JAVA Socket Programming

What is a socket?

- Socket
  - The combination of an IP address and a port number. (RFC 793 ,original TCP specification)
  - The name of the Berkeley-derived *application programming interfaces* (APIs) for applications using TCP/IP protocols.
  - Two types
    - Stream socket : reliable two-way connected communication streams
    - Datagram socket

- Socket pair
  - Specified the two end points that uniquely identifies each TCP connection in an internet.
  - 4-tuple: (client IP address, client port number, server IP address, server port number)

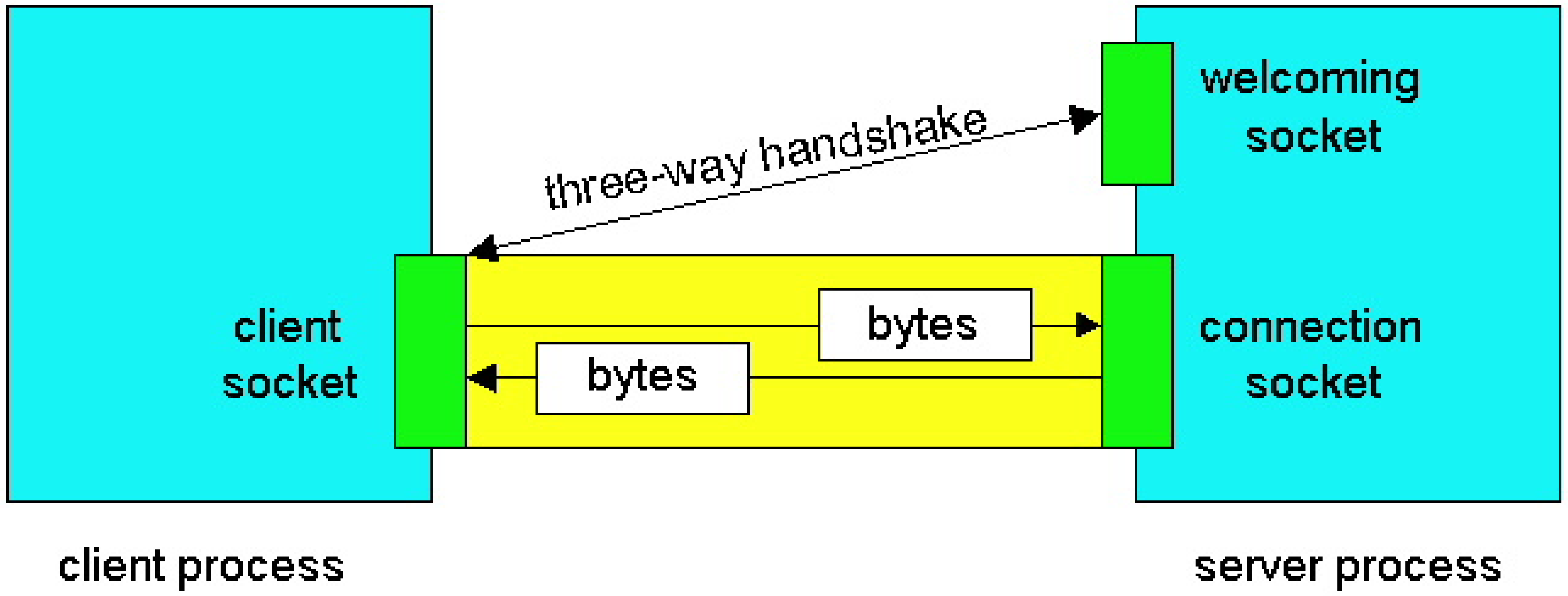
Client-server applications

- Implementation of a protocol standard defined in an RFC. (FTP, HTTP, SMTP...)
  - Conform to the rules dictated by the RFC.
  - Should use the port number associated with the protocol.

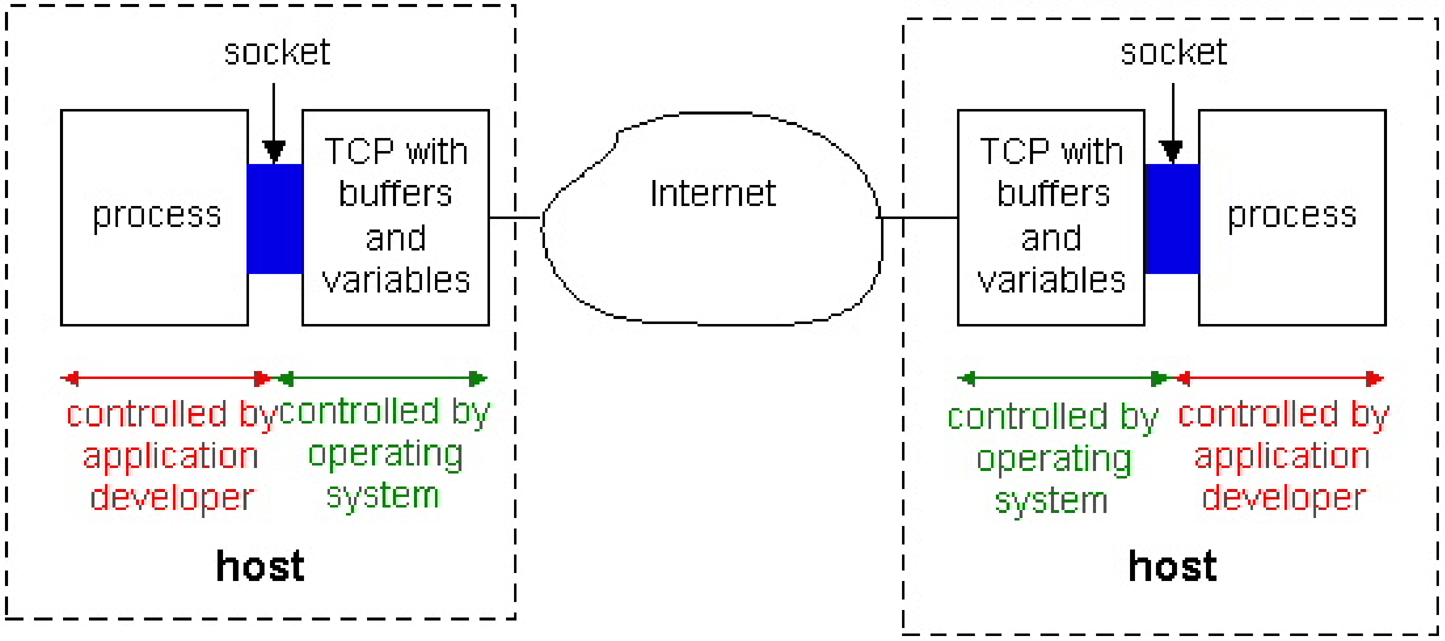
- Proprietary client-server application.
  - A single developer(or team) creates both client and server program.
  - The developer has complete control.
  - Must be careful not to use one of the well-known port number defined in the RFCs.

* well-known port number : managed by the Internet Assigned Numbers Authority(IANA)

Sockets Working Model



Socket Programming with TCP


socket
process
TCP with buffers and variables
controlled by application developer
controlled by operating system
host
Internet
socket
TCP with buffers and variables
process
controlled by operating system
controlled by application developer
host

The application developer has the ability to fix a few TCP parameters, such as maximum buffer and maximum segment sizes.

Sockets for server and client

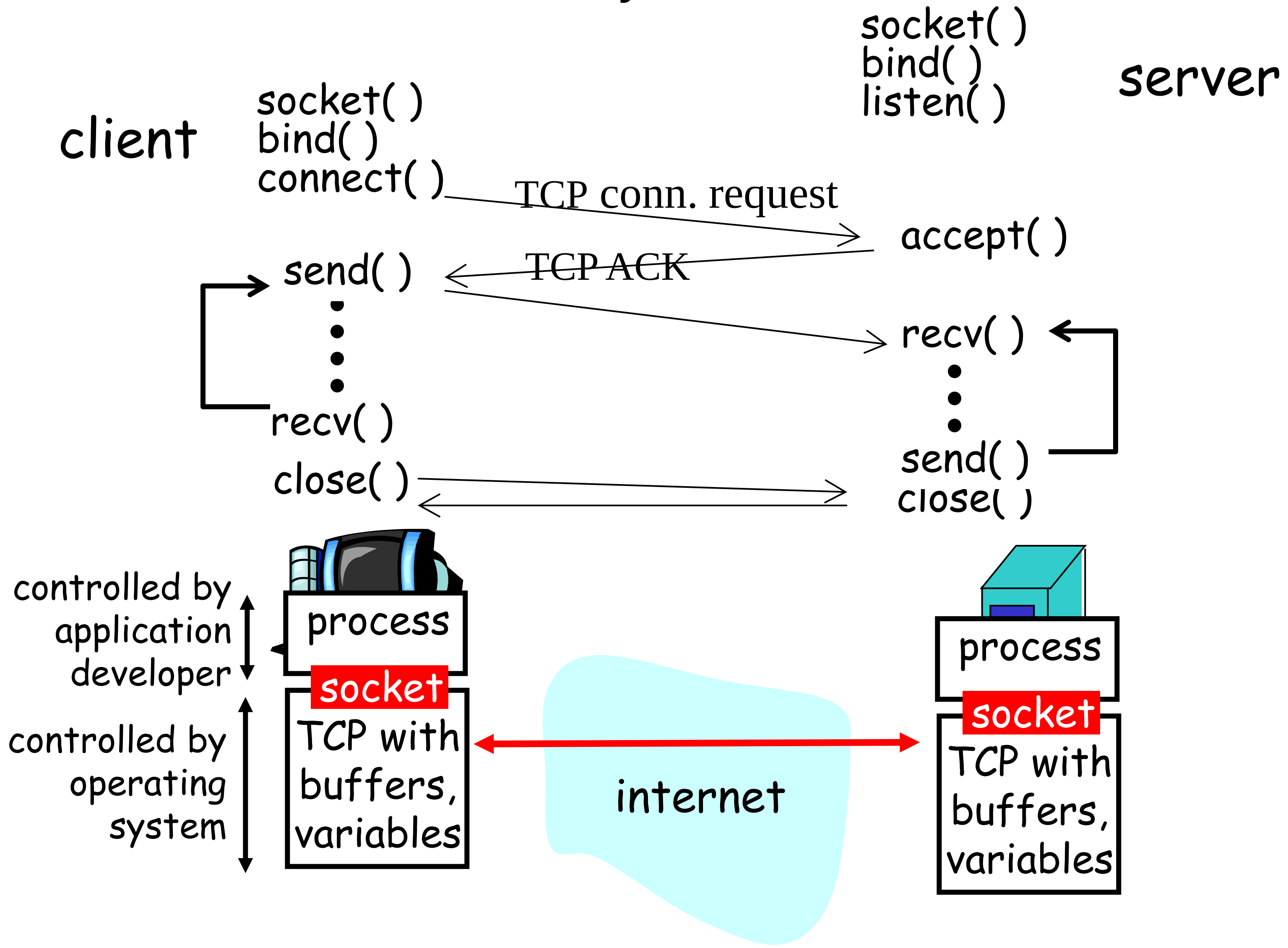
- Server
  - Welcoming socket
    - Welcomes some initial contact from a client.
  - Connection socket
    - Is created at initial contact of client.
    - New socket that is dedicated to the particular client.
- Client
  - Client socket
    - Initiate a TCP connection to the server by creating a socket object. (Three-way handshake)
    - Specify the address of the server process, namely, the IP address of the server and the port number of the process.

Unix/Linux Socket functional calls

- socket (): Create a socket
- bind(): bind a socket to a local IP address and port #
- listen(): passively waiting for connections
- connect(): initiating connection to another socket
- accept(): accept a new connection
- Write(): write data to a socket
- Read(): read data from a socket
- sendto(): send a datagram to another UDP socket
- recvfrom(): read a datagram from a UDP socket
- close(): close a socket (tear down the connection)

Socket-programming using TCP

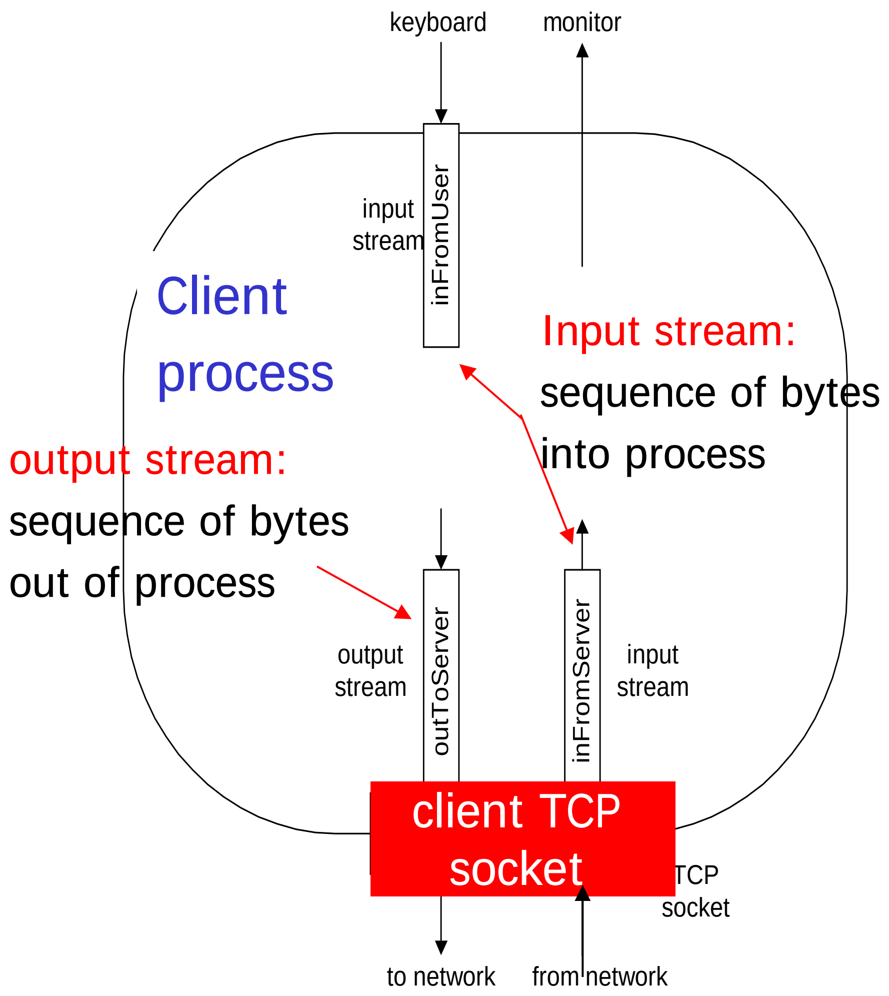
TCP service: reliable byte stream transfer



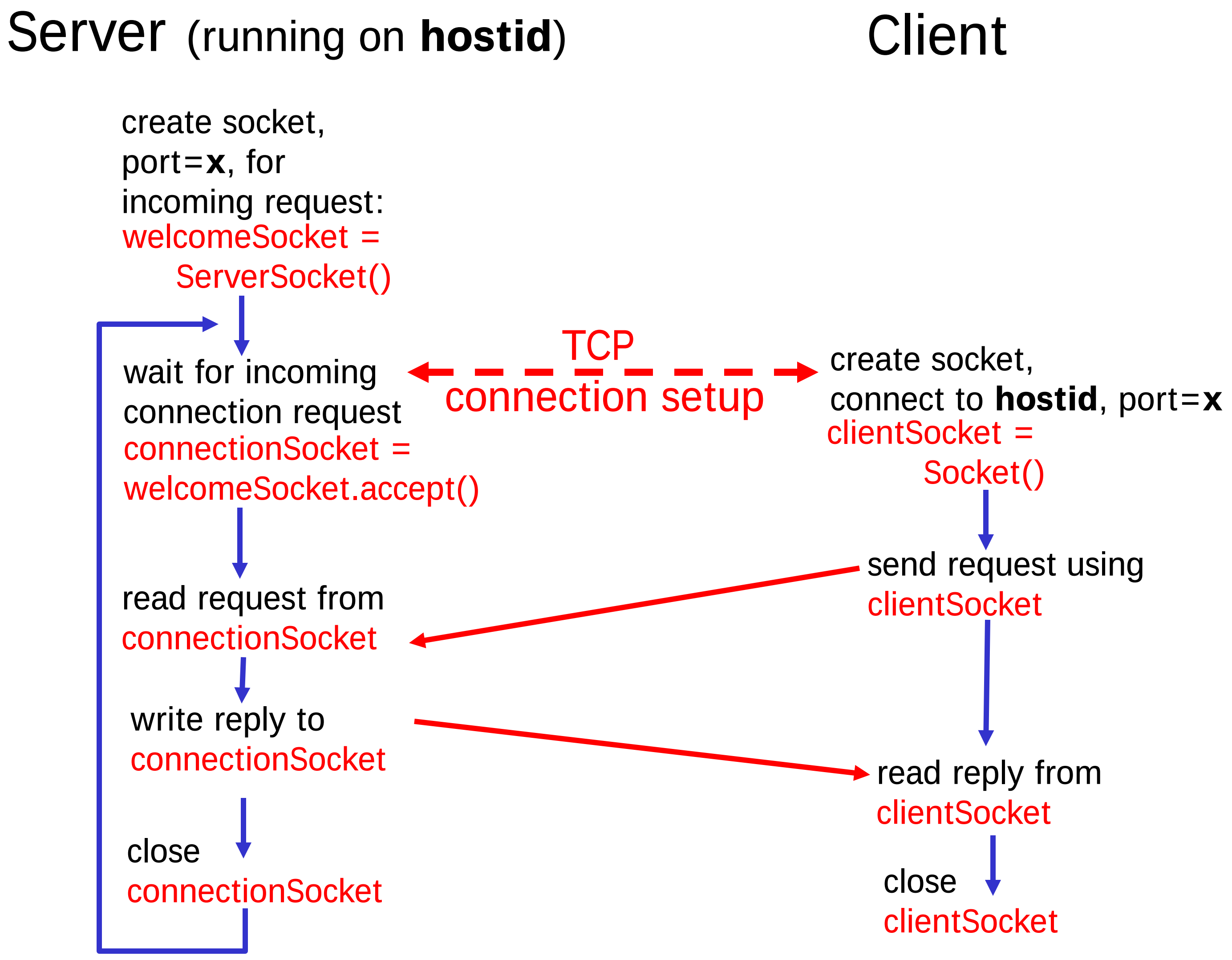
Socket programming with TCP

Example client-server app:

- client reads line from standard input (**inFromUser** stream) , sends to server via socket (**outToServer** stream)
- server reads line from socket
- server converts line to uppercase, sends back to client
- client reads, prints modified line from socket (**inFromServer** stream)



Client/server socket interaction: TCP


Server (running on **hostid**)
Client
create socket, port=**x**, for incoming request:
welcomeSocket = ServerSocket()
wait for incoming connection request
connectionSocket = welcomeSocket.accept()
TCP connection setup
create socket, connect to **hostid**, port=**x**
clientSocket = Socket()
send request using clientSocket
read request from connectionSocket
write reply to connectionSocket
read reply from clientSocket
close connectionSocket
close clientSocket

JAVA Sockets

- In Package java.net
  - java.net.Socket
    - Implements client sockets (also called just “sockets”).
    - An endpoint for communication between two machines.
    - Constructor and Methods
      - Socket(String host, int port): Creates a stream socket and connects it to the specified port number on the named host.
      - InputStream getInputStream()
      - OutputStream getOutputStream()
      - close()
  - java.net.ServerSocket
    - Implements server sockets.
    - Waits for requests to come in over the network.
    - Performs some operation based on the request.
    - Constructor and Methods
      - ServerSocket(int port)
      - Socket Accept(): Listens for a connection to be made to this socket and accepts it. This method blocks until a connection is made.

TCPServer.java

```
import java.io.*;
import java.net.*;
class TCPServer {
    public static void main(String argv[]) throws Exception {
      String clientSentence;
      String capitalizedSentence;

      ServerSocket welcomeSocket = new ServerSocket(6789);

      while(true) {
           Socket connectionSocket = welcomeSocket.accept();

           BufferedReader inFromClient = new BufferedReader(new
                              InputStreamReader(connectionSocket.getInputStream()));
           DataOutputStream  outToClient =
                              new DataOutputStream(connectionSocket.getOutputStream());

           clientSentence = inFromClient.readLine();
           capitalizedSentence = clientSentence.toUpperCase() + '\n';

           outToClient.writeBytes(capitalizedSentence);
        }
    }
}
```

TCPClient.java

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

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

              Socket clientSocket = new Socket("server IP address", 6789);

              DataOutputStream outToServer = new DataOutputStream(clientSocket.getOutputStream());

              BufferedReader inFromServer = new BufferedReader(
                                new InputStreamReader(clientSocket.getInputStream()));
              BufferedReader inFromUser = new BufferedReader(
                                new InputStreamReader(System.in));
              sentence = inFromUser.readLine();

              outToServer.writeBytes(sentence + '\n');
              modifiedSentence = inFromServer.readLine();
              System.out.println("FROM SERVER: " + modifiedSentence);

              clientSocket.close();

    }
}
```

Socket Programming with UDP

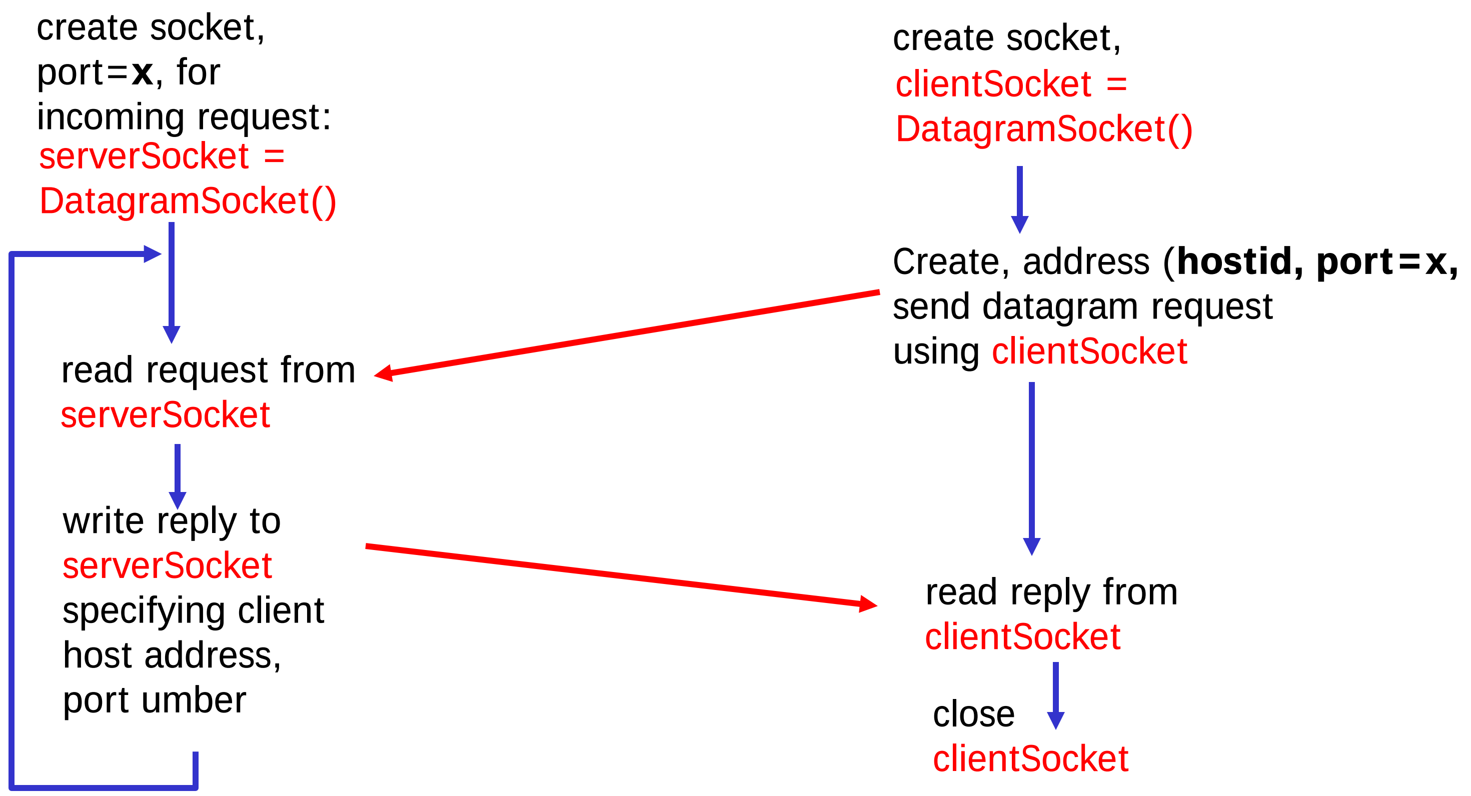
- UDP
  - Connectionless and unreliable service.
  - There isn’t an initial handshaking phase.
  - Doesn’t have a pipe.
  - transmitted data may be received out of order, or lost

- Socket Programming with UDP
  - No need for a welcoming socket.
  - No streams are attached to the sockets.
  - the sending hosts creates “packets” by attaching the IP destination address and port number to each batch of bytes.
  - The receiving process must unravel to received packet to obtain the packet’s information bytes.

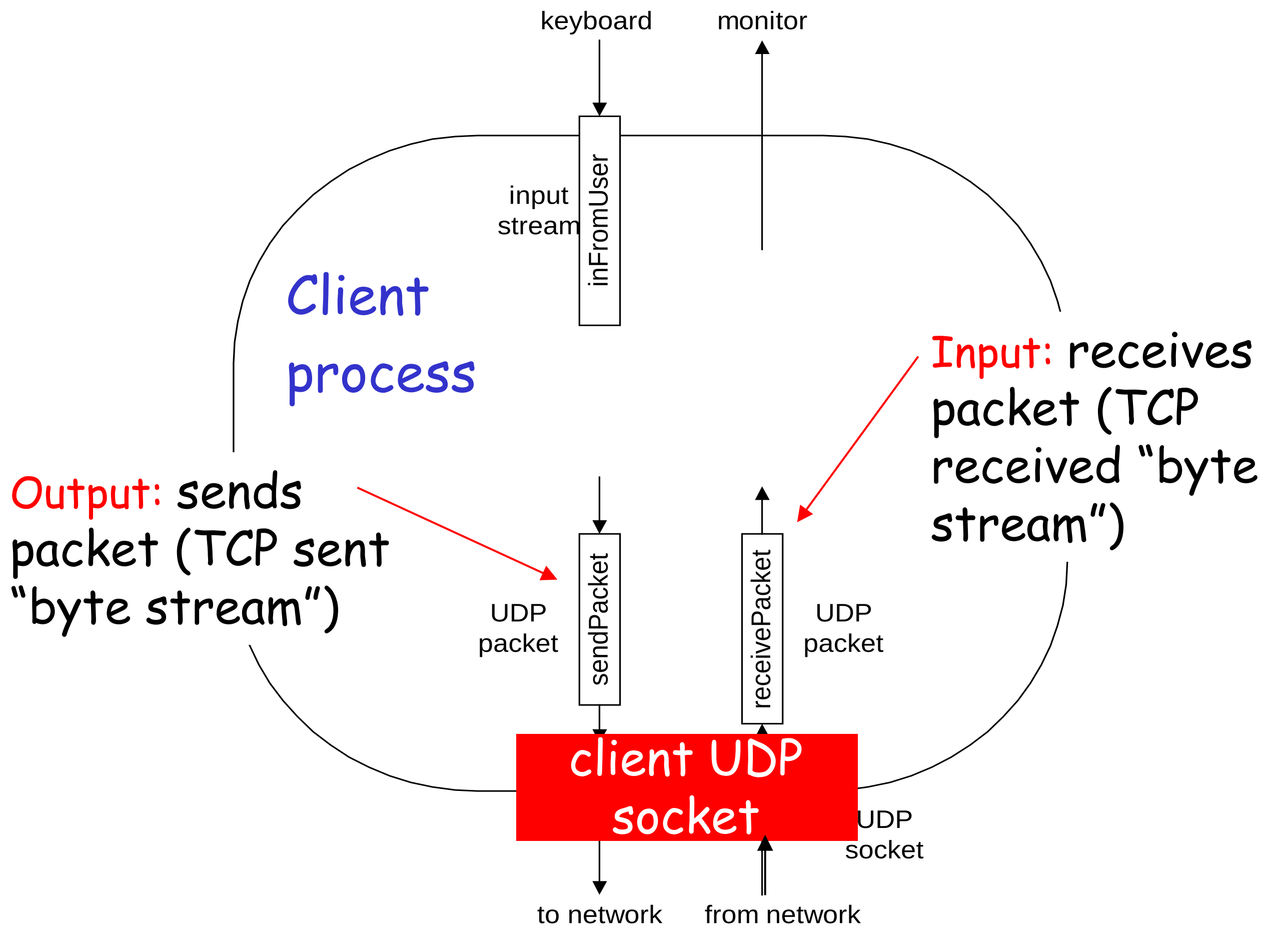
Client/server socket interaction: UDP

Server (running on **hostid**)

Client


create socket, port=**x**, for incoming request: serverSocket = DatagramSocket()
read request from serverSocket
write reply to serverSocket specifying client host address, port umber
create socket, clientSocket = DatagramSocket()
Create, address (**hostid, port=x,** send datagram request using clientSocket
read reply from clientSocket
close clientSocket

Example: Java client (UDP)



JAVA UDP Sockets

- In Package java.net
  - java.net.DatagramSocket
    - A socket for sending and receiving datagram packets.
    - Constructor and Methods
      - DatagramSocket(int port): Constructs a datagram socket and binds it to the specified port on the local host machine.
      - void receive(DatagramPacket p)
      - void send(DatagramPacket p)
      - void close()

UDPServer.java

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

class UDPServer {
        public static void main(String args[]) throws Exception {

            DatagramSocket serverSocket = new DatagramSocket(9876);

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

            while(true) {

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

              String sentence = new String(receivePacket.getData());
              InetAddress IPAddress = receivePacket.getAddress();

              int port = receivePacket.getPort();
              String capitalizedSentence = sentence.toUpperCase();
               sendData = capitalizedSentence.getBytes();

              DatagramPacket sendPacket =
                        new DatagramPacket(sendData, sendData.length, IPAddress, port);

              serverSocket.send(sendPacket);
             }
        }
}
```

UDPClient.java

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

class UDPClient {
      public static void main(String args[]) throws Exception {
         BufferedReader inFromUser = new BufferedReader(new InputStreamReader(System.in));

          DatagramSocket clientSocket = new DatagramSocket();
          InetAddress IPAddress = InetAddress.getByName("hostname");

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

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

       }
}
```

Building a Simple Web Server

- Handles only one HTTP request
- Accepts and parses the HTTP request
- Gets the required file from the server’s file system.
- Creates an HTTP response message consisting of the requested file preceded by header lines
- Sends the response directly to the client

WebServer.java

```
import java.io.*;
import java.net.*;
import java.util.*;
class WebServer{
    public static void main(String argv[]) throws Exception  {
           String requestMessageLine;
          String fileName;
           ServerSocket listenSocket = new ServerSocket(6789);
          Socket connectionSocket = listenSocket.accept();


           BufferedReader inFromClient =
                new BufferedReader(new
                     InputStreamReader(connectionSocket.getInputStream()));


         DataOutputStream outToClient =
               new DataOutputStream(connectionSocket.getOutputStream());
```

WebServer.java

```
requestMessageLine = inFromClient.readLine();

StringTokenizer tokenizedLine =
    new StringTokenizer(requestMessageLine);

if (tokenizedLine.nextToken().equals("GET")){
         fileName = tokenizedLine.nextToken();
         if (fileName.startsWith("/") == true )
                 fileName  = fileName.substring(1);

        File file = new File(fileName);
         int numOfBytes = (int) file.length();
          FileInputStream inFile  = new FileInputStream (fileName);
          byte[] fileInBytes = new byte[numOfBytes];

        inFile.read(fileInBytes);
```

WebServer.java

```
     outToClient.writeBytes("HTTP/1.0 200 Document Follows\r\n");

    if (fileName.endsWith(".jpg"))
        outToClient.writeBytes("Content-Type: image/jpeg\r\n");

    if (fileName.endsWith(".gif"))
        outToClient.writeBytes("Content-Type: image/gif\r\n");

    outToClient.writeBytes("Content-Length: " + numOfBytes + "\r\n");

    outToClient.writeBytes("\r\n");
    outToClient.write(fileInBytes, 0, numOfBytes);
     connectionSocket.close();
   }
    else System.out.println("Bad Request Message");
  }
}
```

Concurrent Server

- Servers need to handle a new connection request while processing previous requests.
  - Most TCP servers are designed to be concurrent.
- When a new connection request arrives at a server, the server accepts and invokes a new process to handle the new client.

How to handle the port numbers

```
cosmos% netstat –a –n –f inet
Active Internet connections (including servers)
Proto   Recv-Q   Send-Q   Local Address            Foreign Address          (state)
tcp     0        0        *.23                     *.*                      LISTEN

cosmos% netstat –a –n –f inet
Proto   Recv-Q   Send-Q   Local Address            Foreign Address          (state)
tcp     0        0        192.249.24.2.23          192.249.24.31.1029       ESTABLISHED
tcp     0        0        *.23                     *.*                      LISTEN

cosmos% netstat –a –n –f inet
Proto   Recv-Q   Send-Q   Local Address            Foreign Address          (state)
tcp     0        0        192.249.24.2.23          192.249.24.31.1029       ESTABLISHED
tcp     0        0        192.249.24.2.23          192.249.24.31.1030       ESTABLISHED
tcp     0        0        *.23                     *.*                      LISTEN
```

Socket programming: references

C-language tutorial (audio/slides):

- "Unix Network Programming" (J. Kurose),

http://manic.cs.umass.edu/~amldemo/courseware/intro.html

Java-tutorials:

- "All About Sockets" (Sun tutorial), http://www.javaworld.com/javaworld/jw-12-1996/jw-12-sockets.html
- "Socket Programming in Java: a tutorial," http://www.javaworld.com/javaworld/jw-12-1996/jw-12-sockets.html