CS 580 Client-Server Programming
Spring Semester, 2009
Doc 3 Intro to Client-Server
Jan 28, 2009

Reading

Java

Java Network Programming, Harold 3rd Ed,

- Chapter 2 - Network Basics
- Chapter 4 Streams
- Chapter 9 Sockets for Clients

Ruby

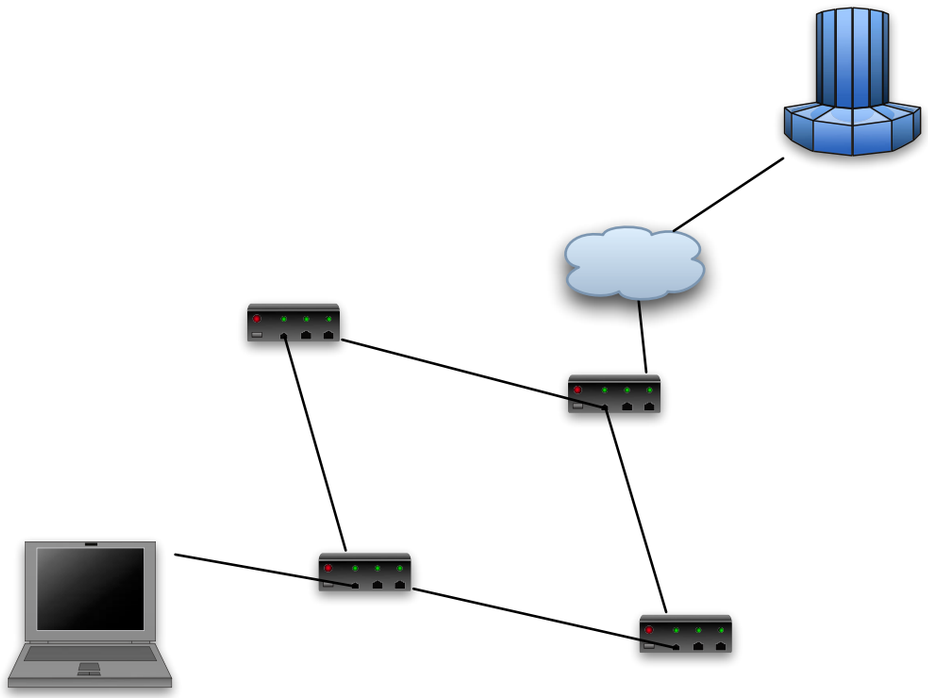
Programming Ruby, Thomas, 2'ed

- Chapter 10 Basic Input & Output
- Class IO documentation (pp 503-515)
- IPSocket & TCPSocket in Appendix A

References

Wikipedia, various articles, explicit references on individual slides

Network Overview



Messages divided into packets

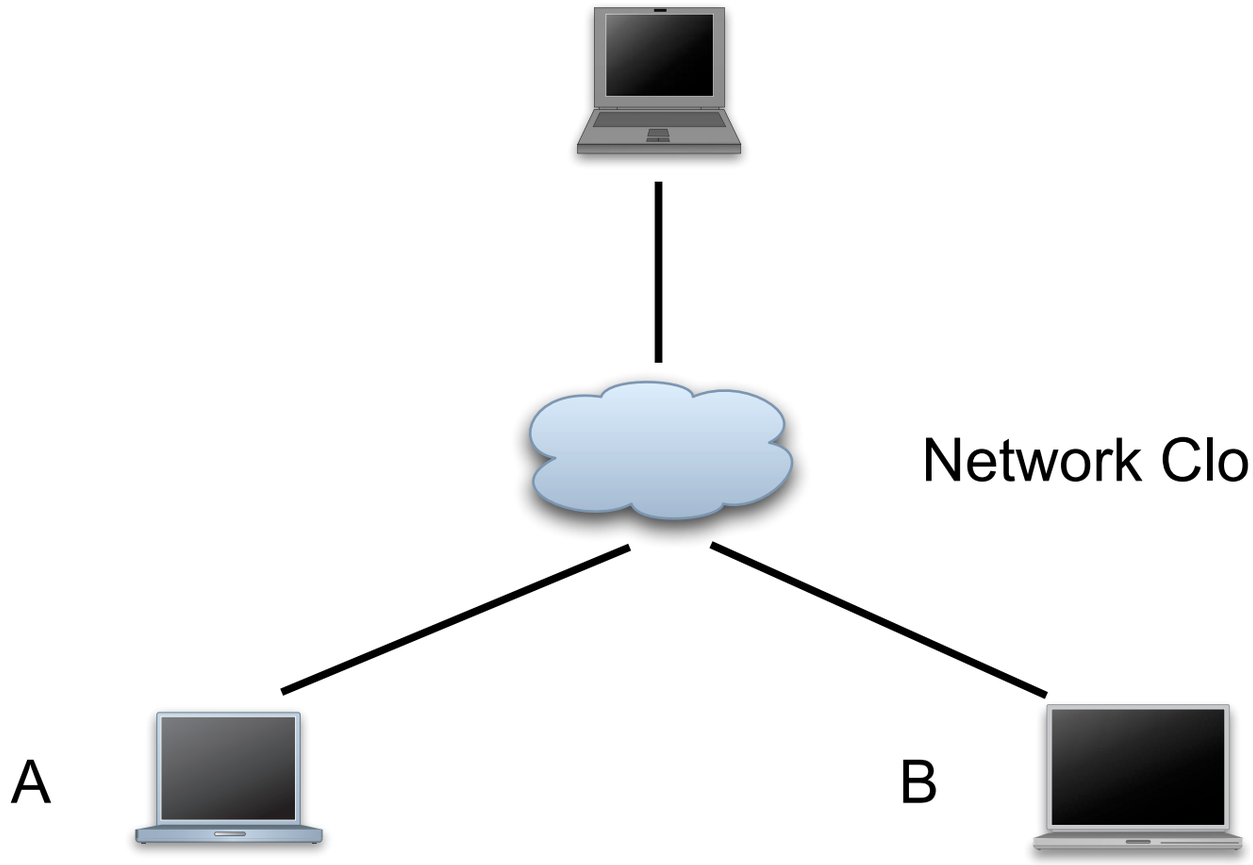
Each packet routed separately

Routing Issues

Overhead issues

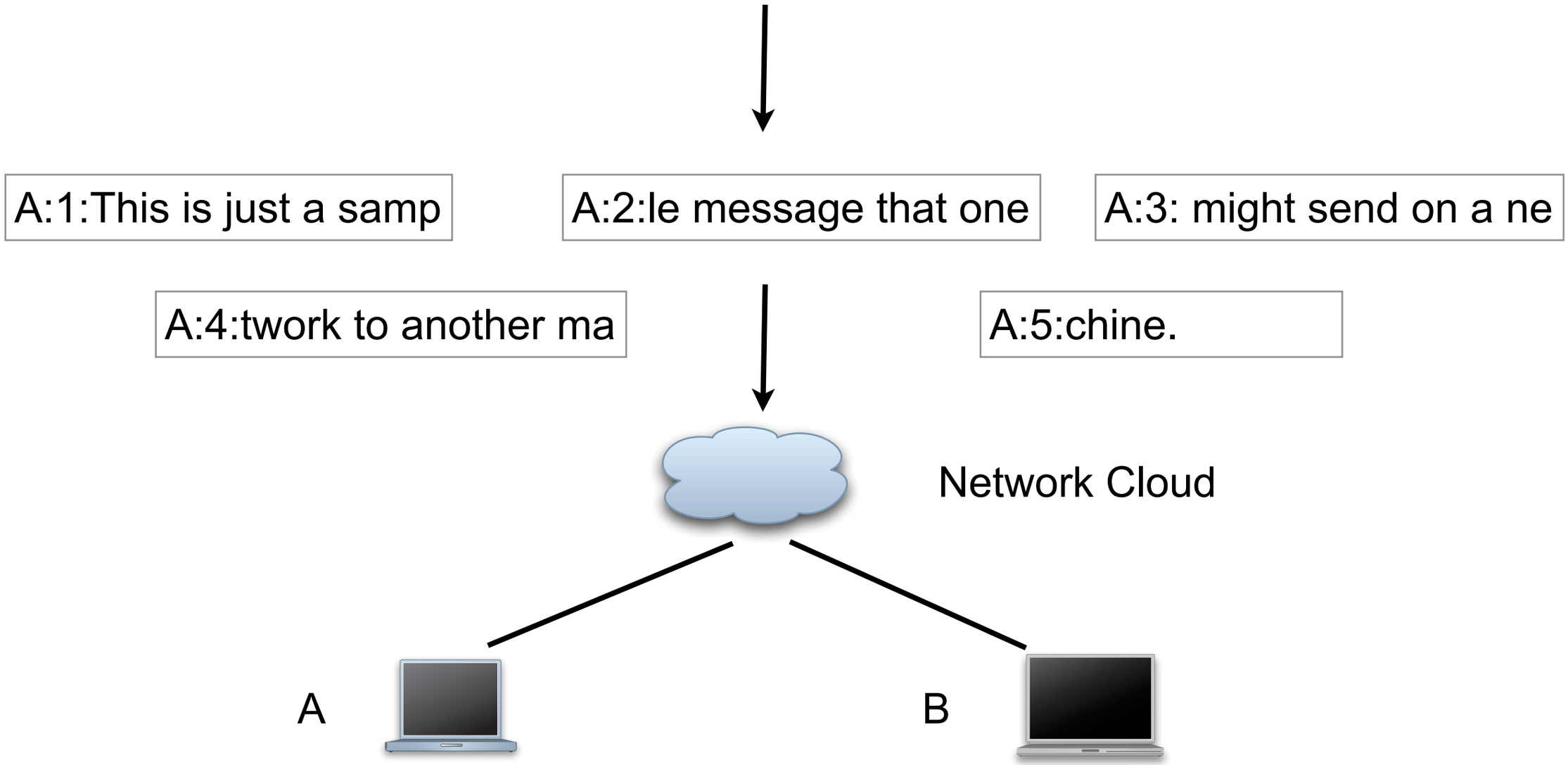
Send Message To Machine A

This is just a sample message that one might send on a network to another machine.



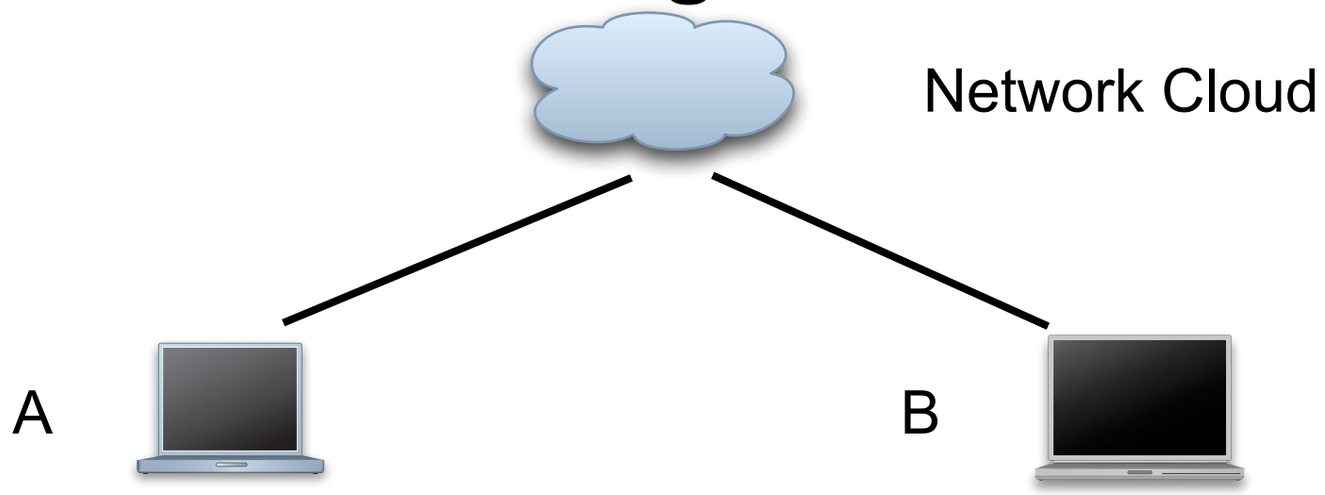
Sending

This is just a sample message that one might send on a network to another machine.



Tanenbaum – please forgive the gross oversimplification here.

Receiving



A:2:le message that one

A:1:This is just a samp

A:5:chine.

A:4:twork to another ma

A:3: might send on a ne

This is just a sample message that one might send on a network to another machine.

Tanenbaum - please forgive the gross oversimplification here.

Issues

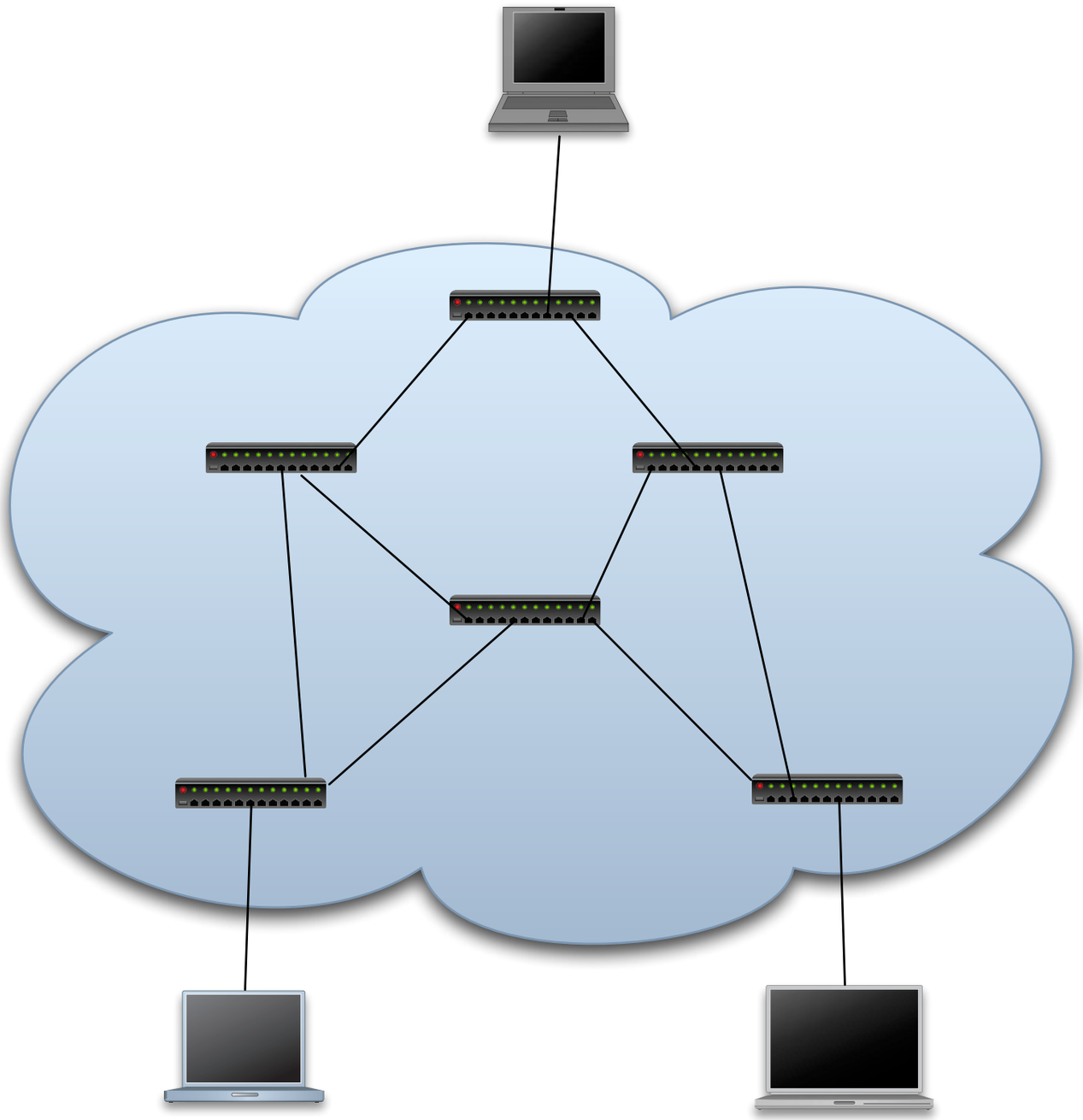
How does the message get to A

How does the message get to the correct program on A

How do packets get lost

How do packets get out of order

Routers



Cover routing tables, delay, buffer overflow, congestions, loops, ttl. See http://en.wikipedia.org/wiki/Router for more information.

Some Useful Programs

netstat

Show status of network connections on machine

lsof

list open files (& pipes & sockets)

traceroute

Show the route to remote machine

netstat

Windows, Unix/Linux

```
Al pro 14->netstat
Active Internet connections
Proto Recv-Q Send-Q  Local Address          Foreign Address        (state)
tcp4   17680      0  10.0.1.192.60840       kusc-pc-stream2..irdmi ESTABLISHED
tcp4       0      0  10.0.1.192.60627       208.43.202.32-st.http  ESTABLISHED
tcp4       0      0  10.0.1.192.60623       adsl-68-20-22-55.28205 ESTABLISHED
tcp4       0      0  localhost.26164        localhost.60431        ESTABLISHED
tcp4       0      0  localhost.60431        localhost.26164        ESTABLISHED
tcp4       0      0  10.0.1.192.afpovertcp  10.0.1.200.53611       ESTABLISHED
tcp4       0      0  localhost.26164        localhost.53896        ESTABLISHED
tcp4       0      0  localhost.53896        localhost.26164        ESTABLISHED
tcp4       0      0  localhost.26164        localhost.51153        ESTABLISHED
tcp4       0      0  localhost.51153        localhost.26164        ESTABLISHED
tcp4       0      0  localhost.26164        localhost.49164        ESTABLISHED
tcp4       0      0  localhost.49164        localhost.26164        ESTABLISHED
tcp4      37      0  10.0.1.192.49163       174.36.30.66-sta.https CLOSE_WAIT
tcp4      37      0  10.0.1.192.49162       174.36.30.67-sta.https CLOSE_WAIT
tcp4       0      0  10.0.1.192.60862       WAREHOUSE-THREE-.55510 TIME_WAIT
tcp4       0      0  10.0.1.192.60861       dhcp128036163075.55165 TIME_WAIT
etc
```


See http://en.wikipedia.org/wiki/Netstat

netstat -s

```
Al pro 13->netstat -s
tcp:
    1290678 packets sent
        169 data packets (52330 bytes) retransmitted
        686952 ack-only packets (8670 delayed)
    1530460 packets received
        332351 acks (for 114678930 bytes)
        8686 duplicate acks
        760 completely duplicate packets (611003 bytes)
        27337 out-of-order packets (34890076 bytes)
    11654 connection requests
    104 connection accepts
    48 bad connection attempts
    8 listen queue overflows
etc.
```

lsof

Unix/Linux

list open files

disk files, pipes and network sockets

Air 18->lsof -i

```
COMMAND     PID     USER   FD   TYPE    DEVICE SIZE/OFF NODE NAME
SystemUIS   194 whitney    9u   IPv4 0x3da8f40      0t0  UDP *:*
adb        1141 whitney    5u   IPv4 0x9f28270      0t0  TCP localhost:5037 (LISTEN)
Safari     3234 whitney   56u  IPv6 0x3dac19c      0t0  TCP localhost:59088->localhost:59087
(TIME_WAIT)
Safari     3234 whitney   71u  IPv4 0x623366c      0t0  TCP 146.244.205.67:50097-
>a198-189-255-145.deploy.akamaitechnolgies.com:http (CLOSE_WAIT)
Safari     3234 whitney   74u  IPv4 0x61fb270      0t0  TCP 146.244.205.67:50099-
>a198-189-255-145.deploy.akamaitechnolgies.com:http (CLOSE_WAIT)
```


See http://en.wikipedia.org/wiki/Lsof

traceroute

tracepath - Linux

tracert - Windows

```
Al pro 15->traceroute www.sdsu.edu
traceroute to www.sdsu.edu (130.191.8.198), 64 hops max, 40 byte packets
 1  10.0.1.1 (10.0.1.1)  0.679 ms  0.192 ms  0.174 ms
 2  ip68-8-224-1.sd.sd.cox.net (68.8.224.1)  8.317 ms  6.879 ms  7.574 ms
 3  fed1sysc01-gex0915.sd.sd.cox.net (68.6.10.106)  15.600 ms  8.736 ms  11.449 ms
 4  fed1sysc10-get0005.sd.sd.cox.net (68.6.8.78)  10.456 ms  10.895 ms  8.740 ms
 5  dt1xaggc01-get0701.sd.sd.cox.net (68.6.8.49)  12.298 ms  23.956 ms  7.625 ms
 6  sdsccbsf01-fex0301.cox-sd.net (209.242.135.150)  7.831 ms  8.904 ms  8.057 ms
 7  sdg-agg3.cenic.net (198.17.46.176)  12.655 ms  230.550 ms  264.670 ms
 8  dc-sdg-agg1--sdg-agg3-ge.cenic.net (137.164.46.16)  15.624 ms  14.830 ms  14.923 ms
 9  dc-sd-csu-egm--sdg-dc1.cenic.net (137.164.41.138)  13.097 ms  13.603 ms  15.632 ms
10  * * *
11  * * *
```

How do packets get out of order

different routes

different wait times in router buffers

Internet Protocol (IP or TCP/IP)

Application Layer

DHCP, DNS, FTP, HTTP, SSH, Telnet, (more)

Transport Layer

TCP, UDP, (more)

Internet Layer

IPv4, IPv6, (more)

Link Layer

Ethernet, DSL, ISDN, FDDI, (more)

http://en.wikipedia.org/wiki/Internet_Protocol

MAP OF THE INTERNET

THE IPv4 SPACE, 2006

THIS CHART SHOWS THE IP ADDRESS SPACE ON A PLANE USING A FRACTAL MAPPING WHICH PRESERVES GROUPING -- ANY CONSECUTIVE STRING OF IPs WILL TRANSLATE TO A SINGLE COMPACT, CONTIGUOUS REGION ON THE MAP. EACH OF THE 256 NUMBERED BLOCKS REPRESENTS ONE /8 SUBNET (CONTAINING ALL IPs THAT START WITH THAT NUMBER). THE UPPER LEFT SECTION SHOWS THE BLOCKS SOLD DIRECTLY TO CORPORATIONS AND GOVERNMENTS IN THE 1990's BEFORE THE RIRs TOOK OVER ALLOCATION.

0 1 14 15 16 19 →
3 2 13 12 17 18
4 7 8 11

= UNALLOCATED BLOCK

http://xkcd.com/195/

TCP

Handles lost packets

Handles packet order

TCP has delays
- Starting of connection
- Closing of connection
- Resending packets

Client & Sever don't have to deal with
- Packet order
- Packet loss

TCP Header

Bit offset	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	Source port																Destination port															
32	Sequence number																															
64	Acknowledgment number																															
96	Data offset			Reserved				CWR	ECE	URG	ACK	PSH	RST	SYN	FIN		Window Size															
128	Checksum																Urgent pointer															
160 ...	Options (if Data Offset > 5) ...																															

From http://en.wikipedia.org/wiki/Transmission_Control_Protocol

IP Header

bit offset	0–3	4–7	8–15	16–18	19–31
0	Version	Header length	Differentiated Services	Total Length	
32	Identification			Flags	Fragment Offset
64	Time to Live		Protocol	Header Checksum	
96	Source Address				
128	Destination Address				
160	Options (if Header Length > 5)				
160 or 192+	Data				

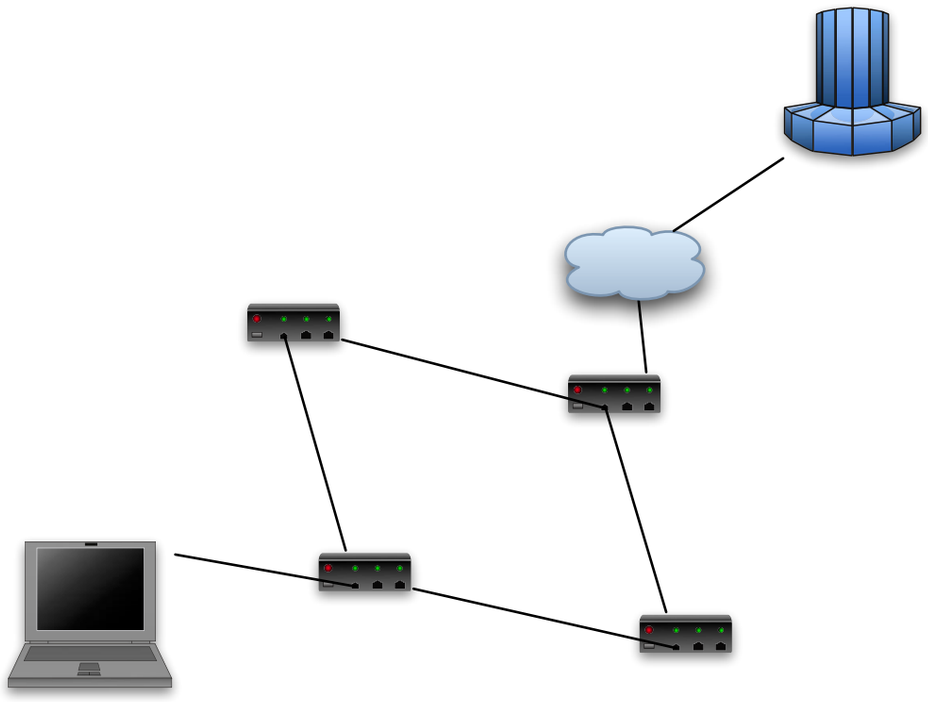
From http://en.wikipedia.org/wiki/IPv4

Ethernet Frame

<table>
<tr><td>Preamble</td><td>Start-of-Frame-Delimiter</td><td>MAC destination</td><td>MAC source</td><td>802.1Q header (optional)</td><td>Ethertype/ Length</td><td>Payload (Data and padding)</td><td>CRC32</td><td>Interframe gap</td></tr>
<tr><td>7 octets of 10101010</td><td>1 octet of 10101011</td><td>6 octets</td><td>6 octets</td><td>(4 octets)</td><td>2 octets</td><td>46–1500 octets</td><td>4 octets</td><td>12 octets</td></tr>
<tr><td colspan="7"></td><td>64–1522 octets</td><td></td></tr>
<tr><td colspan="8">72–1530 octets</td><td></td></tr>
<tr><td colspan="9">84–1542 octets</td></tr>
</table>

http://en.wikipedia.org/wiki/Ethernet

UDP



Fast

Packets are treated individually
Packets may arrive out of order
Packets may be lost

Client & Server must handle resulting problems

Used by:

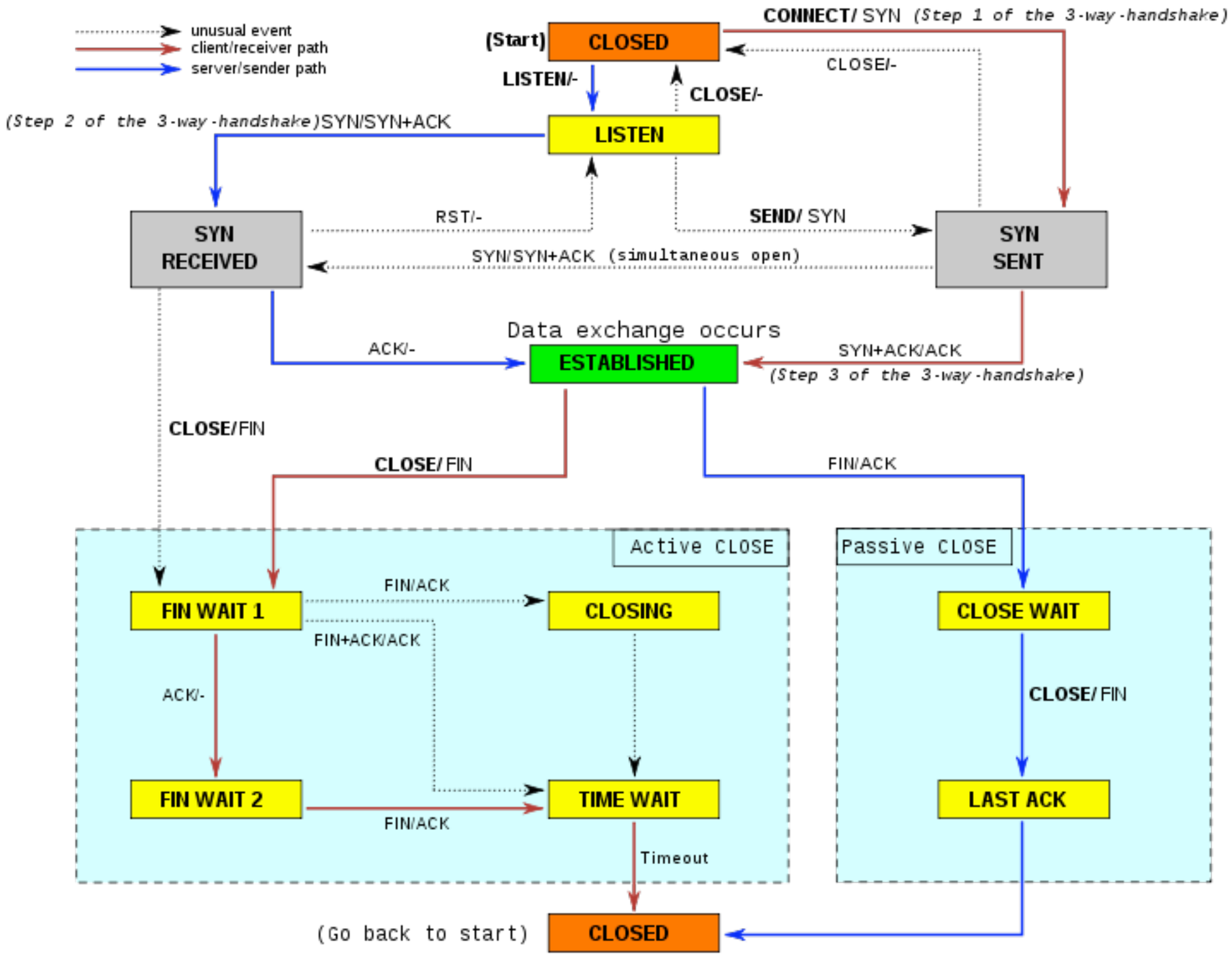
Games
NFS

UDP Header

bits	0 - 15	16 - 31
0	Source Port	Destination Port
32	Length	Checksum
64	Data	

http://en.wikipedia.org/wiki/User_Datagram_Protocol

TCP States



from http://en.wikipedia.org/wiki/File:Tcp_state_diagram_fixed.svg

Flow Control

Receiver

- Tells sender how much data it will buffer (Receive window)

Sender

- Sends one buffer full of data
- Waits for acknowledgement & window update

Congestion Control

Slow start
Congestion avoidance
Fast retransmit
Fast recovery

See http://en.wikipedia.org/wiki/Transmission_Control_Protocol

IP Addresses

IP address is currently a 32-bit number

130.191.3.100 (Four 8 bit numbers)

IPv6 uses 128 bit numbers for addresses

105.220.136.100.0.0.0.0.0.0.18.128.140.10.255.255

69DC:8864:0:0:0:1280:8C0A:FFFF

69DC:8864::1280:8C0A:FFFF

Machines on a network need a unique IP address

What is the difference between

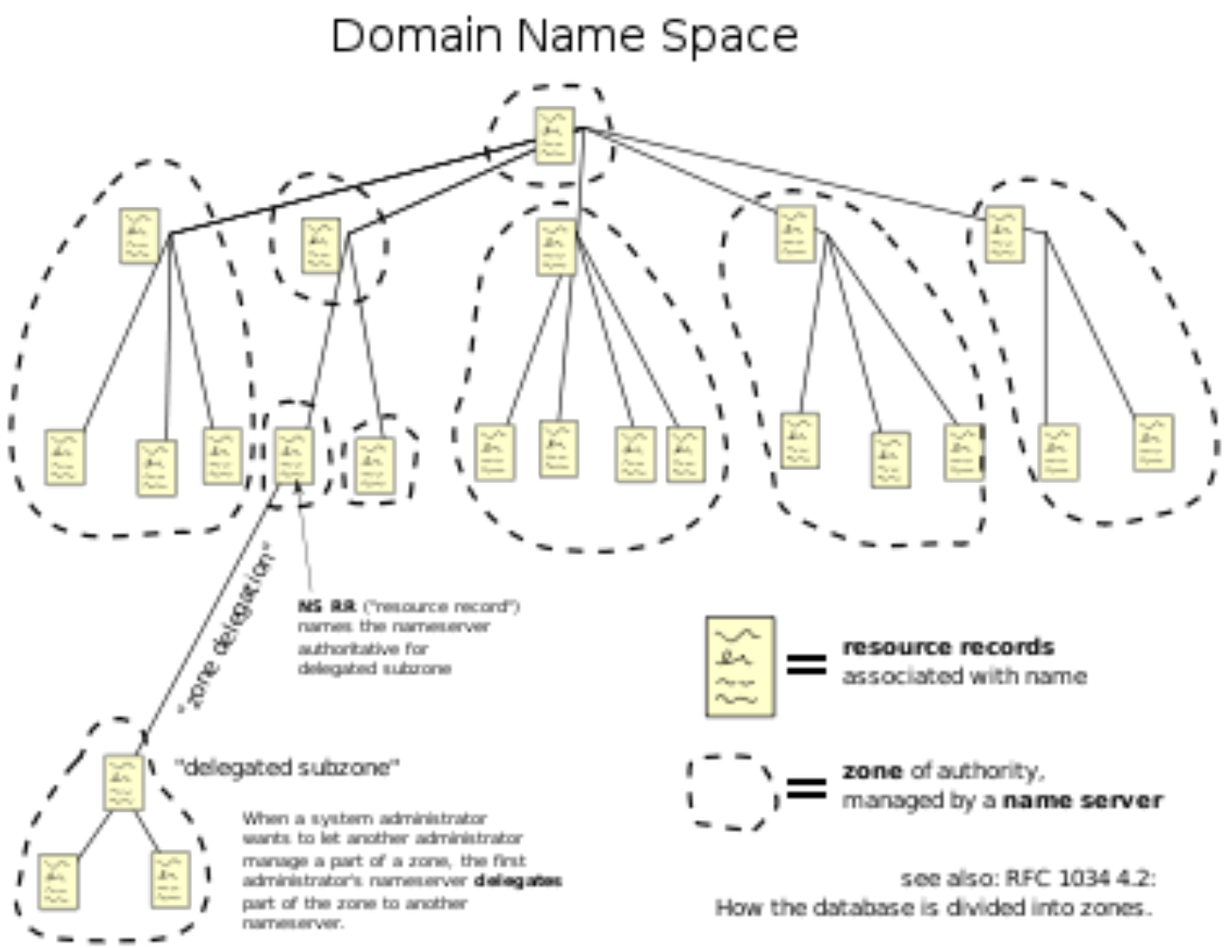
MAC address

IP address

Domain Name System (DNS)

Maps machine names to IP addresses

Internet Corporation for Assigned Names and Numbers (ICANN http://www.icann.org/) oversees assigning TLDs



Graphic is from http://en.wikipedia.org/wiki/Domain_name_system

Unix "host" command

Shows mapping between machine names and IP address

->host rohan.sdsu.edu
rohan.sdsu.edu has address 130.191.3.100

->host 130.191.3.100
100.3.191.130.IN-ADDR.ARPA domain name pointer rohan.sdsu.edu

Ports

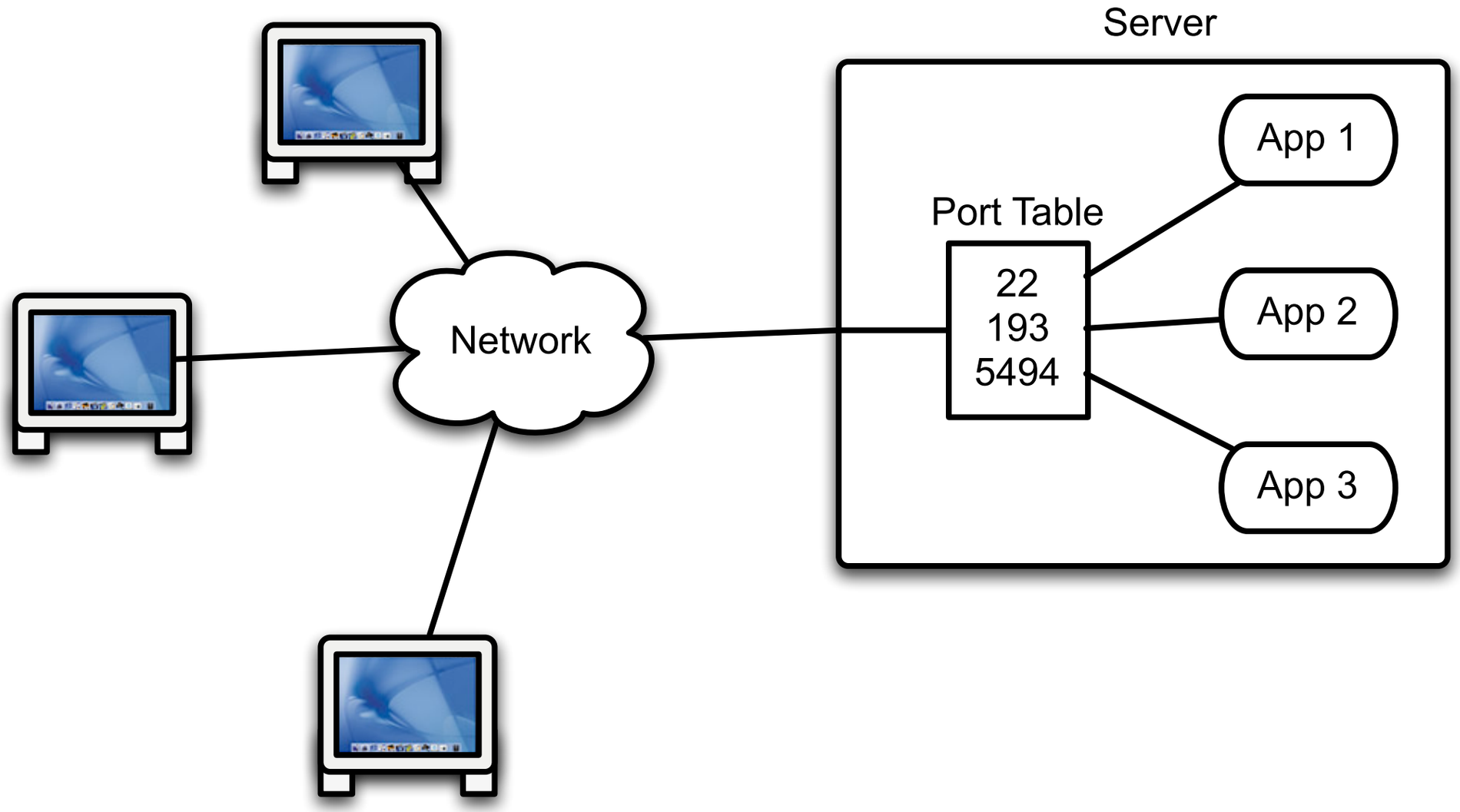
TCP/IP supports multiple logical communication channels called ports

Ports are numbered from 0 - 65535

A connection between two machines is uniquely defined by:

Protocol (TCP or UDP)
IP address of local machine
Port number used on the local machine
IP address of remote machine
Port number used on the remote machine

How Ports Work



When a client connects to a server is has to specify a machine and a port. The OS on the server keeps a table of port numbers and applications (sockets from the program) associated with each port number. When a client request comes in the OS will forward the request to the socket associated with the port number if one is associated (connected) with the port. A similar thing happens on the client side. When you open a socket on the client to connect to the server, the client socket is assigned a port on the client machine. When the server responds to the client it sends the response to that port on the client machine.

Some Port Numbers

Well known Ports	1-1023
Registered Ports	1024-49151
Dynamic/Private Ports	49152-65535

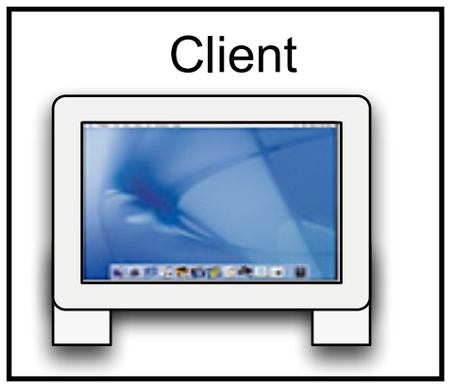
For a local list of services
file://rohan.sdsu.edu/etc/services

For a complete list see:
http://www.iana.org/assignments/port-numbers

See IANA numbers page http://www.iana.org/numbers.html for more information about protocol numbers and assignment of services

Service	Port
echo	7
discard	9
ftp	21
ssh	22
telnet	23
smtp	25
time	37
http	80
pop	110
https	443
doom	666
mysql	3306
postgresql	5432
gnutella	6346 6347

What is Telnet?



Telnet Server

Protocol

Send text between client & server

Server

Requests login

Sends text to shell to be executed

Returns result of commands

Client

Transfers text between user and server

Telnet & Other Text-based Protocols

rohan 37 -> **telnet www.eli.sdsu.edu 80**
GET /courses/spring06/cs580/index.html   HTTP/1.0 <CR>
<CR>

Note <CR> indicates were you need to hit return

rohan 38->**telnet cs.sdsu.edu 110**
Trying 130.191.226.116...
Connected to cs.sdsu.edu.
Escape character is '^]'.
+OK QPOP (version 3.1.2) at sciences.sdsu.edu starting.
USER whitney
+OK Password required for whitney.
PASS typeYourPasswordHere
+OK whitney has 116 visible messages (0 hidden) in 640516 octets.

Simple Date Example - Protocol

Client Commands	Server Response
"date" ended by line feed "date\n"	current date ended by line feed "January 30, 2007\n"
"time" ended by line feed "time\n"	Current time ended by line feed "6:58 pm\n"

Server listens for an incoming request

On request

- reads command
- returns response
- closes connection

On client errors - action not specified

Beware

Can only send bytes across network

Client & server maybe different hardware platforms

What is a newline?

End-of-file indicates connection is closed

Sample Java Client

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

class DateClient {
        String server;
        int port;

        public DateClient(String serverAddress, int port) {
                server = serverAddress;
                this.port = port;
        }

        public String date() {
                return send("date\n");
        }

        public String time() {
                return send("time\n");
        }
```

Java Client Continued

```
private String send(String text) {
        try {
                Socket connection = new Socket(server, port);
                OutputStream rawOut = connection.getOutputStream();
                PrintStream out = new PrintStream(new BufferedOutputStream(rawOut));
                InputStream rawIn = connection.getInputStream();
                BufferedReader in = new BufferedReader(new
InputStreamReader(rawIn));

                out.print(text);
                out.flush();
                String answer = in.readLine();
                out.close();
                in.close();
                return answer;
            }
            catch (IOException e) {
                return "Error in connecting to server";
            }
        }
    }
```


Bad very bad - using PrintStream for network code.

Running the Client

```
System.out.println("hi");
DateClient client = new DateClient("127.0.0.1", 4444);
System.out.println( client.date());
System.out.println( client.time());
```

Issue - Avoid Small Packets

```
OutputStream rawOut = connection.getOutputStream();
PrintStream out = new PrintStream(new BufferedOutputStream(rawOut));
```


Use buffers

Issue - Actually Send the request

```
out.flush();
```

Issue - Client will not work on all platforms

```
String answer = in.readLine();
```


What ends a line?

Don't Do this

```
String answer = in.readLine();
```


I did it to keep the example small. One can not get much code on a slide using 24 point font. Plus the Ruby example is sorter than this.

Issue - Close the connection when done

```
out.close();
in.close();
```

Issue - Testing

How does one test the client?

Issue - Background material

Java

Streams

Read Chapter 4

Sockets

Read Chapter 10

Java Network Programming, Harold 3rd Ed

Ruby Client

```
require 'socket'

class DateClient
    def initialize(serverAddress, port)
      @server = serverAddress
      @port = port
    end

    def date()
      send("date\n")
    end

    def time()
      send("time\n")
    end

  private
    def send(text)
      connection = TCPSocket.new(@server, @port)
      connection.send(text, 0)
      answer = connection.gets("\n")
      connection.close
      answer
    end
end
```

Running the client

```
client = DateClient.new("127.0.0.1", 4444)
puts client.date
puts client.time
```

Issues - Using Standard IO Methods

```
def send(text)
    connection = TCPSocket.new(@server, @port)
    connection.print(text)
    connection.flush
    answer = connection.gets("\n")
    connection.close
    answer
  end
```

Ruby Background

Sockets

Read IPSocket & TCPSocket in Appendix A

IO

Chapter 10 Basic Input & Output
Class IO documentation (pp 503-515)

Programming Ruby, Thomas, 2'ed

Server

Basic Algorithm

```
while (true) {
        Wait for an incoming request;
        Perform whatever actions are requested;
      }
```

Basic Server Issues

How to wait for an incoming request?
How to know when there is a request?
What happens when there are multiple requests?
How do clients know how to contact server?
How to parse client request?
How do we know when the server has the entire request?

Java Date Server

```
public class DateServer {
        private static Logger log = Logger.getLogger("dateLogger");

        public static void main (String args[]) throws IOException {
                ProgramProperties flags = new ProgramProperties( args);
                int port = flags.getInt( "port" , 8765);
                new DateServer().run(port);
        }

        public void run(int port) throws IOException {
                ServerSocket input = new ServerSocket( port );
                log.info("Server running on port " + input.getLocalPort());

                while (true) {
                        Socket client = input.accept();
                        log.info("Request from " + client.getInetAddress());
                        processRequest(
                                client.getInputStream(),
                                client.getOutputStream());
                        client.close();
                }
        }
```

Java Date Server Continued

```
void processRequest(InputStream in,OutputStream out)
        throws IOException {

        BufferedReader parsedInput =
                new BufferedReader(new InputStreamReader(in));

        boolean autoflushOn = true;
        PrintWriter parsedOutput = new PrintWriter(out,autoflushOn);

        String inputLine = parsedInput.readLine();

                if (inputLine.startsWith("date")) {
                        Date now = new Date();
                        parsedOutput.println(now.toString());
                }
        }
}
```

This server needs work

Starting the Server

```
rohan 16-> java -jar DateServer.jar
Feb 19, 2004 10:56:59 AM DateServer run
INFO: Server running on port 8765
```

Ruby Date Server

```
require 'socket'

class DateServer
  def initialize(port)
    @port = port
  end

  def run()
    server = TCPServer.new( @port)
    puts("start " + @port.to_s)
    while (session = server.accept)
      Thread.new(session) do |connection|
        process_request_on(connection)
        connection.close
      end
    end
  end
```

```
  private
    def process_request_on(socket)
      request = canonical_form( socket.gets("\n") )
      now = Time.now
      answer = case request
        when 'time'
          now.strftime("%X")
        when 'date'
          now.strftime("%x")
        else
          "Invalid request"
      end
      socket.send(answer + "\n",0)
    end

    def canonical_form(string)
      string.lstrip.rstrip.downcase
    end
  end
```

Text

Issue - Date Format

What format does the server use for time and date?

Clients need to know so can parse them