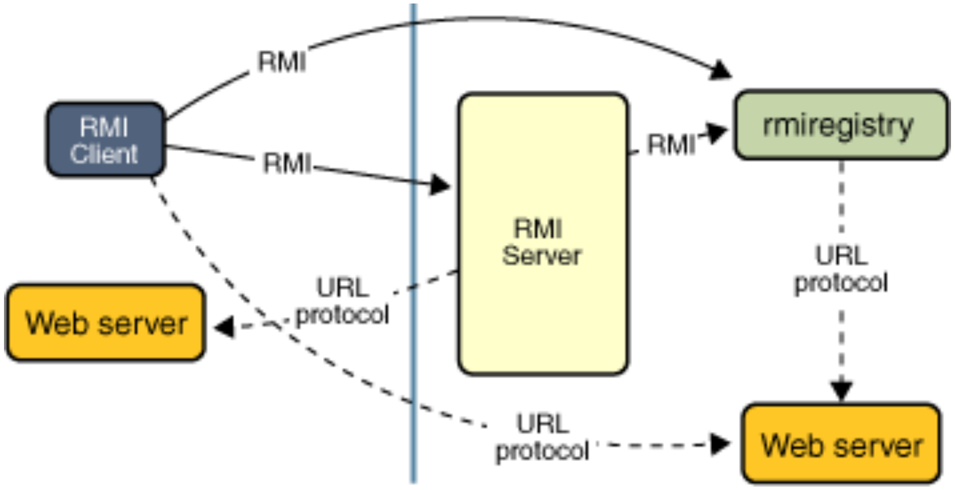
A Typical RMI Application

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

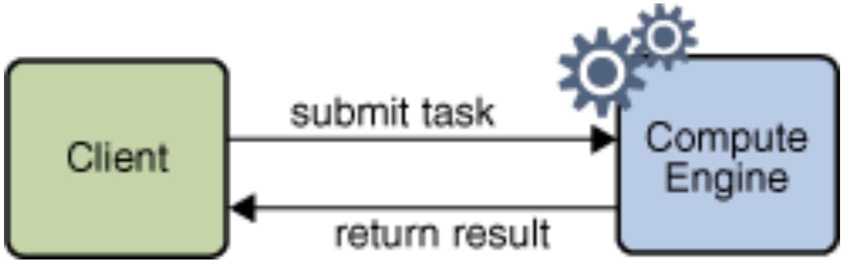


Case Study

- This example taken directly from the Java RMI tutorial
  - http://docs.oracle.com/javase/tutorial/rmi/index.html
- 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 RMI project or with the RMI portion of the final exam
  - For a webserver, I use apache running on my laptop.
  - You can also use
    - http://terpconnect.umd.edu
  - You can also use a simple RMI webserver:
    - http://www.oracle.com/webfolder/technetwork/java/core/basic/rmi/class-server.zip

Compute Server Application

- Goal
  - Execute object methods on a remote machine
  - Often because local resources aren't sufficient
- Real-life example: Amazon EC2
  - Large computing infrastructure -- somewhere in clouds
  - Users push many different kinds of work to these rented machines
    - Examples: Justin.tv, Zillow.com, NY Times (PDF conversion)



Compute Interface

```
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 the Compute interface will be called *ComputeEngine*
- In general, a Remote interface impl should:
  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

- ComputeEngine has a single, 0-arg constructor

```
public ComputeEngine() {
   super();  // optional
}
```

Implement Each Remote Method

- Compute has a single Remote method, executeTask():

```
public <T> T executeTask(Task<T> t) {
        return t.execute();
    }
```

- Client provides ComputeEngine with a Task object
  - Which implements the Task's execute() method
- ComputeEngine executes the Task and returns the result

Implement the Setup Procedure

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

Create and Install a Security Manager

- Security Manager determines whether downloaded code has access to the local file system or can perform any other privileged operations
- Without a security manager, 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 SecurityManager());
}
```

- Policy files can grant specific permissions
  - if you want to modify SecurityManager’ s default perms

Create & Export the Remote Object

- The main method creates an instance of ComputeEngine
  - Compute engine = new ComputeEngine();
- Note 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, caller needs a reference to it
- Can get it from the program (return value, data field, etc.)
- Can look it up in an RMI registry
  - The RMI registry is a simple Remote object naming service
- Start the registry
  - From the command line as a separate process, or
  - From within your Server program
- If registry is started within server, it will be shut down when program shuts down

Add Remote Object to Registry

- The java.rmi.Naming interface is 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);
  ```

- Application can bind, unbind, or rebind Remote object references only with a registry running on the same host
- Once the Remote object is registered, the setup procedure exits

Creating a Client Program

- Two separate classes make up the client in our example
  - ComputePi
  - Pi
- ComputePi gets a reference to a Compute object, creates a Task object, and then requests that the task be executed
- Pi implements the Task interface, calculating Pi to the required degree of precision

ComputePi

- Begins by installing a security manager
- Constructs the name used to look up 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
- Implements Serializable. Why?
  - It's computationally expensive which is why you want to run it on a (presumably) fast compute server

Compiling

- Think of the application as having 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!*
  - Ultimately you should put 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
  - 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
- For this example, no server classes will be downloaded

Compiling

- Build the Client classes

  ```
  cd ClientDevDir
  javac client/ComputePi.java client/Pi.java
  mkdir ClientWebDir/client
  cp client/Pi.class ClientWebDir/client/
  ```

- Client class is now web-accessible

Running Application

- Copy policy file to some directory
  - On Unix I put the file in ./java.policy
- Start the RMI registry (our example does this in code)
  - rmiregistry portNum &
- Start the server

```
java –classpath ServerDevDir/     \
-Djava.rmi.server.codebaseOnly=true    \
-Djava.rmi.server.hostname=ServerName \
-Djava.security.policy==java.policy \
-Djava.rmi.server.logCalls=true \
engine.ComputeEngine
```

- Note: don’t’ need a codebase for this example

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

- Don’t forget trailing “/” on codebase (no “/” for jar files)