COP 4610L: Applications in the Enterprise
Fall 2007

Java Networking and the Internet – Part 2

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Networking

- Java's fundamental networking capabilities are declared by classes and interfaces of the `java.net` package, through which Java offers *stream-based communications*.
- The classes and interfaces of `java.net` also offer *packet-based communications* for transmitting individual packets of information. This is most commonly used to transmit audio and video over the Internet.
- We will focus on both sides of the client-server relationship.
- The client requests that some action be performed, and the server performs the action and responds to the client.

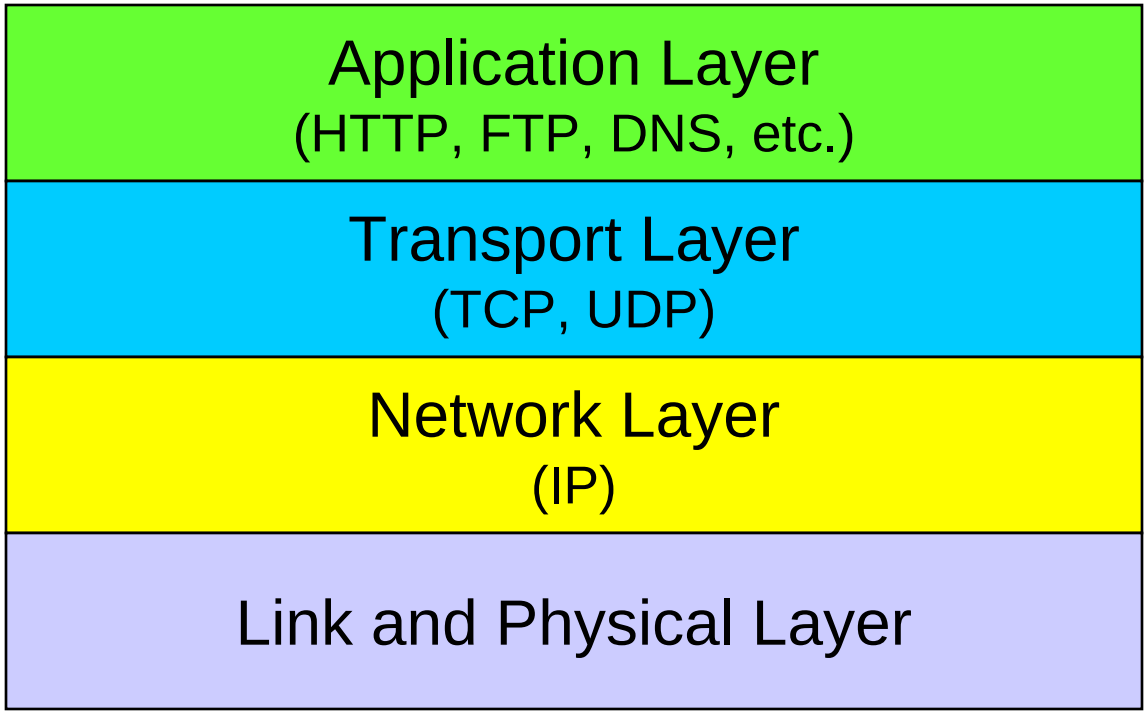
Networking (cont.)

- A common implementation of the request-response model is between Web browsers and Web servers.
  - When a user selects a Web site to browse through a browser (a client application), a request is sent to the appropriate Web server (the server application). The server normally responds to the client by sending the appropriate HTML Web page.

java.net

- "High-level" APIs
  - Implement commonly used protocols such as HTML, FTP, etc.
- "Low-level" APIs
  - Socket-based communications
    - Applications view networking as streams of data
    - Connection-based protocol
    - Uses TCP (Transmission Control Protocol)
  - Packet-based communications
    - Individual packets transmitted
    - Connectionless service
    - Uses UDP (User Datagram Protocol)

Internet Reference Model



See page 22 in part 1 for a more detailed version of this diagram.

Sockets

- Java's socket-based communications enable applications to view networking as if it were file I/O. In other words, a program can read from a socket or write to a socket as simply as reading from a file or writing to a file.
- A socket is simply a software construct that represents one endpoint of a connection.
- Stream sockets enable a process to establish a connection with another process. While the connection is in place, data flows between the processes in continuous streams.
- Stream sockets provide a connection-oriented service. The protocol used for transmission is the popular TCP (Transmission Control Protocol). Provides reliable , in-order byte-stream service

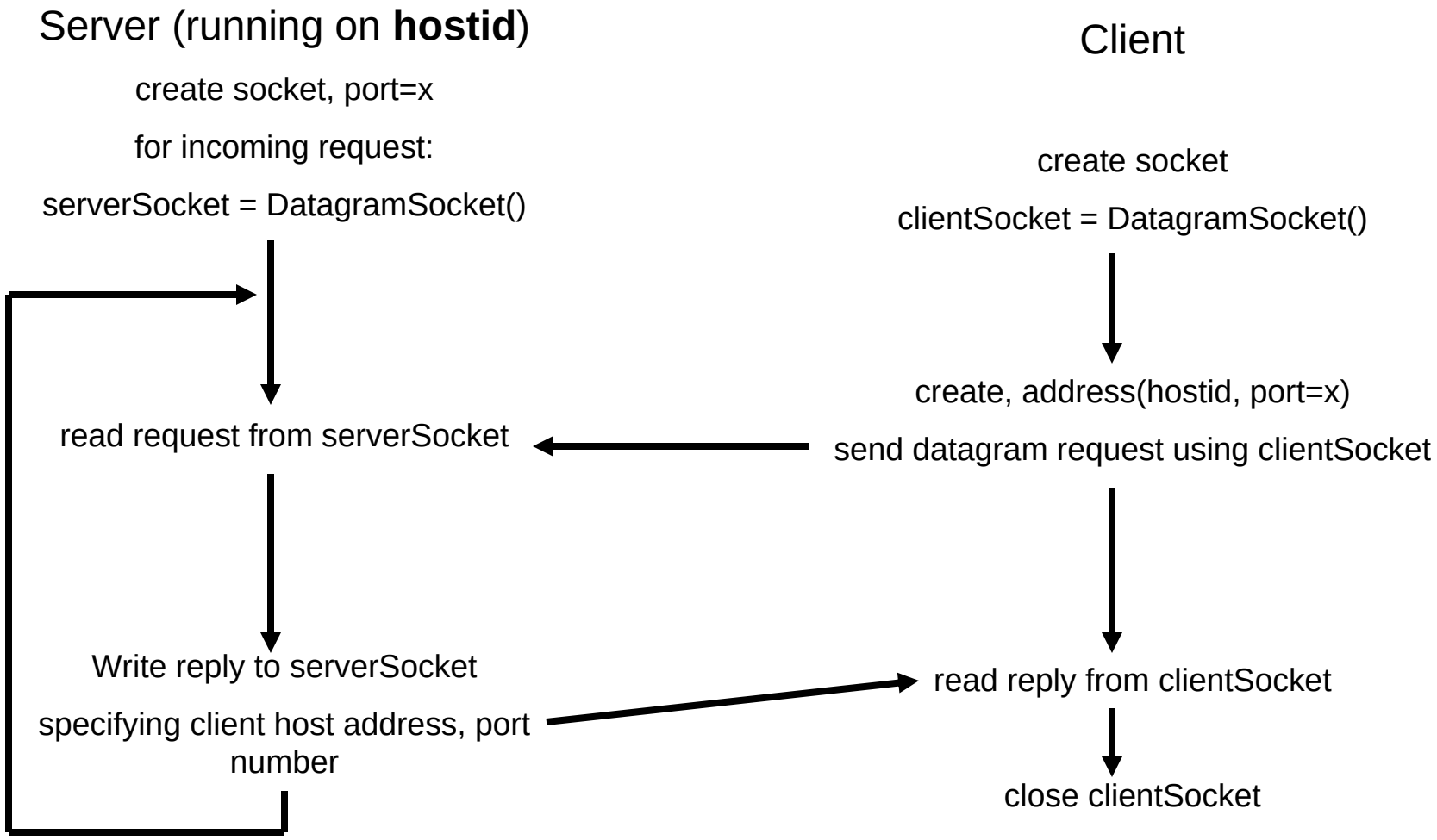
Sockets (cont.)

- Datagram sockets transmit individual packets of information. This is typically not appropriate for use by everyday programmers because the transmission protocol is UDP (User Datagram Protocol).
- UDP provides a connectionless service. A connectionless service does not guarantee that packets arrive at the destination in any particular order.
- With UDP, packets can be lost or duplicated. Significant extra programming is required on the programmer's part to deal with these problems.
- UDP is most appropriate for network applications that do not require the error checking and reliability of TCP.

Sockets (cont.)

- Under UDP there is no “connection” between the server and the client. There is no “handshaking”.
- The sender explicitly attaches the IP address and port of the destination to each packet.
- The server must extract the IP address and port of the sender from the received packet.
- From an application viewpoint, UDP provides unreliable transfer of groups of bytes (“datagrams”) between client and server.

Example: client/server socket interaction via UDP



Example: Java server using UDP

```
import java.io.*;
import java.net.*;

class UDPServer {
  public static void main(String args[]) throws Exception
             {
                          //Create datagram socket on port 9876
                          DatagramSocket serverSocket = new DatagramSocket(9876);

                          byte[] sendData = new byte[1024];
                          byte[] receiveData = new byte[1024];

                          while (true)
                          {
                                       //create space for the received datagram
                                       DatagramPacket receivePacket = new
                                                    DatagramPacket(receiveData,
                                                                 receiveData.length);
                                       //receive the datagram
                                       serverSocket.receive(receivePacket);

                                       String sentence = new String(receivePacket.getData());
```


Example: Java server using UDP (cont.)

```
                    //get IP address and port number of sender
                            InetAddress IPAddress = receivePacket.getAddress();
                            int port = receivePacket.getPort();
                                    String capitalizedSentence =
                                                            sentence.toUpperCase();
                            sendData = capitalizedSentence.getBytes();
                            //create datagram to send to client
                            DatagramPacket sendPacket = new
                    DatagramPacket(sendData, sendData.length, IPAddress, port);
                            //write out the datagram to the socket
                            serverSocket.send(sendPacket);
                    } //end while loop
            }
}
```

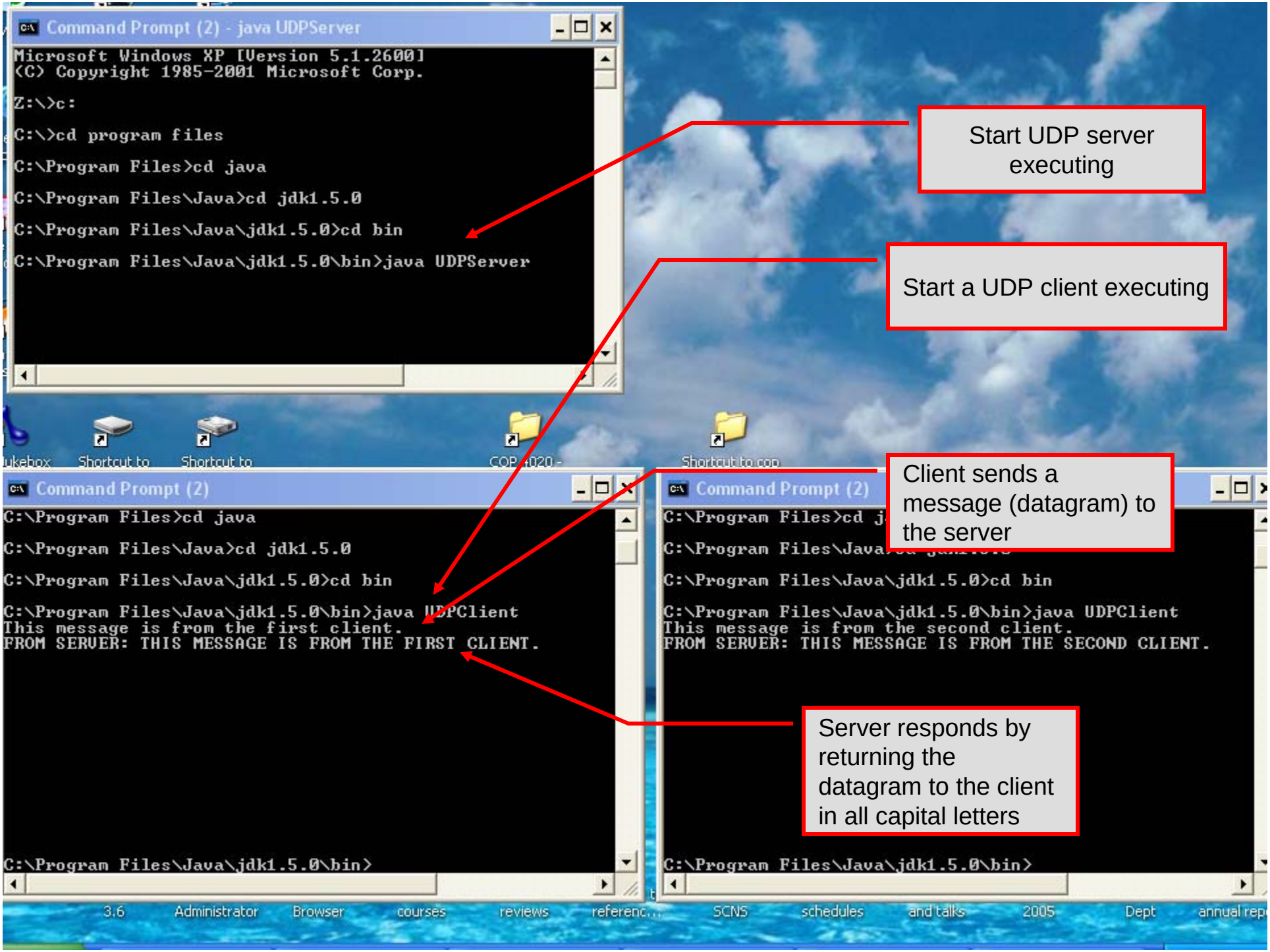

Example: Java client using UDP

```
import java.io.*;
import java.net.*;

class UDPClient {
   public static void main(String args[]) throws Exception
                {
                        //Create input stream
                        BufferedReader inFromUser = new BufferedReader(new
                                                InputStreamReader(System.in));
                        //Create client socket
                        DatagramSocket clientSocket = new DatagramSocket();
                        //Translate hostname to IP address using DNS
                        InetAddress IPAddress = InetAddress.getByName("localhost");

                        byte[] sendData = new byte[1024];
                        byte[] receiveData = new byte[1024];

                        String sentence = inFromUser.readLine();
                        sendData = sentence.getBytes();
```


Example: Java client using UDP (cont.)

```
                DatagramPacket sendPacket = new DatagramPacket(sendData,
                        sendData.length, IPAddress, 9876);
                clientSocket.send(sendPacket);

                DatagramPacket receivePacket = new DatagramPacket(receiveData,
                        receiveData.length);

                clientSocket.receive(receivePacket);

                String modifiedSentence = new String(receivePacket.getData());

                System.out.println("FROM SERVER: " + modifiedSentence);
                clientSocket.close();
        }
}
```

Try executing these two applications on your machine and see how it works. The code for both the server and the client are on the code page.


Command Prompt (2) - java UDPServer
Microsoft Windows XP [Version 5.1.2600]
(C) Copyright 1985-2001 Microsoft Corp.
Z:\>c:
C:\>cd program files
C:\Program Files>cd java
C:\Program Files\Java>cd jdk1.5.0
C:\Program Files\Java\jdk1.5.0>cd bin
C:\Program Files\Java\jdk1.5.0\bin>java UDPServer
Start UDP server executing
Start a UDP client executing
Command Prompt (2)
C:\Program Files>cd java
C:\Program Files\Java>cd jdk1.5.0
C:\Program Files\Java\jdk1.5.0>cd bin
C:\Program Files\Java\jdk1.5.0\bin>java UDPClient
This message is from the first client.
FROM SERVER: THIS MESSAGE IS FROM THE FIRST CLIENT.
C:\Program Files\Java\jdk1.5.0\bin>
Client sends a message (datagram) to the server
Command Prompt (2)
C:\Program Files\Java\jdk1.5.0>cd bin
C:\Program Files\Java\jdk1.5.0\bin>java UDPClient
This message is from the second client.
FROM SERVER: THIS MESSAGE IS FROM THE SECOND CLIENT.
C:\Program Files\Java\jdk1.5.0\bin>
Server responds by returning the datagram to the client in all capital letters

Socket Programming with TCP

- Server process must first be running (must have created a socket). Recall that TCP is not connectionless.
- Client contacts the server by creating client-local socket specifying IP address and port number of server process. Client TCP establishes connection to server TCP.
- When contacted by client, server TCP creates a new socket for server process to communicate with client.
  - Allows server to talk with multiple clients
  - Source port numbers used to distinguish clients
- From application viewpoint: TCP provides reliable, in-order transfer of bytes ("pipe") between client and server.

Establishing a Simple Server Using Stream Sockets

Five steps to create a simple stream server in Java:

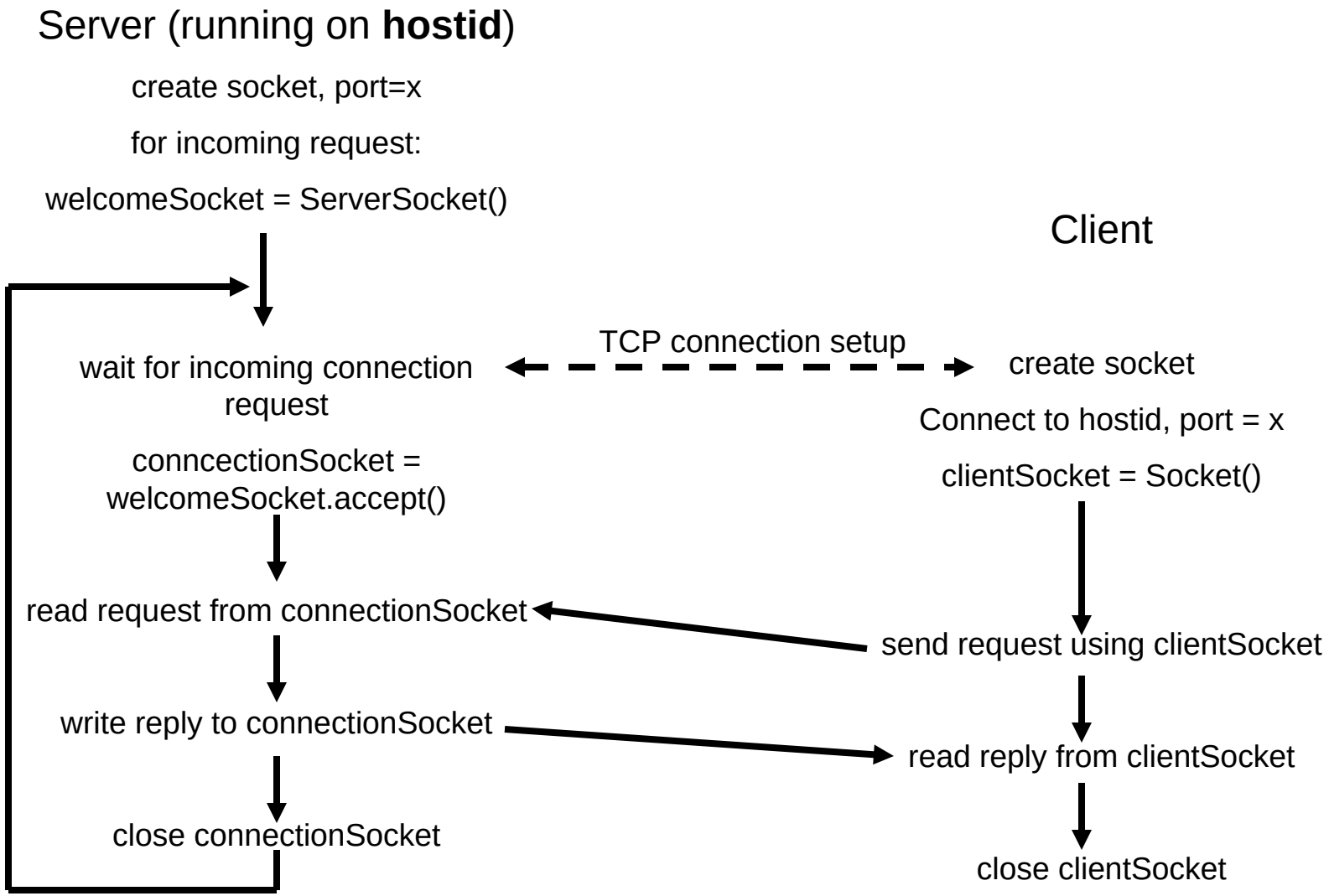
1. `ServerSocket` object. Registers an available port and a maximum number of clients.
2. Each client connection handled with a `Socket` object. Server blocks until client connects.
3. Sending and receiving data
   - `OutputStream` to send and `InputStream` to receive data.
   - Methods `getInputStream` and `getOutputStream` on `Socket` object.
4. Process phase. Server and client communicate via streams.
5. Close streams and connections.

Establishing a Simple Client Using Stream Sockets

Four steps to create a simple stream client in Java:

1. Create a `Socket` object for the client.
2. Obtains `Socket's InputStream` and `OutputStream`.
3. Process information communicated.
4. Close streams and `Socket`.

Example: client/server socket interaction via TCP



Example: Java server using TCP

```
//simple server application using TCP

import java.io.*;
import java.net.*;

class TCPServer {
        public static void main (String args[]) throws Exception
        {
                String clientSentence;
                String capitalizedSentence;

                //create welcoming socket at port 6789
                ServerSocket welcomeSocket = new ServerSocket(6789);

                while (true) {
                        //block on welcoming socket for contact by a client
                        Socket connectionSocket = welcomeSocket.accept();

                        //create input stream attached to socket
                        BufferedReader inFromClient = new BufferedReader(new
                        InputStreamReader
                                (connectionSocket.getInputStream()));
```


Example: Java server using TCP (cont.)

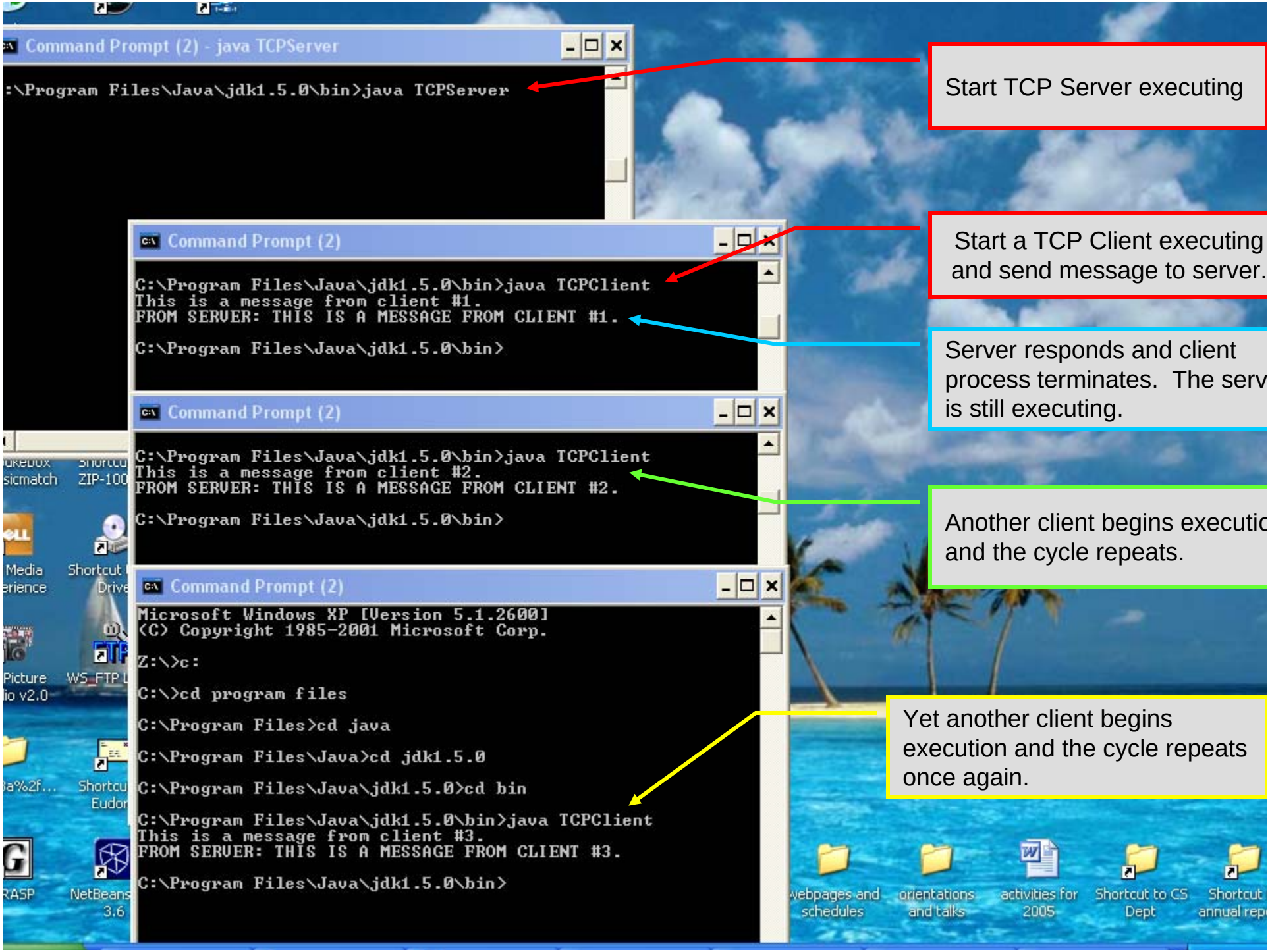
```
                    //create output stream attached to socket
                    DataOutputStream outToClient = new
                    DataOutputStream(connectionSocket.getOutputStream());

                    //read in line from the socket
                    clientSentence = inFromClient.readLine();

                    //process
                    capitalizedSentence = clientSentence.toUpperCase() + '\n';

                    //write out line to socket
                    outToClient.writeBytes(capitalizedSentence);
                }
            }
        }
```


Example: Java client using TCP

```
//simple client application using TCP

import java.io.*;
import java.net.*;

class TCPClient {
        public static void main (String args[]) throws Exception
        {
                String sentence;
                String modifiedSentence;

                //create input stream
                BufferedReader inFromUser = new BufferedReader(new
                        InputStreamReader(System.in));

                //create client socket and connect to server
                Socket clientSocket = new Socket("localhost", 6789);

                //create output stream attached to socket
                DataOutputStream outToServer = new
                        DataOutputStream(clientSocket.getOutputStream());
```


Example: Java client using TCP (cont.)

```
                    //create input stream attached to socket
                    BufferedReader inFromServer = new BufferedReader(new
                    InputStreamReader (clientSocket.getInputStream()));

                    sentence = inFromUser.readLine();

                    //send line to the server
                    outToServer.writeBytes(sentence + '\n');

                    //read line coming back from the server
                    modifiedSentence = inFromServer.readLine();

                    System.out.println("FROM SERVER: " + modifiedSentence);

                    clientSocket.close();
            }
}
```



Command Prompt (2) - java TCPServer
:\Program Files\Java\jdk1.5.0\bin>java TCPServer
Command Prompt (2)
C:\Program Files\Java\jdk1.5.0\bin>java TCPClient
This is a message from client #1.
FROM SERVER: THIS IS A MESSAGE FROM CLIENT #1.
C:\Program Files\Java\jdk1.5.0\bin>
Command Prompt (2)
C:\Program Files\Java\jdk1.5.0\bin>java TCPClient
This is a message from client #2.
FROM SERVER: THIS IS A MESSAGE FROM CLIENT #2.
C:\Program Files\Java\jdk1.5.0\bin>
Command Prompt (2)
Microsoft Windows XP [Version 5.1.2600]
(C) Copyright 1985-2001 Microsoft Corp.
Z:\>c:
C:\>cd program files
C:\Program Files>cd java
C:\Program Files\Java>cd jdk1.5.0
C:\Program Files\Java\jdk1.5.0>cd bin
C:\Program Files\Java\jdk1.5.0\bin>java TCPClient
This is a message from client #3.
FROM SERVER: THIS IS A MESSAGE FROM CLIENT #3.
C:\Program Files\Java\jdk1.5.0\bin>
Start TCP Server executing
Start a TCP Client executing and send message to server.
Server responds and client process terminates. The serv is still executing.
Another client begins executio and the cycle repeats.
Yet another client begins execution and the cycle repeats once again.
webpages and schedules
orientations and talks
activities for 2005
Shortcut to CS Dept
Shortcut annual rep
Media erience
Shortcut Drive
Picture io v2.0
WS_FTP
NetBeans 3.6
RASP

A More Sophisticated TCP Client/Server Example Using GUIs

- Over the next few pages you will find the Java code for a more sophisticated client/server example.
- This example utilizes a GUI and makes things a bit more interesting from the programming point of view.
- Server process appears on pages 25-32. Server test process appears on page 41.
- Client process appears on pages 33-40. Client test process appears on page 42.

Sample Code: Java server using TCP with GUI

Page 1: Server

```
// TCPServerGUI.java
// Set up a TCP Server that will receive a connection from a client, send
// a string to the client, and close the connection.  GUI Version
import java.io.EOFException;
import java.io.IOException;
import java.io.ObjectInputStream;
import java.io.ObjectOutputStream;
import java.net.ServerSocket;
import java.net.Socket;
import java.awt.BorderLayout;
import java.awt.event.ActionEvent;
import java.awt.event.ActionListener;
import javax.swing.JFrame;
import javax.swing.JScrollPane;
import javax.swing.JTextArea;
import javax.swing.JTextField;
import javax.swing.SwingUtilities;

public class TCPServerGUI extends JFrame
{
   private JTextField enterField; // inputs message from user
   private JTextArea displayArea; // display information to user
   private ObjectOutputStream output; // output stream to client
   private ObjectInputStream input; // input stream from client
```


```
private ServerSocket server; // server socket
private Socket connection; // connection to client
private int counter = 1; // counter of number of connections

// set up GUI
public TCPServerGUI()
{
  super( “TCP Server" );

  enterField = new JTextField(); // create enterField
  enterField.setEditable( false );
  enterField.addActionListener(
    new ActionListener()
    {
      // send message to client
      public void actionPerformed( ActionEvent event )
      {
        sendData( event.getActionCommand() );
        enterField.setText( "" );
      } // end method actionPerformed
    } // end anonymous inner class
  ); // end call to addActionListener

  add( enterField, BorderLayout.NORTH );
```

Page 2: Server

```
   displayArea = new JTextArea(); // create displayArea
   add( new JScrollPane( displayArea ), BorderLayout.CENTER );

   setSize( 300, 150 ); // set size of window
   setVisible( true ); // show window
} // end Server constructor

// set up and run server
public void runServer()
{
   try // set up server to receive connections; process connections
   {
      server = new ServerSocket( 12345, 100 ); // create ServerSocket

      while ( true )
      {
         try
         {
            waitForConnection(); // wait for a connection
            getStreams(); // get input & output streams
            processConnection(); // process connection
         } // end try
         catch ( EOFException eofException )
         {
```

Page 3: Server

```
            displayMessage( "\nServer terminated connection" );
         } // end catch
         finally
         {
            closeConnection(); //  close connection
            counter++;
         } // end finally
      } // end while
   } // end try
   catch ( IOException ioException )
   {
      ioException.printStackTrace();
   } // end catch
} // end method runServer

// wait for connection to arrive, then display connection info
private void waitForConnection() throws IOException
{
   displayMessage( "Waiting for connection\n" );
   connection = server.accept(); // allow server to accept connection
   displayMessage( "Connection " + counter + " received from: " +
      connection.getInetAddress().getHostName() );
} // end method waitForConnection
```

Page 4: Server

```
 // get streams to send and receive data
private void getStreams() throws IOException
{
   // set up output stream for objects
   output = new ObjectOutputStream( connection.getOutputStream() );
   output.flush(); // flush output buffer to send header information

   // set up input stream for objects
   input = new ObjectInputStream( connection.getInputStream() );

   displayMessage( "\nGot I/O streams\n" );
} // end method getStreams

// process connection with client
private void processConnection() throws IOException
{
   String message = "Connection successful";
   sendData( message ); // send connection successful message

   // enable enterField so server user can send messages
   setTextFieldEditable( true );
```

Page 5: Server

```
   do // process messages sent from client
   {
      try // read message and display it
      {
         message = ( String ) input.readObject(); // read new message
         displayMessage( "\n" + message ); // display message
      } // end try
      catch ( ClassNotFoundException classNotFoundException )
      {
         displayMessage( "\nUnknown object type received" );
      } // end catch

   } while ( !message.equals( "CLIENT>>> TERMINATE" ) );
} // end method processConnection

// close streams and socket
private void closeConnection()
{
   displayMessage( "\nTerminating connection\n" );
   setTextFieldEditable( false ); // disable enterField
   try
   {
      output.close(); // close output stream
      input.close(); // close input stream
      connection.close(); // close socket
   } // end try
```

Page 6: Server

```
catch ( IOException ioException )
      {
        ioException.printStackTrace();
      } // end catch
   } // end method closeConnection

   // send message to client
   private void sendData( String message )
   {
     try // send object to client
     {
       output.writeObject( "SERVER>>> " + message );
       output.flush(); // flush output to client
       displayMessage( "\nSERVER>>> " + message );
     } // end try
     catch ( IOException ioException )
     {
       displayArea.append( "\nError writing object" );
     } // end catch
   } // end method sendData

   // manipulates displayArea in the event-dispatch thread
   private void displayMessage( final String messageToDisplay )
   {
     SwingUtilities.invokeLater(
       new Runnable()
```

Page 7: Server

```
        {
          public void run() // updates displayArea
          {
            displayArea.append( messageToDisplay ); // append message
          } // end method run
        } // end anonymous inner class
      ); // end call to SwingUtilities.invokeLater
    } // end method displayMessage

    // manipulates enterField in the event-dispatch thread
    private void setTextFieldEditable( final boolean editable )
    {
      SwingUtilities.invokeLater(
        new Runnable()
        {
          public void run() // sets enterField's editability
          {
            enterField.setEditable( editable );
          } // end method run
        }  // end inner class
      ); // end call to SwingUtilities.invokeLater
    } // end method setTextFieldEditable
  } // end class TCPServerGUI
```

Page 8: Server

Sample Code: Java client using TCP with GUI

Page 1: Client

```
// TCPClientGUI.java
// Client that reads and displays information sent from a Server.
import java.io.EOFException;
import java.io.IOException;
import java.io.ObjectInputStream;
import java.io.ObjectOutputStream;
import java.net.InetAddress;
import java.net.Socket;
import java.awt.BorderLayout;
import java.awt.event.ActionEvent;
import java.awt.event.ActionListener;
import javax.swing.JFrame;
import javax.swing.JScrollPane;
import javax.swing.JTextArea;
import javax.swing.JTextField;
import javax.swing.SwingUtilities;

public class TCPClientGUI extends JFrame
{
   private JTextField enterField; // enters information from user
   private JTextArea displayArea; // display information to user
   private ObjectOutputStream output; // output stream to server
   private ObjectInputStream input; // input stream from server
   private String message = ""; // message from server
   private String chatServer; // host server for this application
```


Page 2: Client

```
private Socket client; // socket to communicate with server

// initialize chatServer and set up GUI
public TCPClientGUI( String host )
{
  super( “TCP Client" );

  chatServer = host; // set server to which this client connects

  enterField = new JTextField(); // create enterField
  enterField.setEditable( false );
  enterField.addActionListener(
    new ActionListener()
    {
      // send message to server
      public void actionPerformed( ActionEvent event )
      {
        sendData( event.getActionCommand() );
        enterField.setText( "" );
      } // end method actionPerformed
    } // end anonymous inner class
  ); // end call to addActionListener

  add( enterField, BorderLayout.NORTH );
```


```
   displayArea = new JTextArea(); // create displayArea
   add( new JScrollPane( displayArea ), BorderLayout.CENTER );

   setSize( 300, 150 ); // set size of window
   setVisible( true ); // show window
} // end Client constructor

// connect to server and process messages from server
public void runClient()
{
   try // connect to server, get streams, process connection
   {
      connectToServer(); // create a Socket to make connection
      getStreams(); // get the input and output streams
      processConnection(); // process connection
   } // end try
   catch ( EOFException eofException )
   {
      displayMessage( "\nClient terminated connection" );
   } // end catch
   catch ( IOException ioException )
   {
      ioException.printStackTrace();
   } // end catch
```

Page 3: Client

```
   finally
   {
      closeConnection(); // close connection
   } // end finally
} // end method runClient

// connect to server
private void connectToServer() throws IOException
{
   displayMessage( "Attempting connection\n" );

   // create Socket to make connection to server
   client = new Socket( InetAddress.getByName( chatServer ), 12345 );

   // display connection information
   displayMessage( "Connected to: " +
      client.getInetAddress().getHostName() );
} // end method connectToServer

// get streams to send and receive data
private void getStreams() throws IOException
{
   // set up output stream for objects
   output = new ObjectOutputStream( client.getOutputStream() );
   output.flush(); // flush output buffer to send header information
```

Page 4: Client

```
   // set up input stream for objects
   input = new ObjectInputStream( client.getInputStream() );

   displayMessage( "\nGot I/O streams\n" );
} // end method getStreams

// process connection with server
private void processConnection() throws IOException
{
   // enable enterField so client user can send messages
   setTextFieldEditable( true );

   do // process messages sent from server
   {
      try // read message and display it
      {
         message = ( String ) input.readObject(); // read new message
         displayMessage( "\n" + message ); // display message
      } // end try
      catch ( ClassNotFoundException classNotFoundException )
      {
         displayMessage( "\nUnknown object type received" );
      } // end catch

   } while ( !message.equals( "SERVER>>> TERMINATE" ) );
} // end method processConnection
```

Page 5: Client

```
// close streams and socket
private void closeConnection()
{
   displayMessage( "\nClosing connection" );
   setTextFieldEditable( false ); // disable enterField

   try
   {
      output.close(); // close output stream
      input.close(); // close input stream
      client.close(); // close socket
   } // end try
   catch ( IOException ioException )
   {
      ioException.printStackTrace();
   } // end catch
} // end method closeConnection

// send message to server
private void sendData( String message )
{
   try // send object to server
   {
      output.writeObject( "CLIENT>>> " + message );
      output.flush(); // flush data to output
      displayMessage( "\nCLIENT>>> " + message );
   } // end try
```

Page 6: Client

```
  catch ( IOException ioException )
   {
     displayArea.append( "\nError writing object" );
   } // end catch
} // end method sendData

// manipulates displayArea in the event-dispatch thread
private void displayMessage( final String messageToDisplay )
{
   SwingUtilities.invokeLater(
      new Runnable()
      {
         public void run() // updates displayArea
         {
            displayArea.append( messageToDisplay );
         } // end method run
      }  // end anonymous inner class
   ); // end call to SwingUtilities.invokeLater
} // end method displayMessage
```

Page 7: Client

Page 8: Client

```
  // manipulates enterField in the event-dispatch thread
  private void setTextFieldEditable( final boolean editable )
  {
    SwingUtilities.invokeLater(
      new Runnable()
      {
        public void run() // sets enterField's editability
        {
          enterField.setEditable( editable );
        } // end method run
      } // end anonymous inner class
    ); // end call to SwingUtilities.invokeLater
  } // end method setTextFieldEditable
} // end class TCPClientGUI
```


Sample Code: Java server test

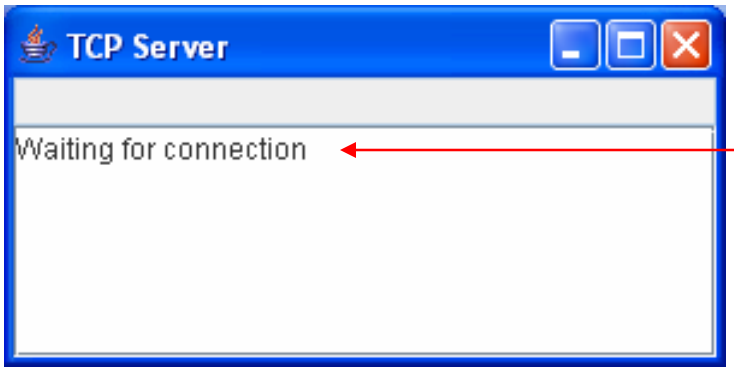
```
// TCPServerTest.java
// Test the TCPServerGUI application.  GUI Version
import javax.swing.JFrame;

public class TCPServerTest
{
   public static void main( String args[] )
   {
      TCPServerGUI application = new TCPServerGUI(); // create server
      application.setDefaultCloseOperation( JFrame.EXIT_ON_CLOSE );
      application.runServer(); // run server application
   } // end main
} // end class TCPServerTest
```


Sample Code: Java client test

```
// TCPClientTest.java
// Test the TCPClientGUI class.  GUI Version
import javax.swing.JFrame;

public class TCPClientTest
{
  public static void main( String args[] )
  {
    TCPClientGUI application; // declare client application

    // if no command line args
    if ( args.length == 0 )
      application = new TCPClientGUI( "127.0.0.1" ); // connect to localhost
    else
      application = new TCPClientGUI( args[ 0 ] ); // use args to connect

    application.setDefaultCloseOperation( JFrame.EXIT_ON_CLOSE );
    application.runClient(); // run client application
  } // end main
} // end class TCPClientTest
```

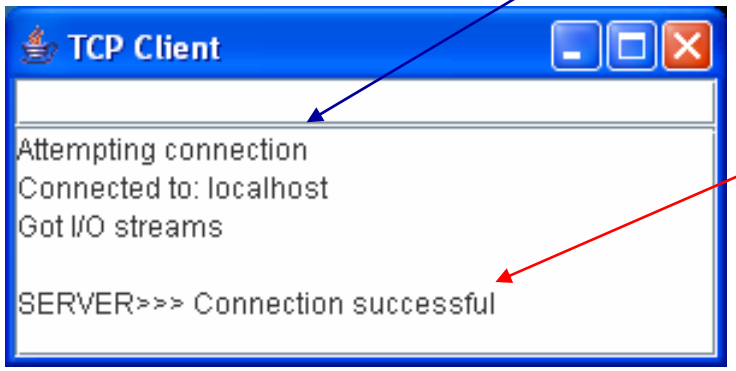
Special IP address to designate localhost.

Sample Screen Shots Illustrating Client/Server Processes



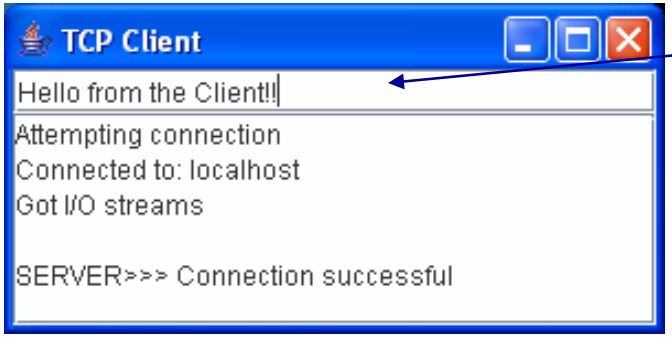
Server process initialized and waiting for a client connection.

Client process attempts connection to localhost.

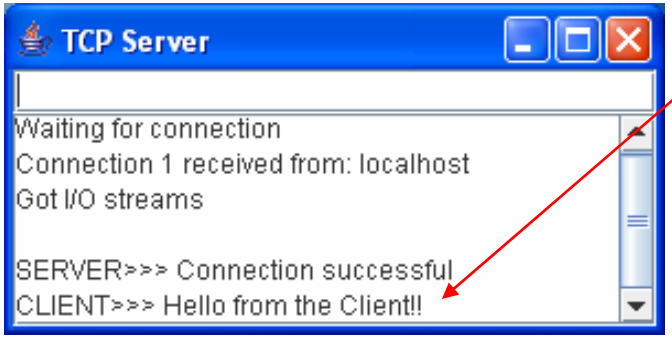


Server responds. Connection to server on localhost is successful. Stream connection is now established between server and client.

Sample Screen Shots Illustrating Client/Server Processes (cont.)

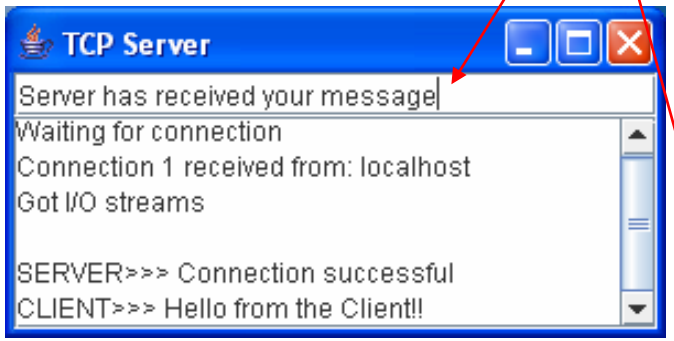


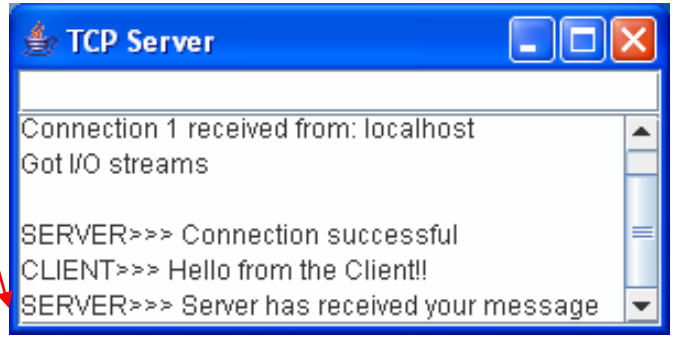
Client sends a message to the server.



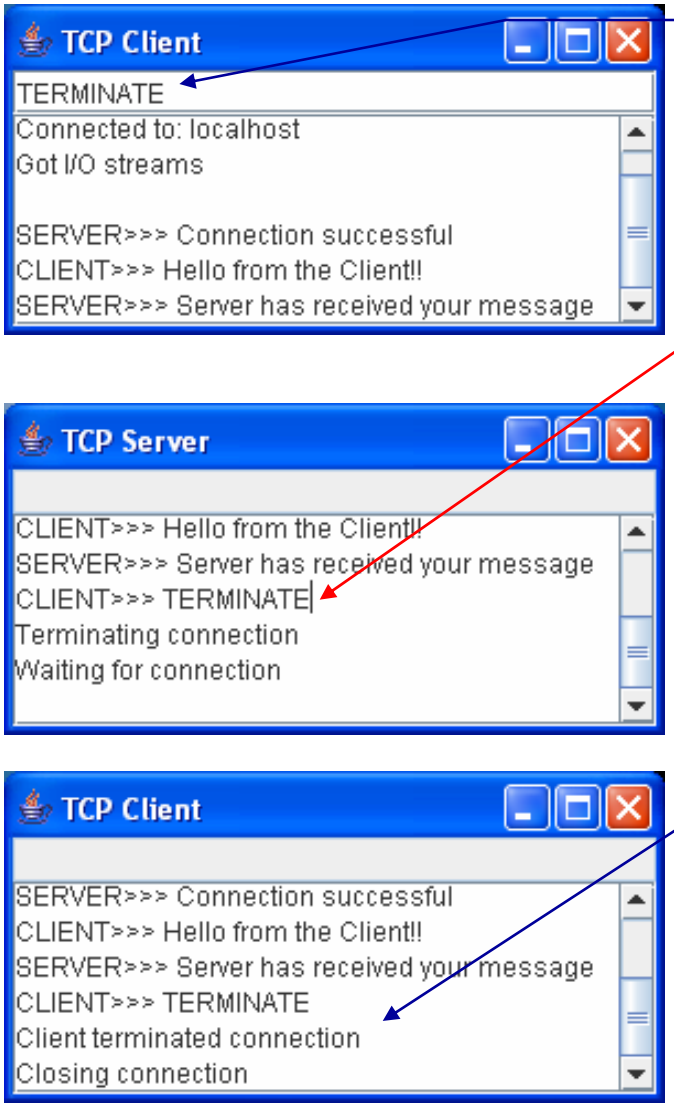
Server message from the client process.

Server responds to client.





Sample Screen Shots Illustrating Client/Server Processes (cont.)

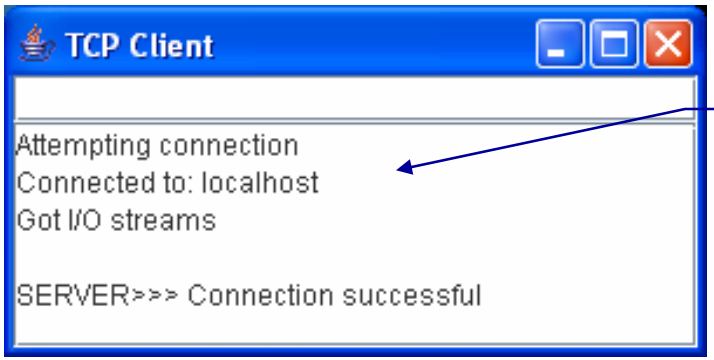


Client issues message to terminate connection.

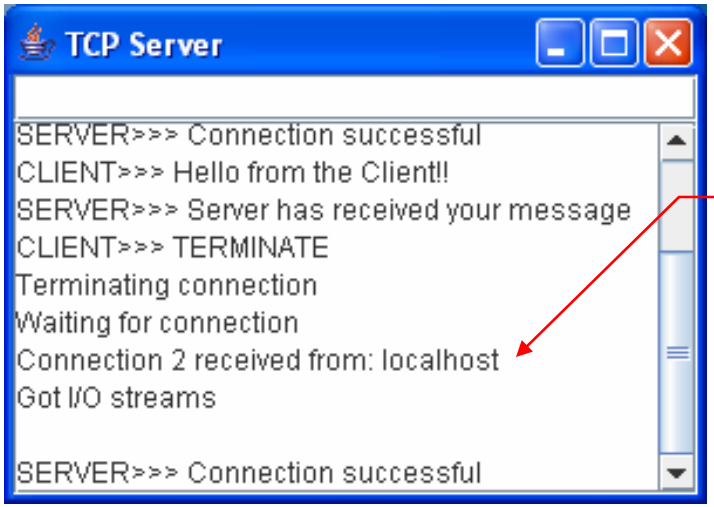
Server receives request from Client to terminate connection. Server responds by terminating connection and then blocking to await a subsequent connection.

Message from Server that Client terminated connection and that the connection is now closed.

Sample Screen Shots Illustrating Client/Server Processes (cont.)



A subsequent connection request from another Client process is accepted by the Server. Server indicates that this is the second connection received from a client.



Server accepts a second connection and is now connected to the second client process.