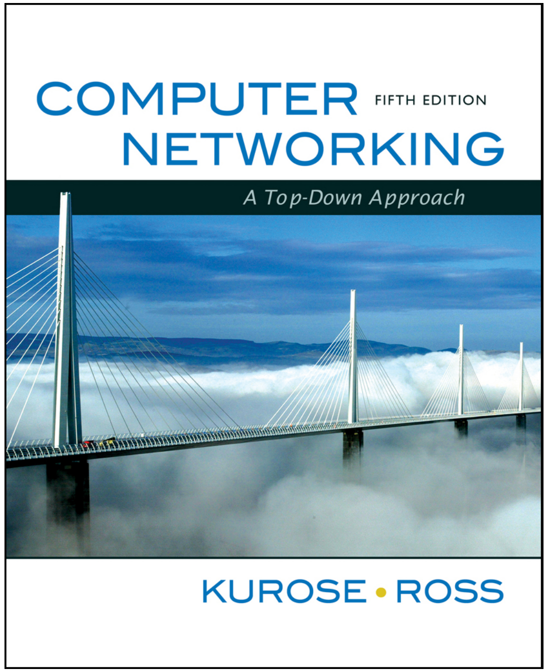
Chapter 2
Application Layer



A note on the use of these ppt slides:

We're making these slides freely available to all (faculty, students, readers). They're in PowerPoint form so you can add, modify, and delete slides (including this one) and slide content to suit your needs. They obviously represent a *lot* of work on our part. In return for use, we only ask the following:

- If you use these slides (e.g., in a class) in substantially unaltered form, that you mention their source (after all, we'd like people to use our book!)
- If you post any slides in substantially unaltered form on a www site, that you note that they are adapted from (or perhaps identical to) our slides, and note our copyright of this material.

Thanks and enjoy! JFK/KWR

Computer Networking: A Top Down Approach,
5th edition.
Jim Kurose, Keith Ross
Addison-Wesley, April 2009.

Socket programming

Goal: learn how to build client/server application that communicate using sockets

Socket API

- introduced in BSD4.1 UNIX, 1981
- explicitly created, used, released by apps
- client/server paradigm
- two types of transport service via socket API:
  - unreliable datagram
  - reliable, byte stream-oriented

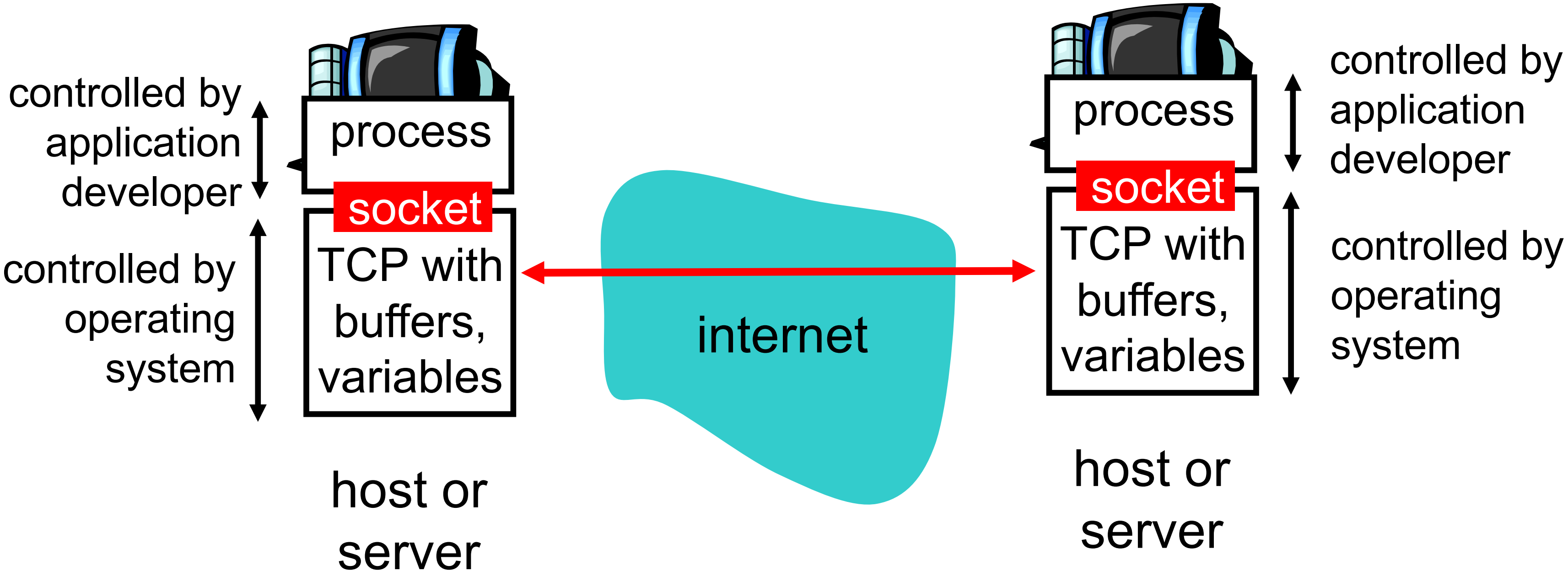
socket

a *host-local*, *application-created*, *OS-controlled* interface (a "door") into which application process can both send and receive messages to/from another application process

Socket-programming using TCP

Socket: a door between application process and end-end-transport protocol (UCP or TCP)

TCP service: reliable transfer of *bytes* from one process to another


controlled by application developer
controlled by operating system
process
socket
TCP with buffers, variables
host or server
internet
process
socket
TCP with buffers, variables
host or server
controlled by application developer
controlled by operating system

Socket programming *with TCP*

Client must contact server

- server process must first be running
- server must have created socket (door) that welcomes client's contact

Client contacts server by:

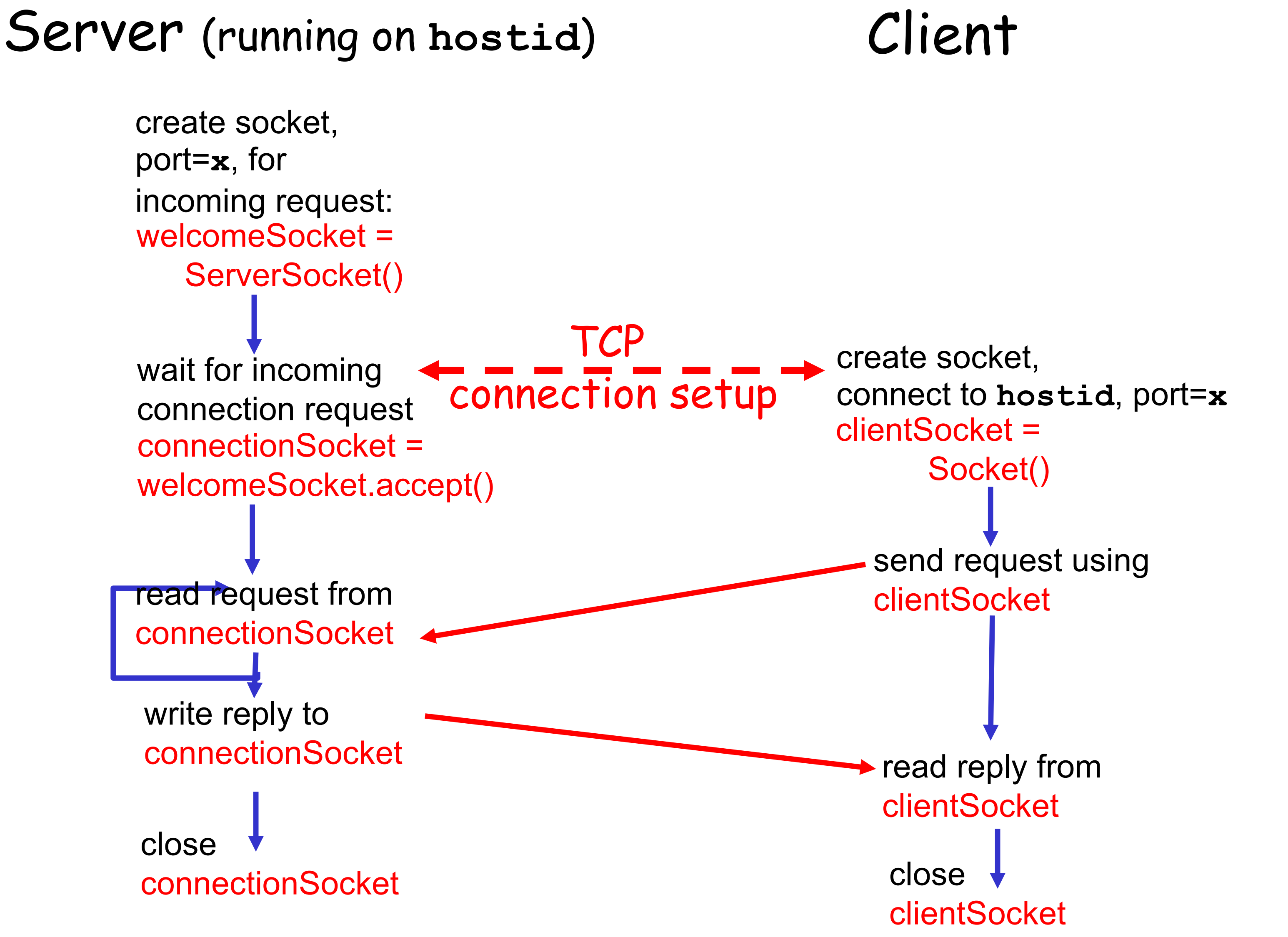
- creating client-local TCP socket
- specifying IP address, port number of server process
- when client creates socket: client TCP establishes connection to server TCP

- when contacted by client, server TCP creates new socket for server process to communicate with client
  - allows server to talk with multiple clients
  - source port numbers used to distinguish clients (more in Chap 3)

application viewpoint

TCP provides reliable, in-order transfer of bytes ("pipe") between client and server

Client/server socket interaction: 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

TCP
connection setup

Client

create socket,
connect to **hostid**, port=**x**
clientSocket =
Socket()

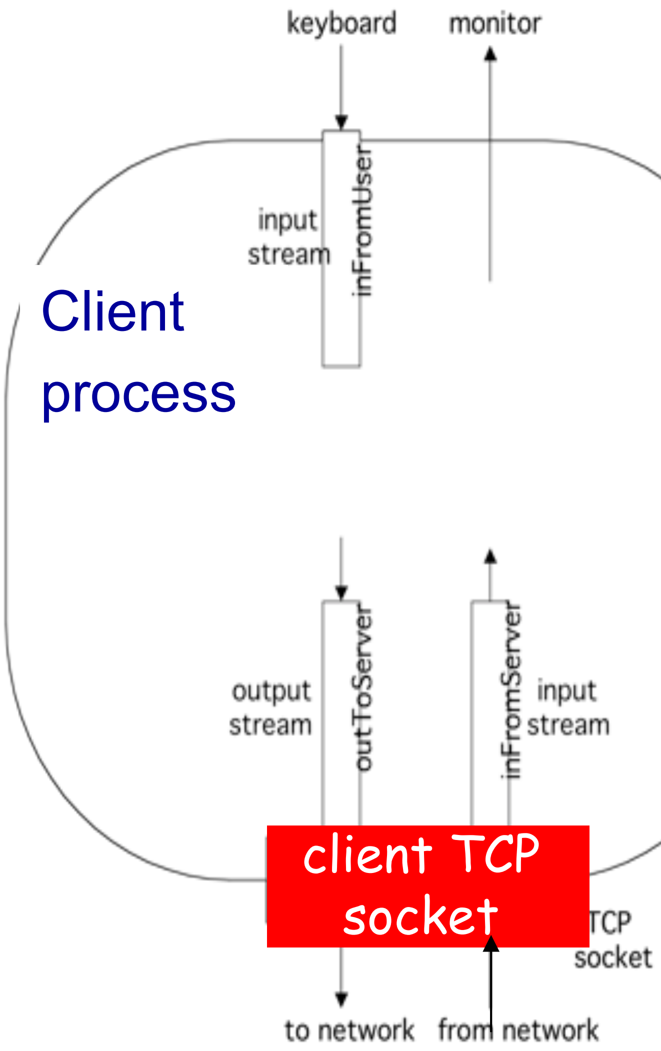
send request using
clientSocket

read reply from
clientSocket

close
clientSocket

Stream jargon

- stream is a sequence of characters that flow into or out of a process.
- input stream is attached to some input source for the process, e.g., keyboard or socket.
- output stream is attached to an output source, e.g., monitor or socket.



Socket programming with TCP

Example client-server app:

1) client reads line from standard input (**`inFromUser`** stream) , sends to server via socket (**`outToServer`** stream)

2) server reads line from socket

3) server converts line to uppercase, sends back to client

4) client reads, prints modified line from socket (**`inFromServer`** stream)

Example: Java client (TCP)

```
import java.io.*;
import java.net.*;
class TCPClient {
```

This package defines Socket() and ServerSocket() classes

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

server name, e.g., www.umass.edu

server port #

create input stream

```
        BufferedReader inFromUser =
          new BufferedReader(new InputStreamReader(System.in));
```

create clientSocket object of type Socket, connect to server

```
        Socket clientSocket = new Socket("hostname", 6789);
```

create output stream attached to socket

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

Example: Java client (TCP), cont.

create input stream attached to socket

```
BufferedReader inFromServer =
  new BufferedReader(new
  InputStreamReader(clientSocket.getInputStream()));

sentence = inFromUser.readLine();
```

send line to server

```
outToServer.writeBytes(sentence + '\n');
```

read line from server

```
modifiedSentence = inFromServer.readLine();

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

close socket (clean up behind yourself!)

```
clientSocket.close();

    }
}
```

Example: Java server (TCP)

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

class TCPServer {

 public static void main(String argv[]) throws Exception
  {
   String clientSentence;
   String capitalizedSentence;
```

create
welcoming socket
at port 6789

```
   ServerSocket welcomeSocket = new ServerSocket(6789);

   while(true) {
```

wait, on welcoming
socket accept() method
for client contact create,
new socket on return

```
      Socket connectionSocket = welcomeSocket.accept();
```

create input
stream, attached
to socket

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

Example: Java server (TCP), cont

create output stream, attached to socket

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

read in line from socket

```
clientSentence = inFromClient.readLine();
```

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

write out line to socket

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

end of while loop,
loop back and wait for
another client connection

Chapter 2: Application layer

2.1 Principles of network applications

2.2 Web and HTTP

2.3 FTP

2.4 Electronic Mail

- SMTP, POP3, IMAP

2.5 DNS

2.6 P2P applications

2.7 Socket programming with TCP

2.8 Socket programming with UDP

Socket programming *with UDP*

UDP: no "connection" between client and server

- no handshaking
- sender explicitly attaches IP address and port of destination to each packet
- server must extract IP address, port of sender from received packet

UDP: transmitted data may be received out of order, or lost

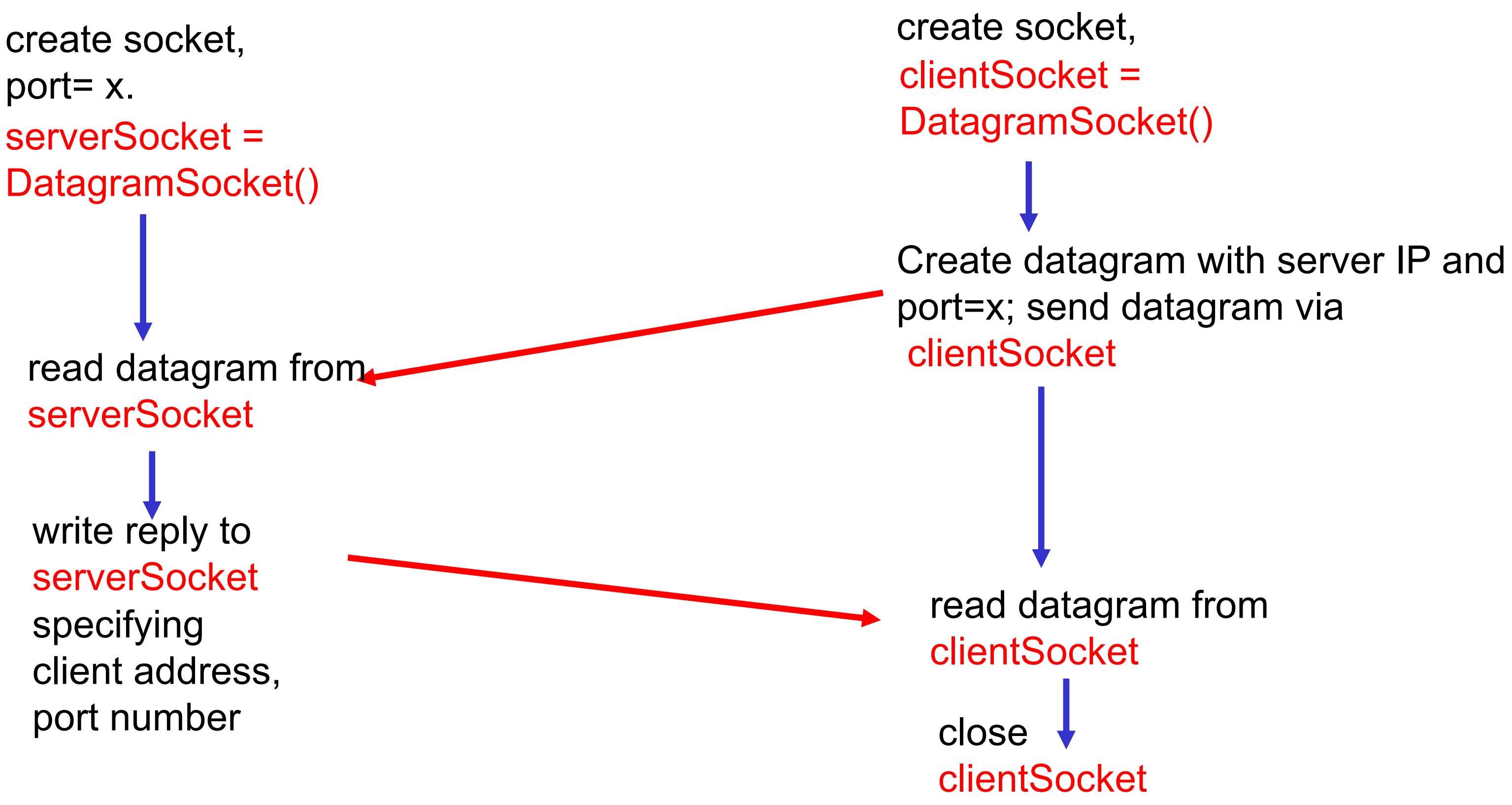
application viewpoint:

UDP provides unreliable transfer of groups of bytes ("datagrams") between client and server

Client/server socket interaction: UDP

Server (running on `hostid`)

Client



create socket,
port= x.
serverSocket =
DatagramSocket()

read datagram from
serverSocket

write reply to
serverSocket
specifying
client address,
port number

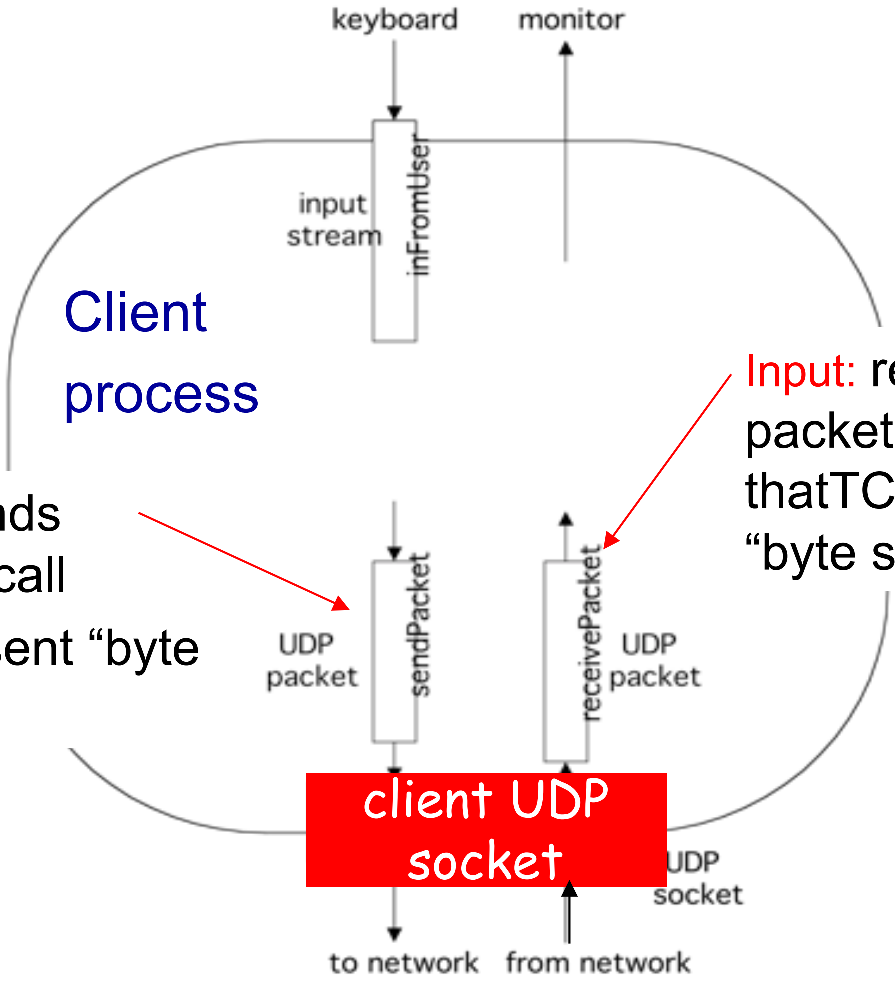
create socket,
clientSocket =
DatagramSocket()

Create datagram with server IP and
port=x; send datagram via
clientSocket

read datagram from
clientSocket

close
clientSocket

Example: Java client (UDP)



Output: sends packet (recall that TCP sent "byte stream")

Input: receives packet (recall thatTCP received "byte stream")

Example: Java client (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("hostname");

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

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

Example: Java client (UDP), cont.

create datagram with data-to-send, length, IP addr, port

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

send datagram to server

```
        clientSocket.send(sendPacket);

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

read datagram from server

```
        clientSocket.receive(receivePacket);

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

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

Example: Java server (UDP)

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

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

create datagram socket at port 9876

```
      DatagramSocket serverSocket = new DatagramSocket(9876);

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

      while(true)
        {
```

create space for received datagram

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

receive datagram

```
           serverSocket.receive(receivePacket);
```

Example: Java server (UDP), cont

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

get IP addr
port #, 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
datagram
to socket

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

end of while loop,
loop back and wait for
another datagram