CSC 4304 - Systems Programming
Fall 2010

LECTURE - XV

NETWORK PROGRAMMING - I

Tevfik Koşar

Louisiana State University
November 9th, 2010

Network Programming

- There is **one** way computers can communicate together
  - By sending network messages to each other
  - All other kinds of communications are built from network messages
- There is **one** way programs can send/receive network messages
  - Through **sockets**
  - All other communication paradigms are built from sockets

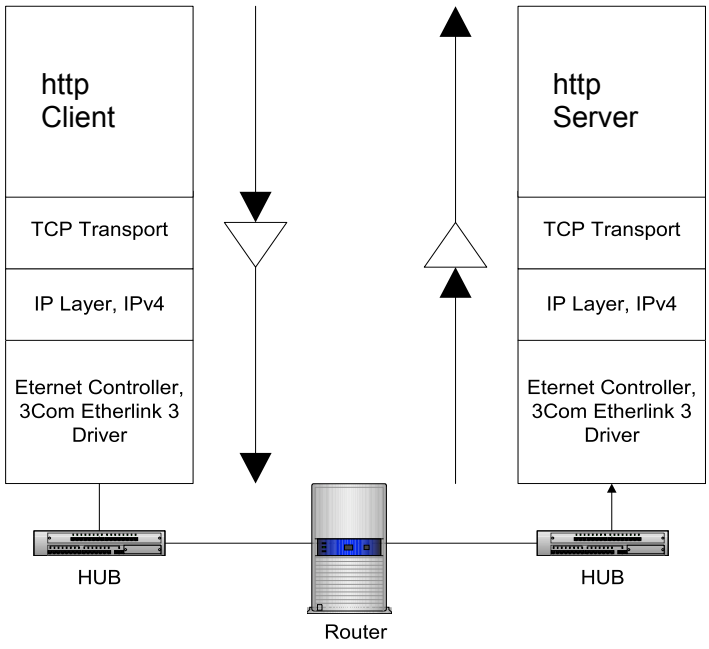
Sockets

- A **Socket** is comprised of:
  - a 32-bit node address (IP address)
  - a 16-bit port number (like 7, 21, 13242)
- Example: 192.168.31.52:1051
  - The 192.168.31.52 host address is in "IPv4 dotted-quad" format, and is a decimal representation of the hex network address 0xc0a81f34
- First developed at UC-Berkeley in 1983, Berkeley Socket API part of BSD 4.2

Ports

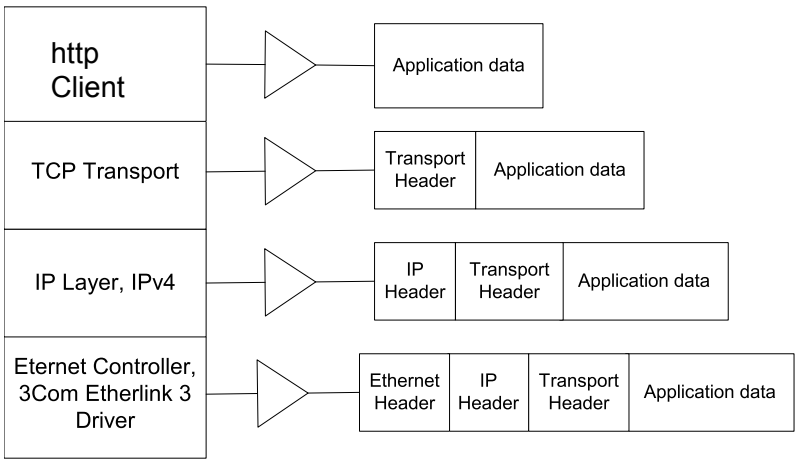
- Ports 0 through 1023 are reserved, *privileged* ports, defined by TCP and UDP well known port assignments
- Ports 1024 through 49151 are ports *registered* by the IANA (Internet Assigned Numbers Authority), and represent second tier common ports (socks (1080), WINS (1512), kermit (1649))
- Ports 49152 through 65535 are *ephemeral* ports, available for temporary client usage

Network Communication



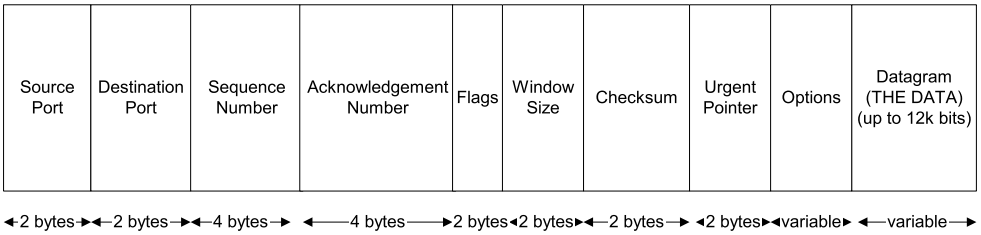
Data Encapsulation

- Application puts data out through a socket
- Each successive layer wraps the received data with its own header:



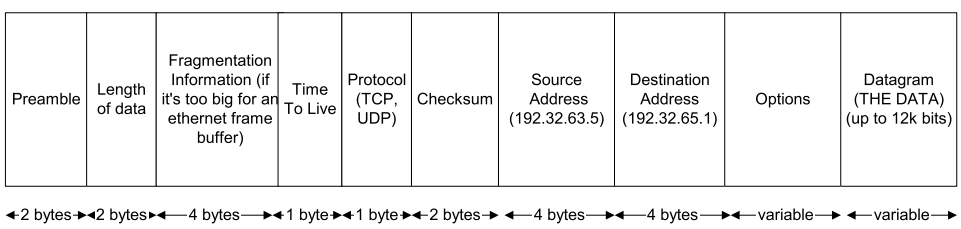
TCP Header Format

- Source and Destination ports
- Sequence Number tells what byte offset within the overall data stream this segment applies
- Acknowledgement number lets the recipient set what packet in the sequence was received OK.



IP Header Format

- Packets may be broken up, or *fragmented*, if original data is too large for a single packet (Maximum Transmission Unit is currently 12k bits, or 1500 Bytes)
- Packets have a Time To Live, number of seconds/ rounds it can bounce around aimlessly among routers until it's killed



Common Network Applications

- FTP (file transfer protocol)
- SMTP (simple mail transfer protocol)
- telnet (remote logins)
- rlogin (simple remote login between UNIX machines)
- World Wide Web (built on http)
- NFS (network filing system – originally for SUNs)
- TFTP (trivial file transfer protocol – used for booting)
- SNMP (simple network management protocol)

Well Known Services & Ports

Service	Port no	Protocol	
echo	7	UDP/TCP	sends back what it receives
discard	9	UDP/TCP	throws away input
daytime	13	UDP/TCP	returns ASCII time
chargen	19	UDP/TCP	returns characters
ftp	21	TCP	file transfer
telnet	23	TCP	remote login
smtp	25	TCP	email
daytime	37	UDP/TCP	returns binary time
tftp	69	UDP	trivial file transfer
finger	79	TCP	info on users
http	80	TCP	World Wide Web
login	513	TCP	remote login
who	513	UDP	different info on users
Xserver	6000	TCP	X windows (N.B. >1023)

TCP & UDP

Both

- built on top of IP
- addressed using port numbers

⇒ process to process
(on UNIX platforms)

TCP

- connection based
- reliable
- byte stream

used in: FTP, telnet, http, SMTP

UDP

- connectionless
- unreliable
- datagram (packet based)

used in: NFS, TFTP

An HTTP Request

- <command> <argument> <HTTP version>
- <optional arguments>
- <blank line>

- GET /index.html HTTP/1.0

Server Response

- <HTTP version> <status code> <status message>
- <aditional information>
- <a blank line>
- <content>

- HTTP/1.1 200 OK
  Date: Thu, 06 Nov 2008 18:27:13 GMT
  Server: Apache

  <HTML><HEAD><BODY> ....

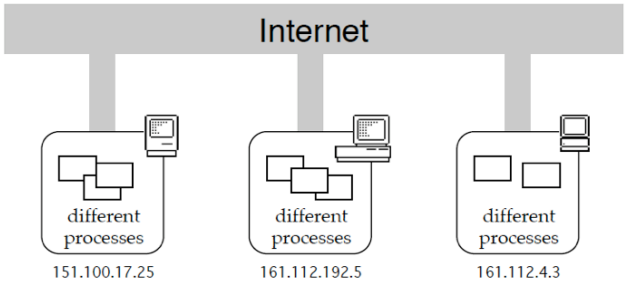
Example

```
$ telnet www.cnn.com 80
Trying 64.236.90.21...
Connected to www.cnn.com.
Escape character is '^]'.
GET /index.html HTTP/1.0

HTTP/1.1 200 OK
Date: Thu, 06 Nov 2008 18:27:13 GMT
Server: Apache
Accept-Ranges: bytes
Cache-Control: max-age=60, private
Expires: Thu, 06 Nov 2008 18:28:14 GMT
Content-Type: text/html
Vary: Accept-Encoding,User-Agent
Connection: close

<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN""http://
www.w3.org/TR/html4/loose.dtd"><html lang="en"><head><title>CNN.com
```

Basics of a Server (Web, FTP ..etc)

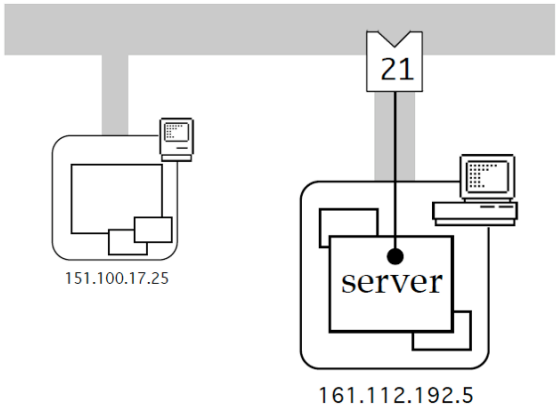
1. Listen to a Network port
2. Interpret incoming messages (requests)
3. Serve requests
   a. Read requested files
   b. Send them over network
4. Run consistently in the background *(daemon process)*

TCP Connection: Initial State



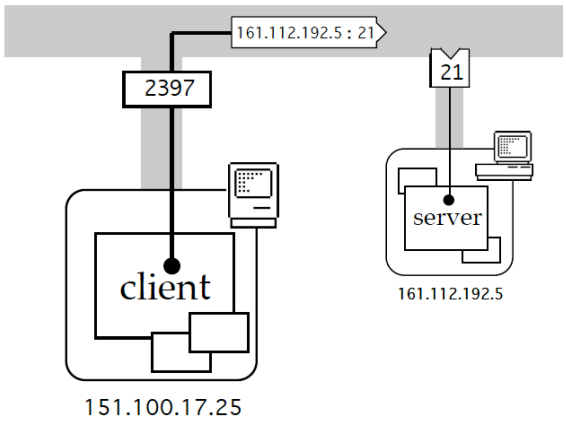
- TCP is connection based
  ... establishing it is a complex multistage process
- initially all machines are the same
- no special 'server' machines
- the difference is all in the software

TCP Connection: Passive Open



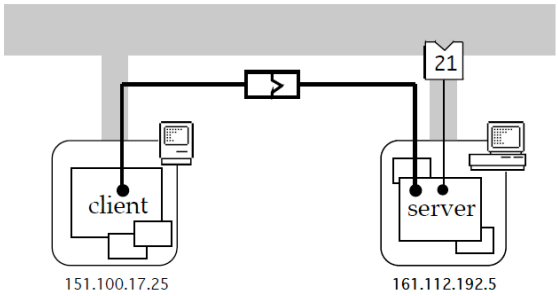
- server process does a 'passive' open on a port
- it waits for a client to connect
- at this stage there is no Internet network traffic
- tells the TCP layer which process to connect to

TCP Connection: Active Open



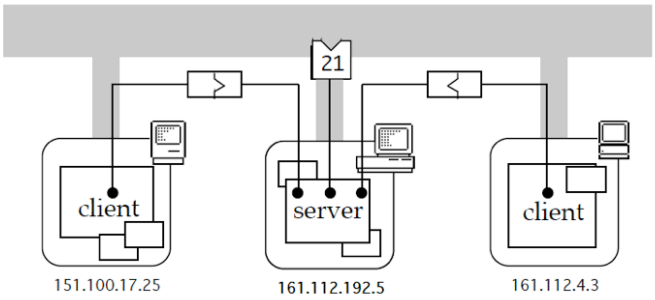
- client process usually on a different machine
- performs an 'active' open on the port
- port number at the client end is needed
  usually automatic (e.g., 2397)
  but can be chosen
- network message → server machine
  requests connection

TCP Connection: Randezvous

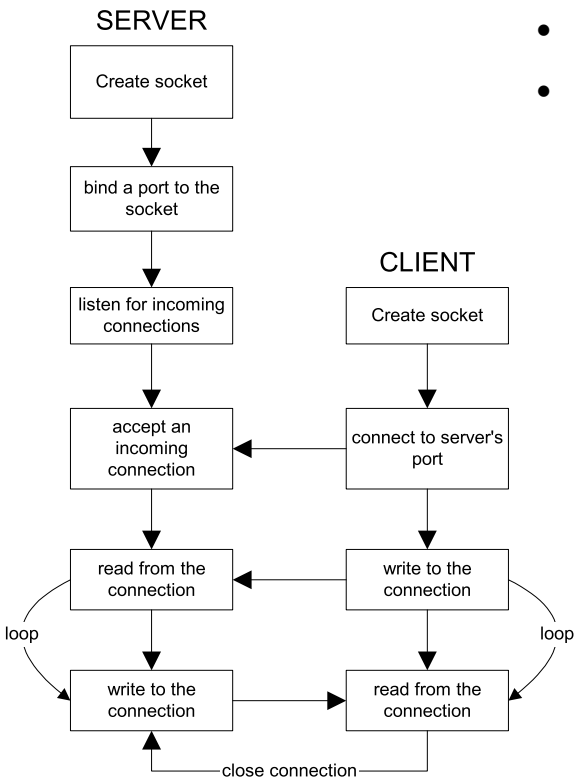


- server side accepts and TCP connection established
- a bi-directional reliable byte-stream
- connection identified by both host/port numbers
  e.g. <151.10017.25:2397/161.112.192.5:21>
- server port is not consumed
  can stay 'passive' open for more connections
- like telephone call desk: one number many lines

TCP Connection: more..

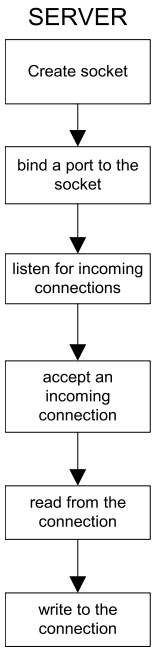


- other clients can connect to the same port
- state for connections in the client/server only
- no information needed in the network
  not like old style relay-based exchanges
- server can restrict access to specified host or port
- server can find out connected host/port



- TCP Client-Server view
- Connection-oriented socket connections

Server Side Socket Details



int socket(int domain, int type, int protocol)
sockfd = socket(PF_INET, SOCK_STREAM, 0);

int bind(int sockfd, struct sockaddr *server_addr, socklen_t length)
bind(sockfd, &server, sizeof(server));

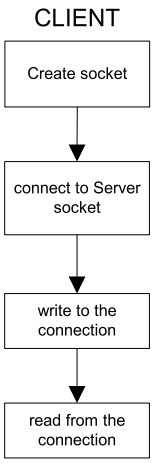
int listen(int sockfd, int num_queued_requests)
listen(sockfd, 5);

int accept(int sockfd, struct sockaddr *incoming_address, socklen_t length)
newfd = accept(sockfd, &client, sizeof(client)); /* BLOCKS */

int read(int sockfd, void * buffer, size_t buffer_size)
read(newfd, buffer, sizeof(buffer));

int write(int sockfd, void * buffer, size_t buffer_size)
write(newfd, buffer, sizeof(buffer));

Client Side Socket Details



int socket(int domain, int type, int protocol)
sockfd = socket(PF_INET, SOCK_STREAM, 0);

int connect(int sockfd, struct sockaddr *server_address, socklen_t length)
connect(sockfd, &server, sizeof(server));

int write(int sockfd, void * buffer, size_t buffer_size)
write(sockfd, buffer, sizeof(buffer));

int read(int sockfd, void * buffer, size_t buffer_size)
read(sockfd, buffer, sizeof(buffer));

Example: A Time Server

```
#include  <stdio.h>
#include  <sys/types.h>
#include  <sys/socket.h>
#include  <netinet/in.h>
#include  <netdb.h>

#define   PORTNUM  8824
#define   oops(msg)      { perror(msg) ; exit(1) ; }
```

```
   void main(int ac, char **av)
{
     struct  sockaddr_in   saddr;   /* build our address here */
     struct   hostent       *hp;   /* this is part of our    */
     char hostname[256];         /* address             */
     int  slen,sock_id,sock_fd;  /* line id, file desc     */
     FILE *sock_fp;              /* use socket as stream   */
     char    *ctime();              /* convert secs to string */
     long    time(), thetime;       /* time and the val       */


       gethostname( hostname , 256);           /* where am I ?         */
       hp = gethostbyname( hostname );         /* get info about host  */
       bzero( &saddr, sizeof(saddr) );         /* zero struct          */
                                              /* fill in hostaddr     */
       bcopy( hp->h_addr, &saddr.sin_addr, hp->h_length);
       saddr.sin_family = AF_INET ;            /* fill in socket type  */
       saddr.sin_port = htons(PORTNUM);        /* fill in socket port  */

       sock_id = socket( AF_INET, SOCK_STREAM, 0 );    /* get a socket */
       if ( sock_id == -1 ) oops( "socket" );

       if ( bind(sock_id, &saddr, sizeof(saddr)) != 0 )/* bind it to   */
               oops( "bind" );                         /* an address   */

       if ( listen(sock_id, 1) != 0 ) oops( "listen" );
```



```
    while ( 1 ){
               sock_fd = accept(sock_id, NULL, NULL); /* wait for call */
         printf("** Server: A new client connected!");
               if ( sock_fd == -1 )
                       oops( "accept" );       /* error getting calls  */

               sock_fp = fdopen(sock_fd,"w");  /* we'll write to the   */
               if ( sock_fp == NULL )          /* socket as a stream   */
                       oops( "fdopen" );       /* unless we can't      */

               thetime = time(NULL);           /* get time             */
                                               /* and convert to strng */
               fprintf( sock_fp, "************************************\n");
               fprintf( sock_fp, "** From Server: The current time is: ");
               fprintf( sock_fp, "%s", ctime(&thetime) );
               fprintf( sock_fp, "************************************\n");

               fclose( sock_fp );              /* release connection   */
              fflush(stdout);            /* force output  */
       }
}
```

Acknowledgments

- Advanced Programming in the Unix Environment by R. Stevens
- The C Programming Language by B. Kernighan and D. Ritchie
- Understanding Unix/Linux Programming by B. Molay
- Lecture notes from B. Molay (Harvard), T. Kuo (UT-Austin), G. Pierre (Vrije), M. Matthews (SC), B. Knicki (WPI), M. Shacklette (UChicago), J. Kim (KAIST), A. Dix (Hiraeth), and J. Schaumann (SIT).