Lecture 3 : Introduction to Socket Programming

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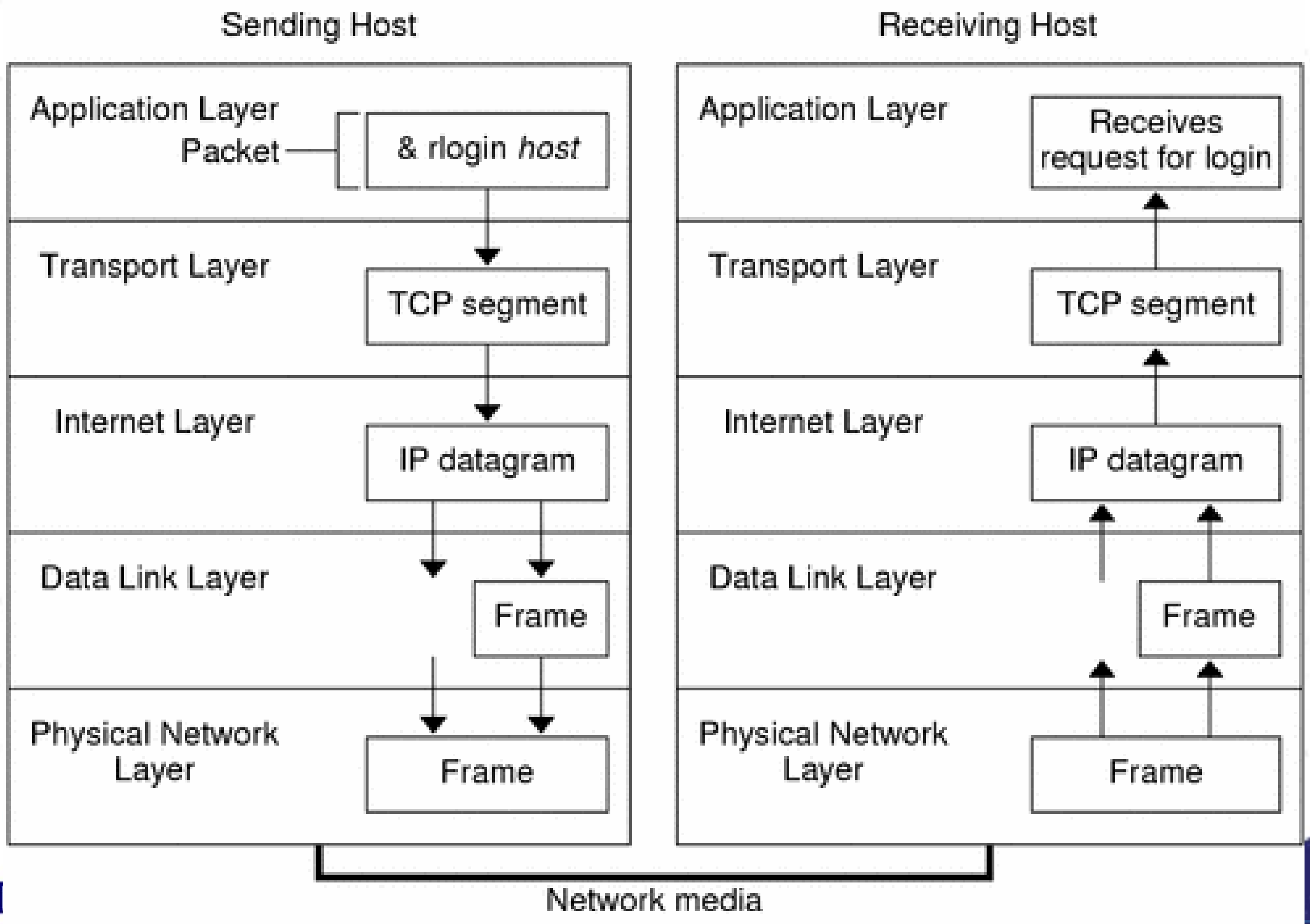
What is a socket?

- Port vs. Socket

- An interface between application and network
  - The application creates a socket
  - The socket *type* dictates the style of communication
    - reliable vs. best effort
    - connection-oriented vs. connectionless

- Once configured the application can
  - pass data to the socket for network transmission
  - receive data from the socket (transmitted through the network by some other host)

TCP/IP Stack



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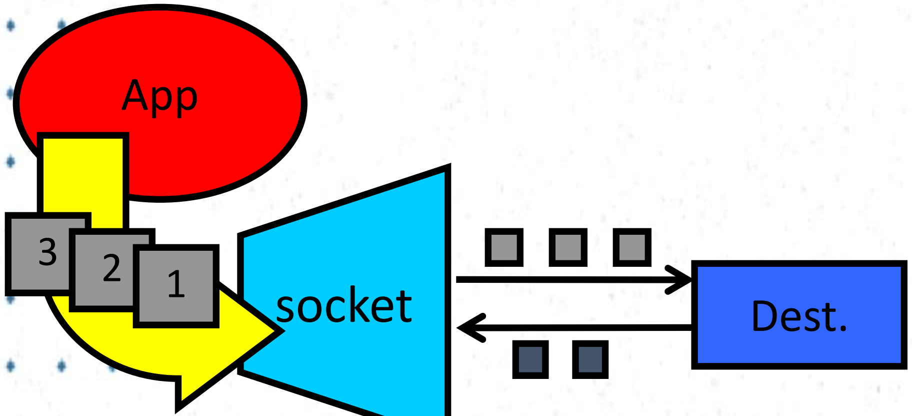
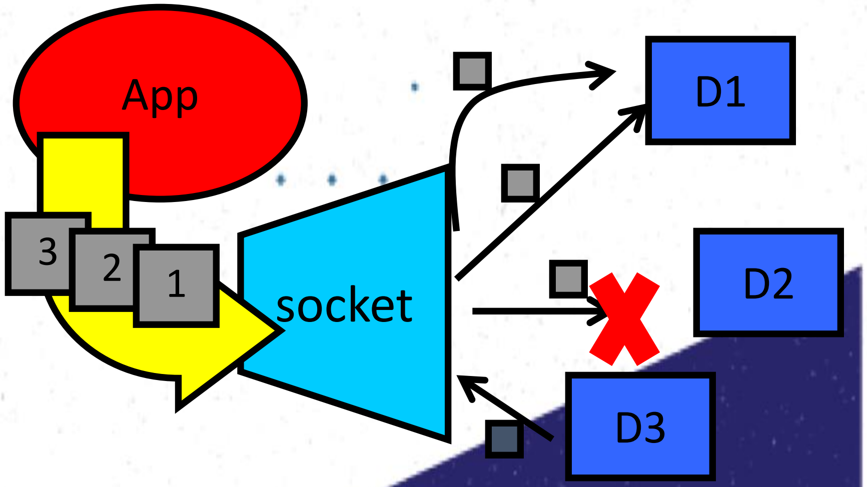
Two essential types of sockets

- TCP Socket
  - reliable delivery
  - in-order guaranteed
  - connection-oriented
  - bidirectional

- UDP Socket
  - unreliable delivery
  - no order guarantees
  - no notion of "connection" – app indicates dest. for each packet
  - can send or receive



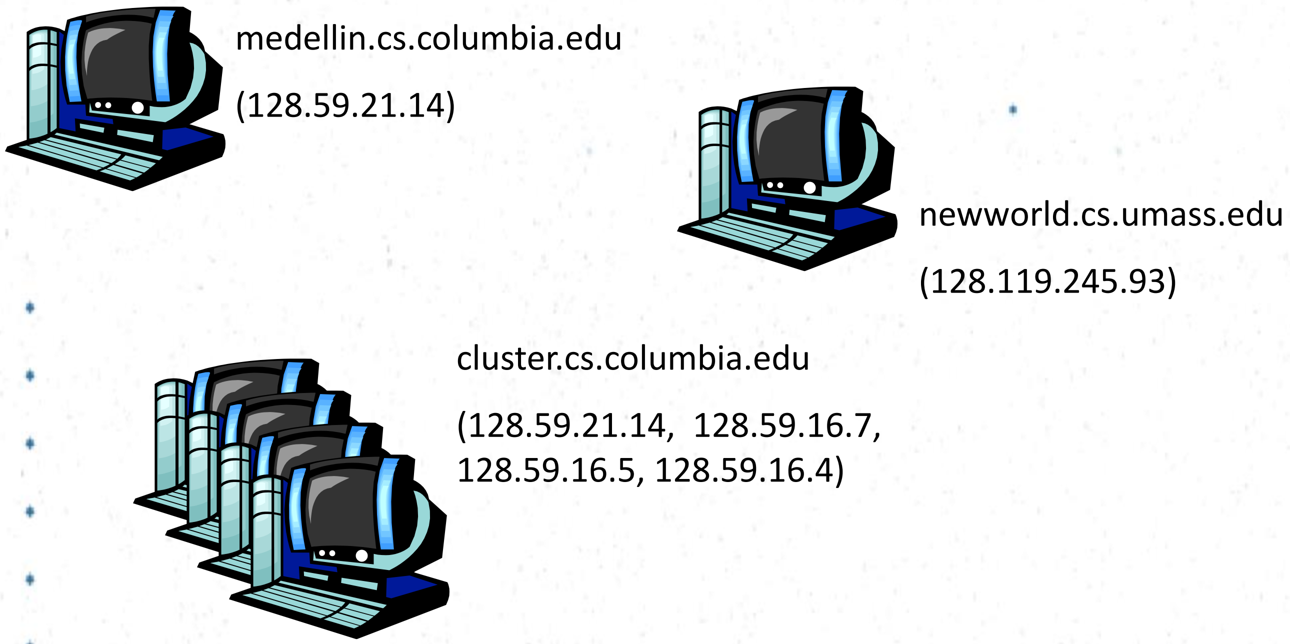


Applications

- TCP (Transmission control protocol)
  - Point to point chat applications, File transfer (FTP), Email (SMTP)
  - Used when there's a requirement for guaranteed delivery

- UDP (User datagram protocol)
  – Streaming, Multicast/Broadcast
  - Useful when the speed of more important than the assurance of delivery

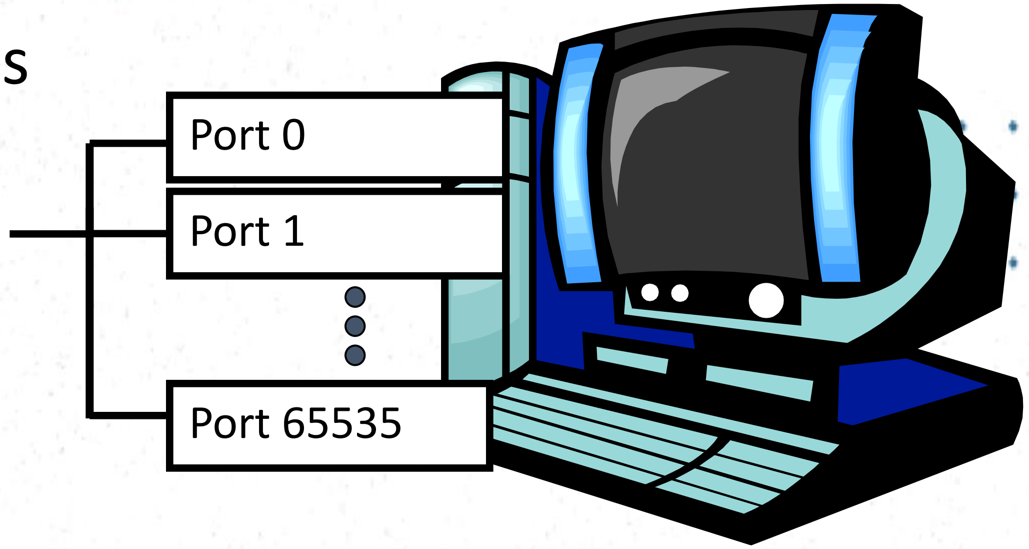
A Socket-eye view of the Internet



- Each host machine has an IP address
- When a packet arrives at a host

Ports

- Each host has 65,536 ports
- Some ports are *reserved for specific apps*
  - 20,21: FTP
  - 23: Telnet
  - 80: HTTP
  - see RFC 1700 (about 2000 ports are reserved)

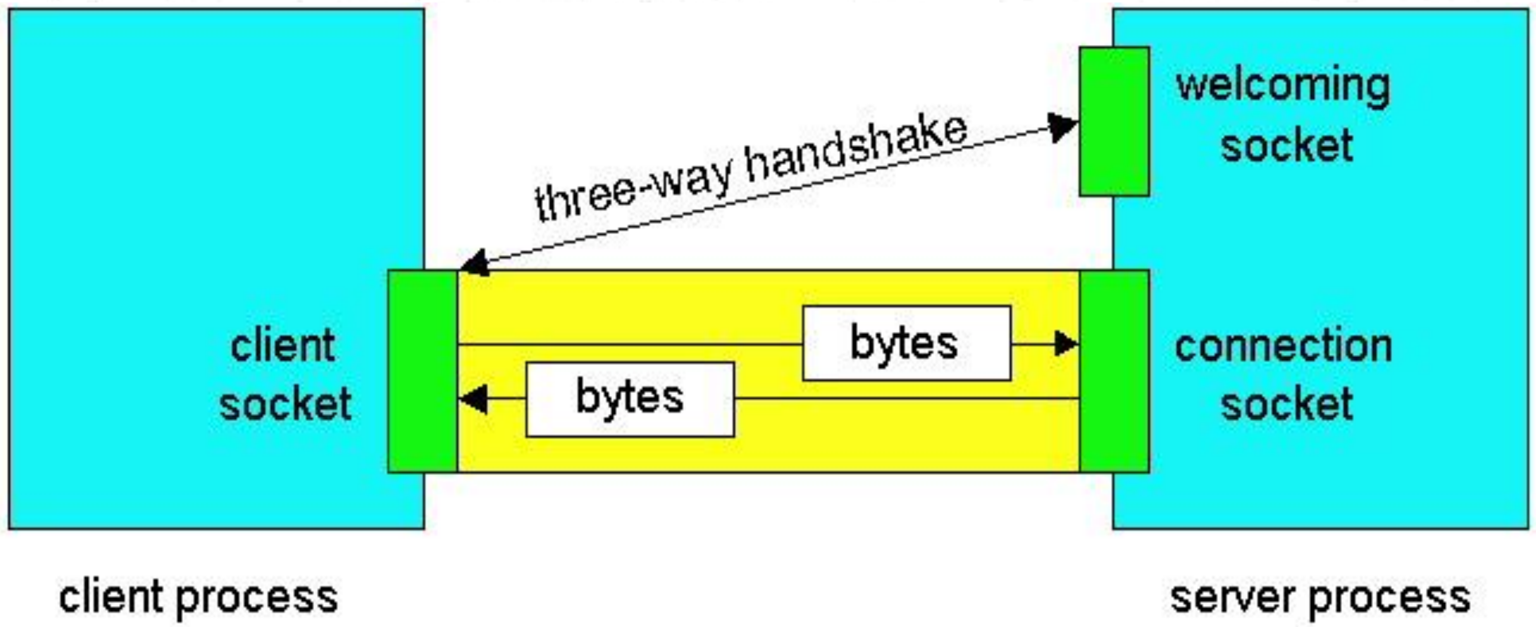


A socket provides an interface to send data to/from the network through a port

Addresses, Ports and Sockets

- In TCP, only one application (process) can listen to a port
- In UDP Multiple applications (processes) may listen to incoming messages on a single port
- Like apartments and mailboxes
  - You are the application
  - Your apartment building address is the address
  - Your mailbox is the port
  - The post-office is the network
  - Each family (process) of the apartment complex (computer) communicates with some same mailbox (port)

TCP Sockets

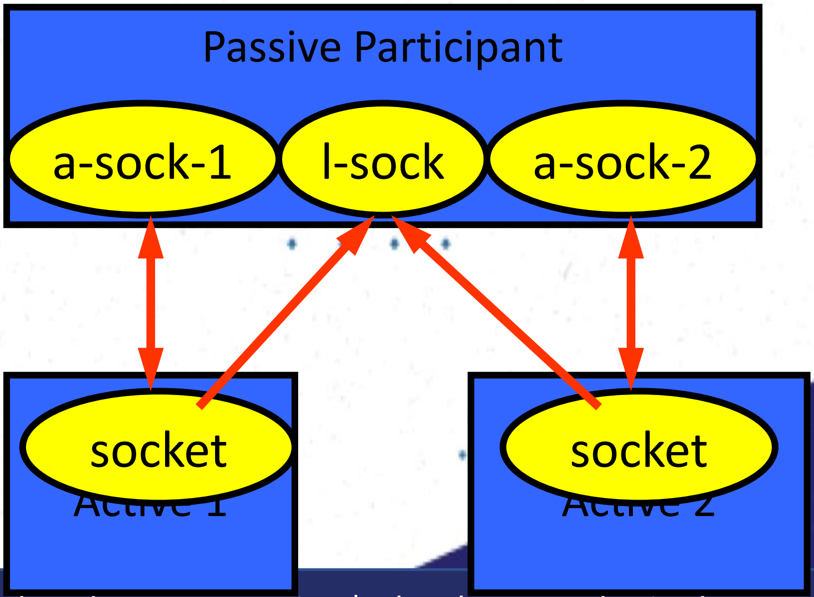


Client socket, welcoming socket (passive) and connection socket (active)

Connection setup

- Passive participant
  - step 1: listen (for incoming requests)
  - step 3: accept (a request)
  - step 4: data transfer
- The accepted connection is on a new socket
- The old socket continues to listen for other active participants

- Active participant
  - step 2: request & establish connection
  - step 4: data transfer



Dealing with blocking

- Calls to sockets can be blocking (no other client may be able to connect to the server)
- Can be resolved using multi-threaded programming
- Start a new thread for every incoming connection

Java Sockets Programming

- The package java.net provides support for sockets programming (and more).

- Typically you import everything defined in this package with:

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

Classes

`InetAddress`

`Socket`

`ServerSocket`

`DatagramSocket`

`DatagramPacket`

InetAddress class

- Static methods you can use to create new InetAddress objects.
  - getByName(String host)
  - getAllByName(String host)
  - getLocalHost()

```
InetAddress x = InetAddress.getByName(
                          “cse.unr.edu”);
```

❖Throws **`UnknownHostException`**

```
try {

   InetAddress a = InetAddress.getByName(hostname);

   System.out.println(hostname + ":" +
         a.getHostAddress());

} catch (UnknownHostException e) {

   System.out.println("No address found for " +
            hostname);

}
```

Socket class

- Corresponds to active TCP sockets only!
  - client sockets
  - socket returned by accept();

- Passive sockets are supported by a different class:
  - ServerSocket

- UDP sockets are supported by
  - DatagramSocket

JAVA TCP Sockets

- java.net.Socket
  - Implements client sockets (also called just “sockets”).
  - An endpoint for communication between two machines.
  - Uses input/output streams to pass messages
    -

- java.net.ServerSocket
  - Implements server sockets.
  - Waits for requests to come in over the network.
  - Accepts the client connection requests
  - Performs some operation based on each request

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Socket Constructors

- Constructor creates a TCP connection to a named TCP server.
  - There are a number of constructors:

```
Socket(InetAddress server, int port);

Socket(InetAddress server, int port,
       InetAddress local, int localport);

Socket(String hostname, int port);
```

Socket Methods

```
void close();
InetAddress getInetAddress();
InetAddress getLocalAddress();
InputStream getInputStream();
OutputStream getOutputStream();
```

- Lots more (setting/getting socket options, partial close, etc.)

Socket I/O

- Socket I/O is based on the Java I/O support
  - in the package **`java.io`**

- InputStream and OutputStream are abstract classes
  - common operations defined for all kinds of InputStreams, OutputStreams…

InputStream Basics

```
// reads some number of bytes and
// puts in buffer array b
int read(byte[] b);

// reads up to len bytes
int read(byte[] b, int off, int len);
```

Both methods can throw **`IOException`**.

Both return –1 on EOF.

OutputStream Basics

```
// writes b.length bytes
void write(byte[] b);

// writes len bytes starting
// at offset off
void write(byte[] b, int off, int len);
```

Both methods can throw **`IOException`**.

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ServerSocket Class (TCP Passive Socket)

- Constructors:

```
ServerSocket(int port);

ServerSocket(int port, int backlog);

ServerSocket(int port, int backlog,
                 InetAddress bindAddr);
```

ServerSocket Methods

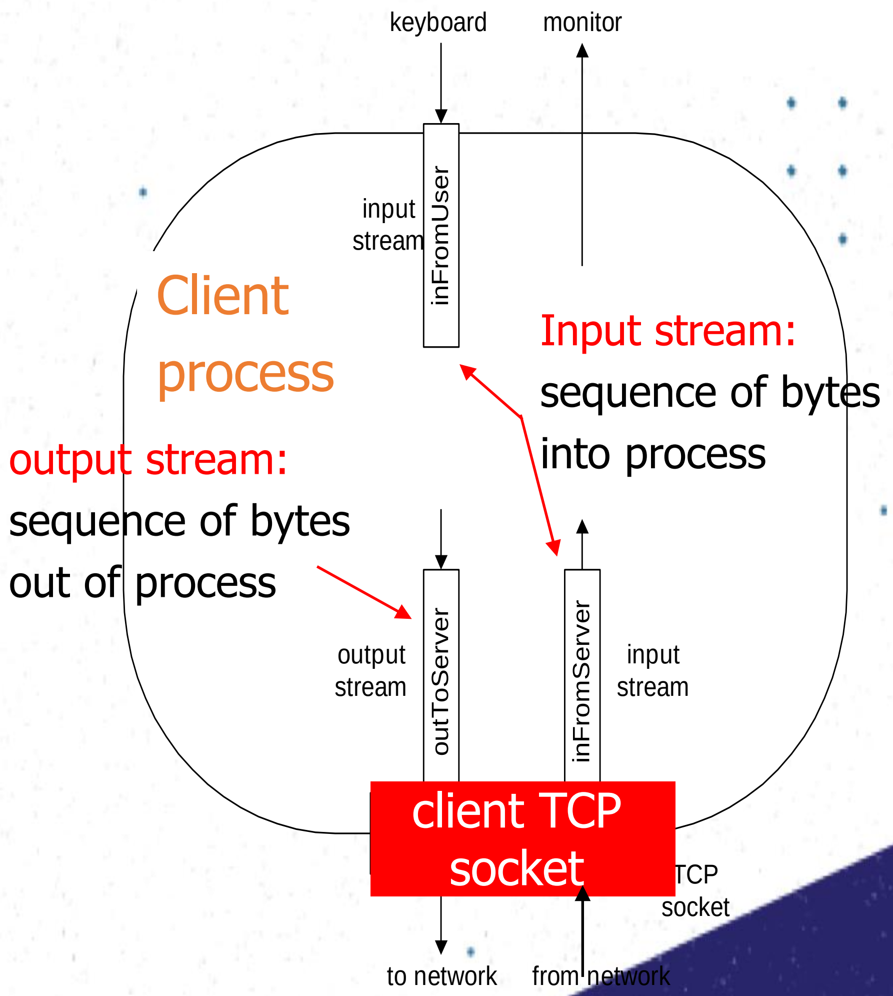
```
Socket accept();

void close();

InetAddress getInetAddress();

int getLocalPort();
```

throw `IOException, SecurityException`

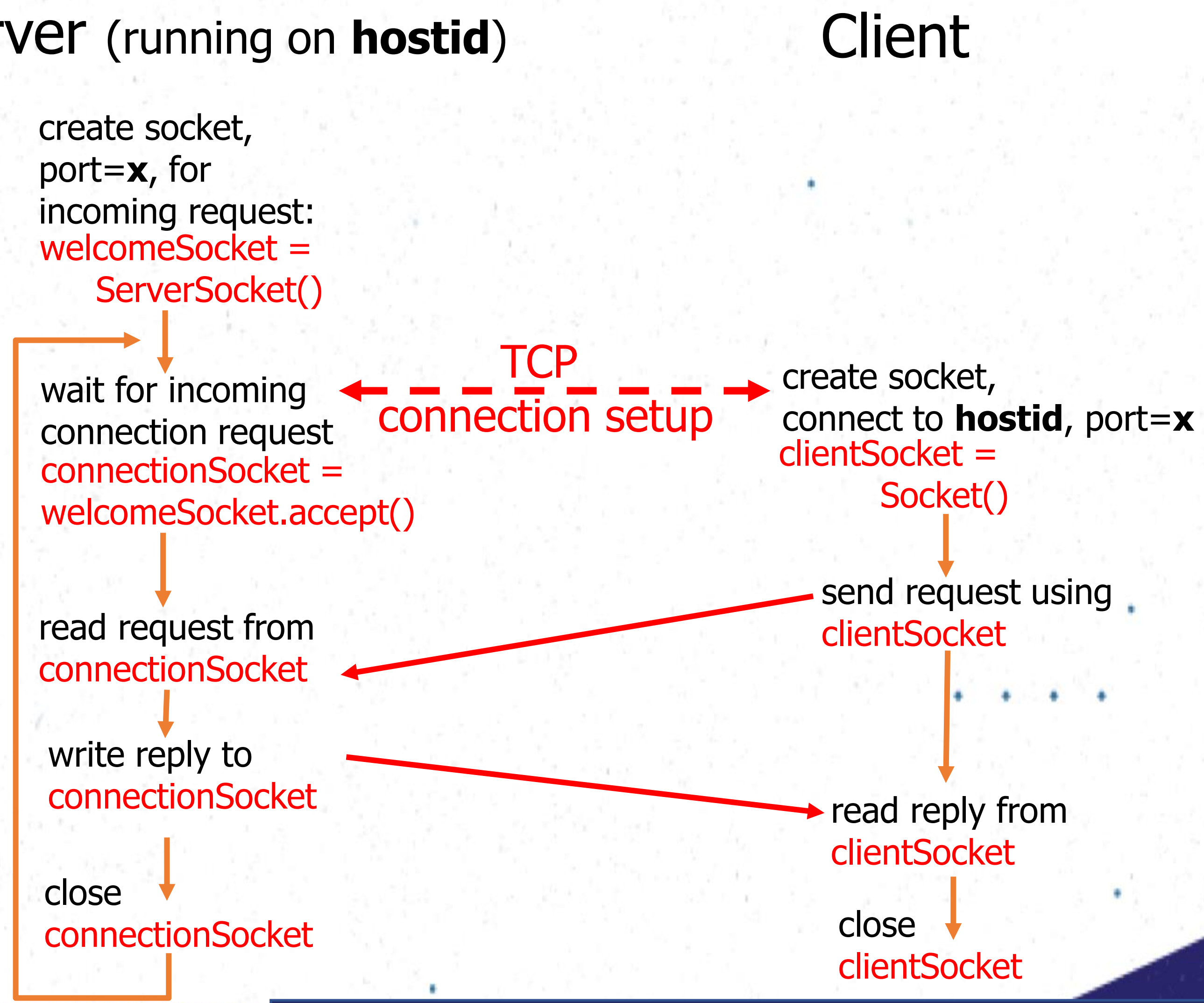
Socket programming with TCP

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

TCPClient.java

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

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

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

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

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

TCPClient.java

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

  sentence = inFromUser.readLine();

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

  modifiedSentence = inFromServer.readLine();

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

  clientSocket.close();

  }
}
```

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()));
```

TCPServer.java

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

      clientSentence = inFromClient.readLine();

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

      outToClient.writeBytes(capitalizedSentence);

    }
  }
}
```

UDP Sockets

- DatagramSocket class

- DatagramPacket class needed to specify the payload
  - incoming or outgoing

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.

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()

DatagramSocket Constructors

```
DatagramSocket();

DatagramSocket(int port);

DatagramSocket(int port, InetAddress a);
```

All can throw SocketException or SecurityException

Datagram Methods

```
void connect(InetAddress, int port);

void close();

void receive(DatagramPacket p);

void send(DatagramPacket p);
```

Lots more!

Datagram Packet

- Contain the payload
  - a byte array
- Can also be used to specify the destination address
  - when not using connected mode UDP

DatagramPacket Constructors

For receiving:

```
DatagramPacket( byte[] buf, int len);
```

For sending:

```
DatagramPacket( byte[] buf, int len
                InetAddress a, int port);
```

DatagramPacket methods

```
byte[] getData();
void setData(byte[] buf);

void setAddress(InetAddress a);
void setPort(int port);

InetAddress getAddress();
int getPort();
```

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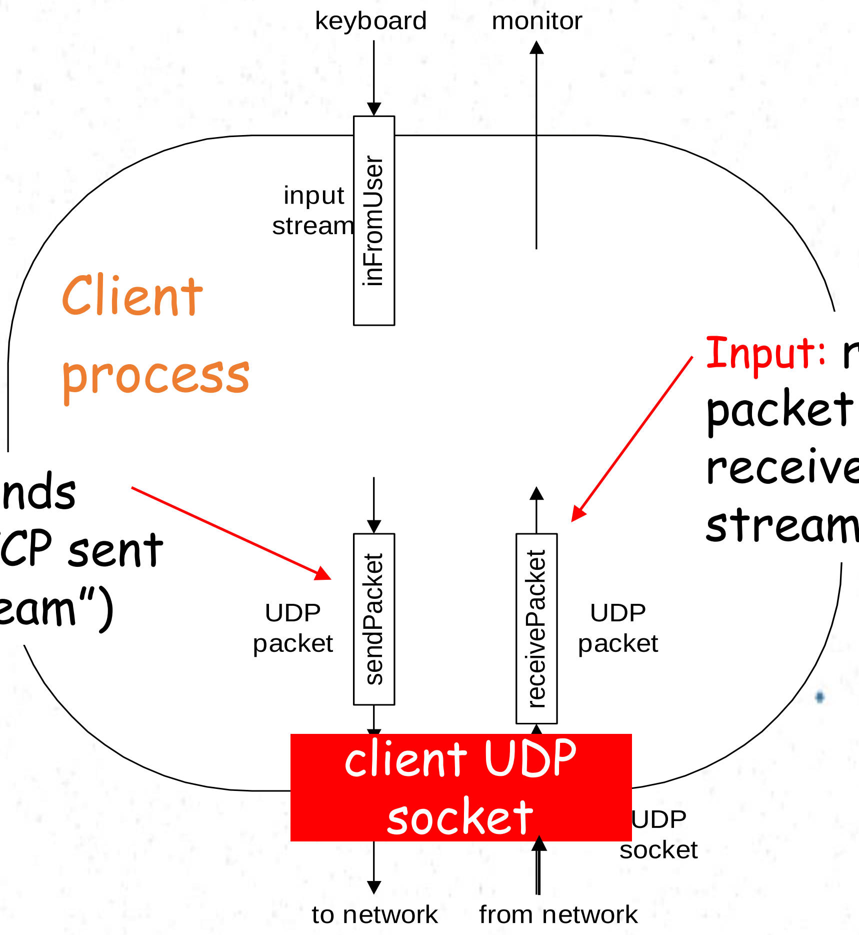
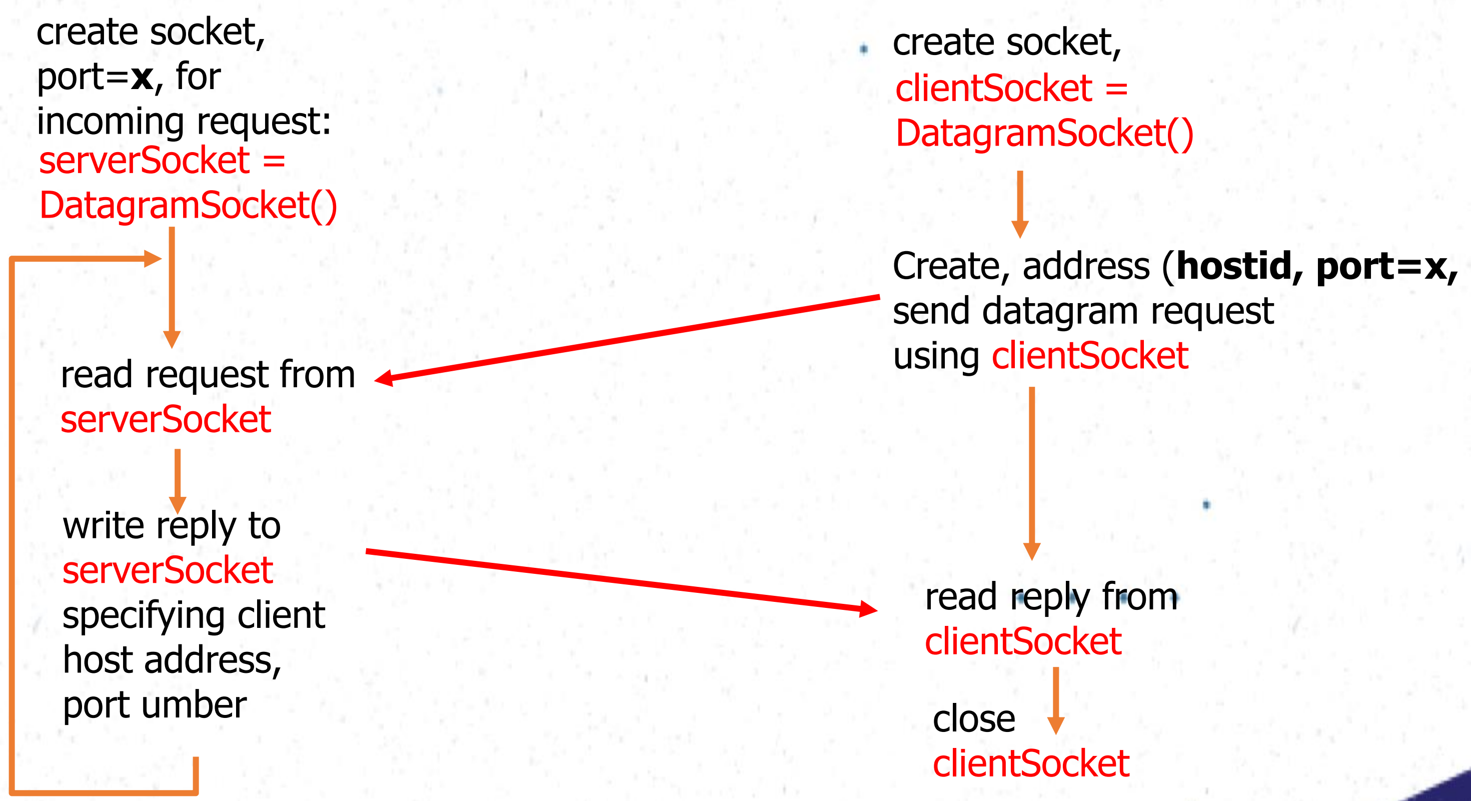
Example: Java client (UDP)



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

Input: receives packet (TCP received "byte stream")

Client/server socket interaction: 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 umber

Client

create socket,
clientSocket =
DatagramSocket()

Create, address (**hostid, port=x,**
send datagram request
using clientSocket

read reply from
clientSocket

close
clientSocket

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();
```

UDPClient.java

```
    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();

    }
}
```

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());
```

UDPServer.java

```
    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);

    }
  }
}
```

Summary

- Socket programming is the most fundamental form of Client-Server distributed computing available for app. developers
- Can be used to develop client-server distributed applications (e.g. Messaging applications)
- However, most real-world distributed systems use more high level distributed computing technologies (E.g. Web services, EJBs)
- Yet the underlying communication mechanism of these high level Dist. Computing frameworks is socket communication