# Chapter 31

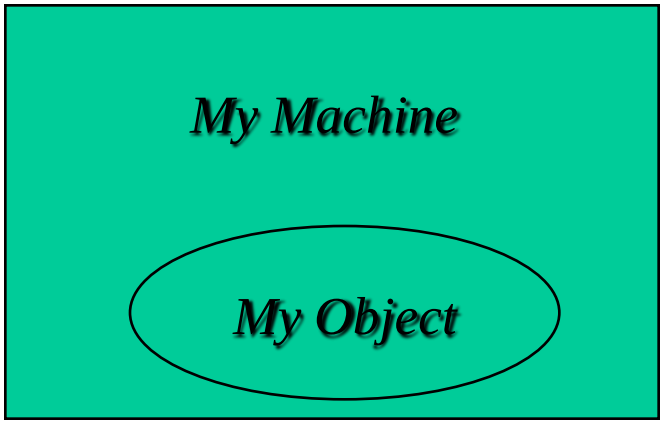
# Remote Method Invocation (RMI)

# Contents

- Overview of RMI
- Network Programming in Java using RMI
- Steps to build an RMI application
- Compiling and Running an RMI program

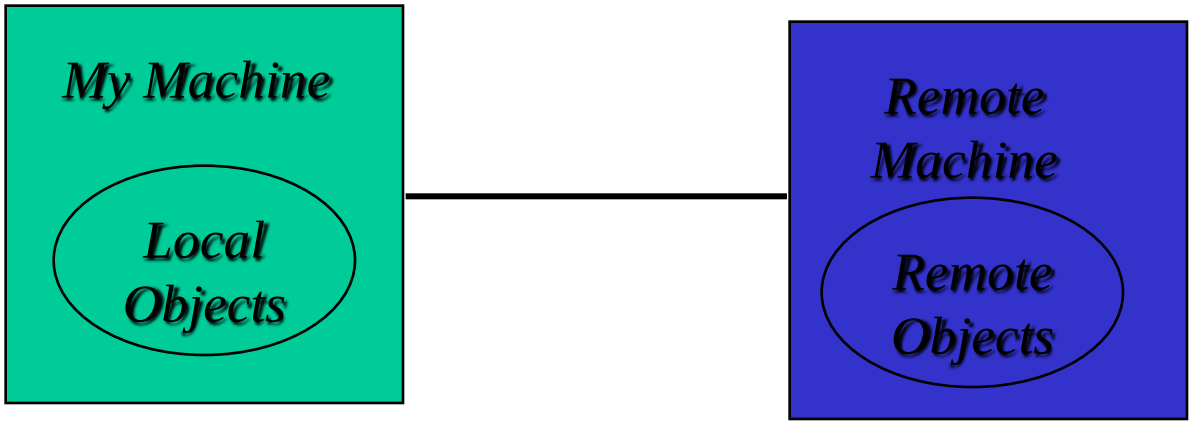
# In the Good Old Days...

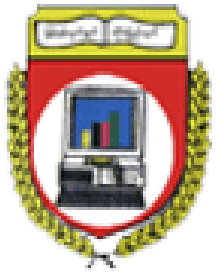
***Only local objects existed***



# Today's World...

*Network and Distributed Objects*





# Different Approaches to Distributed Computation

- High-performance, parallel scientific apps
- Connecting via sockets
  - custom protocols for each application
- RPC / DCOM / CORBA / **RMI**
  - make what looks like a normal function call
  - function is actually invoked on another machine
  - Arguments are *marshalled for transport*
  - Value is *unmarshalled on return*

# What is RMI?

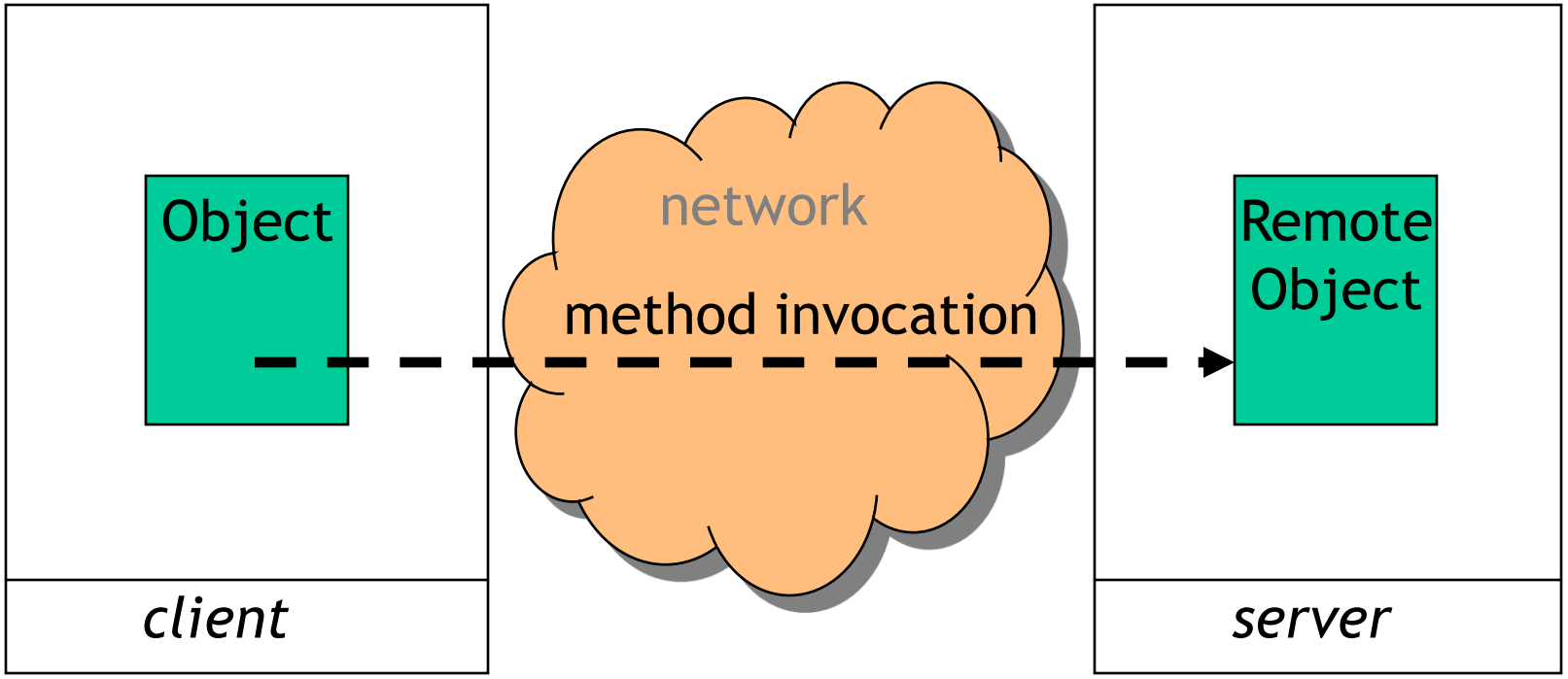
- RMI stands for **R**emote **M**ethod **I**nvocation.

- It facilitates the communication between two remotely placed Java objects.

- RMI applications consist of two separate programs:
  - **Server** : creates some remote objects, makes references to them accessible, and waits for clients to invoke methods on these remote objects.
  - **Client** : gets a remote reference to one or more remote objects in the server and then invokes methods on them.

# What is RMI?

- Remote Method Invocation



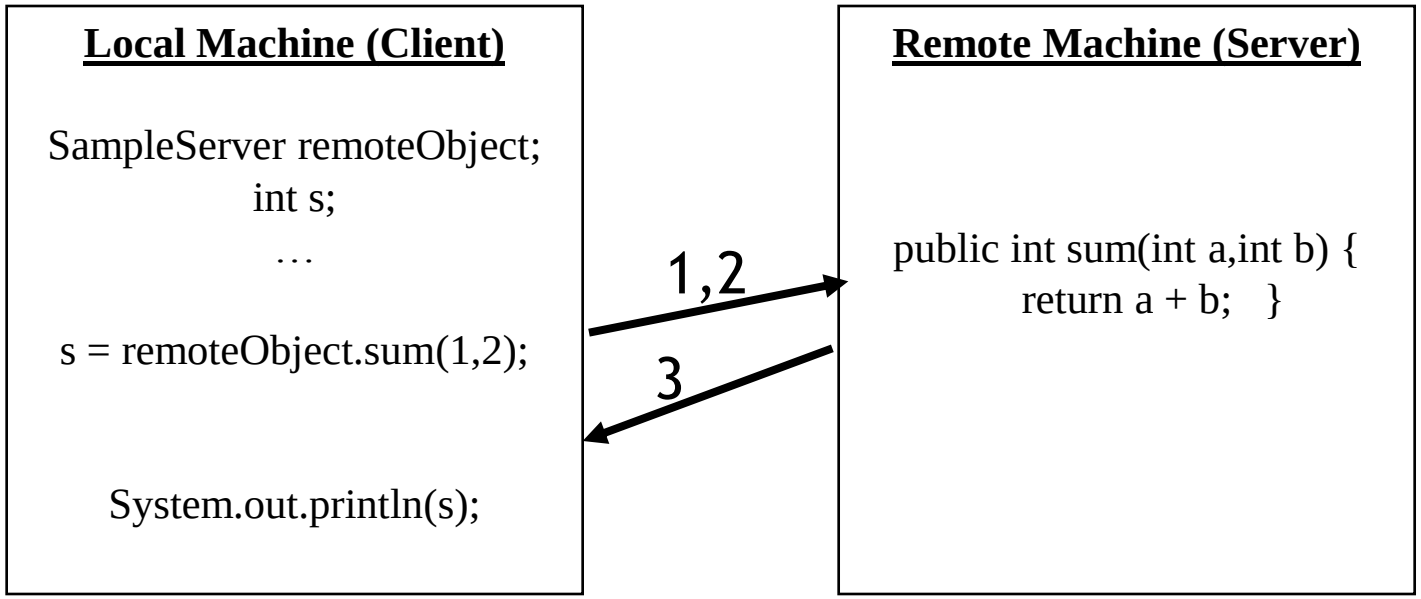
# Clear Definition of RMI

- Mechanism for performing method calls between different Java virtual machines (JVM).

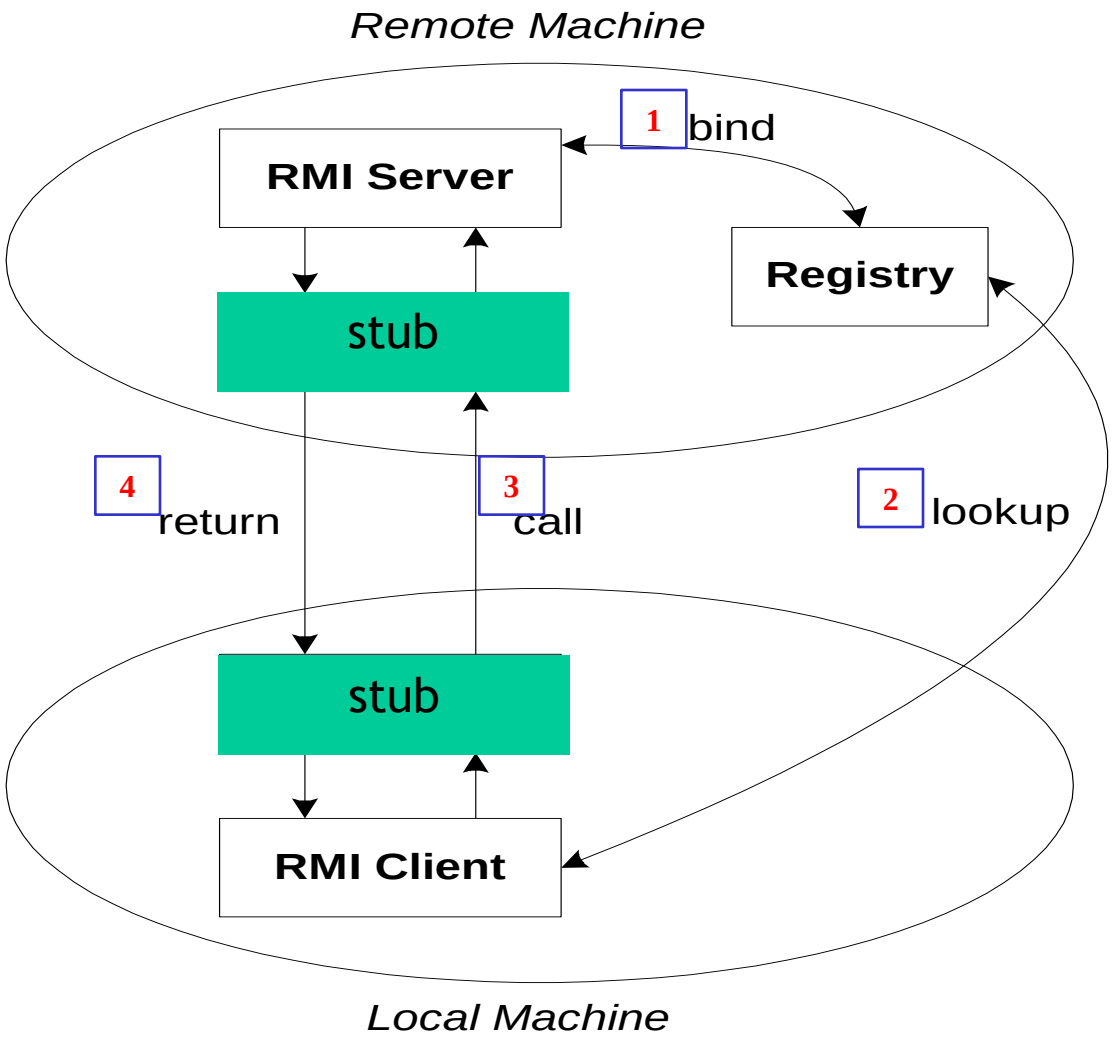
- Attempts to hide all the low level details such as serialization, communication protocol, etc.

# Overview

- Java RMI allowed programmer to execute remote functions in class using the same semantics as local functions calls.



# The General RMI Architecture



# The parts

- **Client - user interface**
- **Server - data source**
- **Stubs**
  - marshals argument data (serialization)
  - unmarshals results data (deserialization)

# Terms and Terminology in Java for RMI

# java.rmi.Remote

- The interface **java.rmi.Remote** is a *marker interface*.
- It declares no methods or fields;
- Extending it tells the RMI system to treat the interface concerned as a remote interface.

# java.rmi.UnicastRemoteObject

- Objects that require remote behavior should extend **RemoteObject**, typically via **UnicastRemoteObject**.

- defines a non-replicated remote object whose references are valid only while the server process is alive.

- provides support for point-to-point active object references (invocations, parameters, and results) using TCP streams.

# java.rmi.RemoteException

- Require all remote methods be declared to throw **RemoteException.**

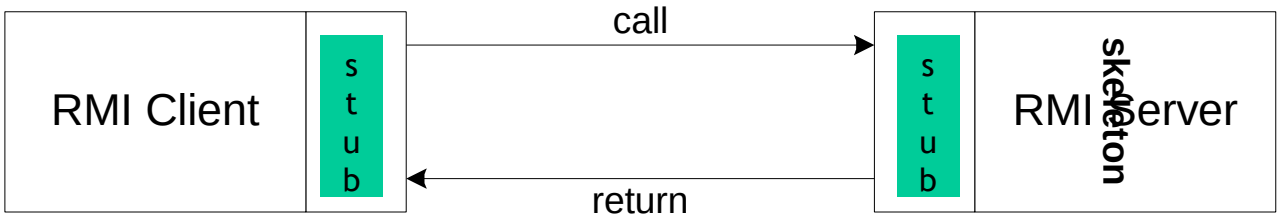
- To handle
  - unexpected failure of the network or remote machine.

# Remote Object and Interfaces

- **Remote Objects** are those that can be referenced remotely
  - extends **java.rmi.UnicastRemoteObject**
  - constructor/methods throws **java.rmi.RemoteException**

- **Remote interfaces** describe services that can be provided remotely
  - extends **java.rmi.Remote** interface
  - all methods throw **java.rmi.RemoteException**

# The **Stub** file




- Functions in client-side
  - responsible for sending the remote call over to the server-side stub
  - opening a socket to the remote server, marshaling the object parameters and forwarding the data stream to the server-side stub.

- Functions in server-side
  - contains a method that receives the remote calls, unmarshals the parameters, invokes the actual remote object implementation, marshaling the result and sending back the data stream to the client-side stub.

# rmic Compiler

- The only “compiler” technology peculiar to RMI => the **rmic** *stub generator*.

  (compiled in the normal way with **javac**)

- input => remote implementation class
- output => a new class (*classname*_Stub.class)

# Marshalling of Arguments

- Objects passed as arguments must be marshaled for transmission over the network.

- Java has a general framework for converting objects to an external representation that can later be read back into an arbitrary JVM.

- This framework is Object Serialization.

# Developing an RMI Application

# Steps for Developing an RMI System

## Implementation

1. Define the remote interface
2. Develop the remote object by implementing the remote interface
3. Develop the client program.

## Compilation

4. Compile the Java source files.
5. Generate the client and server stubs.

## Deployment

6. Start the Java RMI registry
7. Start the server
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.

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

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

# Step 2: Develop the remote object and its interface

- The server is a simple unicast remote server.
- Create server by extending **java.rmi.server.UnicastRemoteObject**.
- The server uses the **RMISecurityManager** to protect its resources while engaging in remote communication.

# Step 2 (Cont.)

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

public class SumImpl extends UnicastRemoteObject
                                implements SumInterface
{
  SumImpl() throws RemoteException
  {
     super();
  }
  public int sum(int a,int b) throws RemoteException
  {
     return a + b;
  }
}
```

# Parameters and Return Values

- Primitive data type
- Remote objects – by reference
- Serializable objects - by copy

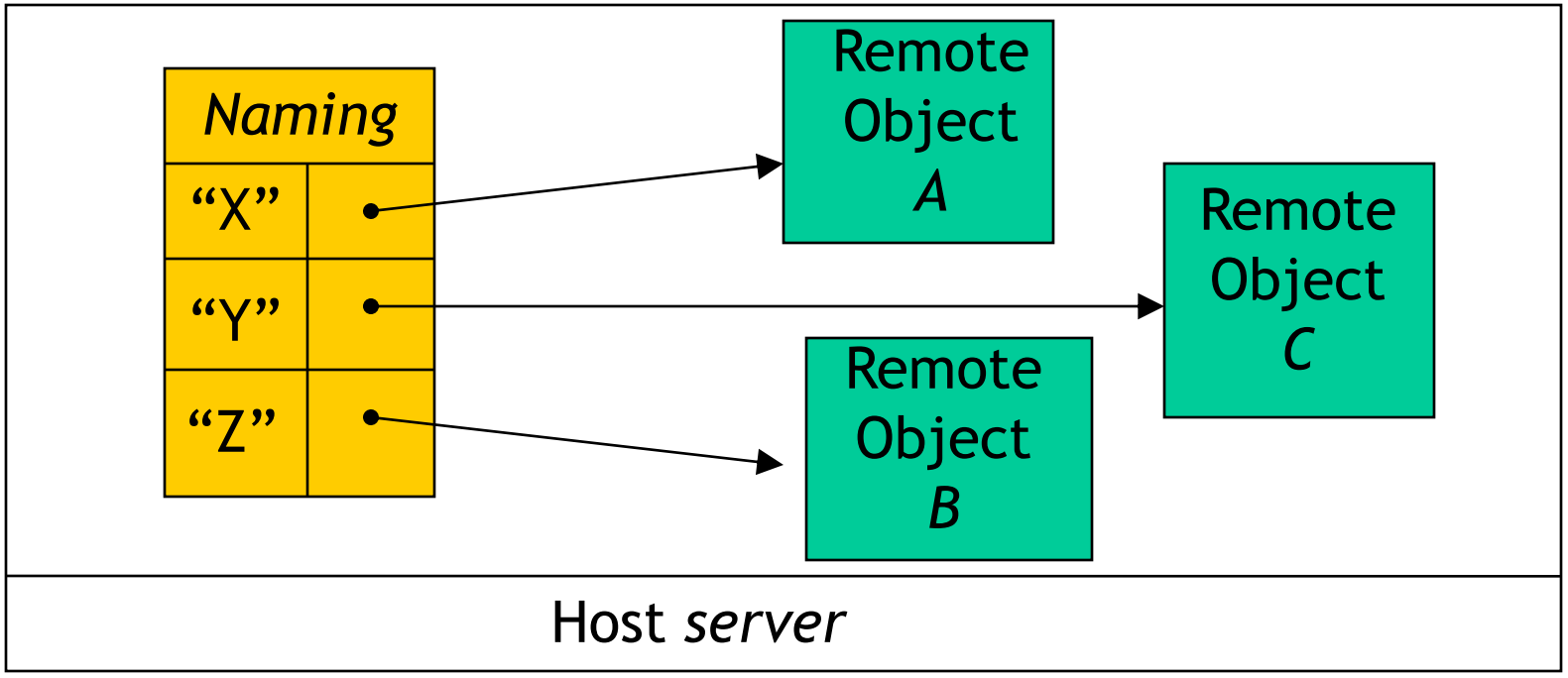
❖ Many of the core classes, including the classes in the packages java.lang and java.util, implement the Serializable interface

# Step 2 : Naming

- The server must bind its object's name to the registry, the client will look up the remote object's name.
- Use **java.rmi.Naming** class to bind the server name to registry.
- In the **main** method of your server object, the RMI security manager can be created and installed.

# Naming Service

- Directory that associates names to remote objects (*bind*)



# Step 2: Naming

```
/* SumImpl.java*/
  public static void main(String args[])
  {  try
      {
        //create a local instance of the object
        SumImpl obj= new SumImpl();

        //put the local instance in the registry
        Naming.rebind("rmi://localhost:1099/sumObj" , obj);

        System.out.println("Server waiting.....");
      }
      catch (java.net.MalformedURLException me)       {
        System.out.println("Malformed URL: " + me.toString());    }
      catch (RemoteException re)  {
         System.out.println("Remote exception: " + re.toString());  }
  }
```

# Step 3: Develop the client program

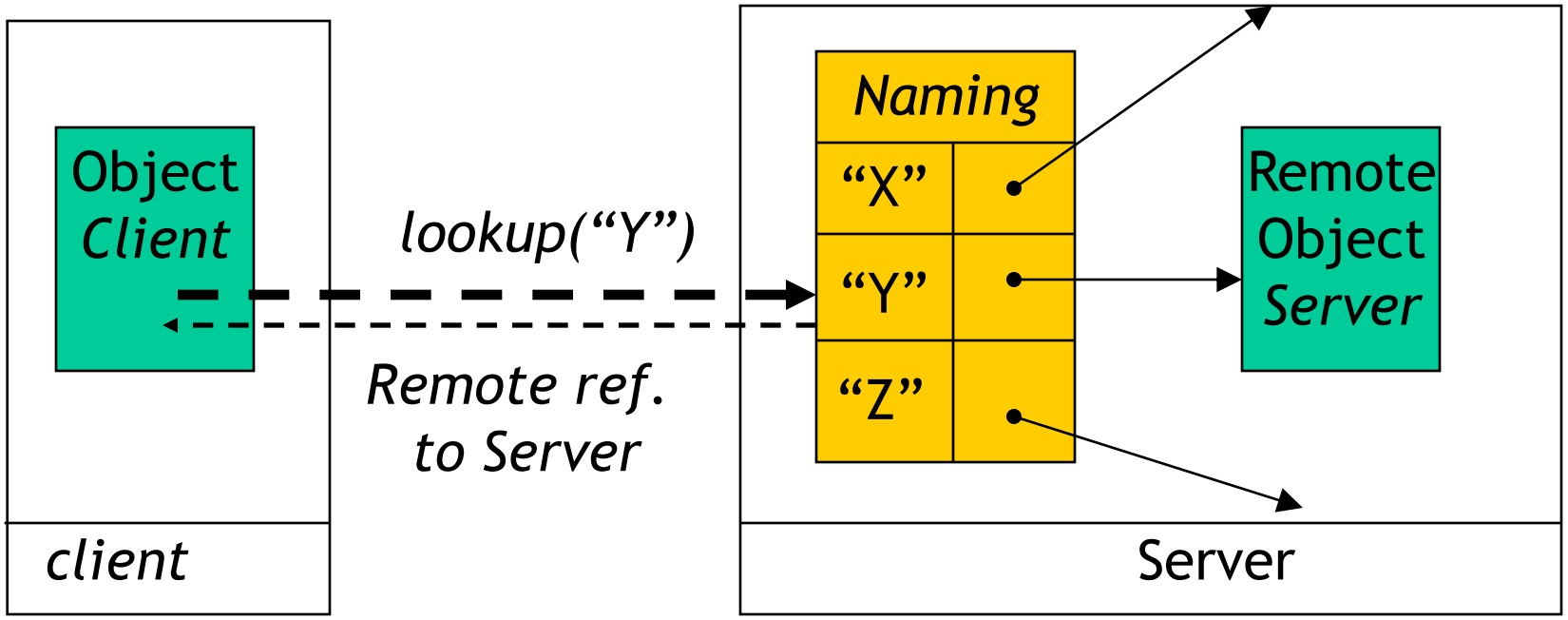
- Create and install a security manager
- Locate the RMI registry
- Get the remote object stub from the RMI registry
- Method call is blocked until the method returns

# Step 3: Develop the client program

```
import java.rmi.*; import java.rmi.server.*; import java.net.*;
public class SampleClient  {
   public static void main(String[]  args)   {
      try
        {
          String url = "rmi://localhost:1099/sumObj";
          SumInterface remoteObject = (SumInterface)Naming.lookup(url);
          System.out.println("Got remote object");
          System.out.println(" 1 + 2 = " + remoteObject.sum(1,2) );
        }
        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());
        }
   }
}
```

# Naming Service : lookup

- Client use Naming Service to find a particular Server object (lookup)



# Step 4 & 5: Compilation & Stub Generation

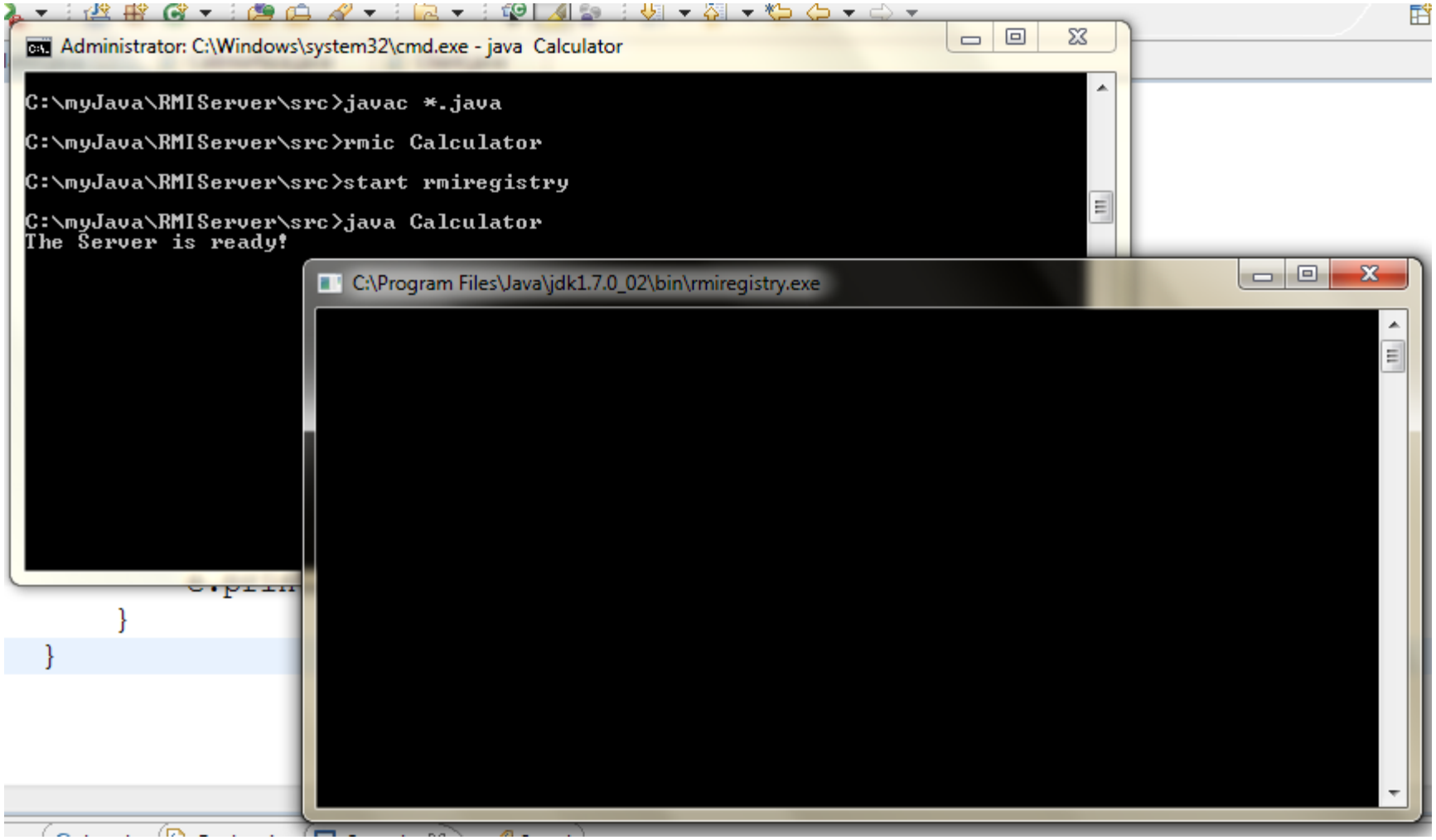
```
elpis:~/rmi> javac SumInterface.java
elpis:~/rmi> javac SumImpl.java
elpis:~/rmi> rmic SumImpl

elpis:~/rmi> javac SampleClient.java
```

# To run

- Copy **stub** file to client machine
- Start the RMI registry
  - invoke **rmiregistry.exe** under
    C:\Program Files\Java\jdk1.7.0_02\bin
- Start the RMI Server
- Start the RMI Client

# Running Server



# Running Client

```
public class Client
{
    public static void main(String[] args)
    {
        try{
            CalInterface remoteObj=(CalInterface)Naming.lookup("rmi://l
            int i=remoteObj.add(10, 20);
            System.out.println("sum = " + i);
```

Administrator: C:\Windows\system32\cmd.exe

```
C:\myJava\RMIClient\src>javac *.java

C:\myJava\RMIClient\src>java Client
sum = 30
sub = -10
mul = 200
div = 5

C:\myJava\RMIClient\src>_
```

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# Example 1: Calculator Program

Client

- CalculatorRMIInterface.java
- CalculatorRMIClient.java

Server

- CalculatorRMIInterface.java
- CalculatorRMIServer.java

# Lets Do Exercises!!!

# Exercise 1: Conversion Program

Write an RMI application in which the server can do the following conversions according to client request:

- Fahrenheit ←→ Celsius
- Miles ←→ Kilometer