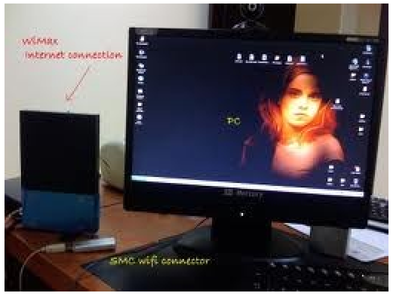
CSCD 330
Network Programming
Spring 2018

Lecture 7
Application Layer –
Socket Programming in Java

Reading: Chapter 2, Java links Relevant Links page

Review Client/Server Programming

Firefox
HTTP 80



- So far,
  - Host has IP Address

    146.187.134.22
    - Network Layer identifier
    - Every network "device" has this identifier
      - Phone, Toaster, etc.
  - Processes running on Hosts
    - Assigned a port number
    - Port numbers identifiers for processes
    - Some port numbers reserved 1 - 1023
    - Other port numbers reserved for widely recognized processes

Review Client/Server Programming

- Communication Between Client/Server
  - Uses object, “Socket”
  - Socket is the API between a program and the TCP/IP stack of the OS
  - It has an input stream and an output stream built in to it
  - Both the client and server define different ends of this socket
  - Link to the Java .net Package API

http://download.java.net/jdk7/archive/b123/docs/api/java/net/package-summary.html

TCP/IP Client/Server

- How this works in Java
  - Server Socket

1. Binds socket to specific port number
2. Listens for incoming connections on that port
3. When connection attempted, it accepts connection, creates a regular socket for communication to client
4. Port number on the client side is different and selected by stack software
5. What you see on the Server side is the same port number for the server program

TCP/IP Client/Server

- Java Code for Server

```
ss = new ServerSocket (port);
// Loop forever
While (true) {
    // Get a connection
    Socket newSocket = ss.accept ();
    // Deal with the connection
    // ....
}
```

Server socket listens on a port

Inside loop waits for connection

Creates a new socket object representing new connection
What is not obvious is that the new connection is through a different port number on the client side

TCP/IP Client/Server

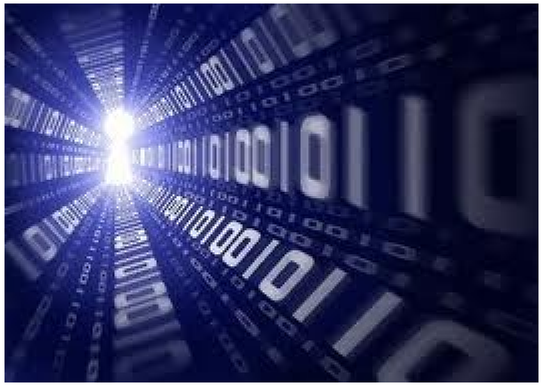
- Java code for Client, Send/Receive Data

```
// Create a socket for communicating with server
    Socket clientSocket = new Socket ("hostname", 6789);
```

Create a client TCP socket, with host and port

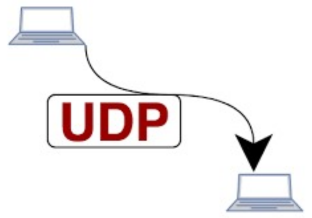
```
// Create data streams for communicating through the socket
   BufferedReader in = new BufferedReader
       (new InputStreamReader (clientSocket.getInputStream ());
     PrintWriter out = new PrintWriter (clientSocket.getOutputStream ());
     System.out.println (in.readLine ()); // Print output to screen
```

Then, create streams to send input and get it back from server



UDP

UDP Introduction



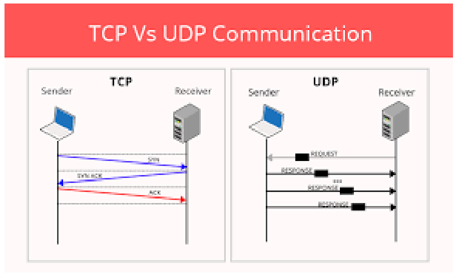
- UDP is a communication protocol that transmits independent packets over the network with no guarantee of arrival and no guarantee of the order of delivery.

- Most communication over the Internet takes place over the Transmission Control Protocol (TCP),

UDP Advantages

- Advantage of UDP is that it requires much less overhead than TCP because
- No hand-shaking,
- No retry if an acknowledge isn't received,
- No buffering and numbering of packets,
- Where do we use UDP?
- Connectionless protocols used either for one-packet messages for which delivery is not crucial
  - Responses to time requests, or
- To reduce the transmission overhead for time-critical data such as streaming audio/video

UDP



- Building UDP applications is very similar to building a TCP system
- Difference is that we don’t establish a point to point connection between a client and a server.

- The setup is very straightforward too. Java ships with built-in networking support for UDP – which is part of the java.net package. Therefore to perform networking operations over UDP, we only need to import the classes from the java.net package:
- java.net.DatagramSocket and java.net.DatagramPacket.

UDP Socket Programming

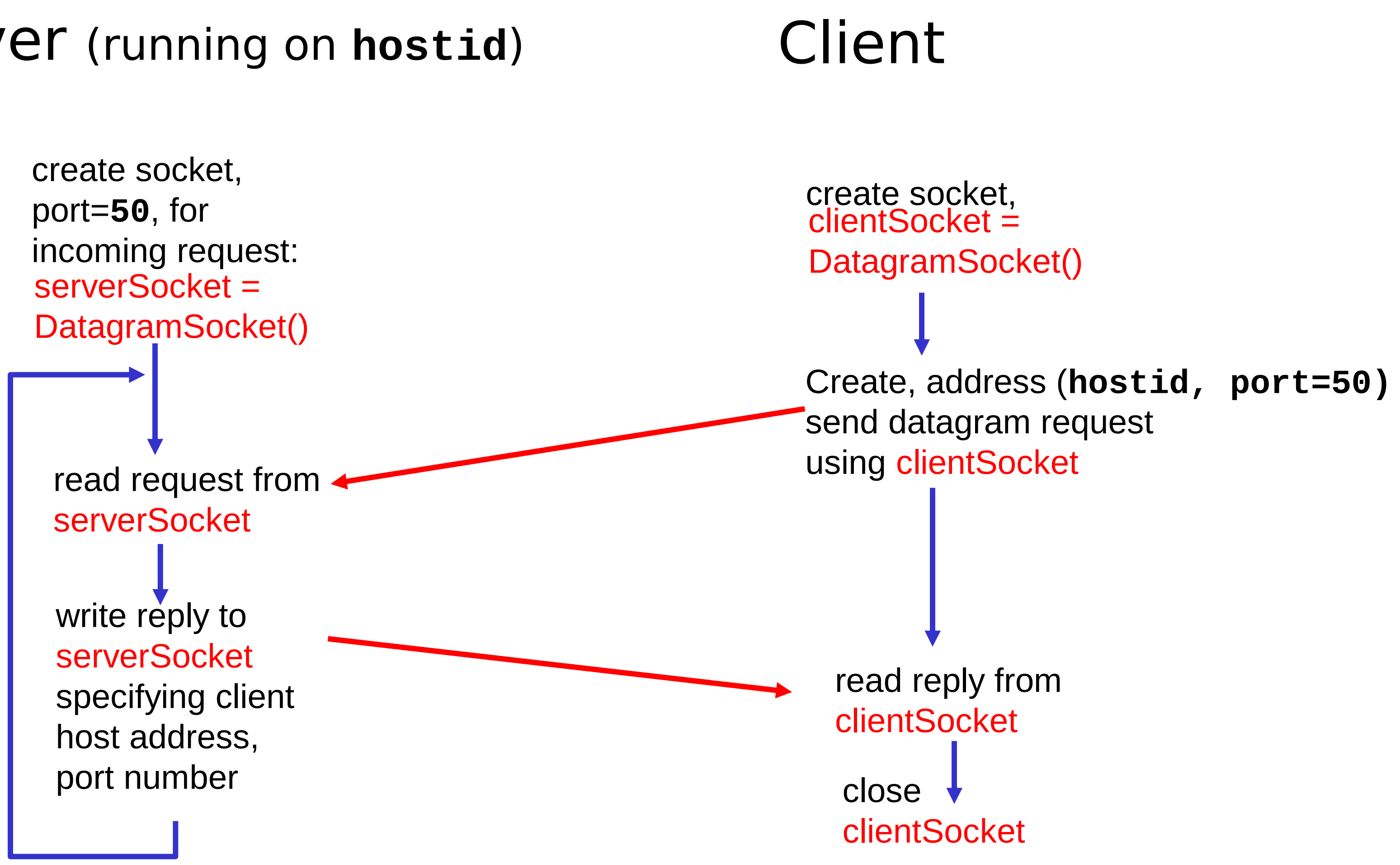
UDP no real "connection" between client and server

- No handshaking
- Sender attaches IP address and destination port to each packet
- Server must extract IP address and port of sender from received packet, so answer can be sent back!

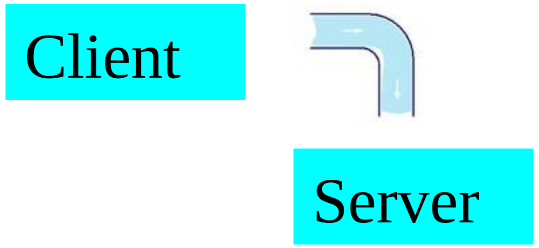
UDP, transmitted data may be

– Received out of order, or
– Lost

Client/server socket interaction: UDP


Server (running on **hostid**)
Client
create socket, port=**50**, for incoming request:
serverSocket = DatagramSocket()
create socket,
clientSocket = DatagramSocket()
Create, address (**hostid, port=50**)
send datagram request using clientSocket
read request from serverSocket
write reply to serverSocket specifying client host address, port number
read reply from clientSocket
close clientSocket

UDP Summary



- No connection setup – no “pipe”

- More Differences with TCP:

1. Each batch of bytes sent with attached address information
2. No special ServerSocket class in java

UDP Summary

- Create a Packet
  - Push it out into the network through a socket
  - Server accepts the packet addressed to him
- Mail is a lot like UDP
  - Each letter needs the address of the destination
  - Independent letters sent to the same address

Java Classes for UDP

- Datagrams for connectionless protocol
- Two classes implement datagrams in Java:
  - java.net.DatagramPacket
  - java.net.DatagramSocket

  - DatagramPacket is **actual packet of information**, an array of bytes, that is transmitted over the network.

  - DatagramSocket is **socket** that sends and receives DatagramPackets across the network.

- Think of DatagramPacket as a letter and DatagramSocket as the mailbox that the mail carrier uses to pick up and drop off your letters
- Need both classes for UDP sockets

Java Classes for UDP

- DatagramPacket class provides programmer with two constructors.
  - First is for DatagramPackets that receive data

    Constructor needs

    Array to store the data

    Amount of data to receive

public DatagramPacket(byte[ ] ibuff, int ilength);

ibuf is the byte array into which the data portion of the datagram will be copied.

ilength is the number of bytes to copy from the datagram into the array receiving the data

Java Classes for UDP

- Second is for DatagramPackets that send data
  - **Constructor needs**
    - Array to store the data, Amount of data to send
    - Plus **destination address** and **port number**

```
public DatagramPacket(byte[] ibuf, int length,
                                    InetAddress iaddr, int iport);
```

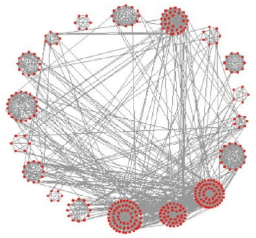
ibuf is the array of bytes that encodes the data of the message,

length is the length of the byte array to place into the datagram.

iaddr stores the IP address of recipient.

port identifies port datagram should be sent to on the receiving host.

Java Classes for UDP



- DatgramSocket represents connectionless socket

  It provides three constructors,

  1. Programmer can specify a port   OR
  2. Allow system to randomly use a port
  3. System can also select a specific IP address
- Methods
  - Two most important methods, send() and receive()
  - Each takes an argument of a constructed **DatagramPacket**

  - send() method
    - Data in packet is sent to specified host and port
  - receive() method
    - Will block execution until a packet is received by underlying socket, then data copied into packet provided

Java Classes for UDP

- Three constructors are available:

- public DatagramSocket() throws IOException
- public DatagramSocket(int port) throws IOException
- public DatagramSocket(int port, InetAddress localAddr)   throws IOException

Java Classes for UDP

public DatagramSocket() throws IOException

- First constructor allows you to create a socket at an unused ephemeral port, generally used for client applications

- Second constructor allows you to specify a port, which is useful for server applications

public DatagramSocket(int port) throws IOException

Java Classes for UDP

public DatagramSocket(int port, InetAddress localAddr)   throws IOException

- Final constructor is useful for machines with multiple IP interfaces.
- You can use this constructor to send and listen for datagrams from one of the IP addresses assigned to the machine

UDP Example Program

Sentence Capitalizer

UDP Sentence Capitalizer Client

1. Read string from keyboard, convert to bytes
2. Create DatagramSocket for communicating to UDP Server
3. Create DatagramPacket with string to send in bytes, length, IPAddress server, port server
4. Send DatagramPacket through Socket
5. Create DatagramPacket to receive reply from Server
6. Receive reply from Server, print Capitalized string

UDP Sentence Capitalizer Server

1. Create socket for server with port
2. Create DatagramPacket to receive sentence from client
3. Wait to receive from client
4. Convert bytes from client to sentence
5. Get IPAddr and port from received packet
6. Capitalize the sentence, convert to bytes
7. Create send DatagramPacket to send back to Client, with IPAddr and port
8. Send packet to client

Sentence Capitalizer (Again) Example: Java client (UDP)

```
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();
```

Create input stream

Keyboard

Create client socket

Translate hostname to IP address using DNS

Read from keyboard

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);
```

Read datagram from server

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

clientSocket.receive(receivePacket);

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

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

```
}
```

Sentence Capitalizer (Again) Example: Java server (UDP)

```
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);
```

Create datagram socket at port 9876

Create space for receive/send datagrams

Receive datagram

Example: Java server (UDP), cont

```
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);
}
}
}
```

Get IP addr port #, of sender

Create datagram to send to client

Write out datagram to socket

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

More Java.net Package

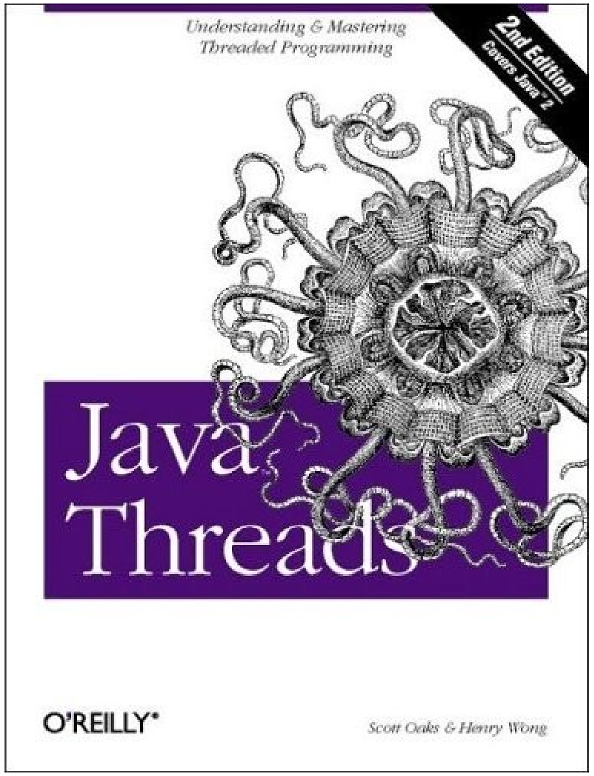
- Always good to see the documentation on the Classes and methods
- Look up DatagramSocket and DatagramPacket

http://download.java.net/jdk7/archive/b123/docs/api/java/net/package-summary.html

Summary

- Brief coverage of Java sockets - TCP/UDP
- Should be enough to get started
  - Examples available as links on the main class page

- Also, practice client-server in next lab
- Read references in RelatedLinks for tutorials and more information on Java Client Server



I put up the next assignment – Web Server in Java
Please read it and we will go over it on Monday