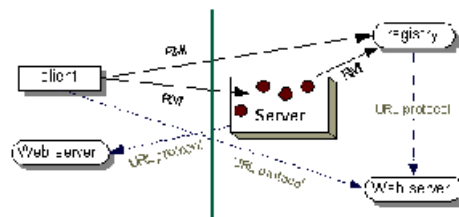


RMI Case Study

- This example taken directly from the Java RMI tutorial
 - <http://java.sun.com/docs/books/tutorial/rmi/>
- Editorial note:
 - Please do yourself a favor and work through the tutorial yourself
 - If you get the tutorial to work, you'll have no problems with project 5 or with the final exam

A Typical RMI Application

- Client and Server run on different machines
- Remote Object(s) registered in rmi registry by Server
- Remote Object(s) looked up by Client
- When necessary, code transferred from web server to point of use
 - Both Client and Server can make code network accessible
- Operations on Remote Objects carried out by RMI



Compute Server Application

- Goal
 - Execute object methods on a remote machine
 - Perhaps because local resources aren't sufficient
- Real-life example:
 - Police car stops a motorist for speeding
 - Officer wants to check driver for warrants
 - Places request with a central computer (i.e., database not in the police car)
- Actual example
 - Client writes job to be done
 - Server executes job and returns result to Client



Compute Interface

```
package compute;
```

```
import java.rmi.Remote;  
import java.rmi.RemoteException;
```

```
public interface Compute extends Remote {  
    Object executeTask(Task t) throws RemoteException;  
}
```

- We refer to an interface that extends Remote as a *remote interface*
 - Methods mentioned in that interface are called *remote methods*
 - Remote methods must throw RemoteException
- Any object whose class implements a remote interface is a *remote object*
 - The object's remote methods can be called from any JVM
 - But the object does not leave the JVM in which it was created
- Compute is a remote interface
 - executeTask() is a remote method

Task Interface

```
package compute;

import java.io.Serializable;

public interface Task extends Serializable {
    Object execute();
}
```

- Task implementations implement Serializable, rather than Remote
 - Why?
- execute() method returns an Object
 - Client must downcast result
 - This method not required to throw RemoteException (Why?)

Implementing Compute Engine

- Our implementation of Compute interface is called *ComputeEngine*
- In general, the implementer of a remote interface must
 1. Declare the remote interfaces being implemented
 2. Define the constructor for the remote object
 3. Implement each remote method in the remote interfaces

Further Requirements for Servers

- The server needs to create and to install the remote objects.
 - The setup procedure often done in `main` method of the remote object
 - but can be done anywhere
- The setup procedure should
 1. Create and install a security manager
 2. Create one or more instances of a remote object
 3. Register at least one of the remote objects with an RMI registry

1. Declare the Remote Interfaces

- The `ComputeEngine` class is declared as
 - `public class ComputeEngine extends UnicastRemoteObject implements Compute`
- This declaration states that
 - the class implements the `Compute` remote interface
 - extends the class `java.rmi.server.UnicastRemoteObject`
 - Much magic happens here!

2. Define the Constructor

- The ComputeEngine class has a single, 0-argument constructor.

```
public ComputeEngine() throws RemoteException {  
    super();  
}
```
- The no-argument constructor for ComputeEngine must declare RemoteException
 - because the UnicastRemoteObject constructor does
 - A RemoteException can occur during construction if the attempt to export the object fails
 - for example, if communication resources are unavailable or the appropriate stub class is not found

3. Implement Each Remote Method

- The Compute interface contains a single remote method, executeTask, which is implemented as follows:

```
public Object executeTask(Task t) {  
    return t.execute();  
}
```
- Client provides the ComputeEngine with a Task object,
 - which has an implementation of the task's execute method
- The ComputeEngine executes the Task and returns the result
- Client must downcast the result

Implement the Setup Procedure

- Create and install a security manager
- Create one or more instances of a remote object
- Register at least one of the remote objects with the RMI registry

1. Create and Install a Security Manager

- The security manager determines whether downloaded code has access to the local file system or can perform any other privileged operations.
- All programs using RMI must install a security manager, or RMI will not download classes (other than from the local class path) for objects received as parameters, return values, or exceptions in remote method calls

```
if (System.getSecurityManager() == null) {  
    System.setSecurityManager(new RMISecurityManager());  
}
```

- We will use a policy file that grants more permissions

2. Create the Remote Object

- The main method creates an instance of the ComputeEngine
 - `Compute engine = new ComputeEngine();`
- Note that engine's type is Compute, not ComputeEngine
 - The interface is available to clients, since they'll get the stub that implements it, not the actual implementation

3. Make the Remote Object Accessible

- To invoke a remote object method caller must have a reference to it
 - Can get it from the program
 - e.g., as part of the return value of a method or as part of a data structure that contains such a reference, or
 - You can look it up in an RMI registry
- The RMI registry is a simple remote object name service that allows remote clients to get a reference to a remote object by name
- Start the registry
 - From the command line as a separate process, or
 - From within your Server program

Add Remote Object to Registry

- The `java.rmi.Naming` interface is used as a front-end API for binding, or registering, and looking up remote objects in the registry
- The `ComputeEngine` class creates a name for the remote object
`String name = "//host/Compute";` // "host" has to be changed to the actual hostname!
- The `ComputeEngine` adds remote object to the registry
`Naming.rebind(name, engine);`
- Note the following about the arguments to the call to `Naming.rebind`.
 - The first parameter is a URL-formatted `java.lang.String` representing the location and the name of the remote object
 - If no port number is given in name, defaults to 1099
- Note that for security reasons, an application can bind, unbind, or rebind remote object references only with a registry running on the same host
- Once the server has registered the remote object, the setup procedure exits

Creating a Client Program

- Two separate classes make up the client in our example.
 - `ComputePi`
 - `Pi`
- `ComputePi` must obtain a reference to a `Compute` object, create a `Task` object, and then request that the task be executed
- `Pi` implements the `Task` interface, calculating `Pi` to some degree of precision

ComputePi

- Begins by installing a security manager
- Constructs a name used to look up a Compute remote object.
- Uses Naming.lookup() to look up the remote object by name in the remote host's registry
- Creates a new Pi object
- Invokes executeTask() on the Compute remote object
- executeTask() returns an object of type java.math.BigDecimal, so the program downcast casts the result and stores it
- Program prints out the result

Pi

- Calculates Pi

Compiling

- Application has 4 directory trees
- Server
 - Application directory – (server code written and compiled here)
 - Web accessible location – (client downloads server code from here)
- Client
 - Application directory (client code written and compiled here)
 - Web accessible location -- (server downloads client code from here)
- Editorial note:
 - You have to put all the code in the right places each time you make changes
 - *So use a makefile!*
 - For testing purposes keep client and server code in separate directory trees / separate machines
 - *Otherwise you may not know if things are really working*

Compiling

- Compile interface classes, build a jar file
 - Move jar file to developer-accessible locations
 - Move jar file to web-accessible locations (client & server) and unpack it
 - Everyone shares these files – don't change them!
- Build Server classes
 - (add classpath info to the following command lines)
 - cd ServerDevDir
 - javac engine/ComputeEngine.java
 - rmic -d . engine.ComputeEngine
 - mkdir ServerWebDir/engine
 - cp engine/ComputeEngine_*.class ServerWebDir/engine
- Stubs and Interfaces are now web-accessible

Compiling

- Build the Client classes
 - `cd ClientDevDir`
 - `javac client/ComputePi.java`
 - `javac -d ClientWebDir client/Pi.java`
- Serializable class and Interfaces are now web-accessible

Running Application

- Copy policy file to home directory
 - On Unix I put the file in `~/java.policy`
- Start the RMI registry
 - `mkdir EmptySubDir`
 - `cd EmptySubDir`
 - `unsetenv CLASSPATH (unset CLASSPATH)`
 - `rmiregistry &` (might also add portnum argument)
- Start the server

```
java -classpath ServerDevDir/ \
-Djava.rmi.server.codebase=http://webHost/WebServerDir/ \
-Djava.rmi.server.hostname=ServerName \
-Djava.security.policy=java.policy \
engine.ComputeEngine
```

Running Application

- Start the client (on another machine)

```
java -classpath ClientDevDir/ \  
-Djava.rmi.server.codebase=http://ClientWebServer/ClientWebDir/ \  
-Djava.security.policy=java.policy \  
client.ComputePi serverName 20
```
- Should produce
 - 3.14159265358979323846

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