A Typical RMI Application

- Client and Server run on different machines
- Remote Object(s) registered in rmiregistry by Server
- Remote Object(s) look’d 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

![Diagram of RMI application](diagram.png)

Case Study

- This example taken directly from the Java RMI tutorial
- 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
Compute Server Application

- Goal
  - Execute object methods on a remote machine
  - Often 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., the database is not in the police car)

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

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

- Any class that implements Compute is a remote object
  - Its remote methods can be called from any JVM
  - Its implementation does not leave the JVM in which it was created
- executeTask() is a remote method
  - It must throw RemoteException
Task Interface

package compute;
public interface Task<T> {
    T execute();
}

• Task doesn’t implement Remote
  – Why not?
• execute() method returns an instance of type T
  – Method not required to throw RemoteException

Implementing Compute Engine

• Our implementation of compute interface will called `ComputeEngine`
• In general, the implementer of a remote interface should at least
  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 the RMI registry

Declare the Remote Interfaces

• The ComputeEngine class is declared as
  – public class ComputeEngine implements Compute
Define the Constructor

- The ComputeEngine class has a single, 0-argument constructor.
  ```java
  public ComputeEngine() {
    super();  // optional
  }
  ```

Implement Each Remote Method

- The Compute interface contains a single remote method, `executeTask`, which is implemented as follows:
  ```java
  public <T> T executeTask(Task<T> 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
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

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

- We will use a policy file that grants more permissions
Create & Export the Remote Object

• The main method creates an instance of ComputeEngine
  – Compute engine = new ComputeEngine();
• Note that engine’s type is Compute, not ComputeEngine
  – The interface is available to clients, not the implementation
  – At runtime, you’ll pass the stub, not the actual implementation
• The main method exports the remote object (activates it)
  – Compute stub = (Compute) UnicastRemoteObject.exportObject(engine, 0);

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
  – 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 = "Compute";
- Then finds the registry
  
  Registry registry = LocateRegistry.getRegistry();
- Then adds remote object to the registry
  
  registry.rebind(name, stub);
- 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 Registry.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
- Program prints out the result

Pi

- Calculates Pi
- Implement Serializable. Why?
- Is computationally expensive which is why you’d want to run it on a fast compute server
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 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
    - 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 client/Pi.java
  - cp client/Pi.class ClientWebDir
- Task class and Interfaces are now web-accessible

Running Application

- Copy policy file to some directory
  - On Unix I put the file in ./java.policy
- Start the RMI registry
  - unsetenv CLASSPATH
  - rmiregistry portNum &
- Start the server
  
  ```java
  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/ \n  -Djava.rmi.server.codebase=http://ClientWebServer/ClientWebDir/ \n  -Djava.security.policy=java.policy \n  client.ComputePi serverName 20

• Should produce
  – 3.14159265358979323846