(suffix) != null) {
            fireNotify(REMOVE_TYPE);
        }
    }

    public EventRegistration addRemoteListener(RemoteEventListener listener)
        throws java.rmi.RemoteException {
        listenerList.add(RemoteEventListener.class, listener);

        return new EventRegistration(0, this, null, 0);
    }
```

```
// Notify all listeners that have registered interest for
// notification on this event type.  The event instance
// is lazily created using the parameters passed into
// the fire method.

protected void fireNotify(long eventID) {
    RemoteEvent remoteEvent = null;

    // Guaranteed to return a non-null array
    Object[] listeners = listenerList.getListenerList();

    // Process the listeners last to first, notifying
    // those that are interested in this event
    for (int i = listeners.length - 2; i >= 0; i -= 2) {
        if (listeners[i] == RemoteEventListener.class) {
            RemoteEventListener listener = (RemoteEventListener) listeners[i+1];
            if (remoteEvent == null) {
                remoteEvent = new RemoteEvent(this, eventID,
                                              0L, null);
            }
            try {
                listener.notify(remoteEvent);
            } catch(UnknownEventException e) {
                e.printStackTrace();
            } catch(RemoteException e) {
```

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```
                    e.printStackTrace();
                }
            }
        }
    }

    public FileClassifierImpl()  throws java.rmi.RemoteException {
        // load a predefined set of MIME type mappings
        map.put("gif", new MIMEType("image", "gif"));
        map.put("jpeg", new MIMEType("image", "jpeg"));
        map.put("mpg", new MIMEType("video", "mpeg"));
        map.put("txt", new MIMEType("text", "plain"));
        map.put("html", new MIMEType("text", "html"));
    }
} // FileClassifierImpl
```

INTERFACING TO HARDWARE

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Lego MindStorms

MindStorms is a ‘‘Robotics Invention System’’

- A 16-bit computer called the RCX (a 16MHz Hitachi H8/3297), with 32k RAM
- The RCX can control 3 motors and read from 3 sensors
- Additional Lego parts - gears, wheels, sensors, motors
- Software can be downloaded by an infra-red link on a serial port
- Programs can be downloaded and run, or ‘‘immediate’’ commands can be run, sent on the IR link
- Normally programmed from a visual programming environment or from VB
- On a PC, interface to RCX is managed by an OCX
- Low-level machine-code is sent across the IR link

RCX programmed from Java

- The RCX can be programmed using the IR link attached to the serial port
- Machine code is sent on this serial port
- Java has a standard extension to drive the serial port, the `CommAPI`
- Dario Laverde has a Java class above this, to encapsulate talking to the RCX

```
package rcx;

public class RCXPort {
    public RCXPort(String port);
    public void addRCXListener(RCXListener rl);
    public boolean open();
    public void close();
    public boolean isOpen();
    public OutputStream getOutputStream();
    public InputStream getInputStream();
    public synchronized boolean write(byte[] bArray);
```

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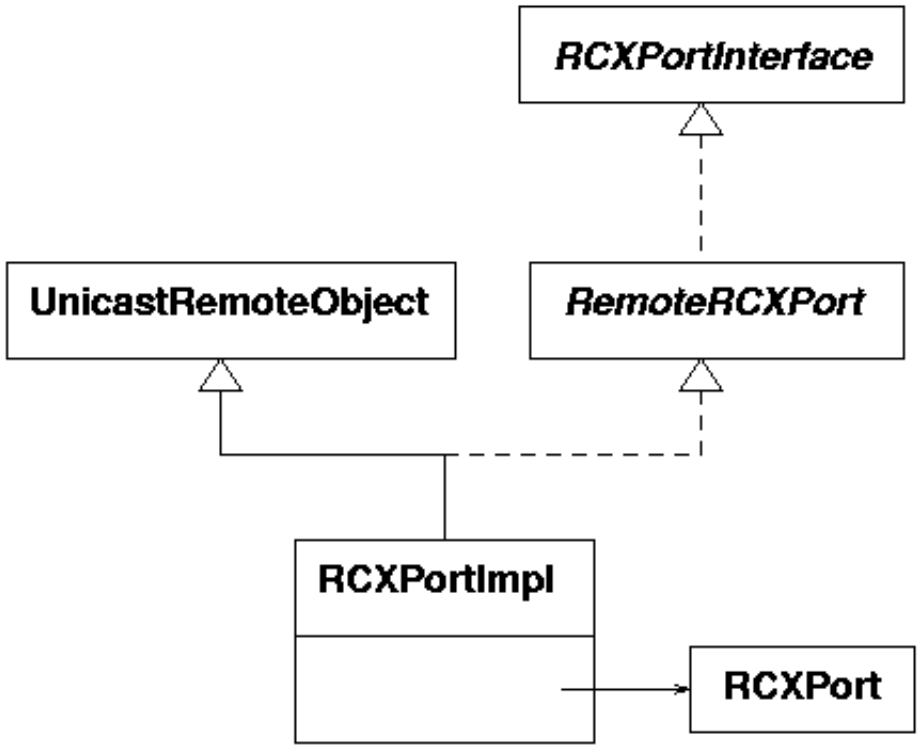
```
        public void processRead();
        public String getLastError();
        public void showTable();
        public static byte[] parseString(String str);
    }
```

MindStorms as a Jini Service



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RCX Port Impl

This is best done as an RMI proxy to the service on the server. The service has an `RCXPort` as attribute, and passes on messages to it.

```
package rcx.jini;

import java.rmi.server.UnicastRemoteObject;
import net.jini.core.event.RemoteEvent;
import net.jini.core.event.RemoteEventListener;
import rcx.*;
import java.io.*;
import java.util.*;

public class RCXPortImpl extends UnicastRemoteObject
    implements RemoteRCXPort, RCXListener {

    protected String error = null;
    protected byte[] message = null;
    protected RCXPort port = null;
    protected RemoteEventListener listener = null;
    protected long messageSeqNo, errorSeqNo;
```

```
public RCXPortImpl()
    throws java.rmi.RemoteException {

    Properties parameters;
    String portName = null;
    File f = new File("parameters.txt");
    if (!f.exists()) {
        f = new File(System.getProperty("user.dir")
                     + System.getProperty("path.separator")
                     + "parameters.txt");
    }
    if (f.exists()) {
        try {
            FileInputStream fis = new FileInputStream(f);
            parameters = new Properties();
            parameters.load(fis);
            fis.close();
            portName = parameters.getProperty("port");
        } catch (IOException e) { }
    } else {
        System.err.println("Can't find parameters.txt with \"port=...\" specified");
        System.exit(1);
    }

    port = new RCXPort(portName);
    port.addRCXListener(this);
```

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```
}

public boolean write(byte[] byteCommands)
    throws java.rmi.RemoteException {
    return port.write(byteCommands);
}

public byte[] parseString(String command)
    throws java.rmi.RemoteException {
    return RCXPort.parseString(command);
}

/**
 * Received a message from the RCX.
 * Send it to the listener
 */
public void receivedMessage(byte[] message) {

    this.message = message;

    // Send it out to listener
    if (listener == null) {
        return;
    }
```

```
        RemoteEvent evt = new RemoteEvent(this, MESSAGE_EVENT, messageSeqNo++, null);
        try {
            listener.notify(evt);
        } catch(net.jini.core.event.UnknownEventException e) {
            e.printStackTrace();
        } catch(java.rmi.RemoteException e) {
            e.printStackTrace();
        }
    }

    /**
     * Received an error message from the RCX.
     * Send it to the listener
     */
    public void receivedError(String error) {
        // System.err.println(error);

        // Send it out to listener
        if (listener == null) {
            return;
        }
        this.error = error;
        RemoteEvent evt = new RemoteEvent(this, ERROR_EVENT, errorSeqNo, null);
        try {
            listener.notify(evt);
        } catch(net.jini.core.event.UnknownEventException e) {
```

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```
            e.printStackTrace();
        } catch(java.rmi.RemoteException e) {
            e.printStackTrace();
        }
    }

    /**
     * Expected use: the RCX has returned a message,
     * and we have informed the listeners. They query
     * this method to find the message for the message
     * seqence number they were given in the RemoteEvent.
     * We could use this as an index into a table of messages.
     */
    public byte[] getMessage(long msgSeqNo) {
        return message;
    }

    /**
     * Expected use: the RCX has returned an error message,
     * and we have informed the listeners. They query
     * this method to find the error message for the error message
     * seqence number they were given in the RemoteEvent.
     * We could use this as an index into a table of messages.
     */
    public String getError(long errSeqNo) {
        return error;
```

```
    }

    /**
     * Add a listener for RCX messages.
     * Should allow more than one, or throw
     * TooManyListeners if more than one registers
     */
    public void addListener(RemoteEventListener listener) {
        this.listener = listener;
        messageSeqNo = 0;
        errorSeqNo = 0;
    }
} // RCXPortImpl
```

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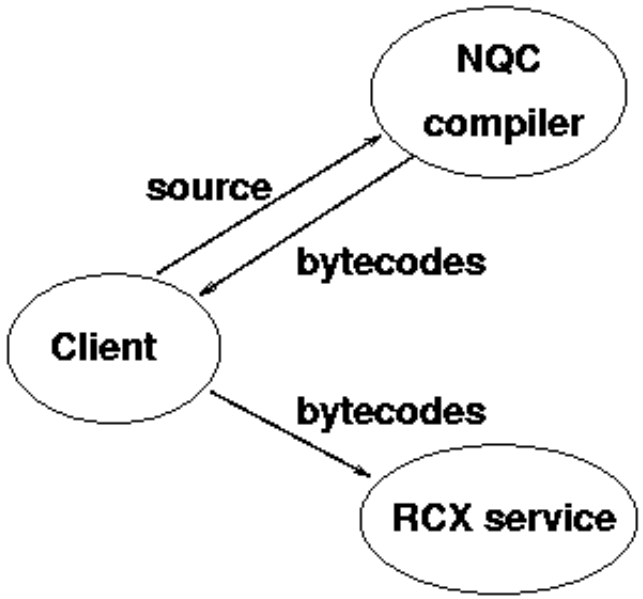
Future MindStorms Work

- Encapsulate client-side in a convenience class
- Make the ‘‘Not Quite C’’ RCX compiler available as a Jini service



- Make the RCX “network aware”, by using e.g. an alternative O/S such as LegOS

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CORBA AND JINI

CORBA

CORBA is also an infrastructure for distributed systems. It is targeted at a slightly different ‘‘space’’ to Jini, and has some minor and major differences.

- It allows specification of objects which can be distributed. The concentration is on distributed objects rather than on distributed services
- It is language-independent, using an Interface Definition Language (IDL) for specification of interfaces
- CORBA objects can be implemented in a number of languages, including C, C++, SmallTalk and Java
- Current versions of CORBA pass remote object references, rather than complete object instances. Each CORBA object lives within a server, and the object can only act within this server. This is more restricted than Jini, where an object can have instance data and class files sent to a remote location and execute there. This limitation in CORBA may change in future with ‘‘pass by value’’ parameters to methods

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CORBA Hello World

- HelloWorld in CORBA IDL can be

```
module corba {
    module HelloApp {
        interface Hello {
            string sayHello();
        };
    };
};
```

- This gives the Java

```
package corba.HelloApp;
public interface Hello
       extends org.omg.CORBA.Object,
```

```
                org.omg.CORBA.portable.IDLEntity {
        String sayHello();
    }
```

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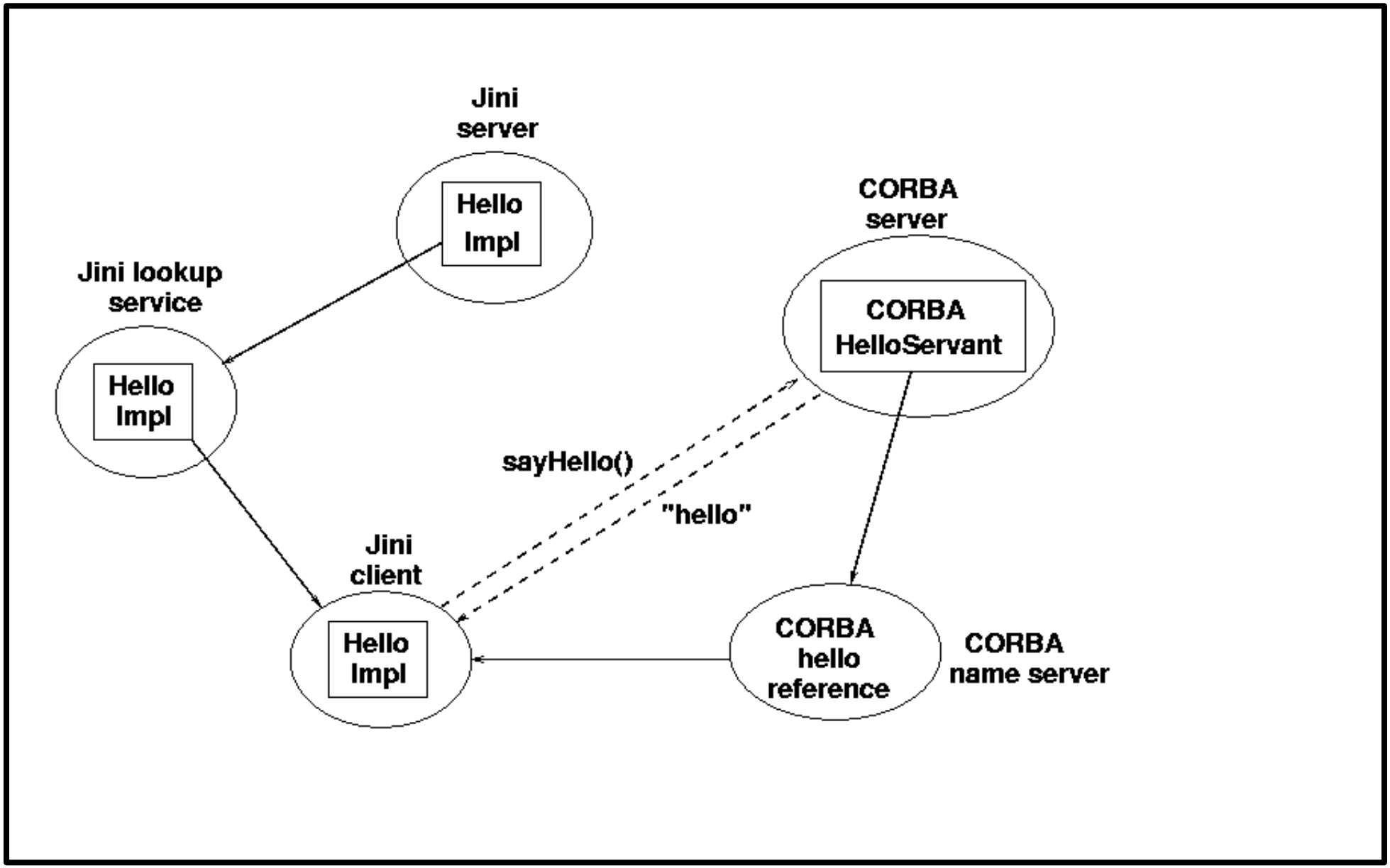
Jini/CORBA interaction



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Jini Hello service

```
package corba;

import org.omg.CosNaming.*;
import org.omg.CORBA.*;
import corba.HelloApp.*;

public class JavaHelloImpl implements JavaHello {

    protected Hello helloRef = null;
    protected String[] argv;

    public JavaHelloImpl(String[] argv) {
        this.argv = argv;
    }

    public String sayHello() {
        // Hello helloRef = null;
```

```
        if (helloRef == null) {
            helloRef = getHelloRef();
        }
        // now invoke methods on the CORBA proxy
        String hello = helloRef.sayHello();
        return hello;
    }

    protected Hello getHelloRef() {
        ORB orb = null;
        // Act like a CORBA client
        try {
            orb = ORB.init(argv, null);

            // find the CORBA name server
            org.omg.CORBA.Object objRef =
                orb.resolve_initial_references("NameService");
            NamingContext ncRef = NamingContextHelper.narrow(objRef);
```

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```
            // find the CORBA Hello proxy
            NameComponent nc = new NameComponent("Hello", "");
            NameComponent path[] = {nc};
            org.omg.CORBA.Object obj = ncRef.resolve(path);
            Hello helloRef = HelloHelper.narrow(obj);
            return helloRef;
        } catch(Exception e) {
            e.printStackTrace();
            return null;
        }
    }
} // JavaHelloImpl
```

Future Work

- Build bridges to other network services (CORBA Trader, JNDI, etc)
- Interface to other network protocols and implementations (BlueTooth, HomeRF, etc)
- Design standard interfaces to service types
- Build Jini proxies for hardware and software services
- Build embedded Jini engines (in Java or other languages) for hardware devices
- How does ‘‘service architecture’’ differ from client-server, CORBA, etc?

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CONCLUSION

Problems and Issues

- Objects moved around must be serializable
- Some common objects are not serializable e.g. Swing Toolbar, Swing JTextArea
- Objects with DLLs are not serializable e.g. MPEG players
- JDK 1.2 memory requirements are enormous compared to JDK 1.1
- Jini v1.0 has some bugs
- Limited documentation

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Conclusion

- Jini works
- The Jini programming model is cleaner than some others
- Hardware can be brought into the Jini world fairly easily
- Software services can be wrapped and brought into Jini
- Some things (like version maintenance in client/server) look much easier
- Speed and memory are problems
- Standard interfaces are required

URLs

- Jini: http://www.jini.org
- Jini FAQ: http://www.artima.com/jini/faq.html
- Lego MindStorms: http://www.legomindstorms.com
- Unofficial Lego MindStorms: http://www.crynwr.com/lego-robotics/
- Jini tutorial: http://pandonia.canberra.edu.au/java/jini/tutorial/Jini.xml
- Motorola Piano: http://www.mot.com/GSS/SSTG/piano/

Jan Newmarch (http://pandonia.canberra.edu.au)

jan@ise.canberra.edu
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