

CMSC 433 – Programming Language
Technologies and Paradigms
Spring 2006

Java RMI

Distributed Computing

- Programs that cooperate and communicate over a network
 - E-mail
 - Web server and web client
 - SETI @Home

Key Features of Distrib. Comp.

- Machines are not all the same
 - But all adhere to same communication protocol
- Network is “slow”
 - Sending a message takes a lot of time
- Network is unreliable
 - Machines may join and leave with no warning
 - Part of the network may fail

3

Different Approaches to Distributed Computation

- Connecting via sockets
 - E.g., project 1, 5 (part II)
 - Custom protocols for each application
- RPC/DCOM/CORBA/RMI
 - Make what looks like a normal function call
 - Function actually invoked on another machine
 - Arguments are *marshalled* for transport
 - Value is *unmarshalled* on return

4

Remote Method Invocation

- Easy way to get distributed computation
- Have stub for remote object
 - Calls to stub get translated into network call
 - Implemented on top of sockets
- Arguments and return values are passed over network
 - Java takes care of the details

5

A Simple Example

```
// runs on one mach.
class ChatServerImpl implements ChatServer ... {
    public void say(String s) {
        System.out.println(s);
    }
    ...
}
class Chatter { // runs on another mach.
    public static void main(String args[]) {
        ChatServer c = // get remote object;
        BufferedReader br = new BufferedReader(new
            InputStreamReader(System.in));

        while (true) {
            System.out.print("> ");
            c.say(br.readLine());
        }
    }
} }
```

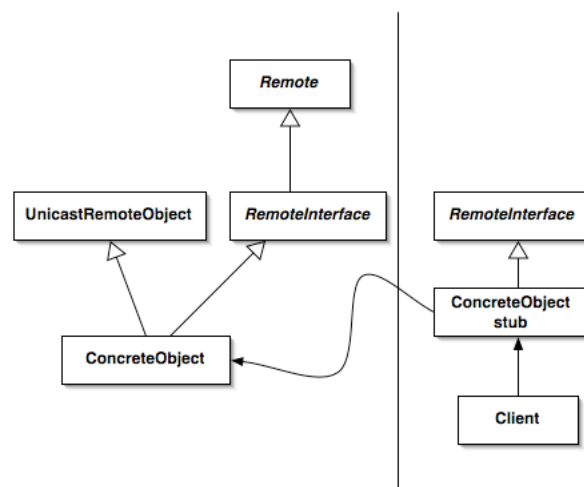
6

Remote Objects

- Object should
 - Extend `java.rmi.server.UnicastRemoteObject`
 - Constructor declared to throw `RemoteException`
 - Implement a *remote interface*
 - A remote interface extends `java.rmi.Remote`
 - All methods in a remote interface throw `RemoteException`
 - “Something bad happened on the network”
 - Side note: actually, don’t need to extend `UnicastRemoteObject`, but it’s much easier

7

Remote Interfaces



8

Stubs

- Client only sees the RemoteInterface
 - ConcreteObject can have other methods
- Remote objects represented using stub
 - Stub sends arguments over network
 - Stub receives result back from network

9

Compiling Stubs with rmic

- Generates stub code for a class
 - For 1.1, also generates skeleton class
 - Stub on client side communicates with skeleton on remote side
 - Skeleton not needed for 1.2+
 - And 1.2+ generates position-independent code
 - Use -v1.2 if you want
- Generates stubs for all methods declared in the class' Remote interface
 - Other methods don't get a stub

10

Passing Arguments

- To pass an argument to a remote method
 - (Or return a result from a remote method)
 - It must be either
 - A primitive type (int, double, etc.),
 - Serializable (e.g., String), or
 - Remote (i.e., implement a sub-interface of Remote)
 - Primitives passed as you'd expect

11

Passing Serializable vs. Remote

- Serializable objects passed by value
 - Same Serializable in different calls materializes different objects at receiver
- Remote objects passed by reference
 - Same Remote object in different calls yields same stub object, which passes arguments back to same remote object

12

Stub Code

- Objects contain both data and code
 - When you receive a remote object, you need the stub for that remote object
- Solution #1: All clients have stub code on their classpath
 - Or stub code for another class with same remote interface

13

Downloading Code

- Solution #2: Provide a *code base* where stub code for objects can be downloaded

```
java -Djava.rmi.server.codebase=<url> ...
```

 - Specifies location of classes originating from this server
 - URL can be, e.g., `http://` or `file:/`

14

Getting the First Remote Object

- Can make objects available in RMI registry
 - Each object has a name (that you specify)
 - Registry listens on a port (1099 default)
- Naming.lookup(url) gets object from reg.
 - E.g., Naming.lookup(“rmi://localhost/Chat”);
 - Use to get first reference to remote object
 - Don’t need to lookup objects returned by remote methods

15

Starting an RMI Registry

- Method 1: Separate RMI registry process
 - Command `rmiregistry`
 - Run with stubs in classpath, or specify codebase
 - Listens on port 1099 by default
- Method 2: Start in same JVM
 - `LocateRegistry.createRegistry(int port)`
 - Advantage: dies when your program dies
 - No registries lying around on machine

16

Advertising Remote Objects

- Call Naming. {bind/unbind/rebind} to place objects in registry
 - E.g., Naming.bind(“rmi://localhost/Chat”);
- Can bind/unbind/rebind name on localhost
- Can lookup name on any host

17

Example: RMI Chat Server

- Server
 - Runs the chat room
- Client
 - Participant in chat room
 - Receives messages from others in room
- Connection
 - Uniquely identifies a client
 - Used to speak in chat room

18

Server

```
interface Server extends Remote {  
  
    Connection logon(String name, Client c)  
        throws RemoteException;  
  
}
```

19

Connection

```
interface Connection extends Remote {  
  
    /** Say to everyone */  
    void say(String msg)  
        throws RemoteException;  
  
    / ** Say to one person */  
    void say(String who, String msg)  
        throws RemoteException;  
  
    String [] who()  
        throws RemoteException;  
  
    void logoff()  
        throws RemoteException;  
}
```

20

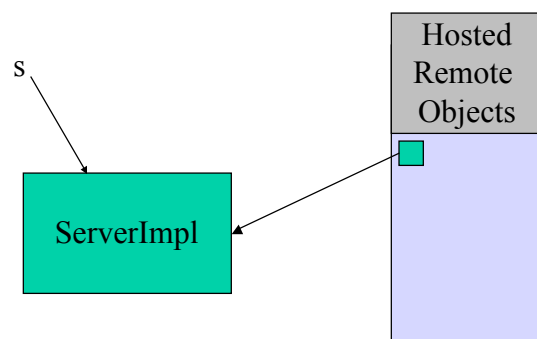
Client

```
interface Client extends Remote {  
  
    void said(String who, String msg)  
        throws RemoteException;  
  
    void whoChanged(String [] who)  
        throws RemoteException;  
}
```

21

Server's Remote Object creation

```
Server s = new ServerImpl();
```



*Object added to table
because it implements
extension of **Remote**
interface*

Server

22

Remote Object registry

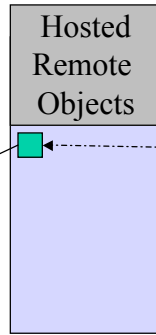
```
Naming.rebind("ChatServer", s);
```

s

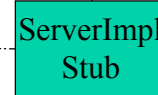


Server

Hosted Remote Objects



ChatServer



RMI Registry

23

Client's Remote Object creation

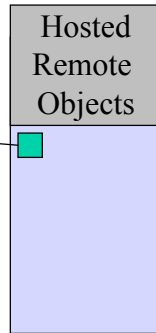
```
Client c = new ClientImpl();
```

c



Client

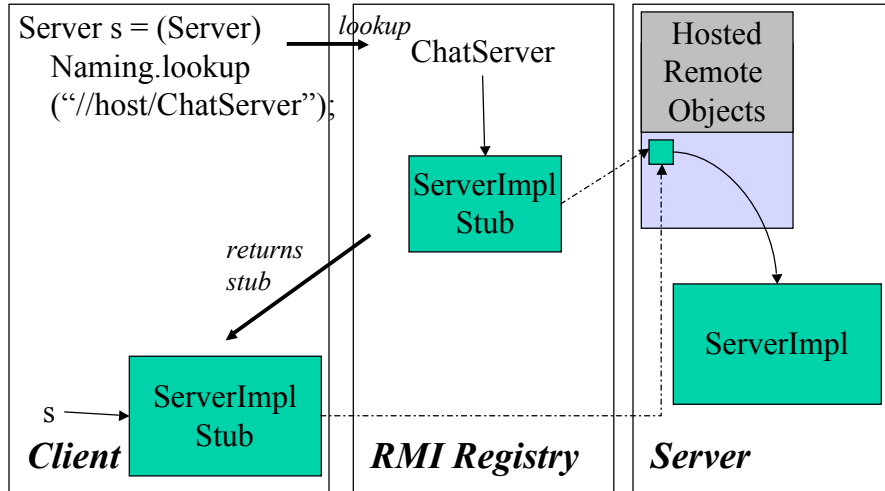
Hosted Remote Objects



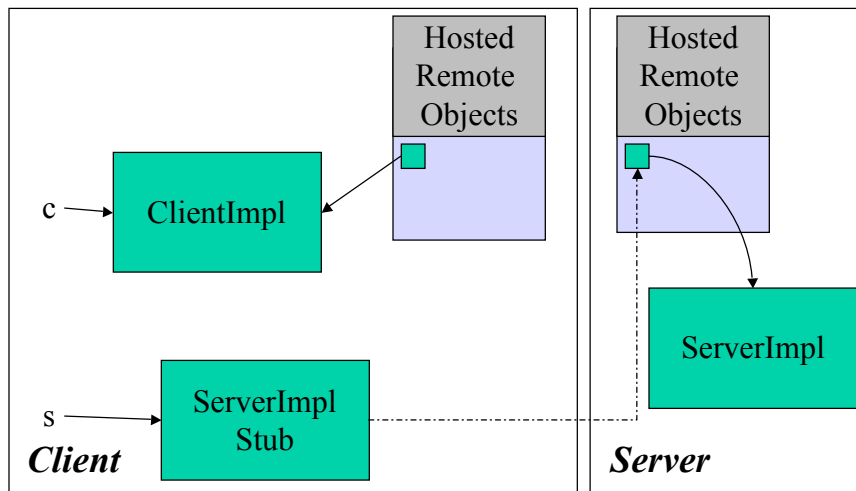
*Client object also implements extension of **Remote** interface*

24

Client looks up Server

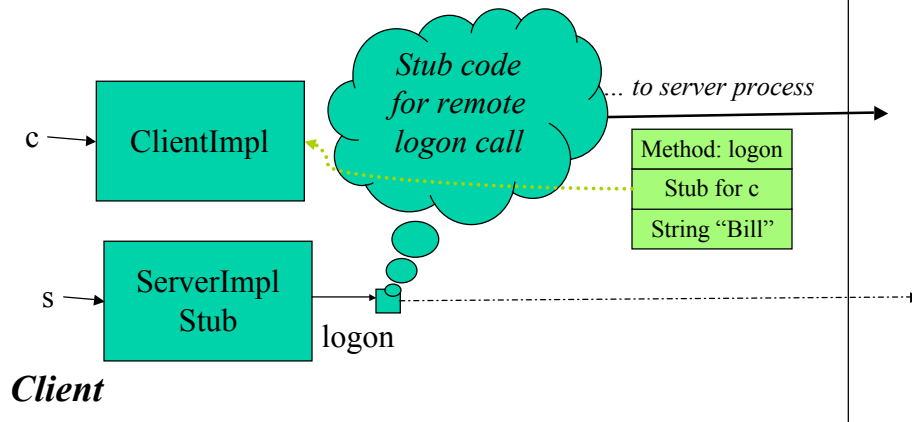


After lookup finished



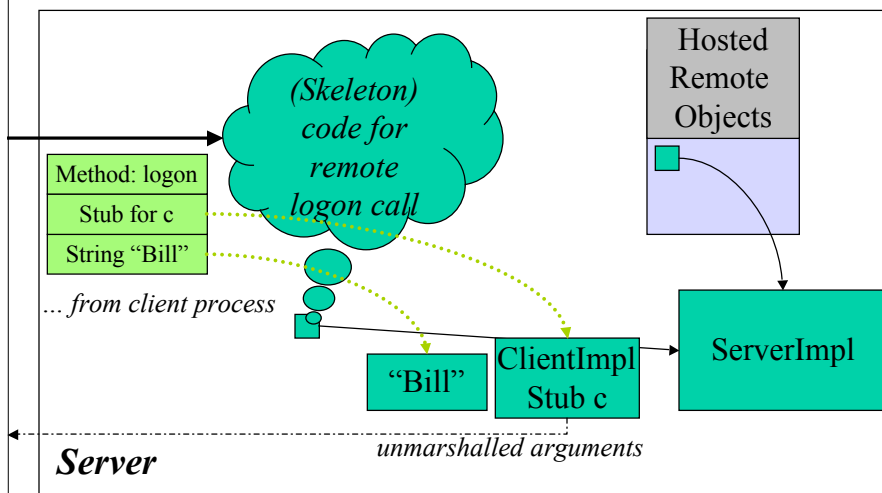
Invokes remote Server method

```
Connection conn = s.logon("Bill", c);
```



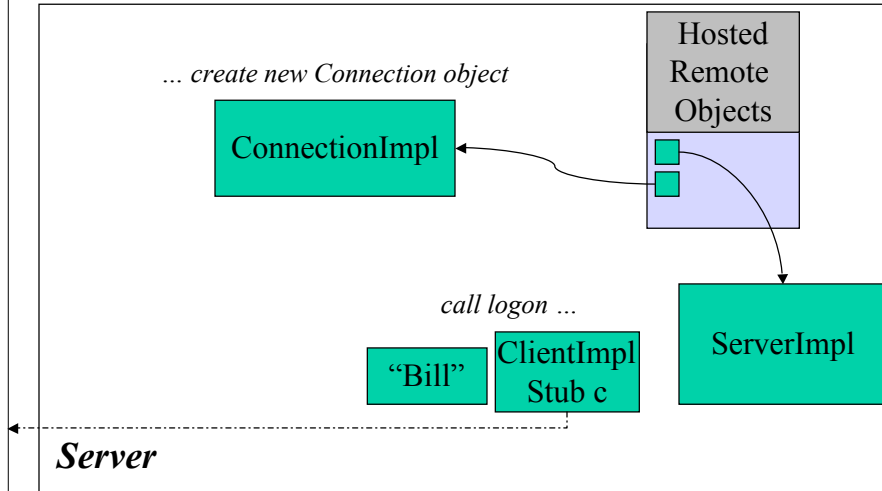
27

Receives remote call



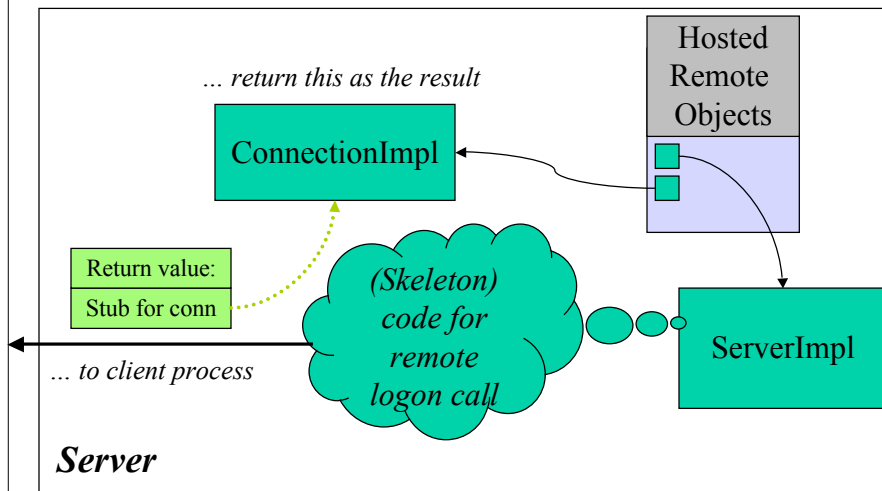
28

Executes the call



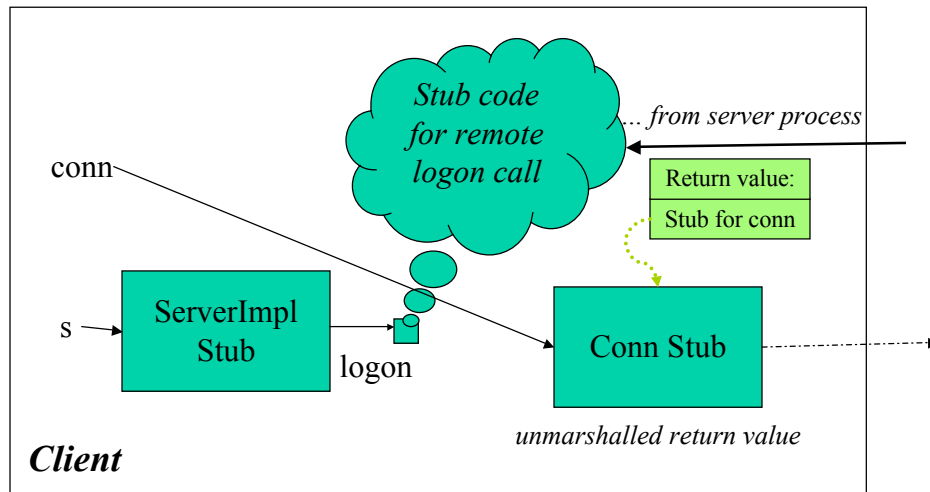
29

Returns the result



30

Receives the result



31

Security Manager

- When using a code base, we must download stub code from a remote site. This is potentially risky
 - Need to limit what downloaded code could do
 - Must install a Security Manager before you download any code from RMI code bases

- Can use

```
System.setSecurityManager(  
    new RMISecurityManager());
```

32

Policy Files

- In addition to security manager, need to specify a security policy

```
grant {  
    permission java.net.SocketPermission  
        "*:1024-65535", "connect,accept";  
    permission java.net.SocketPermission " *:80",  
        "connect";  
};
```

- Set security policy when JVM started
 - `java -Djava.security.policy=<file name>`

33

Project 5

- Project 5 uses the same concepts as RMI
 - There is a “remote” object which can be interacted with using a local stub. Both implement the same interface.
 - `RemoteServer` and `RemoteClient`
- The sending of messages back and forth is implemented manually in the project
 - Uses sockets; messages must be `Serializable`

34