

# CNT 4714: Enterprise Computing Fall 2010

## 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.

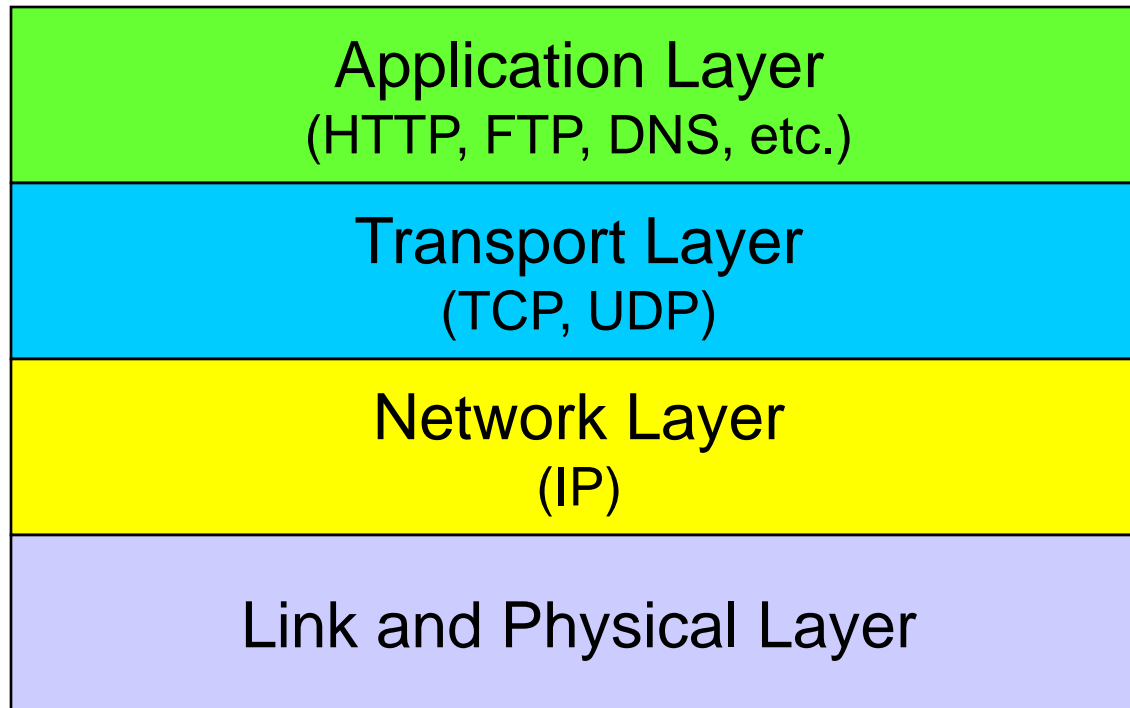


# java.net

- “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

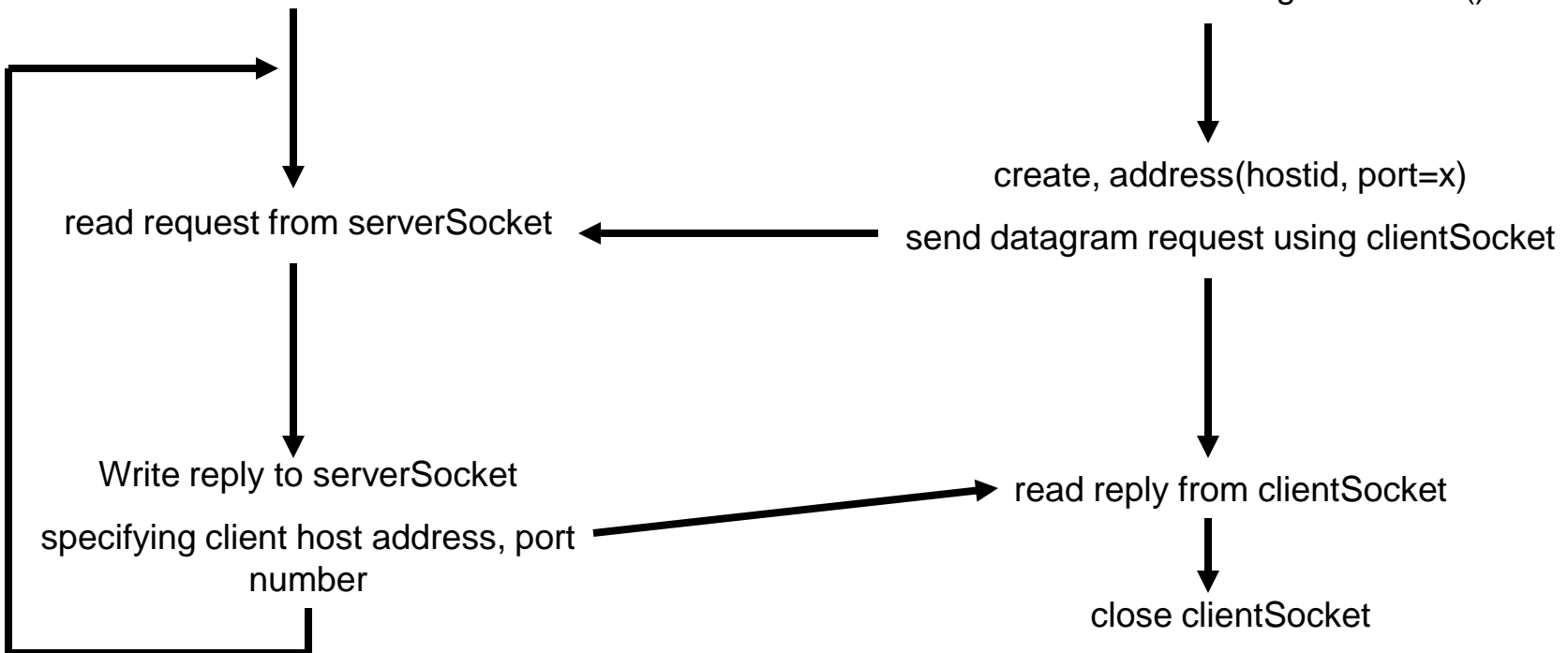
clientSocket = DatagramSocket()

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.

C:\Program Files\Java\jdk1.5.0\bin>
```

Client sends a message (datagram) to the server

Server responds by returning the datagram to the client in all capital letters

```
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 second client.
FROM SERVER: THIS MESSAGE IS FROM THE SECOND CLIENT.

C:\Program Files\Java\jdk1.5.0\bin>
```

# 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`.



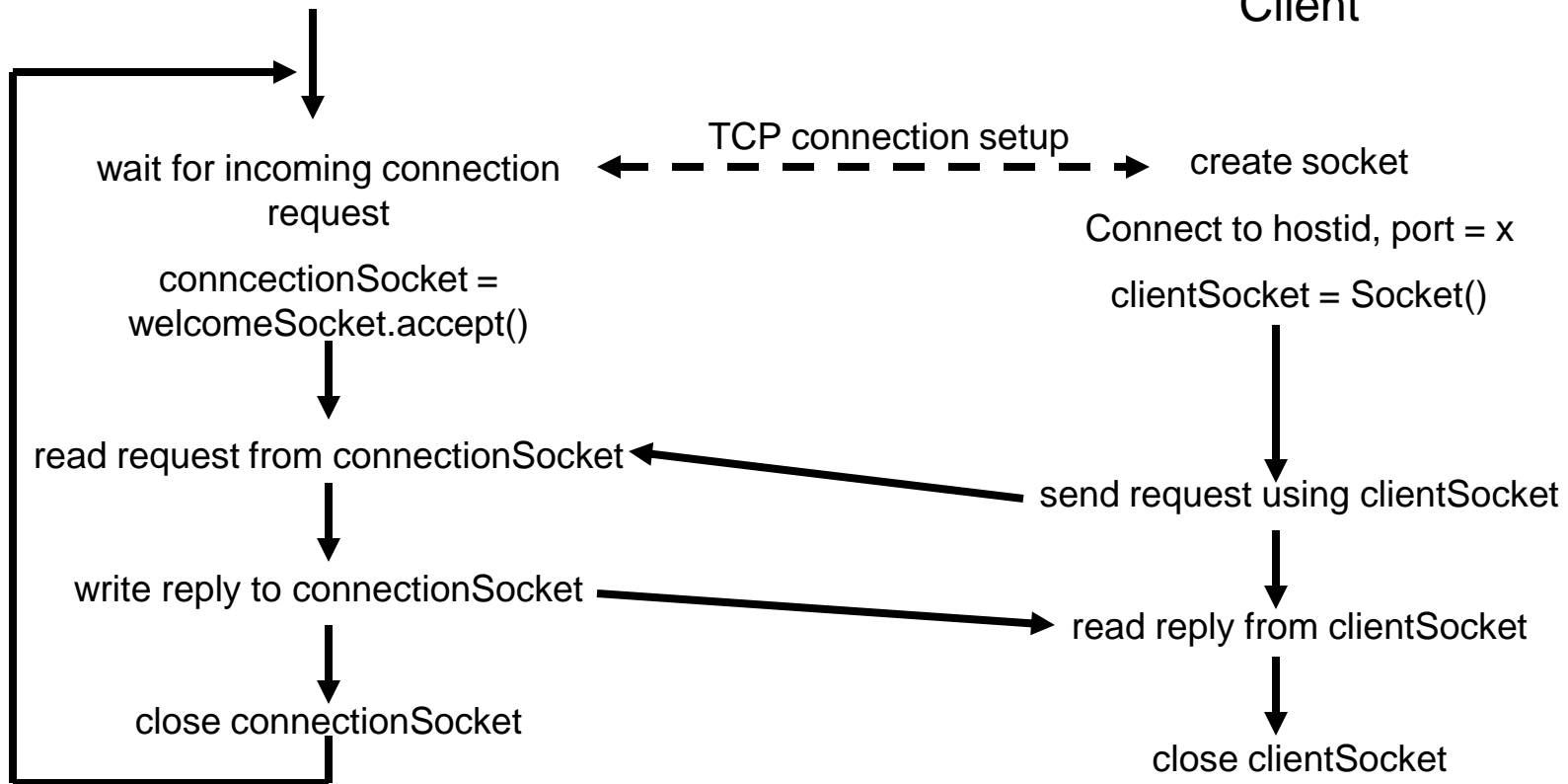
# Example: client/server socket interaction via TCP

Server (running on **hostid**)

create socket, port=x

for incoming request:

welcomeSocket = ServerSocket()



# 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
C:\Program Files\Java\jdk1.5.0\bin>java TCPServer
```

Start TCP Server executing

```
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>
```

Start a TCP Client executing and send message to server.

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

```
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>
```

Another client begins execution and the cycle repeats.

```
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>
```

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

```
// 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
```

Page 1: Server



```
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 )
            {
```



```
        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
```



```
// 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

```

Page 6: Server

```

// 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
```

```
// 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
}
```



```
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
```



```

// 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
```

Page 6: Client

```
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
```



```
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



```
// 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
```

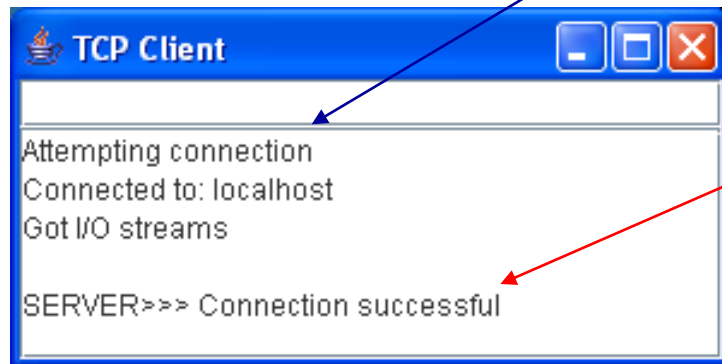
Special IP address to designate localhost.



# Sample Screen Shots Illustrating Client/Server Processes



Server process initialized and waiting for a client connection.

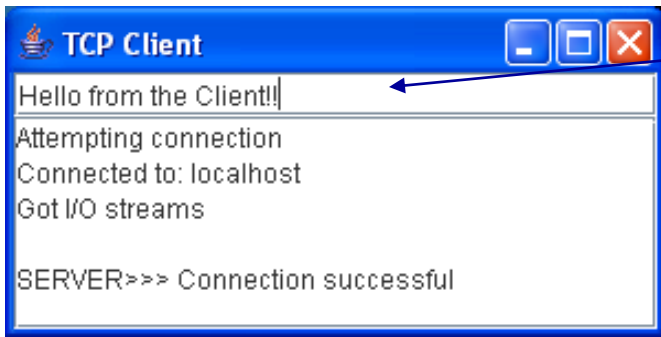


Client process attempts connection to localhost.

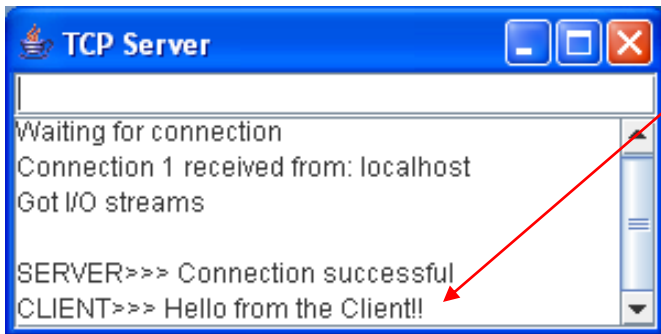
Server responds. Connection to server on localhost is successful. Stream connection is now established between server and client.



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

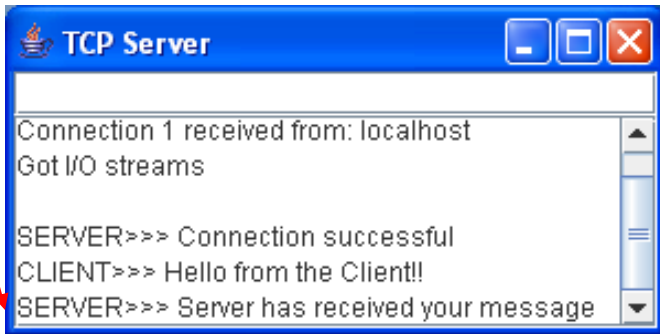
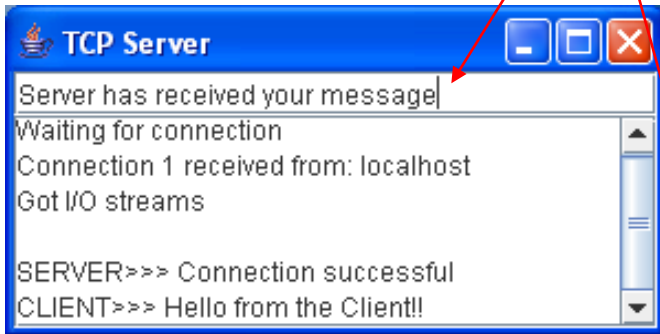


Client sends a message to the server.

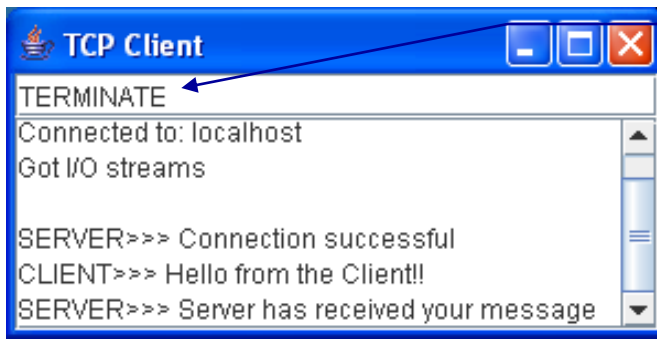


Server message from the client process.

Server responds to client.



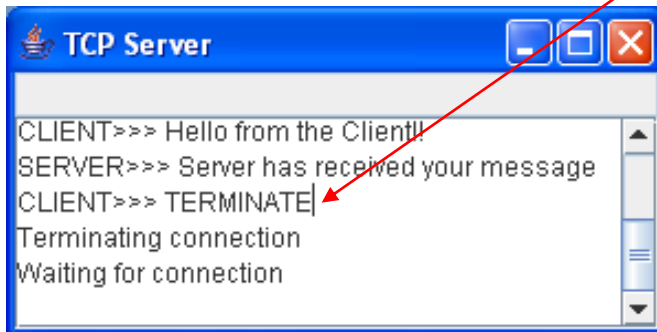
# Sample Screen Shots Illustrating Client/Server Processes (cont.)



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

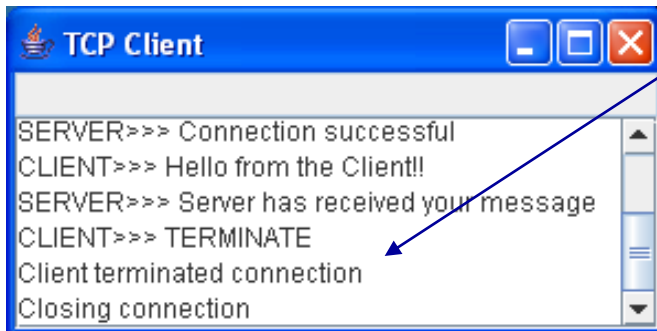
SERVER>>> Connection successful
CLIENT>>> Hello from the Client!!
SERVER>>> Server has received your message
```

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.

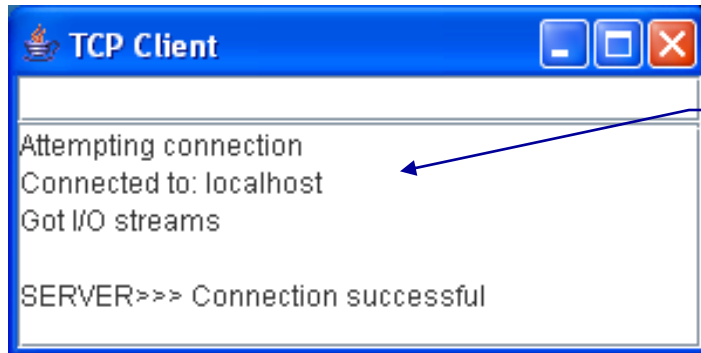


```
TCP Client
SERVER>>> Connection successful
CLIENT>>> Hello from the Client!!
SERVER>>> Server has received your message
CLIENT>>> TERMINATE
Client terminated connection
Closing connection
```

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



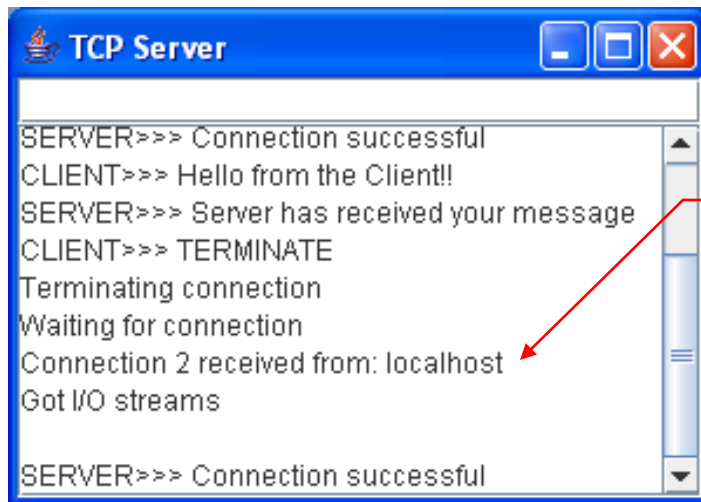
## Sample Screen Shots Illustrating Client/Server Processes (cont.)



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

A screenshot of a Java Swing 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 box on the right 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 Java Swing 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 box on the right to the "Connection 2 received from: localhost" line.

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

