Project Part 2: Background Information

Overview

Read each section below before you start the Part 2 of your project. You will need this information to complete Part 2 of the project. Consult your Open Learning Faculty Member if you have any questions about the project.

Objectives

In completing Project Part 2, you will achieve the following:

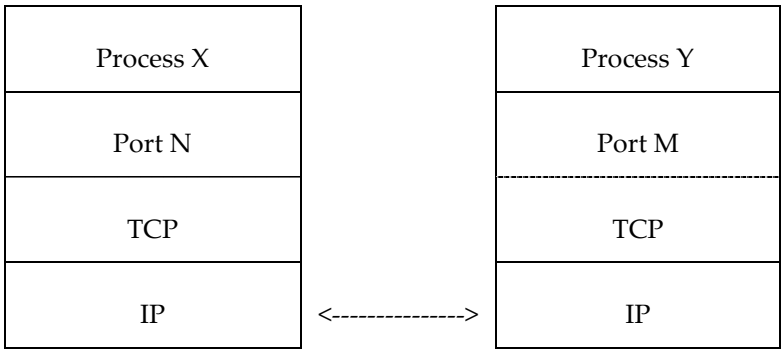
- Gain a better understanding of Transmission Control Protocol (TCP) / Internet Protocol (IP);
- Experience sockets, a communication mechanism, in programming; and
- Use TCP and User Datagram Protocol (UDP) with sockets.

Brief review of TCP/IP protocol suite

<table>
<tr><td>Application</td><td>FTP, TELNET, HTTP, applications</td></tr>
<tr><td>Transport</td><td>TCP, UDP</td></tr>
<tr><td>Network</td><td>IP, ICMP, ARP</td></tr>
<tr><td>Data link</td><td rowspan="2">Ethernet, …</td></tr>
<tr><td>Physical</td></tr>
</table>

- Transmission Control Protocol (TCP)
  - Connection oriented
  - Byte stream
  - Reliable delivery, error and flow control
  - Full duplex
- User Datagram Protocol (UDP)
  - Connectionless
  - Block transfer
  - Best effort delivery

- Full duplex
- Internet Protocol (IP)
  - Best effort delivery



Information needed to exchange data between two application peers over the Internet

- Client/server service model
- Source and destination port addresses
  - Source (or called local) and **destination** (or called remote) **port**:
    - Destination ports should be fixed and known to clients.
    - Source ports are allocated by system kernels.
  - **Protocol**: TCP or UDP
- Source and **destination addresses**
  - IP addresses
  - Destination addresses should be given from the user in the form of dotted decimals or domain names.
  - Source addresses are allocated by system kernels.

Introduction to sockets

A **socket** is a communication mechanism and is identified by an integer that is called the **socket descriptor**.

A socket includes an internal data structure consisting of the following five data items.

- Protocol id;
- The destination host address;
- The destination port number if applicable;
- The local host address;
- The local port number if applicable.

Server applications run first with specific port numbers, and client applications contact the server applications with the server port numbers and the server system address. For popular server applications, the fixed well known port numbers are assigned, so that users can use the applications with the same port numbers. There are a number of functions related to socket to support client/server communication paradigm. These are:

socket()	create a socket
bind()	associate a socket with a server port number
connect()	connect a socket to a server system with its address
listen()	wait for a connection request from a client system
accept()	accept the connection request

In addition, the functions setsockopt(), getsockopt(), fcntl() and ioctl() may be used to manipulate the properties of a socket, the function select() may be used to identify sockets with particular communication statuses. The function **close()** may be used to close a socket.

Data can be written to a socket using any of the functions **write()**,send(), **sendto()** and sendmsg(). Data can be read from a socket using any of the functions **read()**, recv(), **recvfrom()** and recvmsg().

IPv4 socket address structure

```
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>              // required header files

struct in_addr {                     // data structure for an
Internet address
      in_addr_t   s_addr;            // 32-bit IPv4 address
                                     // network byte ordered
};

struct sockaddr_in {                 // data structure for a
socket address
      sa_family_t       sin_family; // AF_INET for IPv4
      in_port_t         sin_port;   // 16-bit TCP or UDP port in
network byte order
      struct in_addr    sin_addr;   // 32-bit IPv4 address
      char              sin_zero[8];      // unused
};

-------------------------------------------------------------------

int8_t      signed 8-bit integer
<sys/types.h>
uint8_t     unsigned 8-bit integer
int16_t     signed 16-bit integer
uint16_t    unsigned 16-bit integer
int32_t     signed 32-bit integer
uint32_t    unsigned 32-bit integer
```

```
      sa_family_t address family of socket address structure
      <sys/socket.h>
      socklen_t   length of socket address structure, normaly uint32_t
      in_addr_t   IPv4 address, normally uint32_t
      <netinet/in.h>
      in_port_t   TCP or UDP port, normally uint16_t
                  0 – 1023: well known port
                  1024 – 49151: registered port
                  49152 – 65535: dynamic and client port

   Example:
      #include <netinet/in.h>
      #include <sys/types.h>
      #include <sys/socket.h>

      struct sockaddr_in      server;

      server.sin_family = AF_INET;              // Address Family -
Internet
      server.sin_port   = htons(9876);               // host byte
order to network byte order for short
      server.sin_addr.s_addr  = inet_addr("198.162.21.132");
```

Network byte order

- Different microprocessors use different models of main memory with respect to addressing for non-one byte data type, like int, short, float, and double.
- Little-endian byte order
  - High-address byte → high-order byte
  - Intel
- Big-endian byte order
  - Low-address byte → high-order byte
  - Motorola

- The numbers used in an Intel system are interpreted in a Motorola system as different numbers. For example, 1 in an Intel system is a very large number in a Motorola system.
- Therefore, we need a common mechanism to handle the above problem. Before senders send data, they change the data from **host byte order** to **network byte order**, and when receivers receive data, they change the data from network byte order back to host byte order. Here are related functions:

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

uint16_t    htons(uint16_t);  // host to network short integer,
e.g., port numbers
uint32_t    htonl(uint32_t);  // host to network long integer,
e.g., IP addresses
uint16_t    ntohs(uint16_t);  // network to host short
uint32_t    ntohl(uint32_t);  // network to host long
```

Address transformation functions

```
// “206.62.226.35” <-> read address of integer value

#include <arpa/inet.h>

int_addr_t  inet_addr(const char *strptr);      // returns
network byte order
char*       inet_ntoa(struct in_addr inaddr);   // from network
byte order

//-- sample code -- convert dotted address to integer

struct sockaddr_in server_addr;
server_addr.sin_addr.s_addr = inet_addr(argv[1]);     // argv[1]
contains a dotted address
```

```
      printf("%x\n", server_addr.sin_add.s_addr);           // %x means
hexadecimal values
      printf("%s\n", inet_ntoa(server_addr.sin_addr));
```

Information about remote hosts, using domain names

```
      #include <netdb.h>


      struct hostent    *gethostbyname(const char *name);  // domain
name or dotted
      struct hostent    *gethostbyaddr(const char *addr, size_t len,
int family);


      //-- sample code -- convert a domain name to address


      struct hostent *host;
      struct in_addr addr;
      host = gethostbyname(argv[1]);      // argv[1] contains a domain
name of a host
      if (host != 0) {
            addr.s_addr = *((u_long *)(host->h_addr_list[0]));
            printf("address for host: %s\n", inet_ntoa(addr));
      }
      addr.s_addr = inet_addr(argv[2]);   // contains a dotted address
      host = gethostbyaddr((char*)(&(addr.s_addr)),
sizeof(addr.s_addr), AF_INET);
      if (host != 0)
            printf("domain name: %s\n", host->h_name);
```

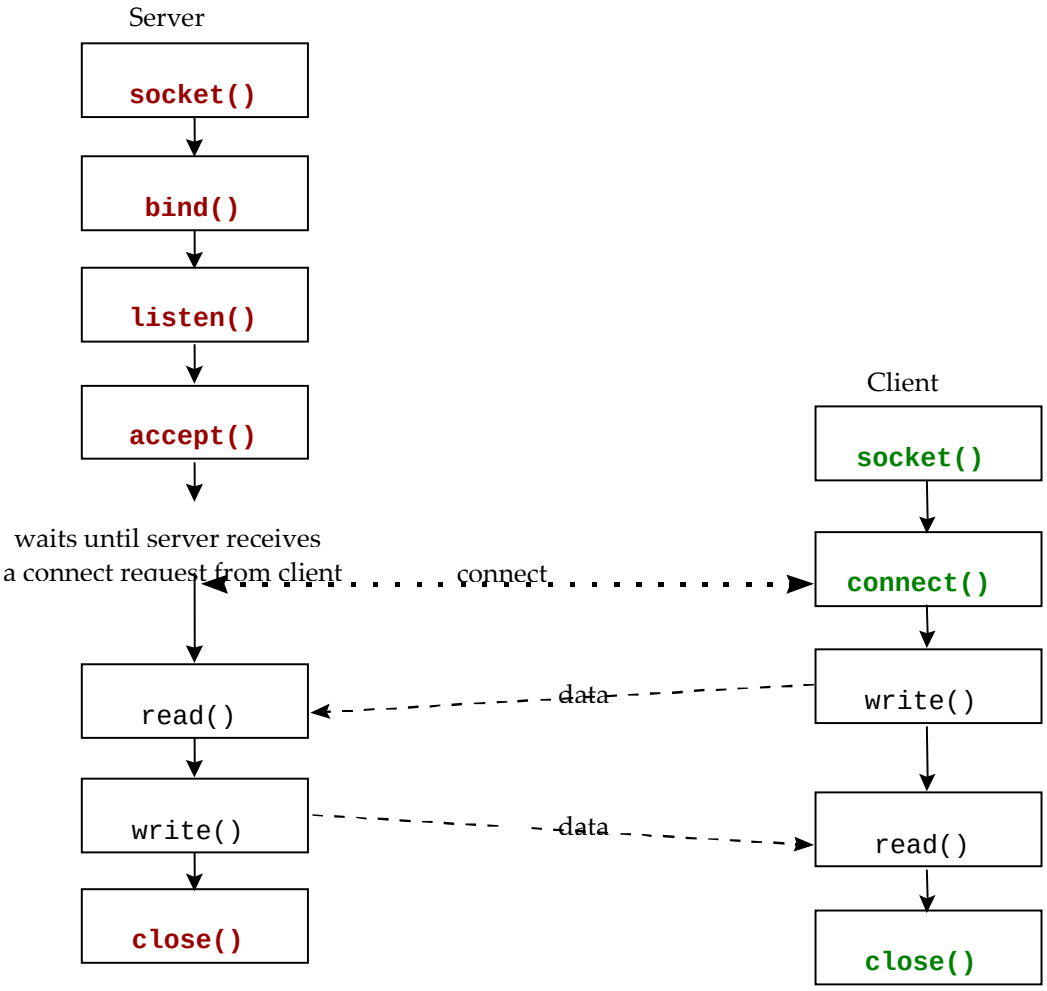
Note: We will not use those functions in this course.

Byte manipulation functions

```
    #include <strings.h>

    void    bzero(void *dest, size_t nbytes);
    void    bcopy(const void *src, void *dest, size_t ntypes);

Example:
    struct sockaddr_in server_addr;
    char    buf[128];
    bzero(buf, 128);                                    // there is no ‘&’ before buf
    bzero(&server_addr, sizeof(server_addr));           // sizeof() returns the
number bytes allocated
    ...;
    bcopy(&erfer_addr, buf, sizeof(server_addr));       // important example; there
is no ‘&’ before buf
```

Elementary TCP Sockets

Introduction



Socket(2) function

To perform network i/o, the first thing a process must do is to call the socket() function, specifying the type of communication protocols desired.

```
#include <sys/types.h>
#include <sys/socket.h>
int   socket(int domain, int type, int protocol);
```

domain	**PF_INET**	**IPv4** protocols	
	PF_INET6	IPv6 protocols	
	PF_LOCAL	Unix domain protocols	
	PF_PACKET	Low level packet interface, e.g., **Ethernet**	
	…		
type	**SOCK_STREAM**	stream socket	**TCP**
	SOCK_DGRAM	datagram socket	**UDP**
	SOCK_RAW	raw socket	**IP**
	SOCK_PACKET	data link socket (obsolete; replaced by packet(7))	
protocol	0	usually 0 for SOCK_STREAM and SOCK_DGRM	

Example:

```
int sd;
sd = socket(PF_INET, SOCK_STREAM, 0);     // for TCP connections
```

bind(2) function

The `bind()` function assigns a local protocol address, i.e., port number and address to permit, to a socket.

```
#include <sys/types.h>
#include <sys/socket.h>
int   bind(int sockfd, struct sockaddr *my_addr, sockllen_t
addrlen);
```

Comment: struct sockaddr_in* (not struct sockaddr*) should be used for *my_addr*. Similarly, it is also applied to accept(), connect(), recvfrom() and sendto().

Example:

```
int sd, r,
struct sockaddr_in server_addr;
sd = socket(PF_INET, SOCK_STREAM, 0);
bzero(&server_addr, sizeof(server_addr));                    //
clear
server_addr.sin_family  = AF_INET;
server_addr.sin_addr.s_addr   = inet_addr(argv[1]);   // argv[1]
contains a dotted address
server_addr.sin_port          = htons(atoi(argv[2])); // argv[2]
contains a server port #
r = bind(sd, (struct sockaddr*)(&server_addr),
   sizeof(server_addr));      // see the type conversion
```

You really need to check all the return values from the system calls. If `r` is negative in the above example, your server port number is probably used by another program.

listen(2) function

The `listen()` function converts an unconnected socket into a **passive socket**, indicating that the kernel should accept incoming connection requests.

```
#include <sys/socket.h>
int   listen(int sockfd, int backlog);
```

backlog the maximum number of connections that the socket can allow

accept(2) function

It is called by a TCP server to return the next completed connection, i.e., a new socket fd for the connection.

```
#include <sys/types.h>
#include <sys/socket.h>
int   accept(int sockfd, struct sockaddr *cliaddr,
            socklen_t *addrlen);  // cliaddr contains the
      client's info
```

Example:

```
int client_socket, addr_length;
struct sockaddr_in client_addr;
addr_length = sizeof(client_addr);
client_socket = accept (sd, (struct sockaddr*)(&client_addr),
&addr_length);
```

connect(2) function

The `connect()` function is used by a TCP client to establish a connection with a TCP server.

```
#include <sys/types.h>
#include <sys/socket.h>
int   connect(int sockfd, struct sockaddr *servaddr,
            socklen_t addrlen);  // servaddr contains the
      server's info
```

Example:

```
struct sockaddr_in server_addr;
r = connect (sd, (struct sockaddr *)(&server_addr),
sizeof(server_addr));
```

Concurrent servers

```
pid_t pid;
int   listenfd, connfd;

listenfd = socket(…);
bind(listenfd, …);
listen(listenfd, …);
for ( ; ; ) {
      connfd = accept(listenfd, …);
      if ((pid = fork()) == 0) {
            close(listenfd);
            doit(connfd);     // do something for the purpose
            close(connfd);
            exit(0);
      }
      close(connfd);
}
```

read() and write() functions

The normal UNIX `read()` and `write()` functions are used to read data from a TCP socket and to write data to a TCP socket respectively. **`read()` returns a negative number when a peer is closed by calling `close()`.**

close() functions

The normal UNIX `close()` function is used to close a socket and terminate a TCP connection.

Exercise Program: TCP_echo_server.c

```
      // argv[1] : port number

      #include ...
      #include ...
      ...

      int sock_server, sock_client, r, len;
      char buf[512];
      struct sockaddr_in my_addr, client_addr;  // not struct sockaddr
type

      sock_server = socket (PF_INET, ..., 0);  // create a socket for
TCP
      if (sock_server < 0)
            ...

      bzero(&my_addr, sizeof(my_addr));  // clear

      my_addr.sin_family = ...;  //Address Family INET
      my_addr.sin_port = htons(atoi(arg[...]));  // server port number
```

```
      my_addr.sin_addr.s_addr = htonl(INADDR_ANY);  // accept from
anywhere

      r = bind(sock_server, (struct sockaddr *)&my_addr,
sizeof(my_addr));
      if (r < 0)
            ...

      r = ...;  // listen requests
      if (r < 0)
            ...

      ... {  // infinite loop
            len = sizeof(client_addr);
            sock_client = accept(sock_server, (struct sockaddr
*)&client_addr, &len);

            n = read (sock_client, buf, ...);   //    read/write    with
      client socket
            while (n > 0) {               //  read()  returns  the  #  of
      bytes read
                  write (...);                  //     read()     returns
            negative value for broken connection
                  ... = read (...);
            }

            close(...);  // close the client socket
      }

      ...;  // close the server socket
```

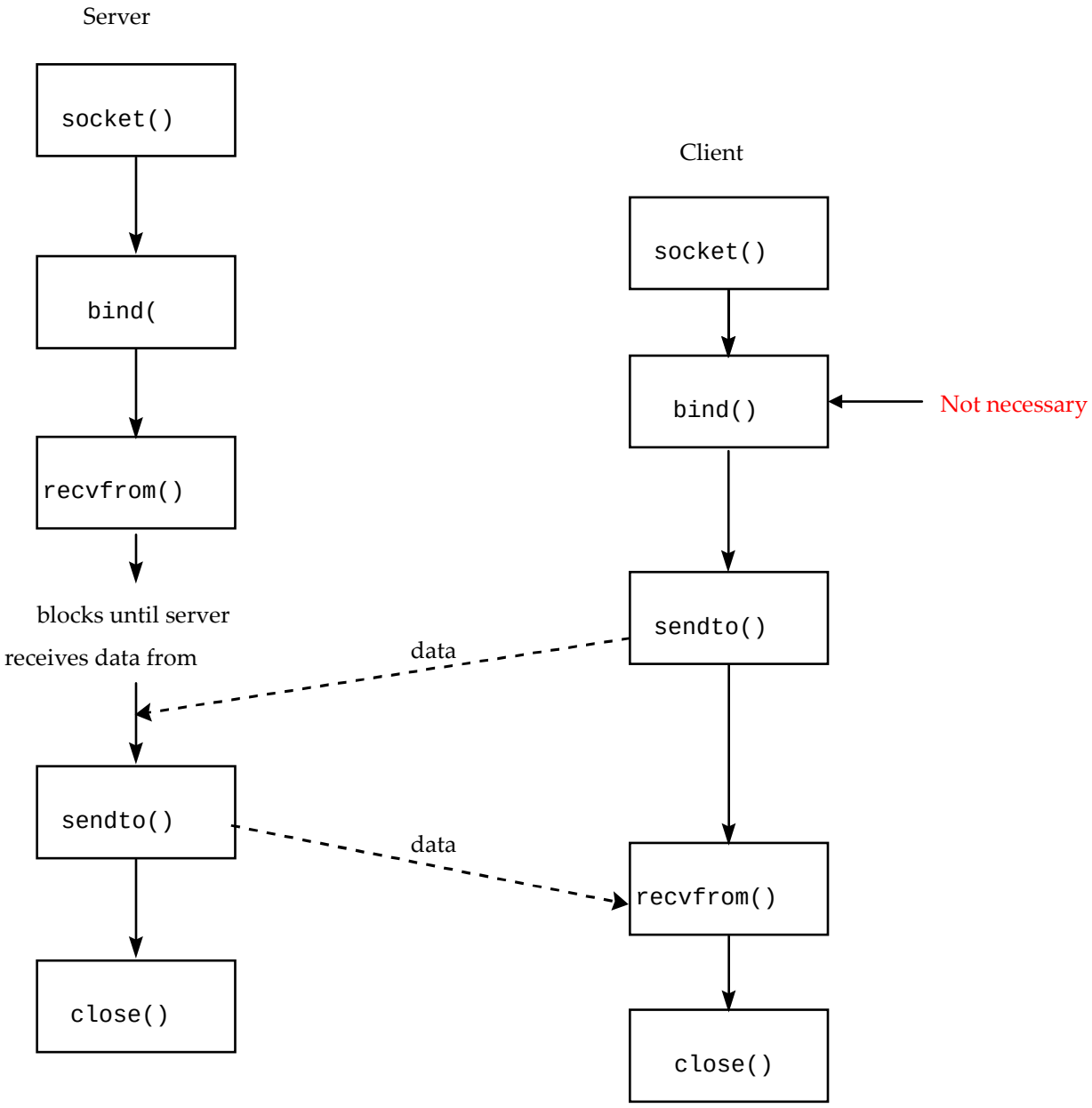
Exercise Program: TCP_echo_client.c

```
      // argv[1] : dotted address of server
      // argv[2] : port number; should be the one used by the TCP echo
server
      // argv[3] : message to send
      // ...

      #include ...
      ...

      int   s, n, port_no, r;
      struct sockaddr_in server_addr;
      char  *haddr, *message;
      char  buf[BUF_LEN+1];

      s = socket(...  // create a socket for TCP

      bzero((char *)&server_addr, sizeof(server_addr));  // clear

      server_addr.sin_family = ...;  // IPv4 Internet family
      server_addr.sin_addr.s_addr = inet_addr(...);  // server address
      server_addr.sin_port = htons(...);  // server port number

      r = connect(s, (struct sockaddr *)&server_addr,
sizeof(server_addr));  // connect to the server

      write(s, ..., ...);  // write a message

      n = read(s, ..., ...);  // read
      if (n < 0)
            ...
      else {
```

```
            buf[n] = ‘\0’;  // in order to put the terminating byte of
a string
            ...  // print
      }

      close(s);
```

Elementary UDP Sockets

Introduction



recvfrom(2) and sendto(2) functions

```
#include <sys/types.h>
#include <sys/socket.h>
ssize_t recvfrom(int sockfd, void *buf, size_t nbytes, int flags,
      struct sockaddr *from, socklen_t *addrlen);
ssize_t sendto(int sockfd, void *buf, size_t nbytes, int flags,
      struct sockaddr *to, socklen_t addrlen);

//-- sample code – server
int sockfd, n, len;
char mesg[MAXLINE];
struct sockaddr_in cliaddr;
sockfd = ...  // create a UDP socket
...  // bind
n = recvfrom (sockfd, mesg, MAXLINE, 0, (struct sockaddr
*)&cliaddr, &len);
            sendto(sockfd, mesg, n,       0, (struct sockaddr
*)&cliaddr, len);
```