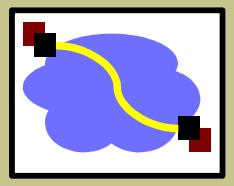
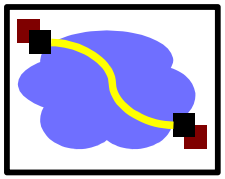


Socket Programming

N. Sujaudeen
AP/CSE

Client-Server Paradigm



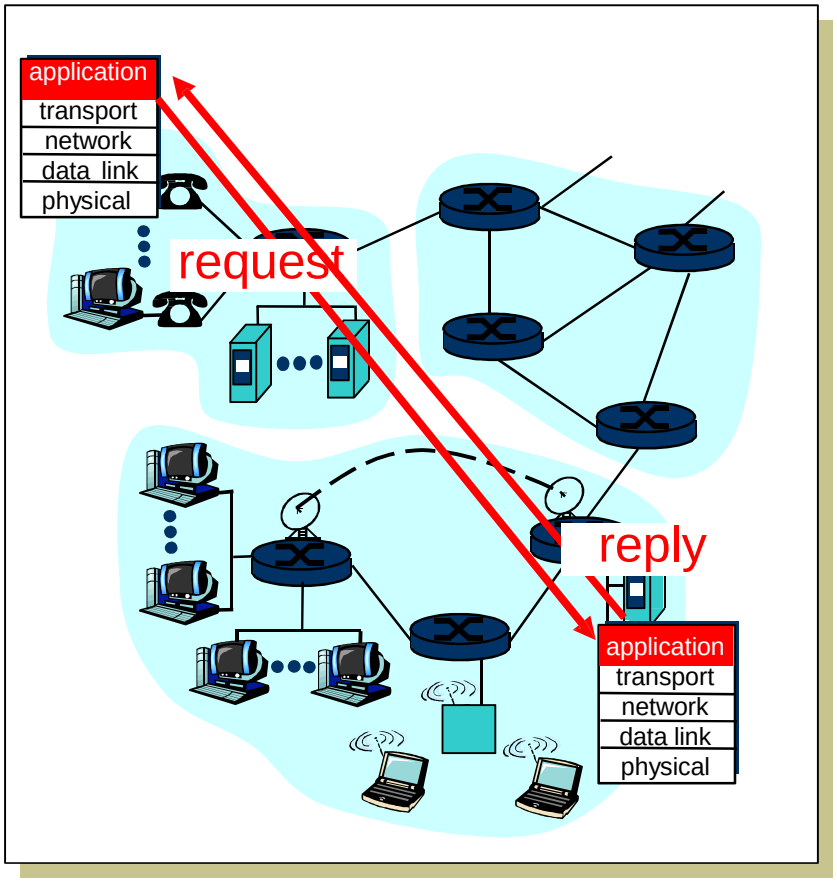
Typical network app has two pieces: *client* and *server*

Client:

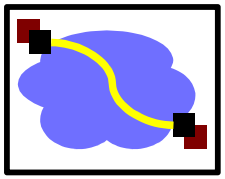
- Initiates contact with server ("speaks first")
- Typically requests service from server,
- For Web, client is implemented in browser; for e-mail, in mail reader

Server:

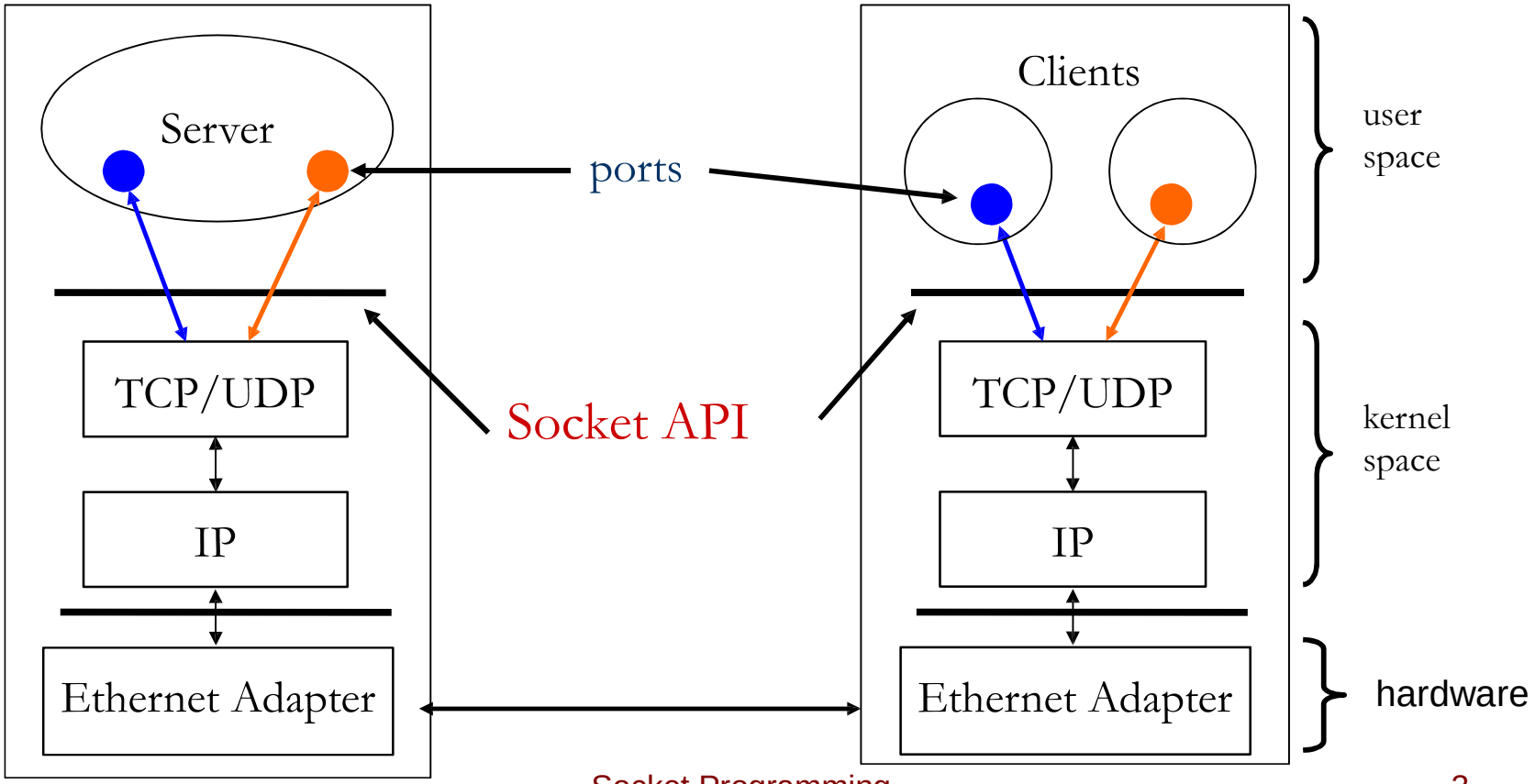
- Provides requested service to client
- e.g., Web server sends requested Web page, mail server delivers e-mail



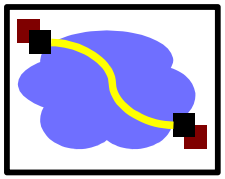
Server and Client



Server and Client exchange messages over the network through a common Socket API



UDP and TCP



UDP

- Single socket to receive messages
- No guarantee of delivery
- Not necessarily in-order delivery
- Datagram – independent packets
- Must address each packet

TCP

- Reliable – guarantee delivery
- Byte stream – in-order delivery
- Connection-oriented – single socket per connection
- Setup connection followed by data transfer

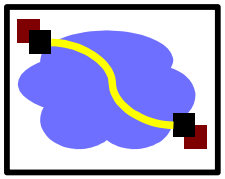
Example UDP applications

Multimedia, voice over IP

Example TCP applications

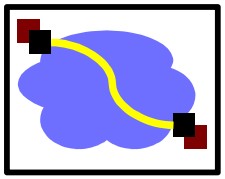
Web, Email, Telnet

Internet Addressing Data Structure



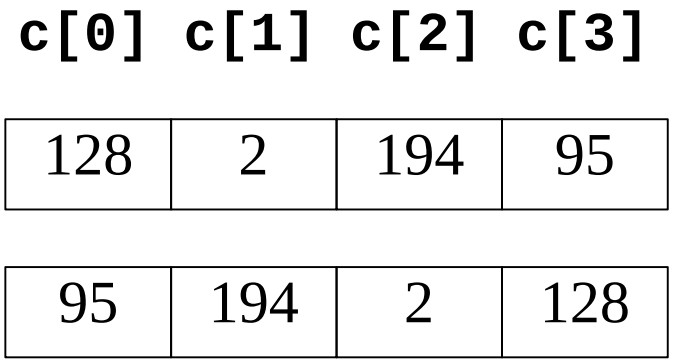
```
#include <netinet/in.h>

/* Internet address structure */
struct in_addr {
        u_long s_addr;          /* 32-bit IPv4 address */
};                              /* network byte ordered */

/* Socket address, Internet style. */
struct sockaddr_in {
      u_char  sin_family;       /* Address Family */
      u_short sin_port;         /* UDP or TCP Port# */
                                /* network byte ordered */
      struct in_addr sin_addr; /* Internet Address */
      char    sin_zero[8];      /* unused */
};
```

Byte Ordering

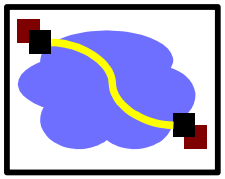


```
128.2.194.95
```

- Big Endian
  - Sun Solaris, PowerPC, ...
- Little Endian
  - i386, alpha, ...
- Network byte order = Big Endian



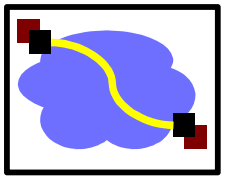
Byte Ordering Functions

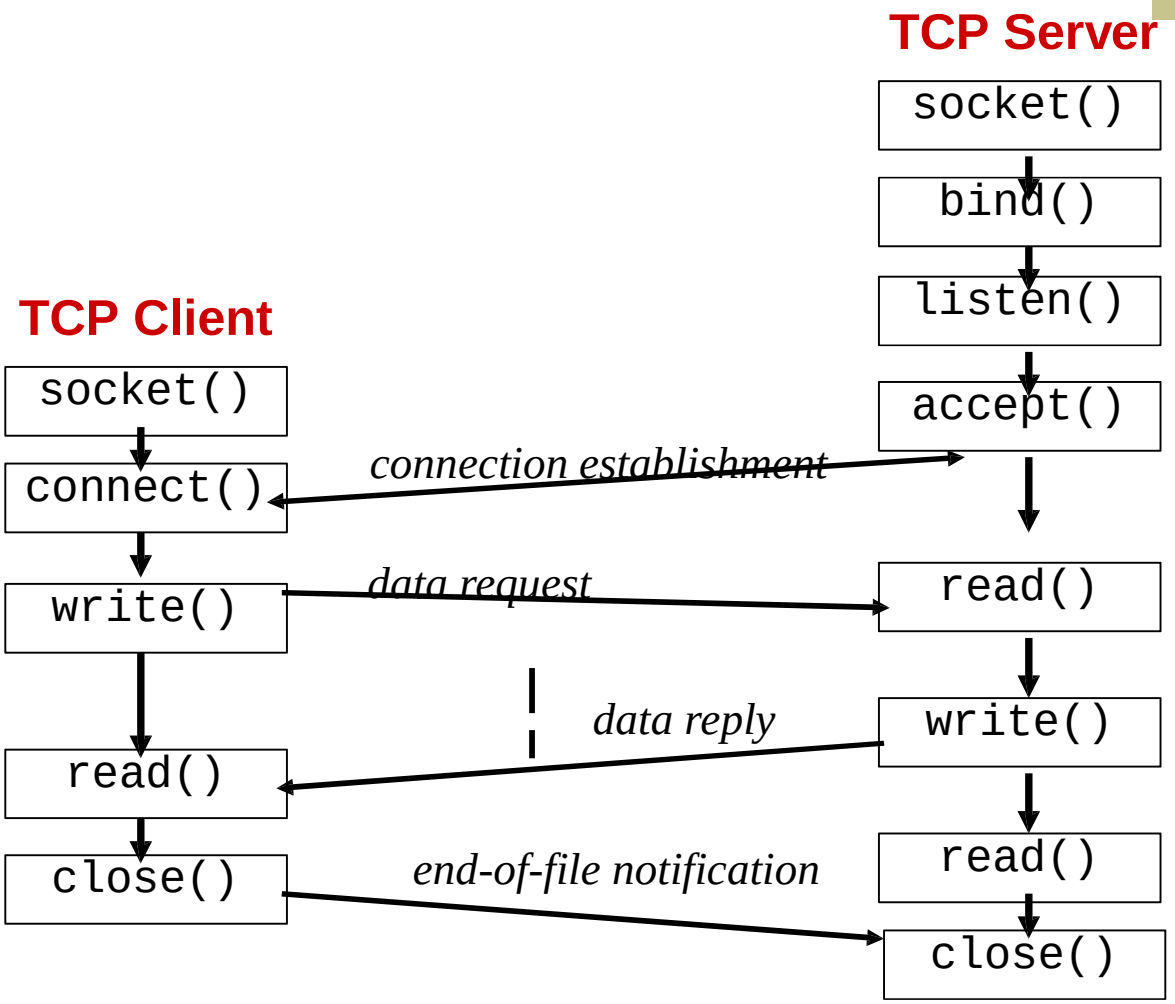


- Converts between **host byte order** and **network byte order**
  - 'h' = host byte order
  - 'n' = network byte order
  - 'l' = long (4 bytes), converts IP addresses
  - 's' = short (2 bytes), converts port numbers

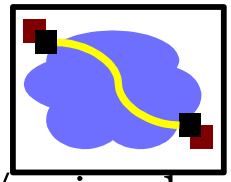
```
#include <netinet/in.h>

unsigned long int htonl(unsigned long int hostlong);
unsigned short int htons(unsigned short int
hostshort);
unsigned long int ntohl(unsigned long int netlong);
unsigned short int ntohs(unsigned short int
netshort);
```

TCP Client-Server Interaction





What is a Socket?

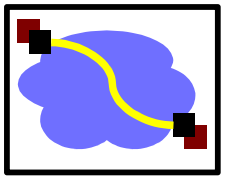


- A socket is a file descriptor that lets an application read/write data from/to the network

  int sd = socket(int domain, int type, int protocol);

  - **Domain / family** : integer, communication domain
    - AF_INET IPv4 protocol
    - AF_INET6 IPv6 protocol
    - AF_LOCAL Unix Domain Protocols
    - AF_ROUTE Routing Sockets
    - AF_KEY Key Socket
  - **type:** communication type
    - SOCK_STREAM: reliable, 2-way, connection-based service
    - SOCK_DGRAM: unreliable, connectionless,
    - SOCK_RAW: Security
  - **protocol:** specifies protocol - usually set to 0

What is a Socket?



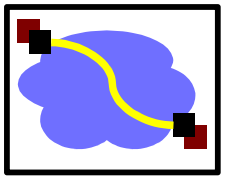
```
int sd;          /* socket descriptor */
if ((sd = socket(AF_INET, SOCK_STREAM, 0)) < 0) }
      perror("socket");
      exit(1);
}
```

socket returns an integer (socket descriptor)

- sd < 0 indicates that an error occurred
- socket descriptors are similar to file descriptors

NOTE: socket call does not specify where data will be coming from, nor where it will be going to – it just creates the interface!

Binding a Socket to a Port



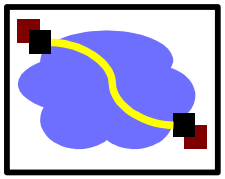
- A **socket** can be bound to a **port**
- ie. reserves a port for use by the socket

  int status = bind(int sockfd, struct sockaddr *address, int addrlen);

  - **sockfd:** integer, socket descriptor
  - **address:** struct sockaddr, the (IP) address and port of the machine (address usually set to INADDR_ANY – chooses a local address)
  - **addrlen:** the size (in bytes) of the address structure
  - **status:** Successful completion returns 0

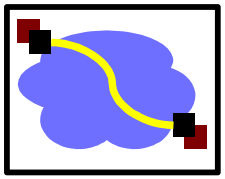
    if bind failed = -1

Binding a Socket to a Port



```
int sd;                                  /* socket descriptor */
struct sockaddr_in server; /* used by bind() */

/* 1) create the socket */
server.sin_family = AF_INET; /* use the Internet addr family */

server.sin_port = htons(80); /* bind socket 'sd' to port 80*/

/* bind: a client may connect to any of my addresses */
server.sin_addr.s_addr = htonl(INADDR_ANY);

if(bind(sd, (struct sockaddr*) & server, sizeof(server)) < 0) {
        perror("bind"); exit(1);
}
```

Listening For Connections

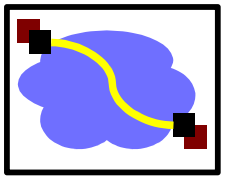


- **listen** indicates that the server will accept a connection

  int status = listen(int sockfd, int backlog);

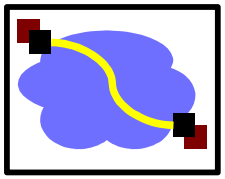
  - **sockfd:** socket descriptor
  - **backlog:** maximum # of active participants that can "wait" for a connection
  - **status:** 0 if listening, -1 if error

Listening For Connections



```
int sd;                          /* socket descriptor */
struct sockaddr_in srv;          /* used by bind() */

/* 1) create the socket */
/* 2) bind the socket to a port */

if(listen(sd, 5) < 0) {
        perror("listen");
        exit(1);
}
```

Accepting a connection



- Takes the first connection request on the queue, creates another socket with the same properties of sockfd.
- If no connection request pending, blocks the server until it receives a connection request from client

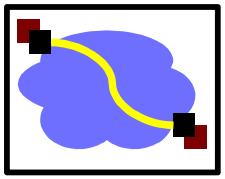
int status = accept(int sockfd, struct sockaddr *addr, int *addrlen);

- **sockfd:** the orig. socket (being listened on)
- **addr:** address of the active participant
- **addrlen:** value/result parameter
- **status:** the new socket (used for data-transfer)

  Successful completion returns 0

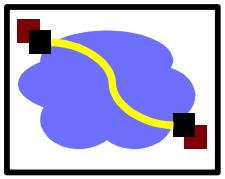
  Error -1

Accepting a connection



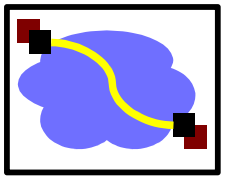
```
int sd;                              /* socket descriptor */
struct sockaddr_in server;           /* used by bind() */
struct sockaddr_in client;           /* used by accept() */
int newfd;                           /* returned by accept() */
int clientlen = sizeof(client);      /* used by accept() */

/* 1) create the socket */
/* 2) bind the socket to a port */
/* 3) listen on the socket */

newfd = accept(sd, (struct sockaddr*) &client &clientlen);
if(newfd < 0) {
        perror("accept");      exit(1);
}
```

Accepting a connection



- How does the server know which client it is?
  - **cli.sin_addr.s_addr** contains the client's **IP address**
  - **cli.sin_port** contains the client's **port number**
- Now the server can exchange data with the client by using **read** and **write** on the descriptor **newfd**.

Connecting a Socket

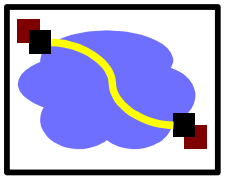


- Attempts to make a connection on a socket

int status = connect(int sockfd, struct sockaddr *addr, int addrlen);

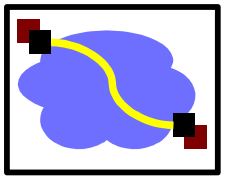
- **sockfd:** socket to be used in connection
- **addr:** address of passive participant
- **addrlen:** size of addr
- **status:** 0 if successful connect, -1 otherwise

Connecting a Socket



```
int sd;                                 /* socket descriptor */
struct sockaddr_in server;              /* used by connect() */
/* 1)create the socket */

server.sin_family = AF_INET; /* connect: use the Internet address
family */
server.sin_port = htons(80); /* connect: socket 'sd' to port 80 */

/* connect: connect to IP Address "128.2.35.50" */
server.sin_addr.s_addr = inet_addr("128.2.35.50");

if(connect(sd, (struct sockaddr*) &server, sizeof(server)) < 0) {
        perror("connect"); exit(1);
}
```

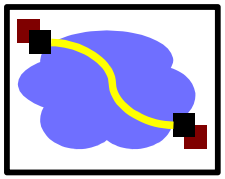
Sending data to a Socket



- **write** can be used with a socket

```
int sd;                          /* socket descriptor */
struct sockaddr_in server;       /* used by connect() */
char buf[512];                           /* used by write() */
int nbytes;                              /* used by write() */

/* 1) create the socket */
/* 2) connect() to the server */

/* Example: A client could "write" a request to a server */
if((nbytes = write(sd, buf, sizeof(buf))) < 0) {
        perror("write");        exit(1);
}
```

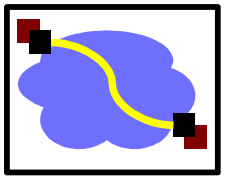
Receiving data from a socket

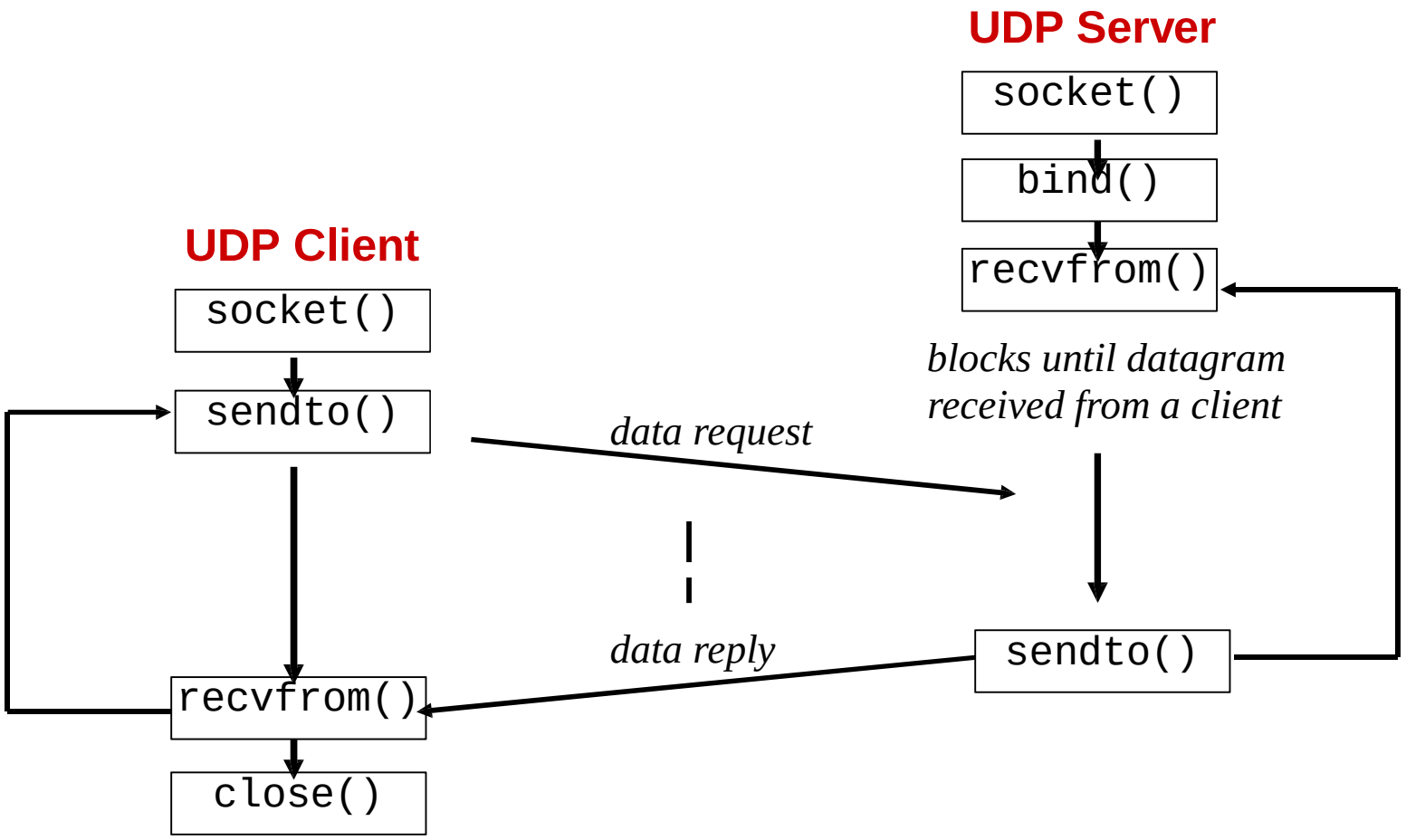


- **read** can be used with a socket

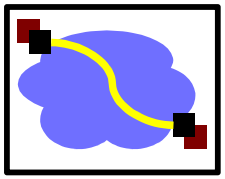
```
int sd;                          /* socket descriptor */
char buf[512];                        /* used by read() */
int nbytes;                        /* used by read() */

/* 1) create the socket */
/* 2) bind the socket to a port */
/* 3) listen on the socket */
/* 4) accept the incoming connection */

if((nbytes = read(sd, buf, sizeof(buf))) < 0) {
        perror("read"); exit(1);
}
```

UDP Client-Server Interaction



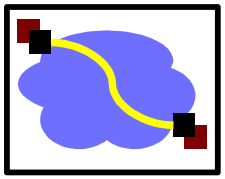


Simple Server Program



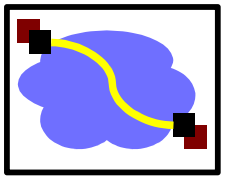
```
 #include<stdio.h>
#include<sys/types.h>
#include<sys/socket.h>
#include<netinet/in.h>
#include<string.h>

int main(int argc,char **argv)
{

 int len;
 int sockfd,newfd,n;
 struct sockaddr_in servaddr,cliaddr;
 char buff[1024];
 char str[1000];
```

Simple Server Program



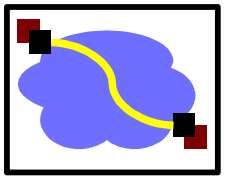
```
sockfd=socket(AF_INET,SOCK_STREAM,0);
 if(sockfd<0)
   perror("cannot create socket");

 bzero(&servaddr,sizeof(servaddr));

 servaddr.sin_family=AF_INET;
 servaddr.sin_addr.s_addr=INADDR_ANY;
 servaddr.sin_port=htons(7228);

 if(bind(sockfd,(struct sockaddr*)&servaddr,sizeof(servaddr))<0)
   perror("Bind error");

 listen(sockfd,2);
```

Simple Server Program



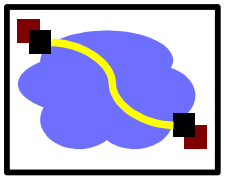
```
len=sizeof(cliaddr);
 newfd=accept(sockfd,(struct sockaddr*)&cliaddr,&len);
// printf("hi");
//Receiving the message

 n=read(newfd,buff,sizeof(buff));
 printf("\nReceived Message is \t%s",buff);

 close(sockfd);
 close(newfd);
 return 0;
}
```

Simple Client Program



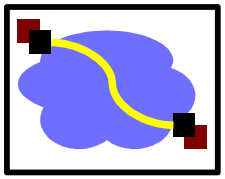
```
#include<stdio.h>
#include<sys/types.h>
#include<sys/socket.h>
#include<netinet/in.h>
#include<string.h>

int main(int argc,char **argv)
{
int len;
int sockfd,n;
struct sockaddr_in servaddr,cliaddr;
```

Simple Client Program



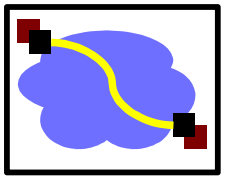
```
char str[1000];
char buff[1024];

sockfd=socket(AF_INET,SOCK_STREAM,0);
if(sockfd<0)
  perror("cannot create socket");

bzero(&servaddr,sizeof(servaddr));

servaddr.sin_family=AF_INET;
servaddr.sin_addr.s_addr=inet_addr(argv[1]);
servaddr.sin_port=htons(7228);
```

Simple Client Program



```
connect(sockfd,(struct sockaddr*)&servaddr,sizeof(servaddr));

//Sending Message
printf("Enter the message");
scanf("%s",buff);
n=write(sockfd,buff,sizeof(buff));


close(sockfd);
return 0;
}
```

Miscellaneous Routines



a. getpeername()

```
#include <sys/socket.h>
int getpeername(int s, struct sockaddr *addr, socklen_t *len);
```

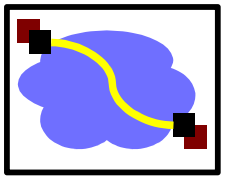
Description

Will tell who is at the other end of a connected stream socket and store that information in addr.

the peer's "name" is it's IP address and port.

Return Value - Returns zero on success, or -1 on error.

Miscellaneous Routines



b. gethostname() – Returns the name of the system

```
#include <sys/unistd.h>
int gethostname(char *name, size_t len);
```

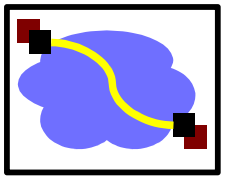
Description

Will get the name of the computer your program is running on and store that info in hostname

Return Value

Returns zero on success, or -1 on error.

Miscellaneous Routines

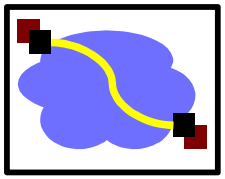


c. gethostbyname(), gethostbyaddr() – Get an IP address for a hostname or vice cersa

```
#include <sys/socket.h>
#include <netdb.h>

struct hostent *gethostbyname(const char *name); // DEPRECATED!
struct hostent *gethostbyaddr(const char *addr, int len, int type);
```

Description: gethostbyname() takes a string like "www.yahoo.com", and returns a struct hostent which contains tons of information, including the IP address. (Other information is the official host name, a list of aliases, the address type, the length of the addresses, and the list of addresses.

Miscellaneous Routines



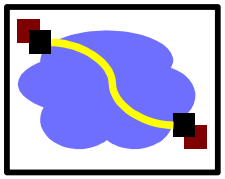
Description

gethostbyaddr() takes a struct in_addr or struct in6_addr and brings you up a corresponding host name (if there is one).

struct hostent

*char *h_name*	The real canonical host name.
*char **h_aliases*	A list of aliases that can be accessed with arrays—the last element is NULL
int h_addrtype	The result's address type, which really should be AF_INET for our purposes.
int length	The length of the addresses in bytes, which is 4 for IP (version 4) addresses.
*char **h_addr_list*	A list of IP addresses for this host. Although this is a char**, it's really an array of struct in_addr*s in disguise. The last array element is NULL.

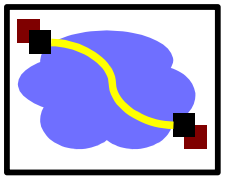
Miscellaneous Routines



Return Value

Returns a pointer to a resultant struct hostent on success, or NULL on error.

Input/Output Multiplexing



Same routines like accept(), receive() block.

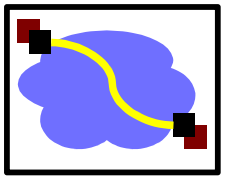
- Make sockets non-blocking

  sockfd=socket(PF_INET, SOCK_STREAM,0)

  fcntl(sockfd, F_SETFL, O_NONBLOCK)

  -Polling (consumes CPU time)
- Fork a separate process for each I/O channel.
- Threading
- Select system call (Highly Recommended)

Miscellaneous Routines



a. getpeername()

```
#include <sys/socket.h>
int getpeername(int s, struct sockaddr *addr, socklen_t *len);
```

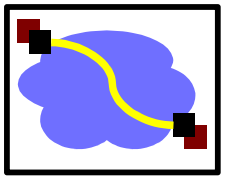
Description

Will tell who is at the other end of a connected stream socket and store that information in addr.

the peer's "name" is it's IP address and port.

Return Value - Returns zero on success, or -1 on error.

Select()



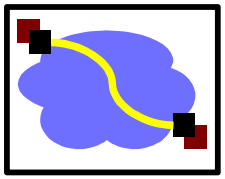
#include <sys/select.h>

int select(int numfds, fd_set *readfds, fd_set *writefds, fd_set *exceptfds, struct timeval *timeout);

- numfds – highest file descriptor + 1
- readfds, writefds, exceptfds: set of file descriptors to monitor for read, write and exceptions operations.
- When select() returns, the set of file descriptors is modified to reflect the ones that is currently ready.
- Timeout: select returns after this period if it still hasn't found any ready file descriptors.

```
struct timeval{
        int tv_sec; // seconds
        int tv_msec; // micro seconds };
```

Useful Macros



FD_ZERO(fd_set *set);

- Clear all entries from the *set*.

FD_SET(int fd, fd_set *set);

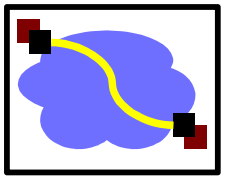
- Add *fd* to the *set*.

FD_CLR(int fd, fd_set *set);

- Remove *fd* from the *set*.

FD_ISSET(int fd, fd_set *set);

- Return true if *fd* is in the *set*.



Thank You…