Lecture 7: Introduction to Sockets

References for Lecture 7:
1) Unix Network Programming, W.R. Stevens, 1990,Prentice-Hall, Chapter 6.
2) Unix Network Programming, W.R. Stevens, 1998,Prentice-Hall, Volume 1, Chapter 3-4.

API (Application Programming Interface) – the interface available to the programmer for using the communication protocols. The API is depend to the OS + the programming language.

In this course, we discuss the socket API. With sockets, the network connection can be used as a file. Network I/O is, however, more complicated than file I/O because:

- Asymmetric. The connection requires the program to know which process it is, the client or the server.
- A network connection that is connection-oriented is somewhat like opening a file. A connectionless protocol doesn't have anything like an open.
- A network application needs additional information to maintain protections, for example, of the other process.
- There are more parameters required to specify a network connection than the file I/O. The parameter have different formats for different protocols.
- The network interface must support different protocols. These protocols may use different-size variable for addresses and other fields.

Socket Address

Because different protocols can use sockets, a generic socket address structure is defined. The socket address structure of the protocol is recast as the generic one when calling socket functions.

```
/* Generic Socket Address Structure, length=16*/
<sys/socket.h>
struct socketaddr {
   unit8_t          sa_len;
   sa_family_t      sa_family;    /* address family: AF_XXX value */
   char             sa_data[14];    /*up to 14 types of protocol-specific address */
};

/* Ipv4 Socket Address Structure, length=16*/
<netinet/in.h>
struct in_addr {
   in_addr_t        s_addr;    /*    32-bit IPv4 address, network byte ordered */
   };
```

```
struct sockaddr_in{
   unit8_t          sin_len;    /* length of structure (16 byte) */
   sa_family_t      sin_family;   /*AF_INET*/
   in_port_t         sin_port;    /* 16-bit TCP or UDP port number, , network byte ordered */
   struct in_addr    sin_addr;    /*32-bit Ipv4 address, network byte ordered */
   char              sin_zero[8];    /* unused – initialize to all zeroes */
};

/* Ipv6 Socket Address Structure, length=24*/
<netinet/in.h>
struct in6_addr {
   unit8_t            s6_addr[16];    /*    128-bit Ipv6 address, network byte ordered */
   };
#define SIN6_LEN /* required for compile-time tests */
struct sockaddr_in6{
   unit8_t            sin6_len; /* length of this structure (24byte) */
   sa_family_t       sin6_family; /*AF_INET6*/
   in_port_t          sin6_port; /* 16-bit TCP or UDP port number, , network byte ordered */
   unit32_t           sin6_flowinfor; /*    priority + flow label, network byte ordered */
   struct in6_addr    sin6_addr; /* Ipv6 address, network byte ordered */
  };

/*Xerox NS Socket Address Structure*/
struct sockaddr_ns{
     u_short             sns_family    /* AF_NS */
     struct ns_addr      sns_addr /* the 12_byte XNS address */
     char                sns_xero[2]    /*unused*/
};

/* Unix Domain Socket Address Structure, variable length, you need to pass the actual length as an argument */
struct sockaddr_un {
short     sun_family;      /*AF_UNIX*/
char       sun_path[108]; /* pathname */
};
```

Different protocols have different Socket Address Structure with different length. Unix has one set of network system calls to support such protocols. So, the socket address structure of the specific protocol is recast as the generic one when using Unix network system calls. That is also why a generic socket address structure is defined. ANSI C has a simple solution, by using void *, but the socket functions (announced in 1982) predate ANSI C.

Byte Ordering Routines

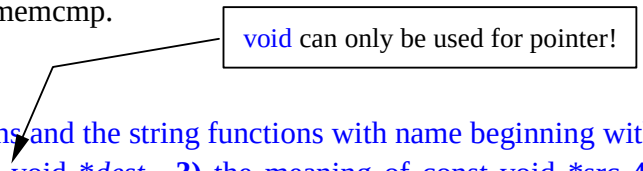
The network protocols use big-endian format. The host processor many not, so there are functions to convert between the two:

<netinet/in.h>

uint16_t htons(uint16_t *host16val*); -- convert 16-bit value from host to network order, used for the port number.
uint32_t htonl(uint32_t *host32val*); -- convert 32-bit value from host to network order, used for the Ipv4 address.
uint16_t ntohs(uint16_t *network16val*); -- convert 16-bit value from network to host order.
uint32_t ntohl(uint32_t *network32val*); -- convert 32-bit value from network to host order.

Note**1:** These functions works equally well for signed integer.
2: These functions don't do anything on systems where the host byte order is big-endian, however, they should be used for portability.

Byte Manipulation Routines
The following functions can be used to initialize or compare memory locations:
System V:
void *memset(void **dest*, int *c*, size_t *nbytes*); -- writes value *c* (converted into an unsigned char) into *nbytes* bytes of dest. Returns *dest*.
void *memcpy(void **dest*, const void **src*, size_t *nbytes*); -- copies *nbytes* of *src* to *dest*. Returns *dest*.
int memcmp(const void **ptrl*, const void **ptr2*, size_t *nbutes*); -- compare *nbytes* of the two strings, Returns 0 if they match, >0 if ptr1 >ptr2, < 0 if ptr1 < ptr2.
BSD 4.3:
bzero(char **dest*, int *nbytes*); -- writes NULL into *nbytes* bytes of *dest*.
bcopy(char **src*, char **dest*, int *nbytes*); -- similar with memcpy.
int bcmp(char **ptrl*, char **ptr2*, int *nbytes*); -- similar with memcmp.



Notice
1) the difference between the Byte Manipulation Functions and the string functions with name beginning with *str,* such as strcpy() and strcmp. **2)** the meaning of void **dest* **3)** the meaning of const void *src **4)** return value of memset() or memcpy()is the same as the first argument.

Address Conversion Routines
An internet address is written as: "192. 43. 234.1", saved as a character string. The functions require their number as a 32-bit binary value. To convert between the two, some functions are available:
<arpa/inet.h>
int inet_aton(const char **strptr*, struct in_addr * *addrptr*);
-- returns 1, 0 on error. Converts from a dotted-decimal string to a network address.
unsigned long inet_addr(char **strptr*);
-- Converts from a dotted-decimal string to 32-bit interger as return value.
char *inet_ntoa(struct in_addr *addrptr*);
-- Returns a pointer to a dotted-decimal string, given a valid network address.

Notice: inet_addr( ) and inet_aton are similar. Use inet_aton in your code.

This can also be done with two functions that support both IPv4 and IPv6 protocol:

int inet_pton(int *family*, const char **strptr*, void **addrptr*);
-- returns 1 if OK, 0 if invalid input format, -1 on error.

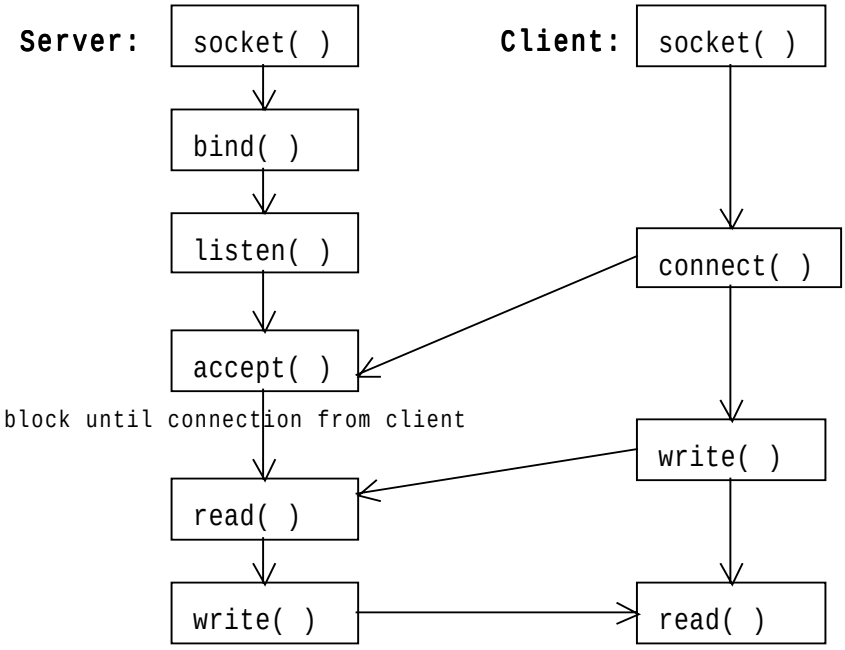
Const char *inet_ntop(int *family*, const void **addrptr*, char **strptr*, size_t *len*);
-- returns pointer to result if OK, NULL on error.

Procedure of Socket Programming

In order to communicate between two processes, the two processes must provide the formation used by ICP/IP (or UDP/IP) to exchange data. This information is the 5-tupe:

{protocol, local-addr, local-process, foreign-addr, foreign-process}.

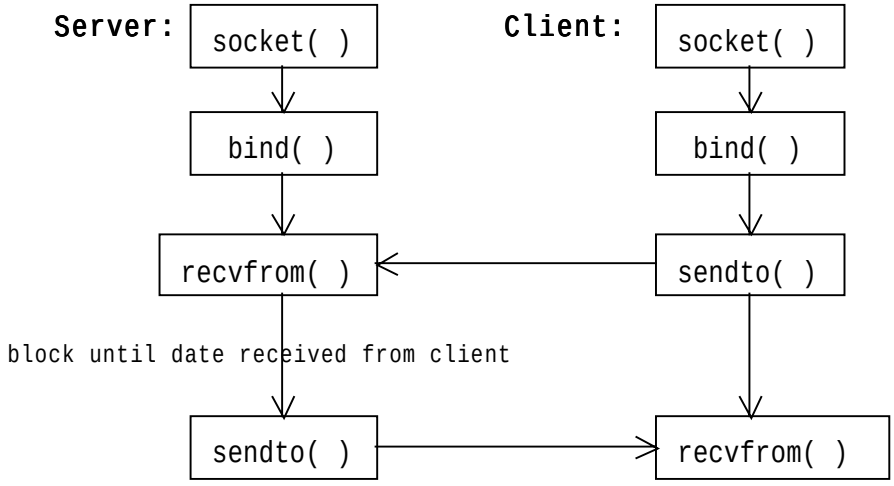
Several network systems calls are used to specify this information and use the socket.



Connection-Orieted Protocol (TCP)

Questions:

1) Why is there no bind( ) for client?
2) Why does server need listen( ) ?
3) Why can UDP not use read( ) or write()?



Connectionless Protocol (UDP)

Notice the difference between TCP and UDP !

The fields in the 5-tuple are set by:

	Protocol	Local-addr	Local-port	Foreign-addr	Foreign-port
Connection-oriented server	socket()	bind()		accept()	
Connection-oriented client	socket()	connect()			
Connectionless server	socket()	bind()		recvfrom()	
Connectionless client	socket()	bind()		sendto()	

Socket Function Calls:

#include <sys/socket.h>

int socket(int *family*, int *type*, int *protocol*); -- returns a socket descriptor, -1 on error.

famly – AF_INET = Ipv4 protocol
AF_INET6 = Ipv6 protocol
AF_LOCAL = Unix domain protocol
AF_NS = Xerox NS protocol
AF_ROUTE = Access routing table information in kernel
AF_KEY = Access cryptographic/security key table in kernel

type – SOCK_STREAM = stream socket (TCP)
SOCK_DGRAM = datagram socket (UDP)
SOCK_RAM = raw socket (IP, also used with AF_ROUTE + AF_KEY)

protocol – usually set to 0 and protocol is chosen based on family and type fields.

Returns – socket descriptor, equivalent to 5-tuple. For your convenience, always associate a 5-tuple association with a socket descriptor.

int connect(int *sockfd*, const struct sockaddr **servaddr*, socklen-t *addrlen*);

sockfd – socket descriptor, value returned by socket( ).

serveraddr – server's socket, contains the IP address and port number of the server.

addrlen – length of the structure sockaddr, to support different protocols.

Notes:

1) **connect( )** sets the local and foreign addresses and port numbers.
2) It initializes an active request for connection between the client and the server.
3) It blocks until the connection is established.
4) Mainly used connection-oriented protocols, e.g., TCP.
5) Connect() can also be used for connectionless protocols. In this case,
   5.1) it doesn't establish a connection.
   5.2) returns immediately.
   5.3) when sending data, the destination socket address are not specified explicitly. Use send() or write() instead of sendto().
   5.4) datagrams from only the designated address can be received. Use read() or recv() intead of recvfrom().
   5.5)connected UDP socket is much faster than unconnected UDP socket.
6) The socket can late be connected to another destination (or become unconnected) by calling connect() again. Use family=AF_UNSPEC to unconnect the socket.

int bind(int *sockfd*, const struct sockaddr **myaddr*, socklen-t *addrlen*); -- returns 0 if OK, -1 on error.
sockfd – value returned by socket( ).
myaddr – protocol-specific address. Values depend on usage.
addrlen – size of the address structure. In order to support different protocols.

Notes:

1) bind assigns the local IP address and port number to the socket.
2) Servers call bind() to their well-known port to the socket. If a server omits the call to bind(), the kernel selects an ephemeral port.
3) Normally a TCP client doesn't bind an IP address and port to its socket. The kernel chooses the IP address and port number when connect is called. A UDP client uses bind( ) so that incoming packets can be delivered to it by the kernel.
4) Using a wildcard, INADDR_ANY, for the IP address allows the kernel to select the IP address.
5) Using 0 for the port allows the kernel to choose the port; you can call getsockname( ) to know a kernel assigned port number—see example 1.
6) Reserved ports: See RFC 1700 for the full list of well-known ports or visit our FAQs. See /etc/services or \WINNT\system32\drivers\etc\services for local definition of reserved ports.

	Internet Port Number
Reserved ports	1--1023
Standard Internet Applications: FTP, TELNET, TFTP, SMTP	1--255
Reserved for future	256-511
Ports assigned by *int rresvport(int *aport)*	512--1023
Let system assign port number	0
Ports automatically assigned by system	1024--5000
User-developed Server	> 5000

int listen(int *sockfd*, int *backlog*); -- returns 0 if OK; -1 on error.
sockfd – value returned by socket().
backlog – number of connections the kernel should queue for the socket. Queued while waiting for an accept().
Notes:
1) listen( ) converts the socket into a passive socket, which allows a server to accept incoming connection requests when the server is processing the present request.
2) It has been tested on my computer that listen( ) must be used for connection-oriented server. See example 1.

int accept(int *sockfd*, stuct sockaddr **cliaddr*, int * *addrlen*); -- returns a new sockfd, -1 on error.
sockfd – value returned by socket().
cliaddr – returns the socket address of the client.
addrlen – **a value-result argument.** The calling process sets a value. The function uses this value and then updates it. In this case the server passes the size of the sockaddr structure and the number of bytes placed in cliaddr is returned.
Notes:
1) accept() blocks until a connection request is received from a client. *sockfd* is unchanged but a new socketfd is returned that specifies the connection to this client. Why ?
2) 3 return values: new socket fd, the client's IP address and port number are placed in *cliaddr*, length of the client's socket address stored in *addrlen*.
3) In example 1, accept(sk, 0, 0) means that "I don't want to know the client's socket address".

int close(int *sockfd*); -- returns 0 if OK; -1 on error. Closes the socket. Data already written to the socket that hasn't been sent yet will be sent and then the connection will be terminated. The call to close() returns immediately, even if unacknowledged data remains.

Miscellaneous Socket Functions:
Int shutdown(int *sockfd*, int *howto*) – returns 0 if OK, -1 on error.

Unlike close, shutdown allows the system to close the socket without waiting for the other process to also close the socket. Operations are:
howto = SHUT_RD(0) – receive on more data on the socket. Buffered data is discarded.
SHUT_WR(1) – send no more data on the socket.
SHUT_RDWR(2) – closes both halves, cannot send or receive data

Besides using read and wirte on connected sockets, special functions are available for sending and receiving data over a socket.
For connection-oriented:
ssize_t recv(int *sockfd*, void **buff*, size_t *nbytes*, int *flags*);
ssize_t send(int *sockfd*, const void **buff*, size_t *nbytes*, int *flags*);
For connectionless:
ssize_t recvfrom(int *sockfd*, void **buff*, size_t *nbytes*, int *flags* struct sockaddr ***from***, socklen_t **addrlen*);
ssize_t sendto(int *sockfd*, void **buff*, size_t *nbytes*, int *flags* struct sockaddr ***to***, socklen_t *addrlen*);
-- returns number of bytes read or written, -1 on error.

-- possible flags are:

MSG_DONTROUT – bypass the routing table lookup. Can be used for LANs.

MSG_DONTWAIT – converts the functions into a nonblocking call.

MSG_OOB – send or receive out-of-band data as opposed to normal data.TCP allows only one byte of OOB data.

MSG_PEEK – receives data, but does not remove it

MSG_WAITALL – doesn't return from a recv() or recvfrom() until the specified number of bytes have been read or an error occurs.

int getpeername(int *sockfd*, struct sockaddr **peer*, socklen_t **addrlen*); – returns 0 if OK, -1 on error.

peer – obtains the opposite process socket address: IP address and port number.

int getsockname(int *sockfd*, struct sockaddr **localaddr*, socklen_t **addrlen*) – returns 0 if OK, -1 on error.

localaddr – obtains IP address and port number of the local process. If bind() uses port number 0, getsockname() will get a new assigned port number – see Note 4 of bind().

#include <unistd.h>

int gethostname(char **name*, size_t *namelen*); – returns 0 if OK, -1 on error.

name -- places the name of a host in name, For example, "gigastar".

Given a machine name or host name, we can obtain the IP address and vice versa.

#include <netdb.h>

struct hostent *gethostbyname(const char **hostname*); – returns NULL on error. gethostbyname() returns a hostent structure containing the *hostname*'s IP addresses and nicknames from local hosts file /etc/hosts or /etc/inet/hosts.

struct hostent *gethostbyaddr(const char **addr*, size_t *leng*, int *family*); – returns NULL on error.

-- *addr* is pointer to a struct in_addr or struct in6_addr.

```
struct hostent{
    char *h_name; /* official name of the host , such as ece, gigastar.eng.wayne.edu*/
    char **h-aliases; /* an array of aliases (names) such as ece.eng.wayne.edu*/
    int h-addrtype; /* host address type: AF_INET or AF_INET6 */
    int h_length; /* length of the address*/
    char **h_addr_list; /* pointer to a list of IP addresses*/
#define h_addr h_addr_list[0] /* first address in the list, for backward compatibility */
}
```

The array of pointers h_addr_list[0], h_addr_list[1], and so on, are not pointers to characters but are pointers to structures of type in_addr which is defined in <netinet/in.h>.

%hostname –-- get the host name of your computer

%ifconfig –a4 –-- get the IP address of your compter

%ping –a gigastar –-- check if a remote host "gigastar" is reachable. –a :get the IP address of the host.

See local hosts file */etc/hosts* or */etc/inet/hosts* or \WINNT\system32\drivers\etc\hosts for local DNS. Do you know how to speed up your surfing speed?

Two types of server

Concurrent server – forks a new process, so multiple clients can be handled at the same time.
Iterative server – the server processes one request before accepting the next.

Concurrent Server

```
listenfd = socket(…);
bind(listenfd,…);
listen(listenfd,…)
for ( ; ; ) {
    connfd = accept(listenfd, …);
    If (( pid = fork()) == 0) {        /* child*/
        close(listenfd);
        /* process the request */
        close(connfd);
        exit(0);
      }
    close(connfd);       /* parent*/
}
```

Iterative Server

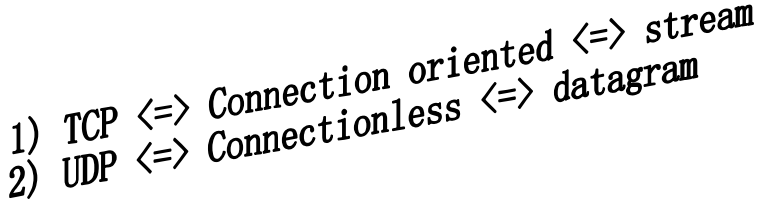
```
listenfd = socket(…);
bind(listenfd,…);
listen(listenfd,…)
for ( ; ; ) {
    connfd = accept(listenfd, …);
    /* process the request */
      close(connfd);
}
```

Client

```
sockfd = socket(…);
connect(sockfd, …)
/* process the request */
close(sockfd);
```

Summary:

1) **Difference between TCP and UDP.**
2) **Difference between stream and datagram.**
3) **Difference between concurrent server and iterative server.**
4) **Socket fd = 5-tuple.**
5) **Socket address = IP address + port number.**
6) **Difference between port number and process number(pid).**
7) **How provide protocols: socket().**
8) **How many typical protocols: socket(family, type, protocol).**
9) **How to provide local socket address: bind() or connect().**
10) **How to provide opposite/peer socket address: sendto() or connect().**
11) **How to get opposite socket address: accept, recvfrom().**
12) **How to check local or opposite socket address: getsockname(), getpeername().**
13) **How to know a host name and its IP address: gethostname(), gethostbyname(), gethostbyaddr().**



Example 1: A concurrent server echoes what client users type on keyboard, using connection-oriented TCP stream

server.c

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

/* This program creates a well-known Internet domain socket. Each time it accepts a connection, it forks a child
to print out messages from the client. It then goes on accepting new connections itself. */

main()
{
   struct sockaddr_in local;
   int sk, len=sizeof(local), rsk;

   /* Create an Internet domain stream socket */
   sk=socket(AF_INET, SOCK_STREAM, 0);

   /* Construct and bind the name using default values */
   local.sin_family=AF_INET;
   local.sin_addr.s_addr=INADDR_ANY;
   local.sin_port=0; /* Let the kernel to assign a port; see Note 6 for bind( ) */
   bind(sk, &local, sizeof(local));

   /* Find out and publish the assigned name */
   getsockname(sk, &local, &len);
   printf("Socket has port %d\n", local.sin_port);

   /* Start accepting connections */
   listen(sk, 5)                  /* Declare the willingness to accept connection. Tested that it
                                     is necessary for connection-oriented server */
   while (1) {
      rsk=accept(sk, 0, 0);      /* Accept new request for connection */
      if (fork()==0) {           /* Create one child to serve each client */
         dup2(rsk, 0);           /* Connect the new connection to "stdin" */
         execl("recho", "recho", 0); }
      else
         close(rsk);
   }
}
```

Can you find some errors in server.c? Hint: child process without exit(0) will fork grand child process.

recho.c

```
#include <stdio.h>
/* Process "recho". This program implements the service provided by the server. It is a child of the server and receives messages from the peer through "stdin" */
main()
{
   char buf[BUFSIZ];
      while (read(0, buf, BUFSIZ)>0)    printf("%s", buf);
   printf("***** ending connection *****\n");
}
```

client.c

```
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>
#include <stdio.h>
#include <netdb.h>
/* This program creates a socket and initiates a connection with the server socket given in the command line. Messages are read from the standard input until EOF (ctrl-d) is encountered. */
main(argc, argv)
int argc;
char *argv[];
{
   char buf[BUFSIZ], *gets();
   struct sockaddr_in remote;
   int sk;
   struct hostent *hp, *gethostbyname();

   sk=socket(AF_INET, SOCK_STREAM, 0);

   remote.sin_family=AF_INET;
   hp=gethostbyname(argv[1]);    /* Get host number from its symbolic name */
   bcopy(hp->h_addr, (char *)&remote.sin_addr, hp->h_length);
   remote.sin_port=atoi(argv[2]);
   connect(sk, &remote, sizeof(remote));    /* Connect to the remote server */

   /* Read input from "stdin" and send to the server */
   while (read(0, buf, BUFSIZ)>0)
      write(sk, buf, strlen(buf));
   close(sk);
}
```

Question: Why does the length field, sin_len, never need to be filled?

Example 2: For connectionless UDP datagrams.

----------sender.c----------

```
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>
#include <netdb.h>
#include <stdio.h>
#define MSG "ECE 5650 is a great course!!!"

main(argc, argv)
int argc;
char *argv[];
{    int sk;
   char buf[BUFSIZ];
   struct sockaddr_in remote;
   struct hostent *hp, *gethostbyname();

   sk=socket(AF_INET, SOCK_DGRAM, 0);

   remote.sin_family=AF_INET;

   hp = gethostbyname(argv[1]);
   bcopy(hp->h_addr, &remote.sin_addr.s_addr, hp->h_length);

   remote.sin_port=atoi(argv[2]);

   sendto(sk, MSG, strlen(MSG), 0, &remote, sizeof(remote));
   read(sk, buf, BUFSIZ);
   printf("%s\n", buf);
   close(sk);
}
```

----------replier.c----------

```
#include <stdio.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>
#define MSG "Are you sure? I doubt!!!"

main()
{ struct sockaddr_in local, remote;
   int sk, rlen=sizeof(remote), len=sizeof(local);
   char buf[BUFSIZ];

   sk=socket(AF_INET, SOCK_DGRAM, 0);

   local.sin_family=AF_INET;
   local.sin_addr.s_addr=htonl(INADDR_ANY);
   local.sin_port=htons(0);
   bind(sk, &local, sizeof(local));

   getsockname(sk, &local, &len);
   printf("socket has port %d\n", local.sin_port);

   recvfrom(sk, buf, BUFSIZ, 0, &remote, &rlen);
   printf("%s\n", buf);
   sendto(sk, MSG, strlen(MSG), 0, &remote, sizeof(remote));
   close(sk);
}
```

Example 3: Unix Domain Streams (without name)

unix-stream.c

```
#include <sys/types.h>
#include <sys/socket.h>
#include <stdio.h>
/* This program accepts several numbers from the command line and forks a child to compute the square and
cube of those numbers. Results are returned back to the parent and printed out. */
main(argc, argv)
int argc;
char *argv[];
{
   int i, cc, pid, sk[2];
   int magic;
   struct {float d, h;} num;

   /* Create a socketpair */
   socketpair(AF_UNIX, SOCK_STREAM, 0, sk);

       if (fork()==0) {      /* This is the child process */
         close(sk[0]);
         pid=getpid();
         /* Read the number and return the results until the parent ended */
         while (read(sk[1], &magic, sizeof(magic))>0) {
            printf("Child[%d]: the magic number is %d\n", pid, magic);
            num.d=magic * magic;
            num.h=magic * num.d;
            write(sk[1], &num, sizeof(num)); }
         close(sk[1]);
         exit(1); }

      /* This is the parent process */
      close(sk[1]);
     for (i=1; i<argc; i++) {    /* Write the numbers to children */
         magic=atoi(argv[i]);
         write(sk[0], &magic, sizeof(magic)); }
      for (i=1; i<argc; i++) {    /* Read the results from children */
         if (read(sk[0], &num, sizeof(num))<0)
            break;
         printf("parent: square=%f, cub=%f\n", num.d, num.h); }
      close(sk[0]);
}
```

Note: Unix domain unnamed stream is similar to PIPE, but is bi-directional.
Remember all sockets are full-duplex.

Example 4: Unix Domain Datagram (with name)

server.c

```
#include <sys/types.h>
#include <sys/socket.h>
#include <sys/un.h>
#include <stdio.h>
/* This program creates a UNIX domain datagram socket, binds a name to it, then reads from the socket. */
#define NAME "name-socket-number"      /* define the name of the socket */
main()
{ struct sockaddr_un local;
   int sk;
   char buf[BUFSIZ];

   sk=socket(AF_UNIX, SOCK_DGRAM, 0);    /* Create an UNIX domain datagram socket from which to read */
   local.sun_family=AF_UNIX;             /* Define the socket domain */
   strcpy(local.sun_path, NAME);         /* Define the socket name */
   bind(sk, &local, strlen(NAME)+2);     /* Bind the name to the socket, the actual length of socket address is passed*/
   read(sk, buf, BUFSIZ);                /* Read from the socket */
   printf("%s\n", buf);                  /* Print the message */
   unlink(NAME);                         /* Delete the i-node bound to the socket */
   close(sk);
}
```

client.c

```
#include <sys/types.h>
#include <sys/socket.h>
#include <sys/un.h>
#include <stdio.h>
/* This program sends a message in datagram to the receiver. */
#define MSG "ECE 5650 is a great course!!!"
#define NAME "name-socket-number"
main()
{ int sk;
   struct sockaddr_un remote;
   char buf[BUFSIZ];
   sk=socket(AF_UNIX, SOCK_DGRAM, 0);    /* Create an UNIX domain datagram socket on which to send */
   remote.sun_family=AF_UNIX;            /* Construct the name of socket to send to */
   strcpy(remote.sun_path, NAME);

   sendto(sk, MSG, strlen(MSG), 0, &remote, strlen(NAME)+2);    /* send message */
   close(sk);
}
```

Note: Datagram client doesn't need to use bind( ).

Example 5 Client-Server Example:

```
/* Example of server using TCP protocol. */
#include<stdio.h>
#include<sys/types.h>
#include<sys/socket.h>
#include<netinet/in.h>
#include<arpa/inet.h>                                          } inet.h
#define  SERV_UDP_PORT   6000
#define  SERV_TCP_PORT   6000
#define  SERV_HOST_ADDR      "192.43.235.6"        /*  host       addr for server */

char*pname;
main(argc, argv)
int   argc;
char*argv[];
{     int               sockfd, newsockfd, clilen, childpid;
      struct sockaddr_in      cli_addr, serv_addr;
      pname = argv[0];
      /*    Open a TCP socket (an Internet stream socket).          */
      if ( (sockfd = socket(AF_INET, SOCK_STREAM, 0)) < 0)
            err_dump("server: can't open stream socket");

      /*      * Bind our local address so that the client can send to us.       */
      bzero((char *) &serv_addr, sizeof(serv_addr));
      serv_addr.sin_family            = AF_INET;
      serv_addr.sin_addr.s_addr = htonl(INADDR_ANY);
      serv_addr.sin_port              = htons(SERV_TCP_PORT);

      if (bind(sockfd, (struct sockaddr *) &serv_addr, sizeof(serv_addr)) < 0)
            err_dump("server: can't bind local address");
      listen(sockfd, 5);
      for ( ; ; ) {/* Wait for a connection from a client process. This is an example of a concurrent server. */
            clilen = sizeof(cli_addr);
            newsockfd = accept(sockfd, (struct sockaddr *) &cli_addr, &clilen);
            if (newsockfd < 0) err_dump("server: accept error");
            if ( (childpid = fork()) < 0)err_dump("server: fork error");
            else if (childpid == 0) {     /* child process */
                  close(sockfd);          /* close original socket */
                  str_echo(newsockfd); /* process the request */
                  exit(0);
            }
            close(newsockfd);           /* parent process */
      }
}
```

```
/ * Example of client using TCP protocol. */

#include"inet.h"

main(argc, argv)
int   argc;
char*argv[];
{
      int               sockfd;
      struct sockaddr_in      serv_addr;
      pname = argv[0];

      /* Fill in the structure "serv_addr" with the address of the server that we want to connect with. */

      bzero((char *) &serv_addr, sizeof(serv_addr));
      serv_addr.sin_family            = AF_INET;
      serv_addr.sin_addr.s_addr = inet_addr(SERV_HOST_ADDR);
      serv_addr.sin_port              = htons(SERV_TCP_PORT);

      /*    Open a TCP socket (an Internet stream socket).    */

      if ( (sockfd = socket(AF_INET, SOCK_STREAM, 0)) < 0)
            err_sys("client: can't open stream socket");

      /*
        * Connect to the server.
        */

      if (connect(sockfd, (struct sockaddr *) &serv_addr,
                                    sizeof(serv_addr)) < 0)
            err_sys("client: can't connect to server");

      str_cli(stdin, sockfd);        /* do it all */

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

/* * Read a stream socket one line at a time, and write each line back to the sender. Return when the connection is terminated. */

```
#define  MAXLINE   512
str_echo(sockfd)
int   sockfd;
{     int   n;
      charline[MAXLINE];
      for ( ; ; ) {
            n = readline(sockfd, line, MAXLINE);
            if (n == 0)     return;          /* connection terminated */
            else if (n < 0)
                  err_dump("str_echo: readline error");
            if (writen(sockfd, line, n) != n)
                  err_dump("str_echo: writen error");
      }
}
```

/* * Read the contents of the FILE *fp, write each line to the stream socket (to the server process), then read a line back from the socket and write it to the standard output. Return to caller when an EOF is encountered on the input file. */

```
#include<stdio.h>
#define  MAXLINE   512
str_cli(fp, sockfd)
register FILE       *fp;
register int    sockfd;
{     int   n;
      charsendline[MAXLINE], recvline[MAXLINE + 1];

      while (fgets(sendline, MAXLINE, fp) != NULL) {
            n = strlen(sendline);
            if (writen(sockfd, sendline, n) != n)
                  err_sys("str_cli: writen error on socket");

            /* Now read a line from the socket and write it to our standard output.*/
            n = readline(sockfd, recvline, MAXLINE);
            if (n < 0)     err_dump("str_cli: readline error");
            recvline[n] = 0;   /* null terminate */
            fputs(recvline, stdout);
      }
      if (ferror(fp))
            err_sys("str_cli: error reading file");
}
```