

COP 4610L: Applications in the Enterprise Fall 2006

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.

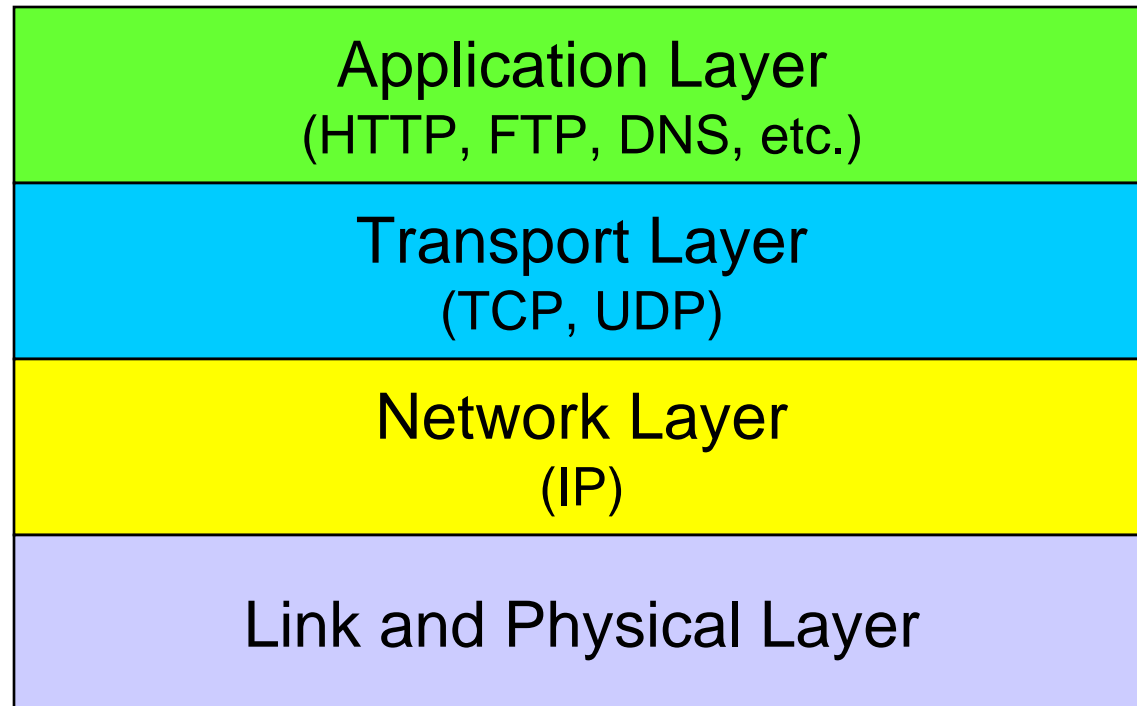


java.net

- “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

Server (running on **hostid**)

create socket, port=x

for incoming request:

serverSocket = DatagramSocket()

read request from serverSocket

Write reply to serverSocket

specifying client host address, port number

Client

create socket

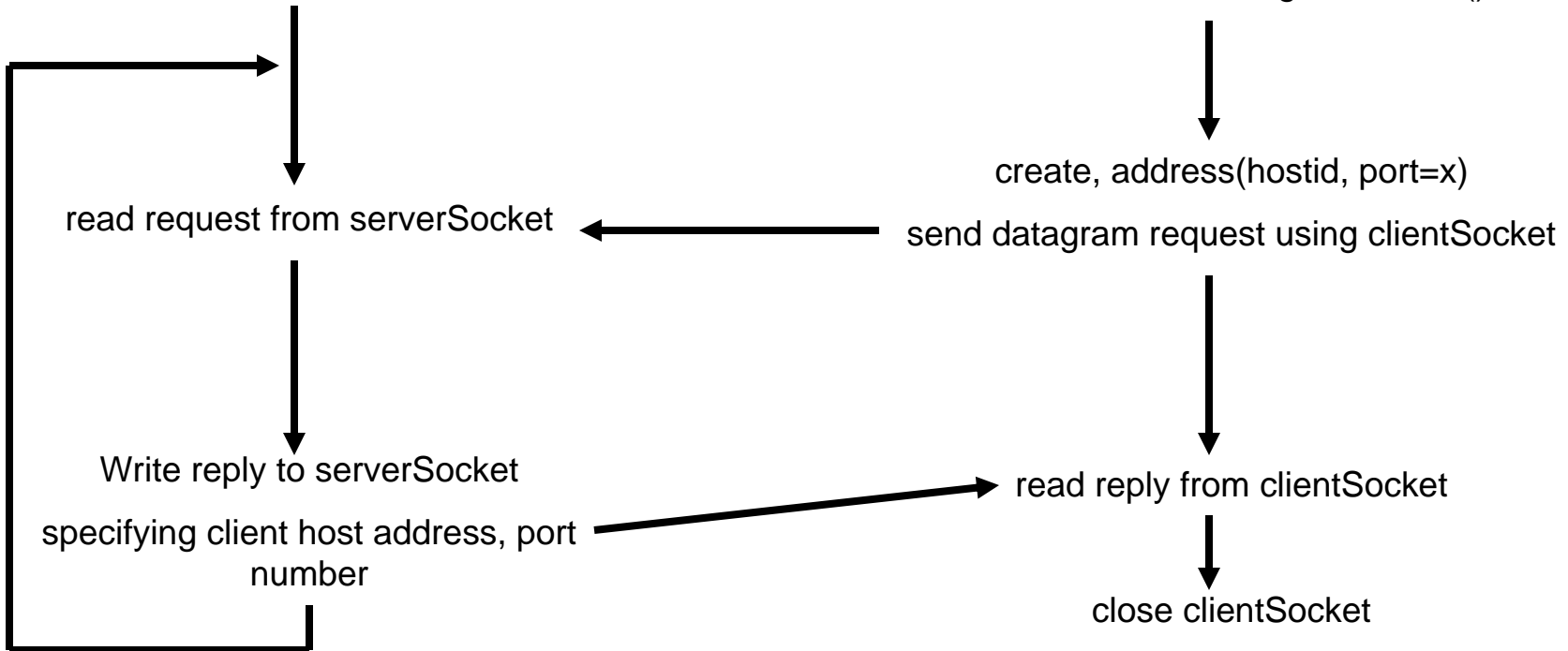
clientSocket = DatagramSocket()

create, address(hostid, port=x)

send datagram request using clientSocket

read reply from clientSocket

close clientSocket



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.



```
ca 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

```
ca 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.
```

```
ca Command Prompt (2)
C:\Program Files>cd j
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 second client.
FROM SERVER: THIS MESSAGE IS FROM THE SECOND CLIENT.
```

Client sends a message (datagram) to the server

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

Server (running on **hostid**)

create socket, port=x

for incoming request:

welcomeSocket = ServerSocket()

wait for incoming connection request

connectionSocket = welcomeSocket.accept()

read request from connectionSocket

write reply to connectionSocket

close connectionSocket

Client

create socket

Connect to hostid, port = x

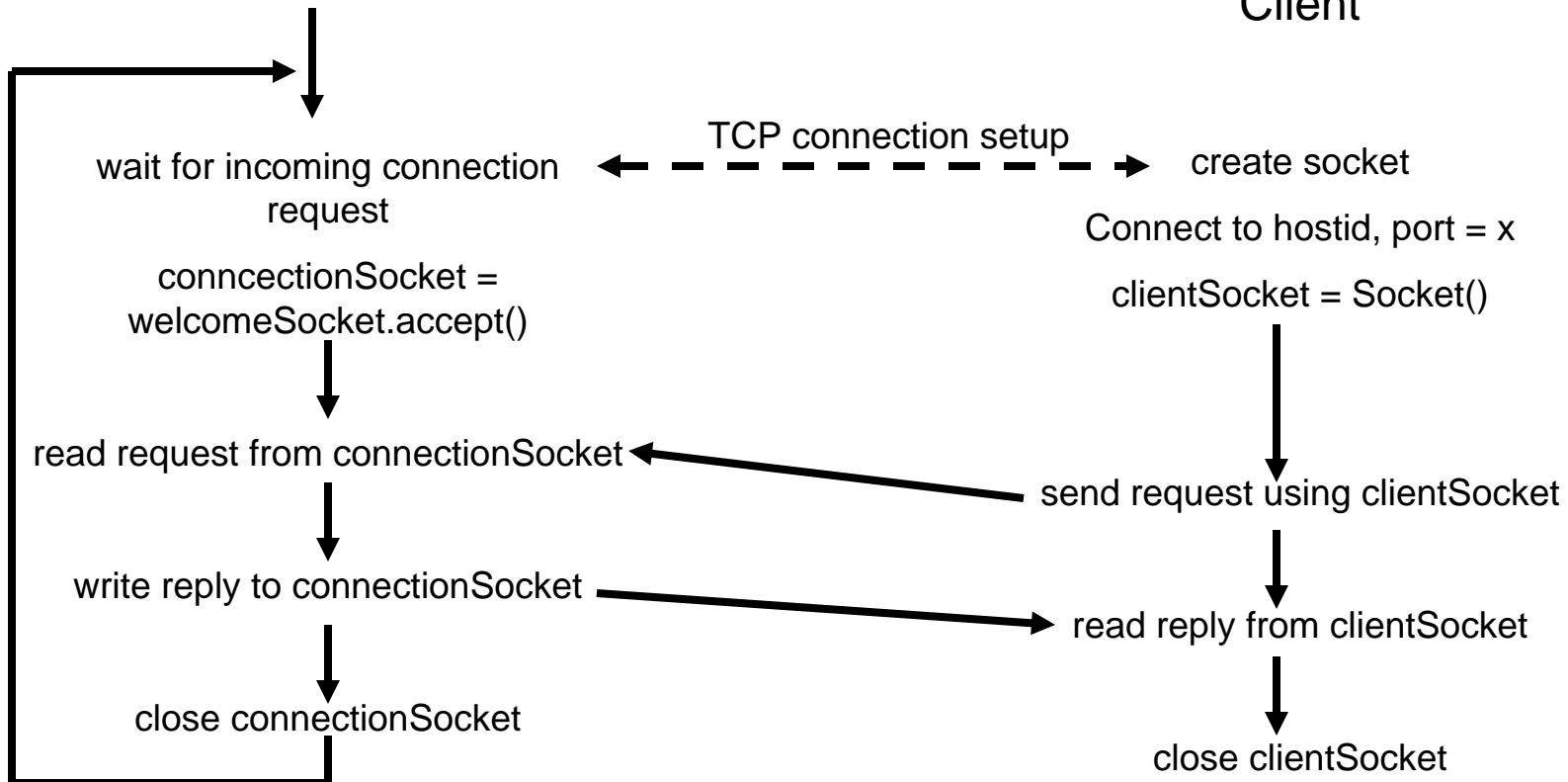
clientSocket = Socket()

send request using clientSocket

read reply from clientSocket

close clientSocket

TCP connection setup



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();

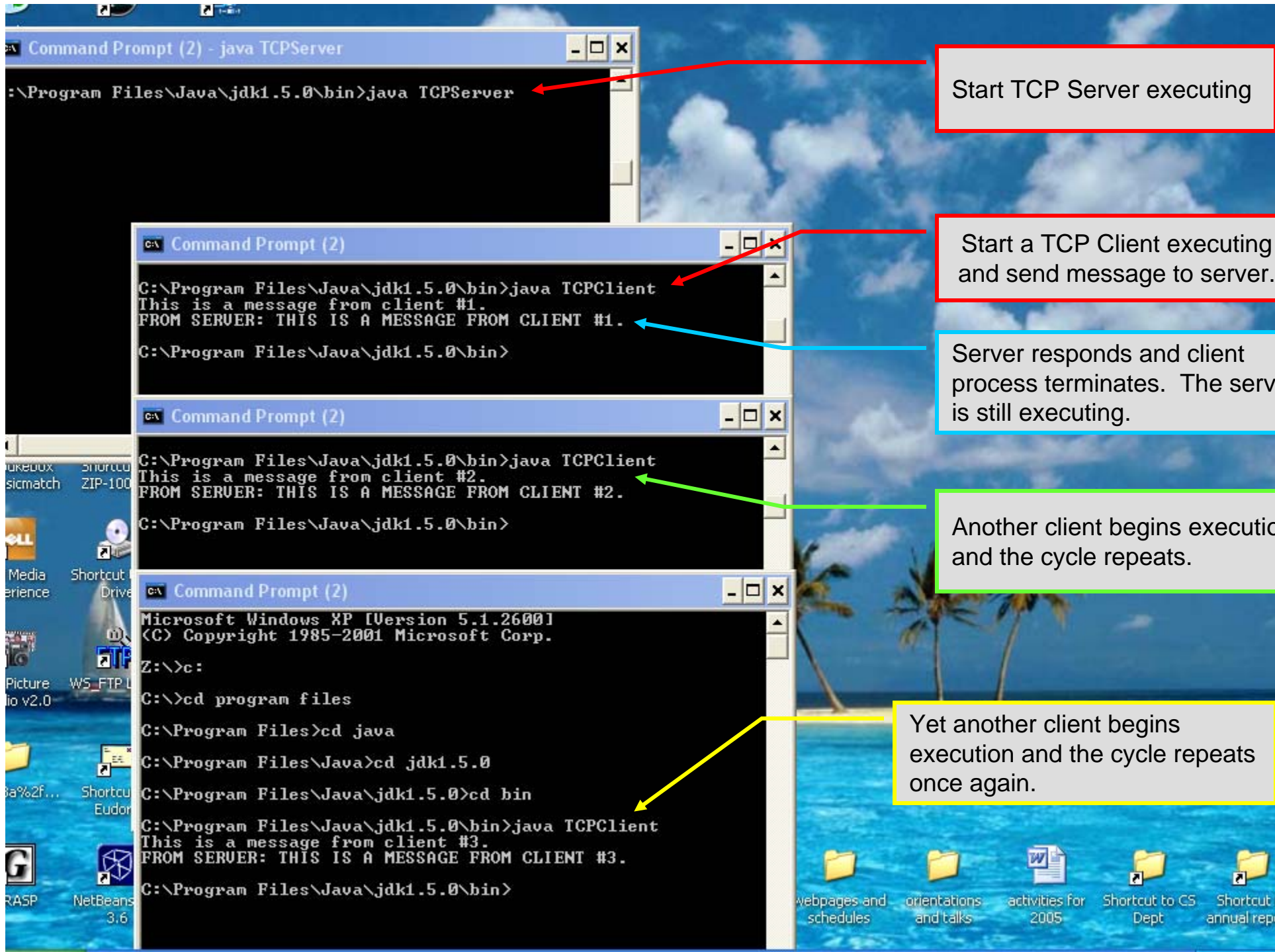
//send line to the server
outToServer.writeBytes(sentence + '\n');

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

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

clientSocket.close();
    }
}
```





Start TCP Server executing

Start a TCP Client executing and send message to server.

Server responds and client process terminates. The server is still executing.

Another client begins execution and the cycle repeats.

Yet another client begins execution and the cycle repeats once again.

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
```

Page 2: Server

```
// 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 );
```



```
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
```

Page 4: Server

```
// 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
```



```
// 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 );
}
```



```
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
}
```



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

Page 7: Server

```
// 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()
```



```
{
    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
```



Sample Code: Java client using TCP with GUI

```
// 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 1: Client



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

Page 2: Client

```
// 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 );
```

Page 3: Client

```
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
}
```



```
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.getByByName( 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
```



```
// 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

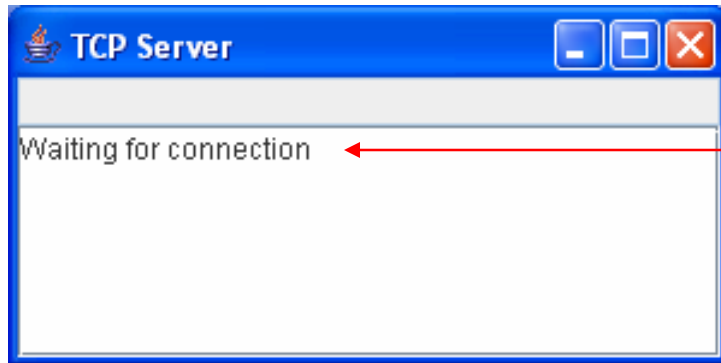
        // if no command line args
        if ( args.length == 0 )
            application = new TCPClientGUI( "127.0.0.1" ); // connect to localhost
        else
            application = new TCPClientGUI( args[ 0 ] ); // use args to connect

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

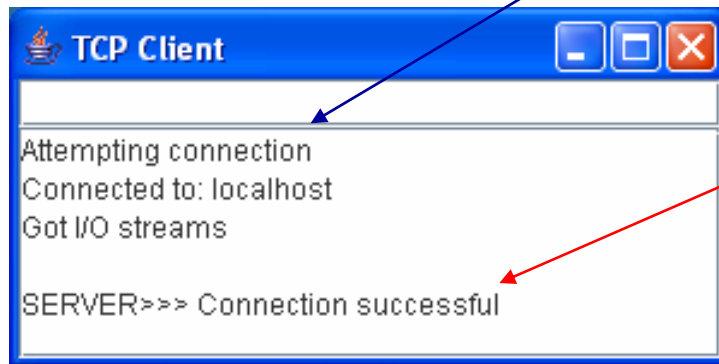
Special IP address to designate localhost.



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.)

```
TCP Client
Hello from the Client!!
Attempting connection
Connected to: localhost
Got I/O streams

SERVER>>> Connection successful
```

Client sends a message to the server.

```
TCP Server
Waiting for connection
Connection 1 received from: localhost
Got I/O streams

SERVER>>> Connection successful
CLIENT>>> Hello from the Client!!
```

Server message from the client process.

Server responds to client.

```
TCP Server
Server has received your message
Waiting for connection
Connection 1 received from: localhost
Got I/O streams

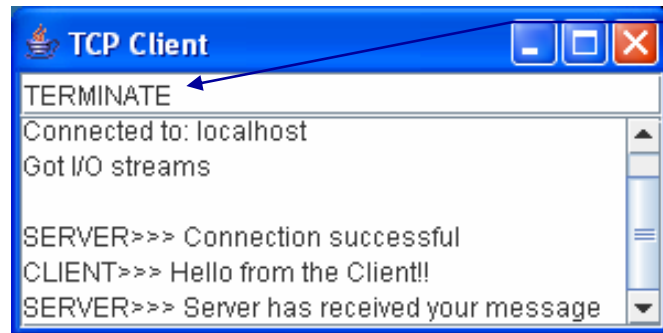
SERVER>>> Connection successful
CLIENT>>> Hello from the Client!!
```

```
TCP Server
Connection 1 received from: localhost
Got I/O streams

SERVER>>> Connection successful
CLIENT>>> Hello from the Client!!
SERVER>>> Server has received your message
```



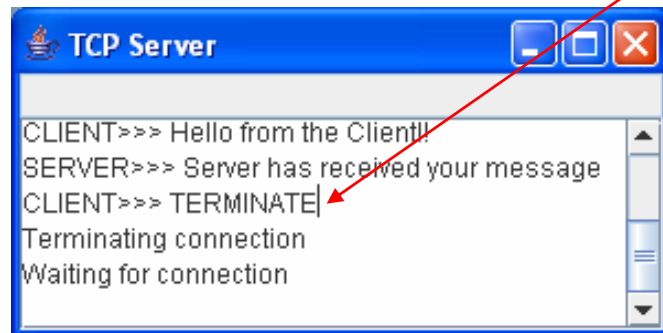
Sample Screen Shots Illustrating Client/Server Processes (cont.)



```
TCP Client
TERMINATE
Connected to: localhost
Got I/O streams

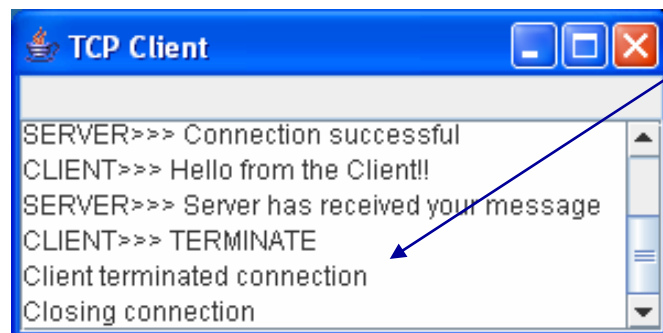
SERVER>>> Connection successful
CLIENT>>> Hello from the Client!!
SERVER>>> Server has received your message
```

Client issues message to terminate connection.



```
TCP Server
CLIENT>>> Hello from the Client!!
SERVER>>> Server has received your message
CLIENT>>> TERMINATE
Terminating connection
Waiting for connection
```

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

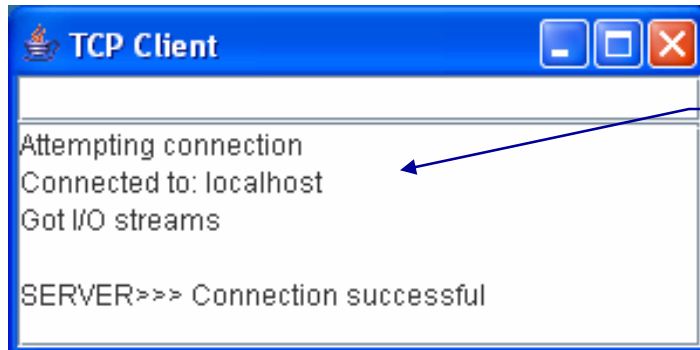


```
TCP Client
SERVER>>> Connection successful
CLIENT>>> Hello from the Client!!
SERVER>>> Server has received your message
CLIENT>>> TERMINATE
Client terminated connection
Closing connection
```

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



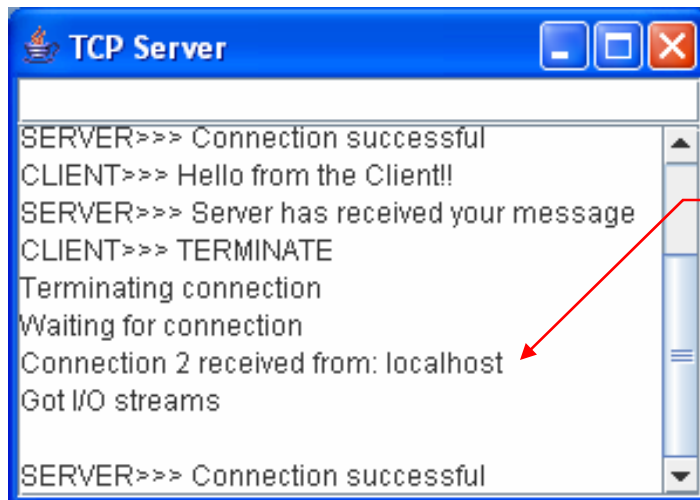
Sample Screen Shots Illustrating Client/Server Processes (cont.)



```
TCP Client
Attempting connection
Connected to: localhost
Got I/O streams
SERVER>>> Connection successful
```

A screenshot of a Windows-style window titled "TCP Client". The window has a blue title bar with standard minimize, maximize, and close buttons. The main content area is white and contains the following text: "Attempting connection", "Connected to: localhost", "Got I/O streams", and "SERVER>>> Connection successful". A blue arrow points from the text in the adjacent callout box to the "Connected to: localhost" line.

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.



```
TCP Server
SERVER>>> Connection successful
CLIENT>>> Hello from the Client!!
SERVER>>> Server has received your message
CLIENT>>> TERMINATE
Terminating connection
Waiting for connection
Connection 2 received from: localhost
Got I/O streams
SERVER>>> Connection successful
```

A screenshot of a Windows-style window titled "TCP Server". The window has a blue title bar with standard minimize, maximize, and close buttons. The main content area is white and contains the following text: "SERVER>>> Connection successful", "CLIENT>>> Hello from the Client!!", "SERVER>>> Server has received your message", "CLIENT>>> TERMINATE", "Terminating connection", "Waiting for connection", "Connection 2 received from: localhost", "Got I/O streams", and "SERVER>>> Connection successful". A red arrow points from the text in the adjacent callout box to the "Connection 2 received from: localhost" line.

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

