CS 635 Advanced Object-Oriented Design & Programming
Spring Semester, 2005
Doc 18 Pipe Filters and Broker

Contents

Reference

Pattern-Oriented Software Architecture, Buschmann et al., 1996, Wiley, pp 53-70, 99-122

Architectural Patterns

Deal with basic structure of an application

Specify subsections of an application

Observer verses MVC

Observer indicates how to solve a problem in your code

MVC specifies components of a GUI application

Pipes & Filters

Unix Example

```
ls | grep -i b | wc -l
```

Context

Processing data streams

Problem

Building a system that processes or transforms a stream of data

Forces

- Small processing steps are easier to reuse than large components
- Non-adjacent processing steps do not share information
- System changes should be possible by exchanging or recombining processing steps, even by users
- Final results should be presented or stored in different ways

Solution

Divide task into multiple sequential processing steps or filter components

Output of one filter is the input of the next filter

Filters process data incrementally

- Filter does not wait to get all the data before processing

Data source – input to the system

Data sink – output of the system

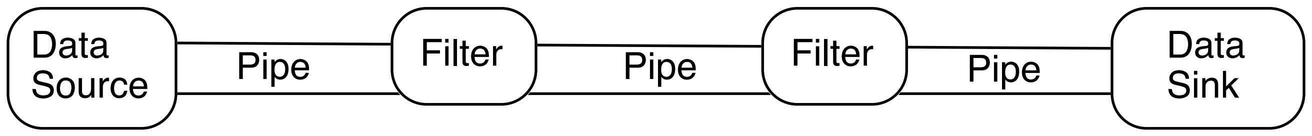
Pipes - connect the data source, filters and data sink

Pipe implements the data flow between adjacent processes steps

Processing pipeline – sequence of filters and pipes

Pipeline can process batches of data

Structure



A Filter can be triggered by:

- Subsequent pipeline element pulls output from the filter
- Previous pipeline element pushes new data into filter
- Active Filter – pulls data from input and pushes data down the pipeline

If two active filters are adjacent the pipe between them synchronizes them

Some Implementation issues

Dividing the system into separate tasks

Data format passed between filters

This may require filters to convert from common format to a usable format

Implementing the pipes

Filter could directly push/pull data from another filter

Using a separate pipe mechanism
- More flexible
- Makes it easier to test filters
- Permits active filters

Error handling

What happens if 1/2 data is processed when one filter has a runtime exception?

How does one inform the other filters?

Can one restart the pipeline to process the next batch of data?

Simple Java Example

SharedQueue for Java Pipe

```
import java.util.ArrayList;
public class SharedQueue
  {
  ArrayList elements = new ArrayList();

  public synchronized void append( Object item )
     {
     elements.add( item);
     notify();
     }

  public synchronized Object get( )
     {
     try
        {
        while ( elements.isEmpty() )
           wait();
        }
     catch (InterruptedException threadIsDone )
        {
        return null;
        }
     return elements.remove( 0);
     }

  public int size()
     {
     return elements.size();
     }
  }
```

```
public class Source extends Thread
  {
  private static final char END_OF_PIPELINE = '@';
  String in;
  SharedQueue out;

  public Source(String input, SharedQueue output)
     {
     in = input;
     out = output;
     }

  public void run()
     {
     for (int k = 0; k < in.length(); k++)
        {
        out.append(new Character(in.charAt(k)));
        }
     }
  }
```

```
public class UpperCaseFilter extends Thread
  {
  private static final char END_OF_PIPELINE = '@';
  SharedQueue in;
  SharedQueue out;

  public UpperCaseFilter(SharedQueue input, SharedQueue output)
     {
     in = input;
     out = output;
     }

  public void run()
     {
     Character currentObject = (Character) in.get();
     char current = currentObject.charValue();
     while (current != END_OF_PIPELINE)
        {
        out.append(new Character(Character.toUpperCase(current)));
        currentObject = (Character) in.get();
        current = currentObject.charValue();
        }
     }
  }
```

```
public class Display extends Thread
  {
  private static final char END_OF_PIPELINE = '@';
  SharedQueue in;
  SharedQueue out;

  public Display(SharedQueue input, SharedQueue output)
    {
    in = input;
    out = output;
    }

  public void run()
    {
    Character currentObject = (Character) in.get();
    char current = currentObject.charValue();
    while (current != END_OF_PIPELINE)
      {
      System.out.println(current);
      currentObject = (Character) in.get();
      current = currentObject.charValue();
      }
    }
  }
```

Running the Example

```
public class Example
  {
  public static void main(String[] args) throws IOException,
        NoSuchAlgorithmException
     {
     SharedQueue first = new SharedQueue();
     SharedQueue second = new SharedQueue();
     Source start = new Source("cat man@", first);
     UpperCaseFilter filter = new UpperCaseFilter(first, second);
     Display end = new Display(second, null);
     start.start();
     filter.start();
     end.start();

     }
  }
```

Smalltalk Version

```
endOfPipeline := $@.
```

```
upperCaseFilter :=
    [:input :output |
    | nextCharacter |

    [nextCharacter := input next.
    nextCharacter ~= endOfPipeline]
        whileTrue: [output nextPut: nextCharacter asUppercase]].

noBeesFilter :=
    [:input :output |
    | nextCharacter |

    [nextCharacter := input next.
    nextCharacter ~= endOfPipeline]
        whileTrue:
          [nextCharacter ~= $B
            ifTrue: [output nextPut: nextCharacter]]].

display :=
    [:input |
    | nextCharacter |

    [nextCharacter := input next.
    nextCharacter ~= endOfPipeline]
        whileTrue: [Transcript nextPut: nextCharacter; flush]].
```

Running Example

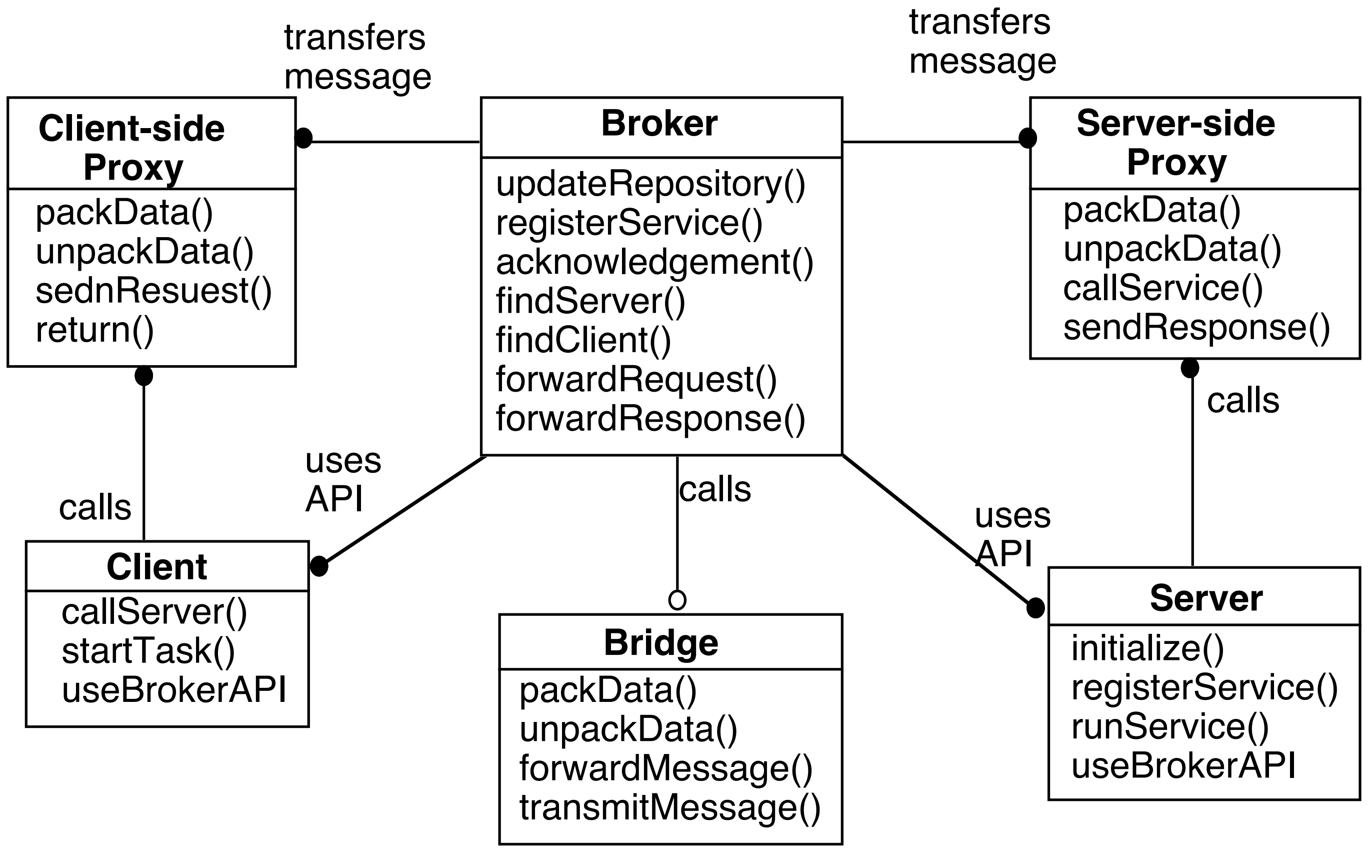
```
dataStream :='Hi Mom. How is Bob@' readStream.
pipeA := SharedQueue new.
pipeB := SharedQueue new.

[upperCaseFilter value: dataStream value: pipeA] fork.
[noBeesFilter value: pipeA value: pipeB] fork.
[display value: pipeB ] fork.
```

But this example not an Application!

How does it differ from using Streams?

The Broker Pattern



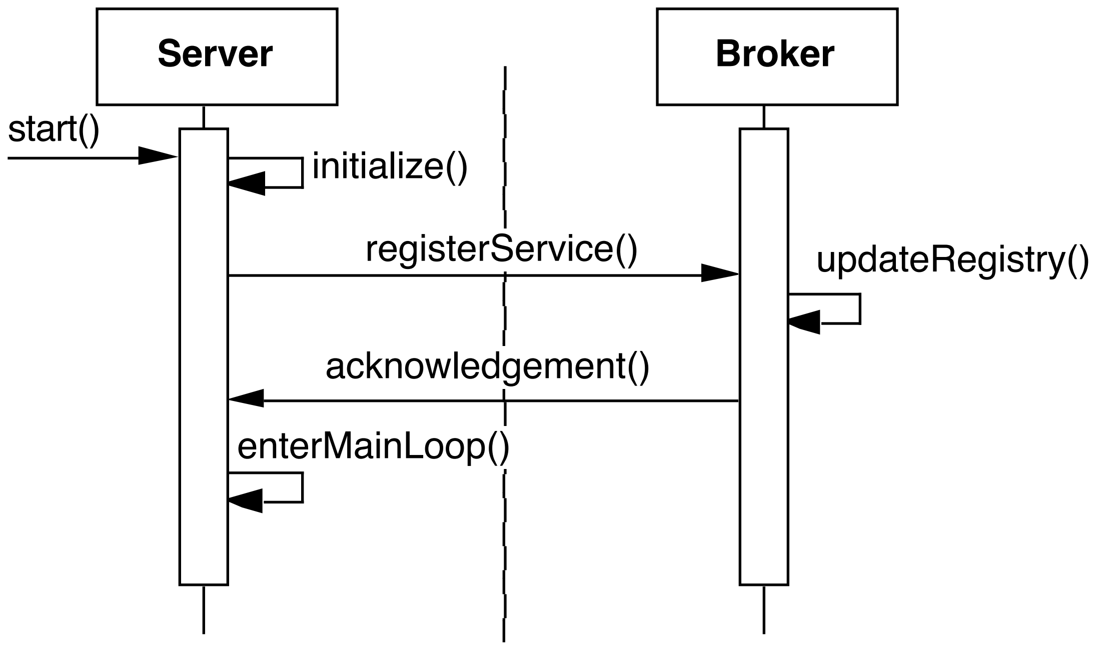
A broker

- Handles the transmission of requests from clients to servers
- Handles the transmission of responses from servers to clients
- Must have some means to identify and locate server
- If server is hosted by different broker, forwards the request to other broker
- If server is inactive, active the server
- Provides APIs for registering servers and invoking server methods

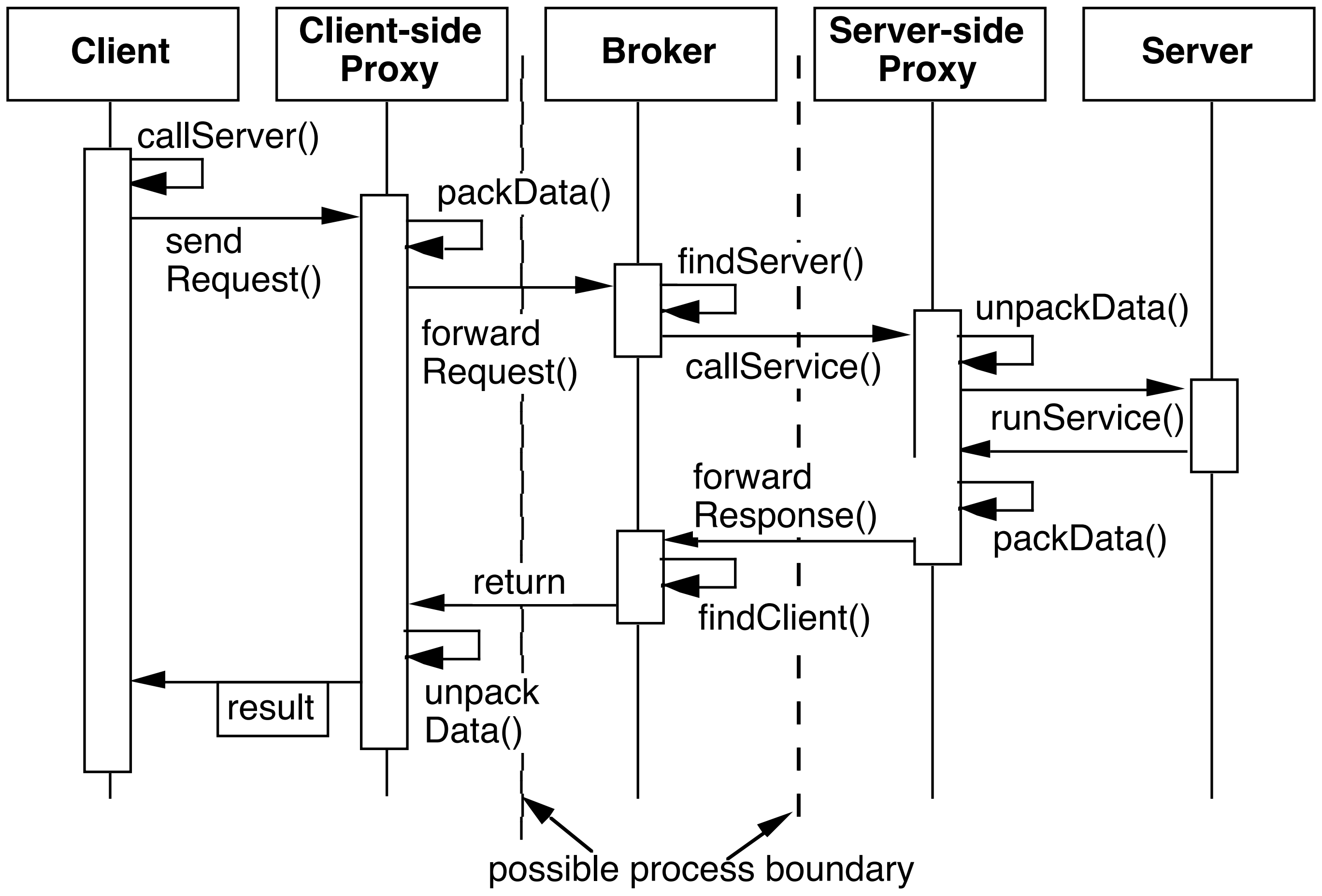
Bridge

- Optional components used for hiding implementation details when two brokers interoperate

Dynamics
Registering Server



Client Server Interaction



Variants

Direct Communication Broker System

- Broker gives the client a communication channel to the server
- Client and server interact directly
- Many CORBA implementation use this variant

Message Passing Broker System

- Clients and servers pass messages rather than services (methods)

Trader System

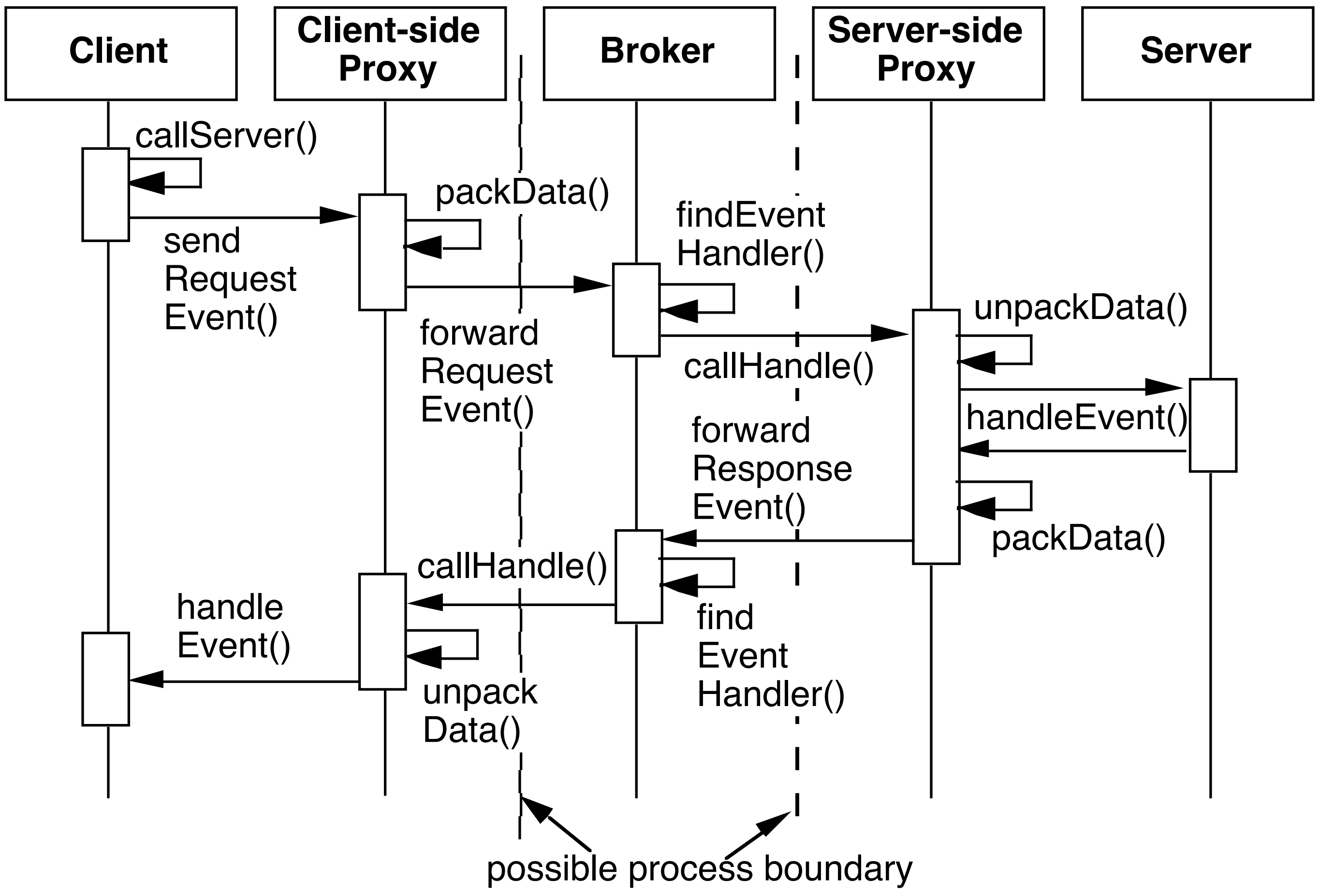
- Clients request a service, not a server
- Broker forwards the request to a server that provides the service

Adapter Broker System

- Hide the interface of the broker component to the servers using an additional layer
- The adapter layer is responsible for registering servers and interacting with servers
- For example if all server objects are on the same machine as application a special adapter could link the objects to the application directly

Callback Broker System

- Eliminate the difference between clients and servers
- When an event is registered with a broker, it calls the component that is registered to handle the event



Known Uses

CORBA

IBM's SOM/DSOM

Mircosoft OLE 2.x

RMI

Consequences
Benefits

Location Transparency

Clients (servers) do not care where servers (clients)are located

Changeability and extensibility of components

Changes to server implementations are transparent to clients if they don't change interfaces

Changes to internal broker implementation does not affect clients and servers

One can change communication mechanisms without changing client and server code

Portability of Broker System

Porting client & servers to a new system usually just requires recompiling the code

Benefits - Continued

Interoperability between different Broker System

Different broker systems may interoperate if they have a common protocol for the exchange of messages

DCOM and CORBA interoperate

DCOM and RMI interoperate

RMI and CORBA interoperate

Reusability

In building new clients you can reuse existing services

Liabilities

Restricted Efficiency

Lower fault tolerance compared to non-distributed software

Benefits and Liabilities

Testing and Debugging

A client application using tested services is easier to test than creating the software from scratch

Debugging a Broker system can be difficult

Some RMI

A First Program - Hello World

Modified from "Getting Started Using RMI"

The Remote Interface

```
public interface Hello extends java.rmi.Remote
  {
  String sayHello() throws java.rmi.RemoteException;
  }
```

The Server Implementation

```
// Required for Remote Implementation
import java.rmi.*;
import java.rmi.server.UnicastRemoteObject;

// Used in method getUnixHostName
import java.io.BufferedReader;
import java.io.IOException;
import java.io.InputStreamReader;

public class HelloServer
      extends UnicastRemoteObject
      implements Hello
   {

   public HelloServer() throws RemoteException
      {
      }

   // The actual remote sayHello
   public String sayHello() throws RemoteException
      {
      return  "Hello World from " + getUnixHostName();
      }
```

// Works only on UNIX machines

```
protected String getUnixHostName()
   {
   try
      {
      Process  hostName;
      BufferedReader  answer;

      hostName = Runtime.getRuntime().exec( "hostname" );
      answer = new BufferedReader(
                     new InputStreamReader(
                        hostName.getInputStream()) );

      hostName.waitFor();
      return answer.readLine().trim();
      }
   catch (Exception noName)
      {
      return "Nameless";
      }
   }
```

// Main that registers with Server with Registry

```
public static void main(String args[])
   {
   // Create and install a security manager
   System.setSecurityManager(new RMISecurityManager());

   try
      {
      HelloServer serverObject = new HelloServer ();

      Naming.rebind("//roswell.sdsu.edu/HelloServer",
                        serverObject );

      System.out.println("HelloServer bound in registry");

      }
   catch (Exception error)
      {
      System.out.println("HelloServer err: ");
      error.printStackTrace();
      }
   }
}
```

The Client Code

```
import java.rmi.*;
import java.net.MalformedURLException;

public class HelloClient
  {
  public static void main(String args[])
     {
     try {
        Hello remote = (Hello) Naming.lookup(
                                "//roswell.sdsu.edu/HelloServer");

        String message = remote.sayHello();
        System.out.println( message );
        }
     catch ( Exception error)
        {
        error.printStackTrace();
        }
     }
  }
```

Note the multiple catches are to illustrate which exceptions are thrown

Running The Example
Server Side

Step 1. Compile the source code

Server side needs interface Hello and class HelloServer

```
javac Hello.java  HelloServer.java
```

Step 2. Generate Stubs and Skeletons (to be explained later)

The rmi compiler generates the stubs and skeletons

```
rmic   HelloServer
```

This produces the files:

```
HelloServer_Skel.class
HelloServer_Stub.class
```

The Stub is used by the client and server
The Skel is used by the server

The normal command is:

```
rmic   fullClassname
```

Step 3. Insure that the RMI Registry is running

For the default port number

```
rmiregistry &
```

For a specific port number

```
rmiregistry portNumber &
```

On a UNIX machine the rmiregistry will run in the background and will continue to run after you log out

This means you manually kill the rmiregistry

Step 4. Register the server object with the rmiregistry by running HelloServer.main()

```
java HelloServer &
```

Client Side

The client can be run on the same machine or a different machine than the server

Step 1. Compile the source code

Client side needs interface Hello and class HelloClient

```
javac Hello.java HelloClient.java
```

Step 2. Make the HelloServer_Stub.class is available

Either copy the file from the server machine

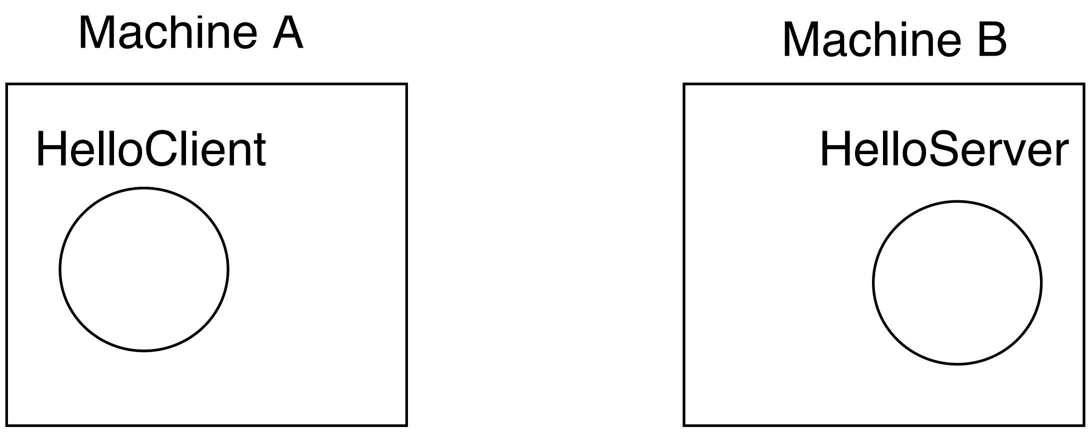
or

Compile HelloServer.java on client machine and rum rmic

Step 3. Run the client code

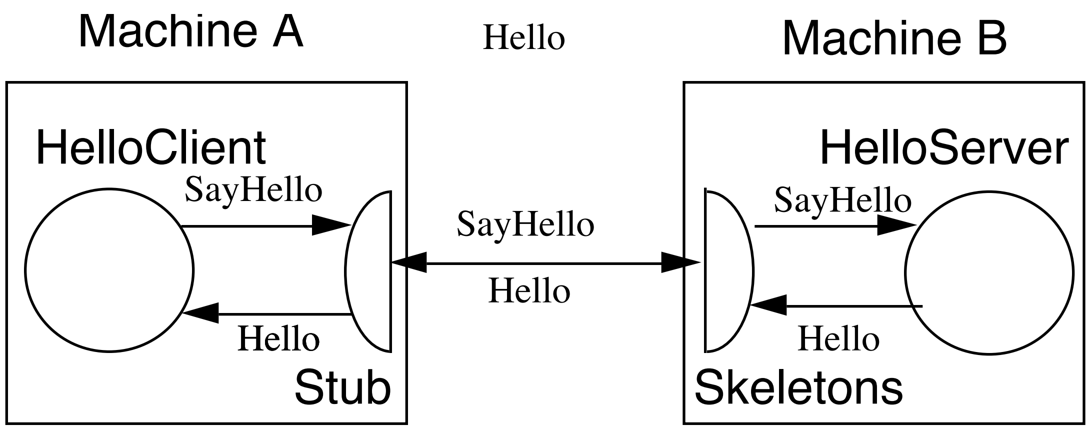
```
java HelloClient
```

Proxies
How do HelloClient and HelloSever communicate?



Client talks to a Stub that relays the request to the server over a network

Server responds via a skeleton that relays the response to the Client


Machine A
Hello
Machine B
HelloClient
SayHello
Hello
Stub
SayHello
Hello
HelloServer
SayHello
Hello
Skeletons