Chapter 5

Distributed Programming

Computer Science and Engineering Department@SoEEC

Advanced Programming(CSE 3312)

Key Objectives:

At the end of this chapter, you will be able to learn:

- RMI
- RMI architecture
- Serialization
- Steps to develop RMI application

RMI - Remote Method Invocation

- Java RMI is a mechanism to allow the invocation of methods that reside on different Java Virtual Machines (JVMs).
- The JVMs may be on different machines or they could be on the same machine.
  - In either case, the method runs in a different address space than the calling process.
- Java RMI is an object-oriented remote procedure call mechanism.
- RMI is a distributed object system that enables you to easily develop distributed Java applications.
- Developing distributed applications in RMI is simpler than developing with sockets since there is no need to design a protocol, which is an error-prone task
- Java RMI allowed programmer to execute remote function class using the same semantics as local function calls.

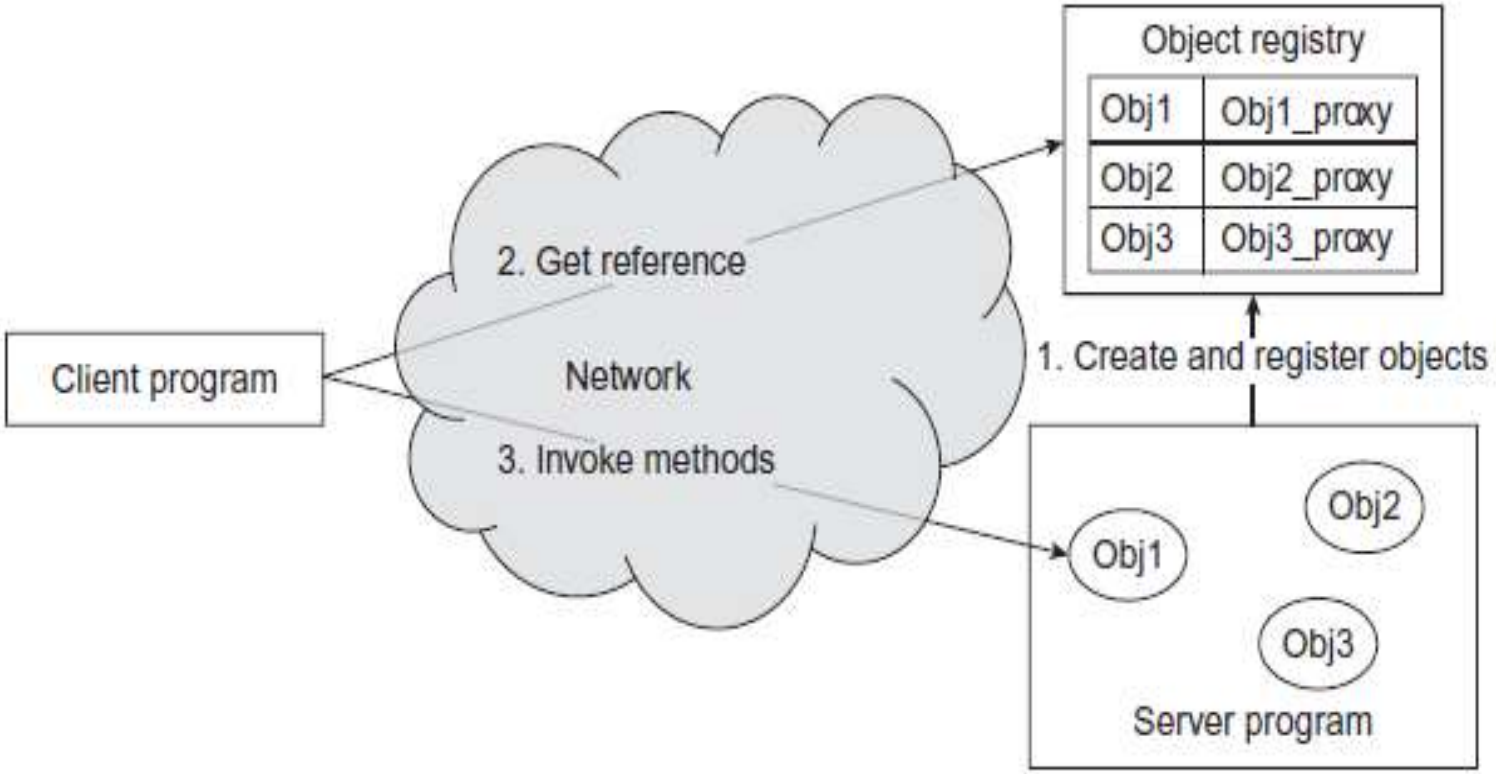


Figure 1: RMI Programming Model

- The underlying communication between clients and server in this model takes place seamlessly using sockets. It means that the message from the client is not method invocation in the OO sense. Instead, it is a stream of data that must be interpreted by the server before it can invoke method on the target object. However, RMI application developers need not know this complex socket communication.
- Originally, in general, RMI architecture was developed taking the following goals into consideration:
  - ❖ A primary goal of Java RMI technology was to allow programmers to develop distributed Java programs with the same syntax and semantics used for non-distributed programs.
  - ❖ Another goal was to create a distributed object model that fits the Java programming language and the local object model naturally. RMI architects finally succeeded in creating such a powerful system that extends the safety and robustness of the Java architecture to the distributed computing world.

2. RMI Application Components

- Three entities are often involved in an RMI application: a ***server*** program, a ***client*** program and ***object registry***.

1. Server

- This is a program that typically creates a *remote* object to be used for method invocation. This object is an ordinary object except that its class implements a Java RMI interface. Upon creation, the object is exported and registered with a separate application called *object registry* (or simply registry).

….. RMI Application Components

2. Client

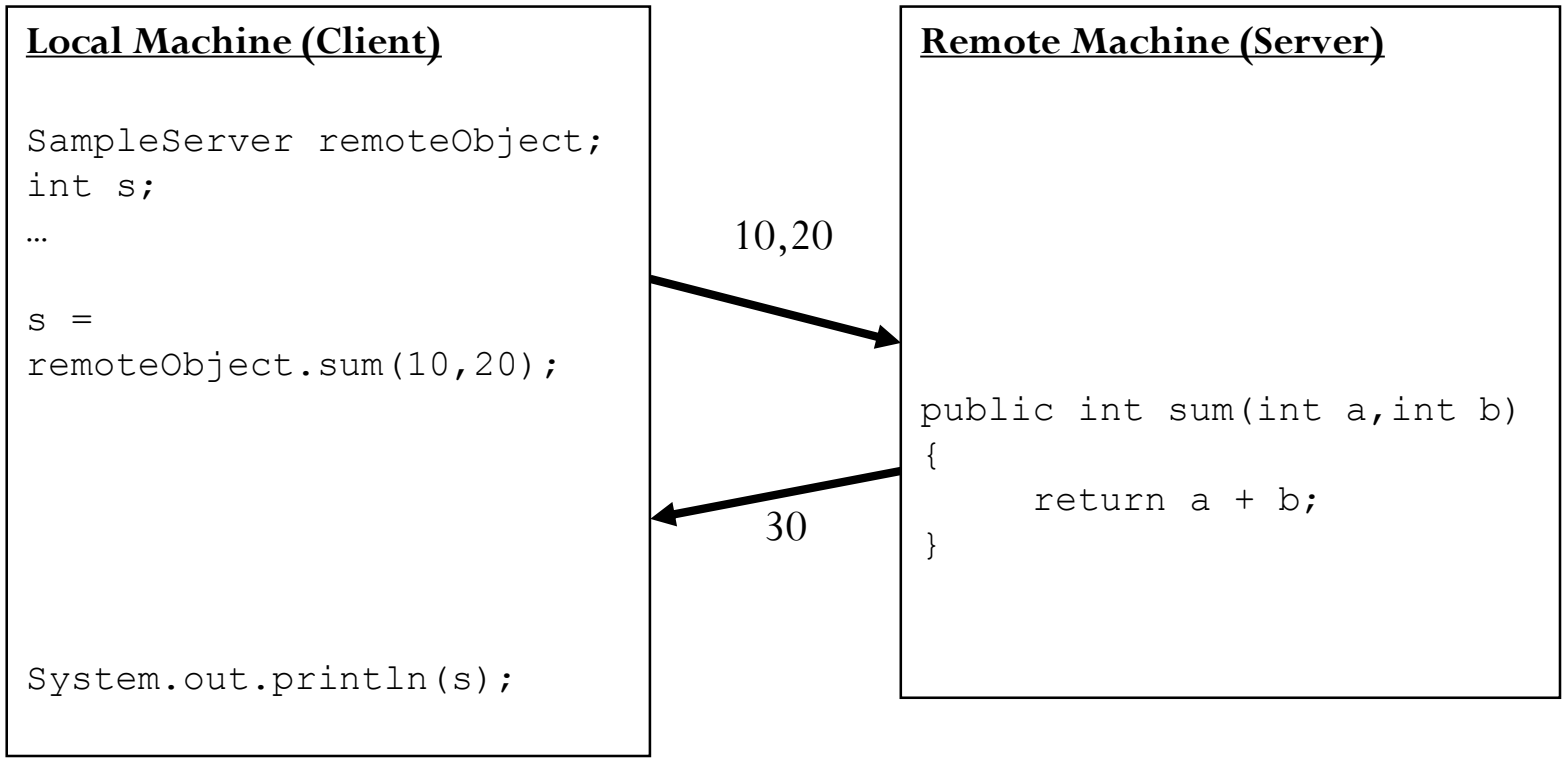
- A client program typically consults the object registry to get a reference to a remote object with a specified name. It can then invoke methods on the remote object using this reference as if the object is stored in the client's own address space. The RMI handles the details of communication (using sockets) between the client and the server and passes information back and forth. Note that this complex communication procedure is absolutely hidden to the client and server applications.

…..RMI Application Components

3. Object Registry

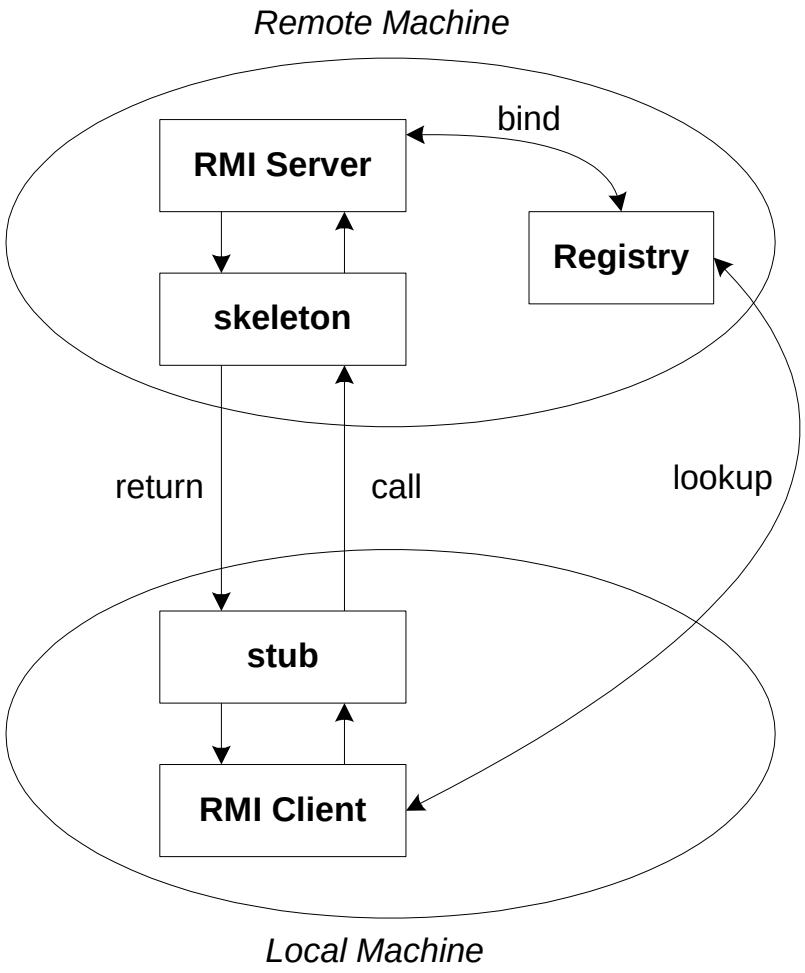
- It is essentially a table of objects. Each entry of the table maps the object name to its proxy known as stub. The server registers the stub by a name to the object registry. Once the stub is registered to the object registry successfully, the object is said to be available for others' use. Clients can now get a reference to the remote object (actually stub) from this registry and can invoke methods on it.

.....RMI

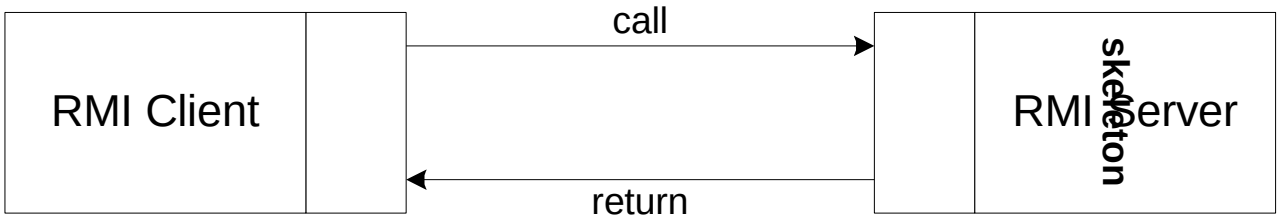

Local Machine (Client)
SampleServer remoteObject;
int s;
…
s =
remoteObject.sum(10,20);
System.out.println(s);
10,20
30
Remote Machine (Server)
public int sum(int a,int b)
{
return a + b;
}

General RMI Architecture

- The server must first bind its name to the registry
- The client lookup the server name in the registry to establish remote references.
- The Stub serializing the parameters to skeleton, the skeleton invoking the remote method and serializing the result back to the stub.



The Stub and Skeleton



- A client invokes a remote method, the call is first forwarded to stub.
- The stub is responsible for sending the remote call over to the server-side skeleton
- The stub opening a socket to the remote server, marshaling the object parameters and forwarding the data stream to the skeleton.
- A skeleton contains a method that receives the remote calls, unmarshals the parameters, and invokes the actual remote object implementation.
- RMI uses only TCP, UDP is not supported by RMI.
- **Marshalling and UnMarshalling:** refers to the process of converting the data or object being transfered into a byte stream and unmarshalling is the reverse- converting the stream into an object or data; conversion is achieved via object serialization.

Serialization

- Serialization is the process of writing the state of an object to a byte stream.
- This is useful when we want to save the state of our object to a persistent storage such as a file.
- At a later time, we may restore these objects by using the process of de-serialization.
- The class whose object we want to write to a file, must implement the Serializable interface.
- Serializable interface is a marker interface means it does not have any method, it only informs the tools that are involved in serialization that the class is ready for serialization.
- **For eg.**

```
class Test implements Serializable{

}
```

RMI – Merits and Demerits

- Merits
  - Ease of programming
  - No complicated Interface Definition Language (IDL) to learn
- Demerits
  - Uses Proprietary Protocol
    - Java Remote Method Protocol (JRMP)
  - No cross-language support

Steps for Developing an RMI System

1. Define the remote interface
2. Develop the remote object by implementing the remote interface.
3. Develop the client program.
4. Compile the Java source files.
5. Generate the client stubs and server skeletons.
6. Start the RMI registry.
7. Start the remote server objects.
8. Run the client

Step 1: Defining the Remote Interface

- To create an RMI application, the first step is the defining of a remote interface between the client and server objects.
- The interface definition:
  - must be public
  - must extend the interface ***java.rmi.Remote***
  - every method in the interface must declare that it thows ***java.rmi.RemoteException***
  - but other exceptions may be thrown as well

```
/* SampleServer.java */
import java.rmi.*;

public interface SampleServer extends Remote
{
  public int sum(int a,int b) throws RemoteException;
}
```

Step 2: Develop the remote object and its interface

- The server must implement the Remote interface
- It should extend **java.rmi.server.UnicastRemoteObject** class
  - This will allow the methods to be invoked remotely
- Each method must throw **RemoteException**
  - Because remote procedure calls might fail
- The server uses the **RMISecurityManager** to protect its resources while engaging in remote communication.

Step 2: Develop the remote object and its interface

```
/* SampleServerImpl.java */
import java.rmi.*;
import java.rmi.server.*;
import java.rmi.registry.*;

public class SampleServerImpl extends UnicastRemoteObject
                              implements SampleServer
{
  SampleServerImpl() throws RemoteException
  {
     super();
  }
  // Implement the remote methods
  public int sum(int a,int b) throws RemoteException
  {
     return a + b;
  }
}
```

Develop the remote object.....

- The server must **bind** its name to the registry, the client will **look up** the server name.
- Use **`java.rmi.Naming`** class to bind the server name to registry.
  In this example, lets use the name "SAMPLE-SERVER".
- In the main method of your server object, the RMI security manager is created and installed.

```
/* SampleServerImpl.java */
public static void main(String args[])
{ try
 {
   //set the security manager
   System.setSecurityManager(new RMISecurityManager());
      //create a local instance of the object
     SampleServerImpl Server = new SampleServerImpl();
   //put the local instance in the registry
    Naming.rebind("SAMPLE-SERVER" , Server);
    System.out.println("Server waiting.....");
 }
catch (RemoteException re)
   { System.out.println("Remote exception: " + re.toString());  }
 }
}
```

Step 3: Develop the client program

- In order for the client object to invoke methods on the server, it must first look up the name of server in the registry. Use the **`java.rmi.Naming`** class to lookup the server name.
- The server name is specified as URL in the form **(rmi://host:port/name)**
  - Default RMI port is 1099.
- The name specified in the URL must exactly match the name that the server has bound to the registry.
  - In this example, the name is "SAMPLE-SERVER"
- The remote method invocation is programmed using the remote interface name (`remoteObject`) as prefix and the remote method name (`sum`) as suffix.

Step 3: Develop the client program

```
import java.rmi.*;
import java.rmi.server.*;
public class SampleClient
{ public static void main(String[]  args)
   {  // set the security manager for the client
      System.setSecurityManager(new RMISecurityManager());
     try
     {  //get the remote object from the registry
         String url = "rmi://localhost/SAMPLE-SERVER";
         SampleServer remoteObject = (SampleServer)Naming.lookup(url);
         System.out.println("Got remote object");
         System.out.println(" 1 + 2 = " + remoteObject.sum(10,20) );
     }
     catch (RemoteException exc) {
        System.out.println("Error in lookup: " + exc.toString());
     }
     catch (java.net.MalformedURLException exc) {
          System.out.println("Malformed URL: " + exc.toString());
     }
     catch (java.rmi.NotBoundException exc)  {
         System.out.println("NotBound: " + exc.toString());
     }
   }
}
```

Step 4 & 5: Compile the Java source files & Generate the client stubs and server skeletons

- Compile the java source files in command prompt

```
> javac SampleServer.java
> javac SampleServerImpl.java
> javac SampleClient.java
```

- Generate stubs and skeleton code. The RMI system provides an RMI compiler (`rmic`) that takes the implemented interface class and produces stub code on itself.

```
> rmic SampleServerImpl
```

Step 6: Start the RMI registry

- The `rmiregistry` uses port 1099 by default. You can also bind `rmiregistry` to a different port by indicating the new port number as : `rmiregistry <new port>`

- *Type the following in the command line:*

```
> start rmiregistry
```

Steps 7 & 8: Start remote server objects & Run client

- Once the Registry is started, the server can be started and will be able to store itself in the Registry.
- In the command line, to start the remote server:

```
> java SampleServerImpl
```

- NOTE: The registry and server processes are running in the background. Be sure to kill the registry and server processes when you're done.
- Finally, to run the client:

```
> java SampleClient  10  20
```

- The Final Output becomes:

```
Got remote object
10 + 20 = 30
```

Java Policy File

- Because of the grained security model in Java 2.0, you must setup a security policy for RMI by updating the java.policy file.
- In Java 2, the java application must first obtain information regarding its privileges.
- It can obtain the security policy through a policy file.
- In above example, we allow Java code to have all permissions, the contents of the java.policy file are:

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

Distributing the Application

- The easiest way to try a distributed architecture is *to copy all required files manually* to correct machines/directories:
- Copy **SampleClient.class** (client), **SampleServerImpl_Stub.class** (stub), **SampleServer.class** (interface) to a directory on the client machine .
- Copy **SampleServer.class** (interface), **SampleServerImpl.class** (its implementation), and **SampleServerImpl_Stub.class** (stub) to a directory on the server machine.
- *** If your implementation has a database connection, you can consider putting the database in a third machine=> 3 Tier


THANKS