A tutorial on Jini

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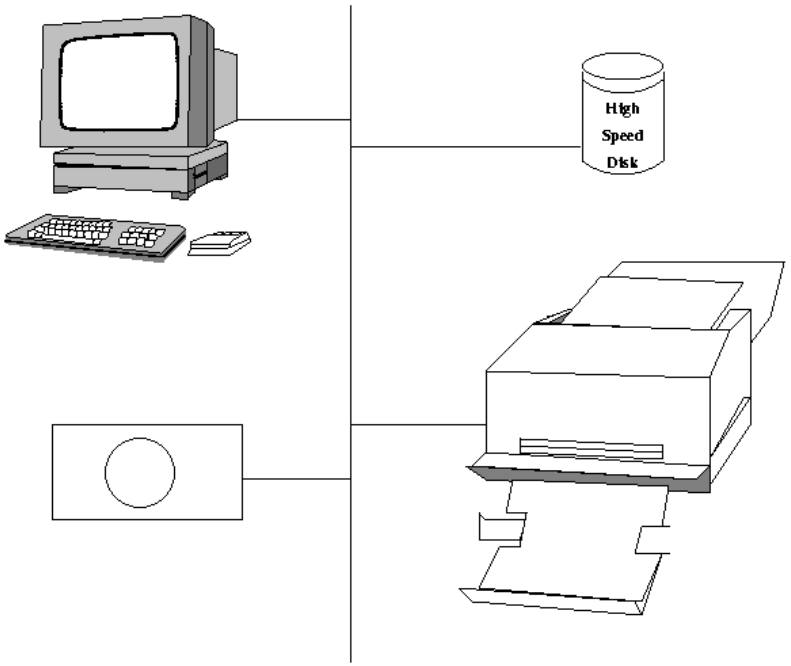
OVERVIEW

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



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

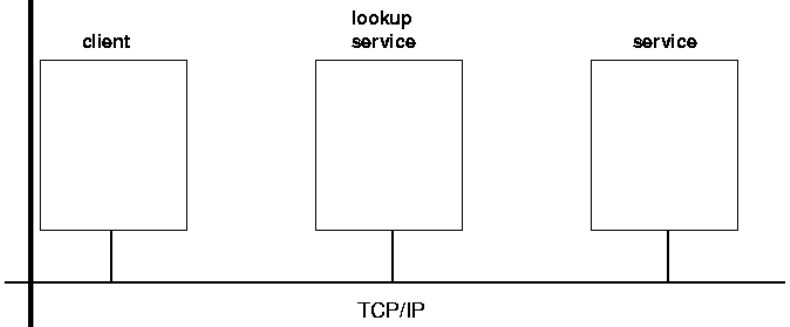


Figure 1: Components of a Jini federation

Service Registration

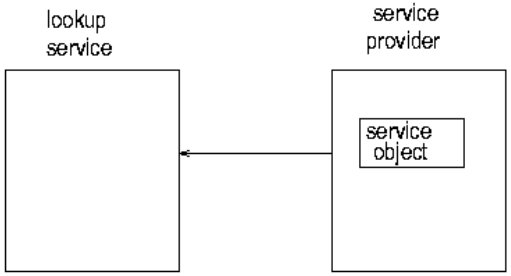


Figure 2: Querying for a service locator

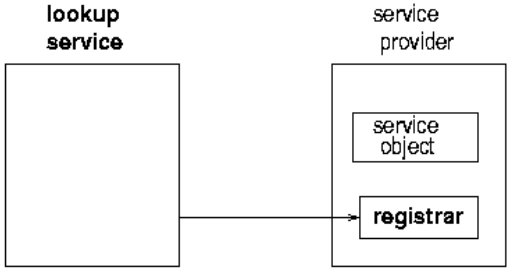


Figure 3: Registrar returned

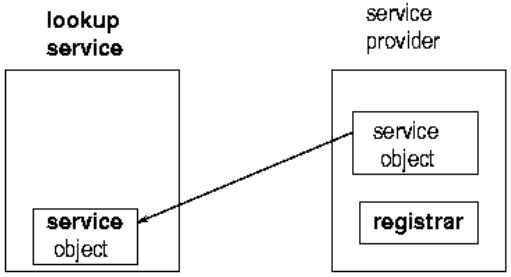


Figure 4: Service uploaded

Client Lookup

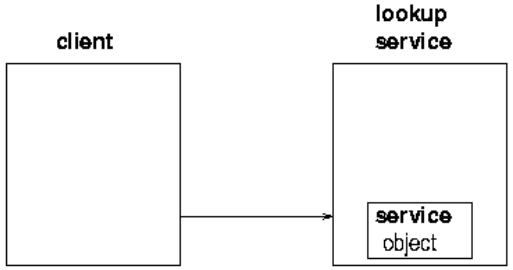


Figure 5: Querying for a service locator

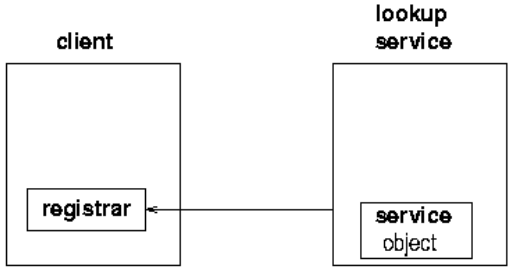


Figure 6: Registrar returned

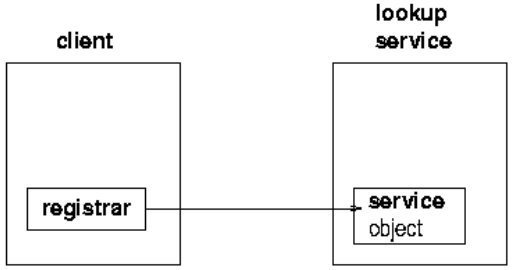


Figure 7: Asking for a service

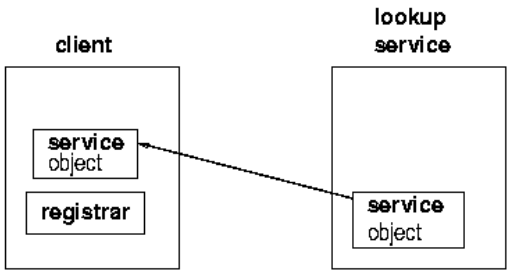
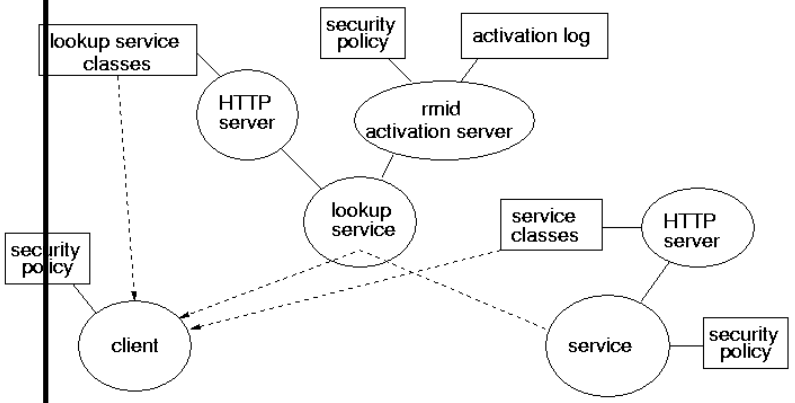


Figure 8: Service returned

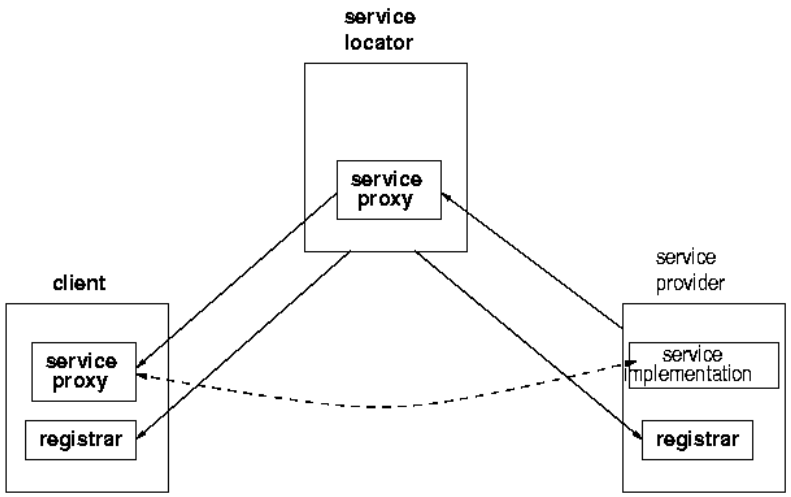
Support Services

- 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
- Services may use RMI Activation and may need to have rmid running
- Security permissions will need to be set using JDK 1.2 security model



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



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

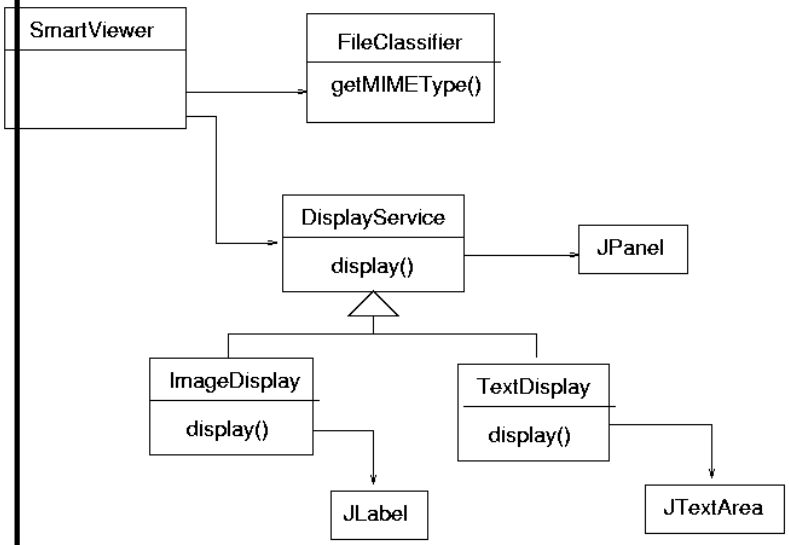
Service Location

- 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

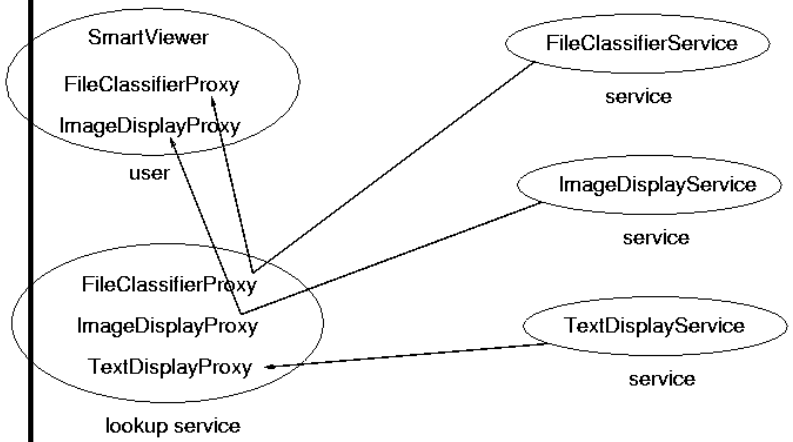
Leasing

- 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



Distributed Version



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
```


Server Structure

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

DISCOVERING A LOOKUP SERVICE

Multicast discovery

- Broadcast discovery is done using the class `LookupDiscovery`

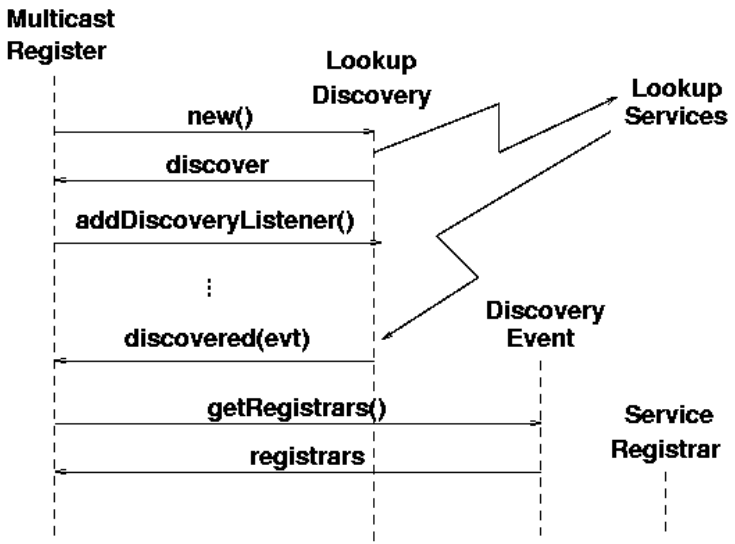
```
public class LookupDiscovery {
    public LookupDiscovery(String[] groups);

    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();
}
```



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;
        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
```

ServiceRegistrar

- Unicast and multicast 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

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")};
```

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

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)

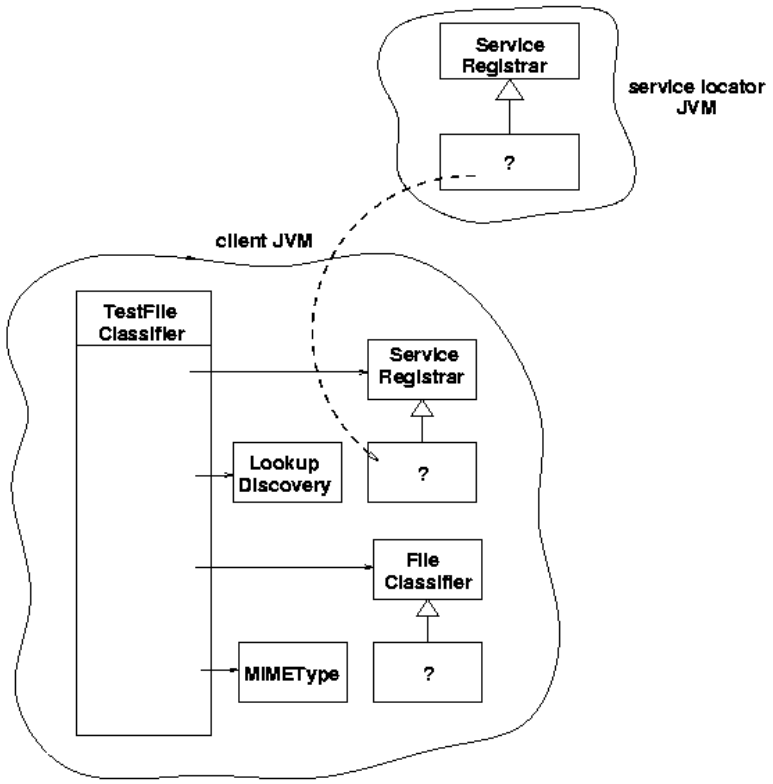
- A file classifier can take a filename and use this to work out the MIME type, using an internal table

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

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

Client and service locator JVM's

The two JVM's look like



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);

    }

    public void discovered(DiscoveryEvent evt) {

        ServiceRegistrar[] registrars = evt.getRegistrars();
        Class [] classes = new Class[] {FileClassifier.class};
```

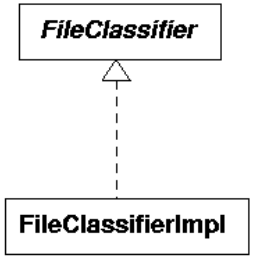


```
        FileClassifier classifier = null;
        ServiceTemplate template = new ServiceTemplate(null, classes,
                                                       null);

        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
```

PROXY IMPLEMENTATION CHOICES

Proxy is the Service

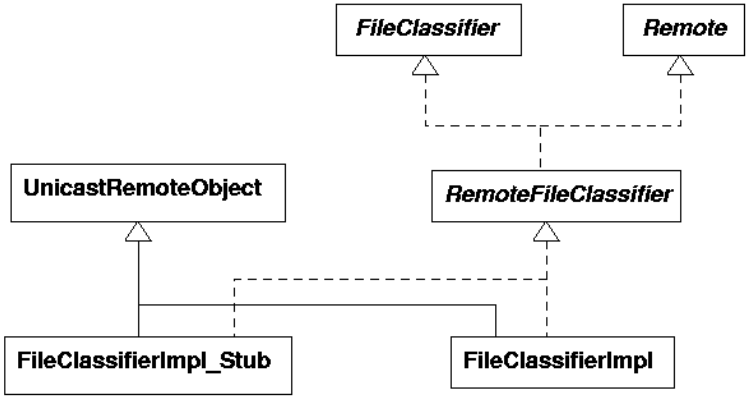
- The complete service may be uploaded, so there is no separate proxy



- 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 the server side

RMI Proxies

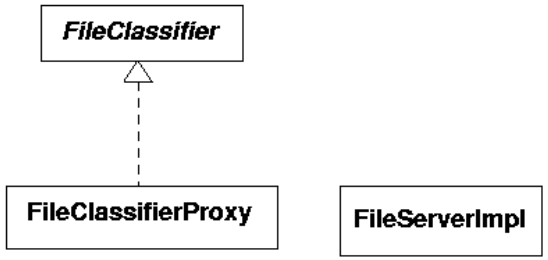
- If RMI stubs are used to implement the proxy, it looks like



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

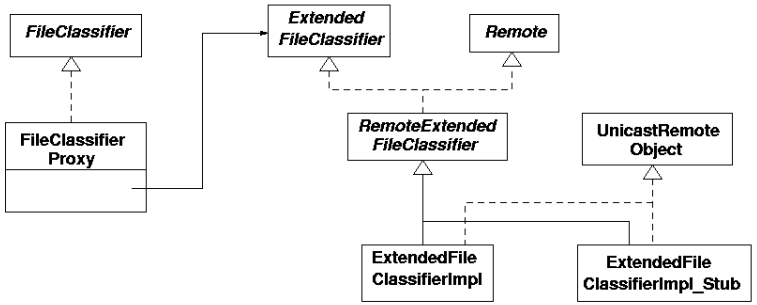
- If RMI is not used, the proxy must be explicitly created



- The client uses `FileClassifier` (like before - it doesn't care what the proxy is)
- 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 `FileClassifierProxy`
- The server creates a `ExtendedFileClassifierImpl` and a `FileClassifierProxy`
- The server exports a `FileClassifierProxy` and an `ExtendedFileClassifierImpl_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

Service implementation

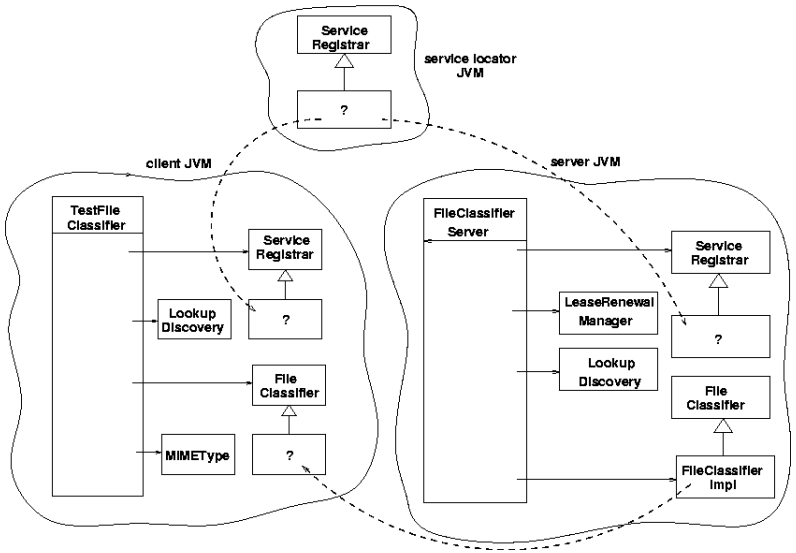
```
package option2;

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
```


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);
        }

        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
```


All the JVM's



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 "", "";
};
```

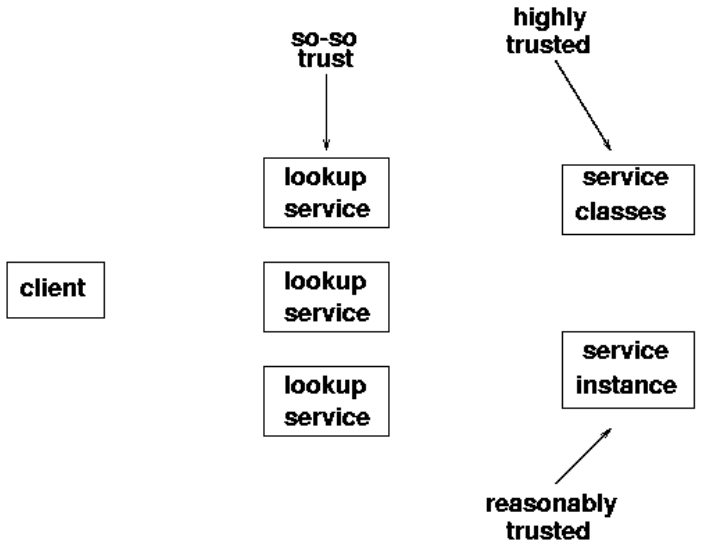
- Leave it like this of production only at your peril

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



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

};
```


REMOTE EVENTS

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

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();
}
```

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);
}
```

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;
        }

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

    public void addType(String suffix, MIMEType type)
        throws java.rmi.RemoteException {
```

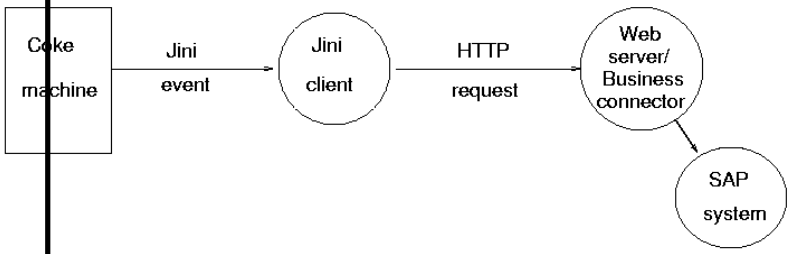


```
        map.put(suffix, type);
        fireNotify(ADD_TYPE);
    }

    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) {
                    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
```


Realistic Use of Events

- Interfacing a Coke machine to an SAP inventory system



INTERFACING TO HARDWARE

Lego MindStorms

MindStorms is a ‘‘Robotics Invention System’’

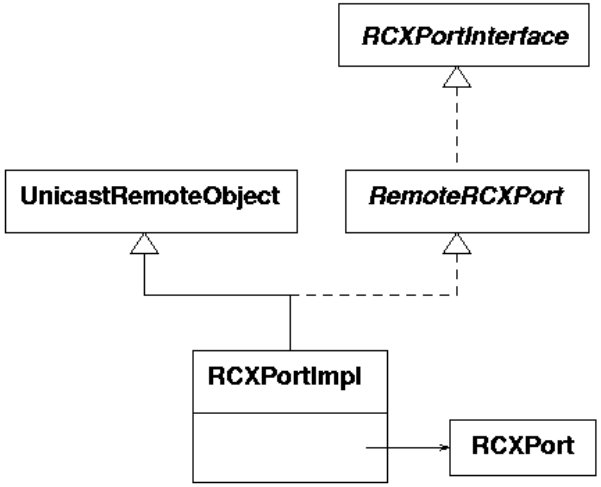
- A 16-bit computer called the RCX (a 16MHz Hitachi H8/3297), with 32k RAM
- The RCX can control 3 motors and read from 3 sensors
- Additional Lego parts - gears, wheels, sensors, motors
- Software can be downloaded by an infra-red link on a serial port
- Programs can be downloaded and run, or ‘‘immediate’’ 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);
    public void processRead();
    public String getLastError();
    public void showTable();
    public static byte[] parseString(String str);
}
```


MindStorms as a Jini Service



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);

    }

    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) {
            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
```


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 (but several books in print, including mine from 2001)
- J2ME (micro edition Java) doesn't support Jini yet

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)

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