Remote Method Invocation

Based on Notes by D. Hollinger

Also based on Sun's Online Java Tutorial

Network Programming Paradigms

- Sockets programming: design a protocol first, then implement clients and servers that support the protocol.
- RMI: Develop an application, then (statically) move some objects to remote machines.
  - Not concerned with the details of the actual communication between processes – everything is just method calls.

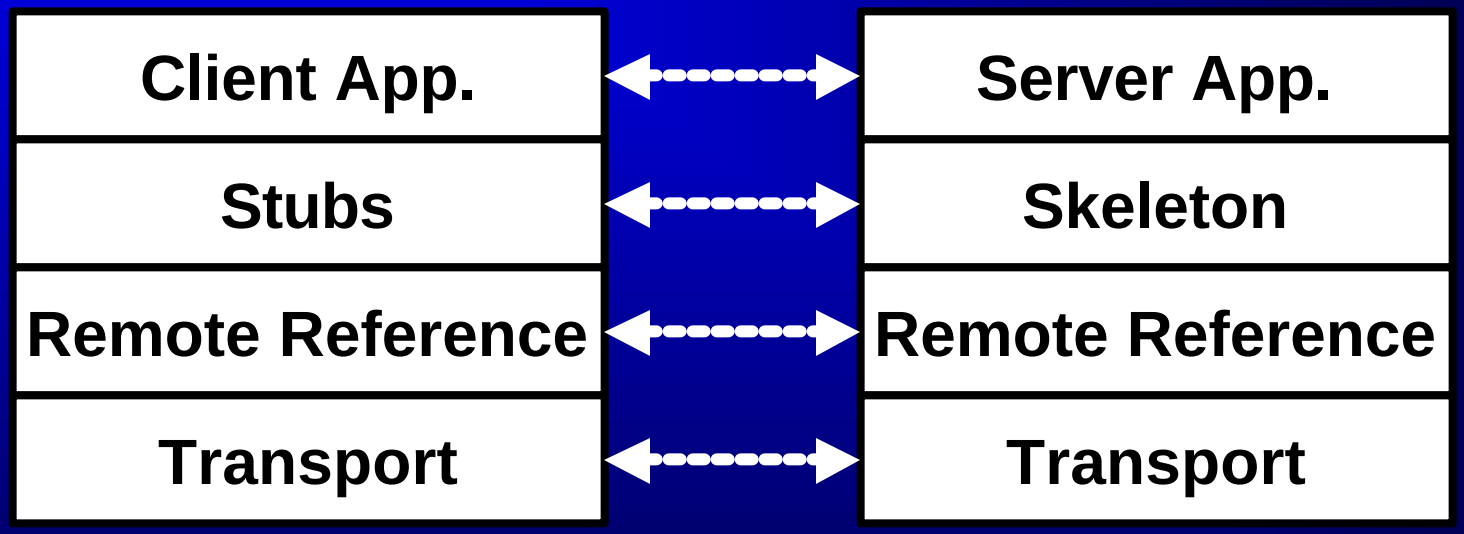
Call Semantics

- Method Call Semantics – what does it mean to make a call to a method?
  - How many times is the method run?
  - How do we know the method ran at all?
- RMI does a great job of providing *natural* call semantics for remote objects/methods.
  - Simply a few additional Exceptions that you need to handle.
  - Objects implementing the Remote interface are passed by reference. Non-remote (serializable) objects and primitive types are passed by value.

Finding Remote Objects

- It would be awkward if we needed to include a hostname, port and protocol with every remote method invocation.
- RMI provides a *Naming Service* through the RMI Registry that simplifies how programs specify the location of remote objects.
  - This naming service is a JDK utility called **`rmiregistry`** that runs at a well known address (by default).

RMI Adds a few layers



Remote Object References

- The client acquires a reference to a remote object.
  - This part is different from creating a local object.

- The client calls methods on the remote object
  - No (syntactic) difference!
  - Just need to worry about a few new exceptions.

Overview of RMI Programming

- Define an **`interface`** that declares the methods that will be available remotely.
- The *server* program must include a **`class`** that implements this **`interface`**.
- The *server* program must create a remote object and register it with the naming service.

- The *client* program creates a remote object by asking the naming service for an object reference.

Java Interfaces

- Similar to Class
- No implementation! All methods are abstract (virtual for C++ folks).
- Everything is public.
- No fields defined, just Methods.
- No constructor
- an Interface is an API that can be implemented by a Class.

Interfaces and Inheritance

- In Java a class can only extend a single superclass (single inheritance).
- A class can implement any number of interfaces.
  - end result is very similar to multiple inheritance.

Sample Interface

```
public interface Shape {
  public double getArea();
  public void draw();
  public void fill(Color c);
}
```

Implementing an Interface

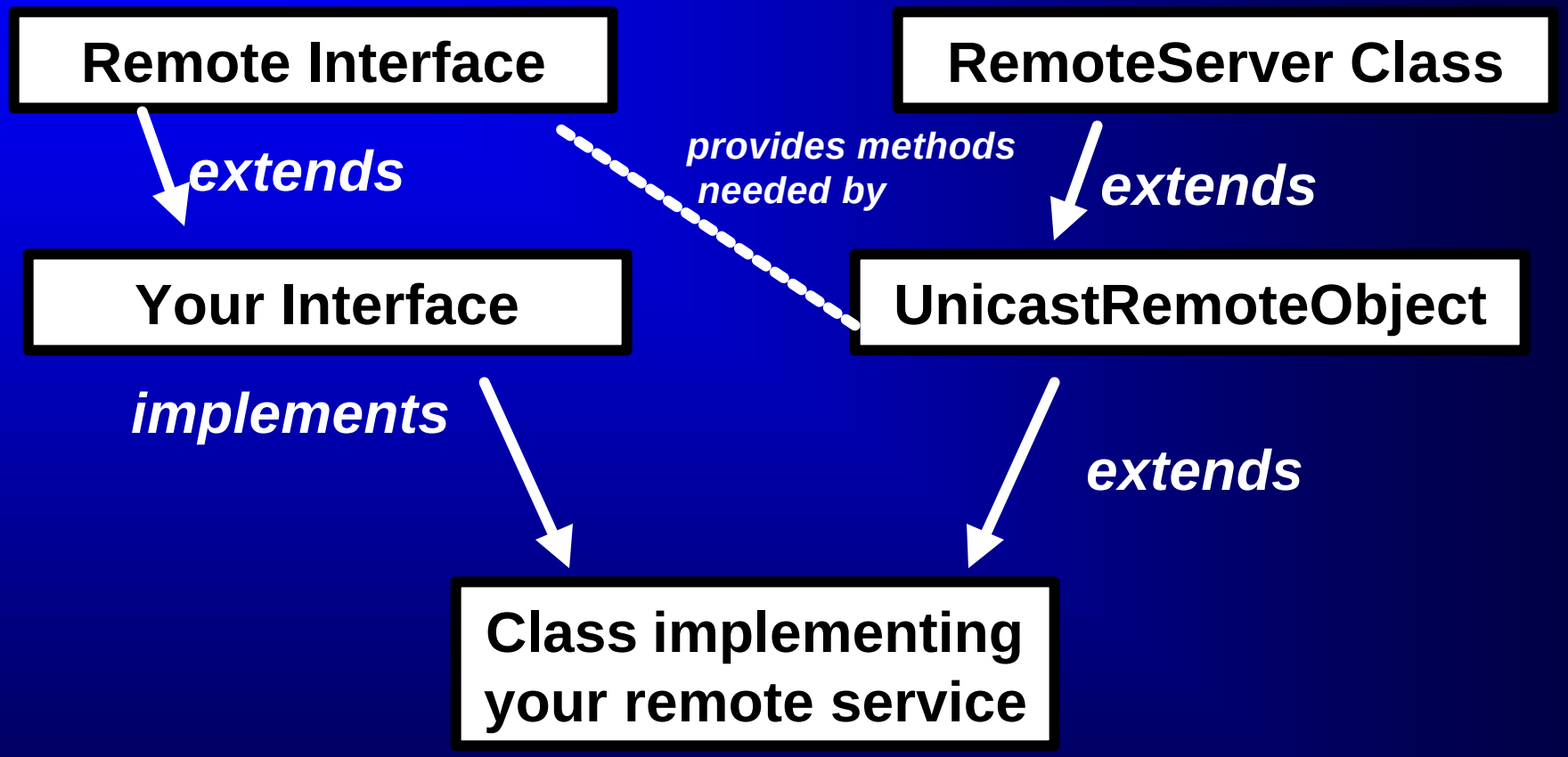
```
public class Circle implements Shape {
      private double radius;
      private Point center;

      // define a constructor and other
      // methods

      // MUST define the methods:
      //   getArea();
      //   draw();
      //   fill(Color c);
}
```

Server Details – extending Remote

- Create an *interface* the extends the **`java.rmi.Remote`** interface.
  - This new interface includes all the public methods that will be available as remote methods.

```
import java.rmi.*;
public interface MyRemote extends Remote {
  public int foo(int x) throws RemoteException;
  public String blah(int y) throws RemoteException;
  . . .
}
```

How the interface will be used



Server Details – Implementation Class

- Create a class that *implements* the interface.
  - The class should extend **`UnicastRemoteObject`***
- This class needs a constructor that throws **`RemoteException`** !
- This class is now used by **`rmic`** to create the stub and skeleton code.

*It doesn't have to extend `UnicastRemoteObject`, there is another way…

Remote Object Implementation Class

```
public class MyRemoteImpl extends
  UnicastRemoteObject implements MyRemote {


    public MyRemoteImpl() throws RemoteException
      {}


    public int foo(int x) {
      return(x+1);
    }
    public String blah(int y) {
      return("Your number is " + y);
    }
}
```

Generating stubs and skeleton

- Compile the remote interface and implementation:

```
> javac MyRemote.java MyRemoteImpl.java
```

- Use **`rmic`** to generate **`MyRemoteImpl_stub.class`**, **`MyRemoteImpl_skel.class`**

```
> rmic MyRemoteImpl
```

Server Detail – main()

- The server **`main()`** needs to:
  - create a remote object.
  - register the object with the Naming service.

```
public static void main(String args[]) {
  try {
     MyRemoteImpl r = new MyRemoteImpl();
     Naming.bind("joe",r);
  } catch (RemoteException e) {
     . . .
```

Client Details

- The client needs to ask the naming service for a reference to a remote object.
  - The client needs to know the hostname or IP address of the machine running the server.
  - The client needs to know the name of the remote object.
- The naming service uses URIs to identify remote objects.

Using The Naming service

- **`Naming.lookup()`** method takes a string parameter that holds a URI indicating the remote object to lookup.

  `rmi://hostname/objectname`

- **`Naming.lookup()`** returns an **`Object`**!
- **`Naming.lookup()`** can throw
  - **`RemoteException`**
  - **`MalformedURLException`**

Getting a Remote Object

```
try {
  Object o =
  Naming.lookup("rmi://monica.cs.rpi.edu/joe");

  MyRemote r = (MyRemote) o;
  // . . . Use r like any other Java object!
} catch (RemoteException re) {
  . . .
} catch (MalformedURLException up) {
   throw up;
}
```

Starting the Server

- First you need to run the Naming service server:

```
rmiregistry
```

- Now run the server:

```
java MyRemoteImpl
```

Sample Code

- There is sample RMI code on the course homepage:
  - BankAccount: remote access to a bank account
  - SimpleRMI: remote integer arithmetic
  - AlternativeSimpleRMI: Implementation class doesn't extend UnicastRemoteObject
  - RemoteSort: remote sort server – uses Java List objects