ECE453 – Introduction to Computer Networks

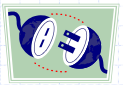
Lecture 15 – Transport Layer (II)

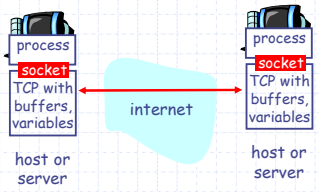
Transport Services

- Connection-oriented Service
  - TCP
  - Reliable data transfer
  - TCP flow control
  - TCP congestion control
  - TCP connection management
- Connectionless Service
  - UDP

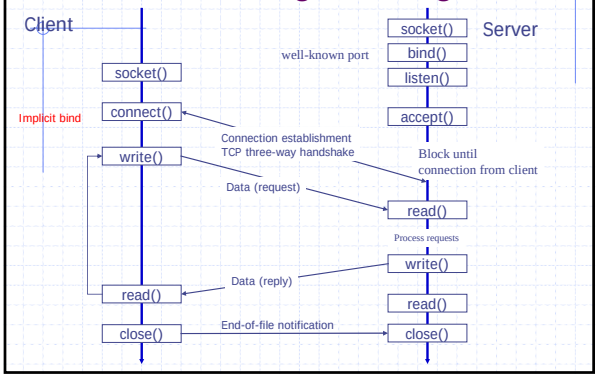
Through socket programming

Socket Programming

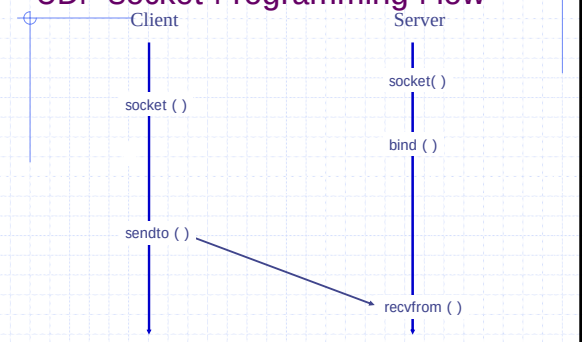




TCP Socket Programming Flow



UDP Socket Programming Flow



Socket APIs

```
result = socket(pf, type, protocol)
close(socket)
bind(socket, localaddr, addrlen)
```

Create A Socket

```
result = socket(pf, type, protocol)
```

- **Pf**: protocol family, example, **PF_INET (TCP/IP)**, **PF_UNIX (IPC, local)**
- Type: specify the type of communication (service model) desired, example, **SOCKET_STREAM (TCP), SOCKET_DGRAM (UDP), SOCKET_RAW (bypass TCP/UDP, use IP directly)**
- Protocol: select a specific protocol within the family. It is needed when there are more than one protocol to support the type of service desired. Usually is 0

Close A Socket

```
close(socket)
```

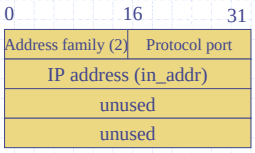
- Socket: specify the descriptor of socket to be closed
- Internally, a call to **close()** decrements the reference count for a socket and destroys the socket if the count reaches zero
  - Socket can be used by multiple applications

Specify Local Address

```
bind(socket, localaddr, addrlen)
```

- localaddr: a structure that specifies the local address to which the socket should be bound
- addrlen: an integer that specifies the length of address measured in bytes

Structure of Local Address




```
struct sockaddr_in {
  short sin_family;  /* must be AF_INET */
  u_short sin_port;  /* protocol port, can ignore */
  struct in_addr sin_addr; /* IP address */
  char sin_zero[8];  /* Not used, must be zero */
};
struct in_addr {
  in_addr_t s_addr;  /* 32 bit ipv4 address, network
                        byte ordered */
};
```

Connect Sockets to Destination

```
connect(socket, destaddr, addrlen)
```

- destaddr: a socket address structure that specifies the destination address to which a socket should be bound.

Specify A Queue Length for A Server

```
listen(socket, qlength)
```

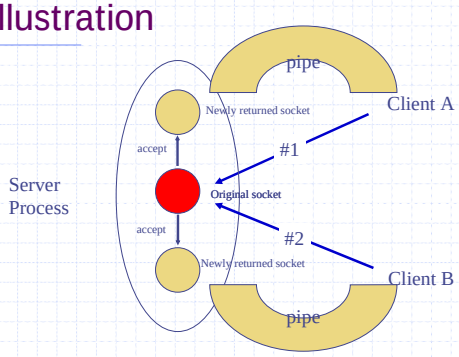
- listen() allows server to prepare a socket for incoming connections, and it puts the socket in a passive mode ready to accept connections
- It also tells server to en-queue up to “qlength” requests for connections, when full, discard new requests
- listen() only applies to sockets that have selected reliable data delivery services

Accepts Connections

```
newsock=accept(socket,addr,addrlen)
```

- A call to accept() blocks until a connection requests arrives
- When the request arrives, the system fills in argument “addr” with the address of the client that has placed the request, and “addrlen” to the length of the address
- Return a *new socket* with its destination connected to the requesting client
- The original socket still has a wild card foreign destination address, and it still remains open

Accepts Connection: Illustration



Send Data Through Socket

```
write(socket,buffer,length)
```

```
writev(socket,iovector,vectorlen)
```

```
send(socket,message,length,flags)
```

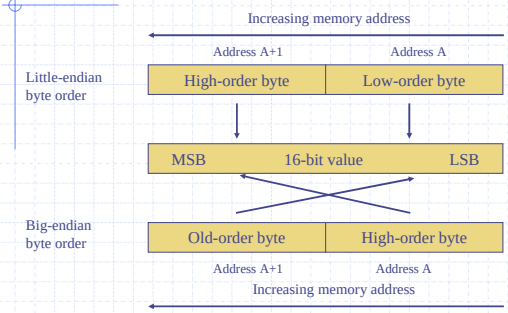
```
sendto(socket,message,length,flags,
       Destaddr, addrlen)
```

```
sendmsg(socket,messagestruct,flags)
```

Receive Data Through Socket

```
read(socket,buffer,length)
readv(socket,iovector,vectorlen)
recv(socket,message,length,flags)
recvfrom(socket,message,length,
    flags,Destaddr, addrlen)
recvmsg(socket,messagestruct,flags)
```

Byte Ordering



Implications of Byte Order

- Unfortunately there is no standard between these two byte orderings and we encounter systems that use both formats
- We refer to the byte ordering used by a given system as host byte order
- The sender and the receiver must agree on the order in which the bytes of these multi-byte field transmitted: specify network byte order, which is big-endian byte ordering

Byte Order Functions

```
#include <netinet.h>
uint16_t htons(uint16_t host16bitvalue)
Converts a 16-bit integer from host to network byte
  order

uint32_t htonl(uint32_t host32bitvalue)
Converts a 32-bit integer from host to network byte
  order
```

Both return: value in network byte order

```
uint16_t ntohs(uint16_t net16bitvalue)
uint32_t ntohl(uint32_t net32bitvalue)
```

Both return: value in host byte order

Byte Manipulation Functions

```
#include <strings.h>
/* Berkeley-derived functions */
void bzero(void *dest, size_t nbytes)
Set the first part of an object to null bytes

void bcopy(const void *src, void *dest, size_t nbytes);
int bcmp(const void *ptr1, const void *ptr2, size_t
  nbytes)  /* return:0 if equal, nonzero if unequal */

#include <string.h>
/* ANSI C defined functions */
void *memset(void *dest,int c,size_t len)
Sets the first len bytes in memory dest to the value of c

void *memcpy(void *dest,const void *src, size_t nbytes)
void memcmp(const void *ptr1, const void *ptr2, size_t
  nbytes)
```

Address Conversion Functions

```
#include <arpa/inet.h>

int inet_aton(const char *strptr, struct in_addr
  *addrptr); /* return 1 if string was valid,0 error */
Convert an IP address in string format (x.x.x.x) to the
  32-bit packed binary format used in low-level network
  functions

in_addr_t inet_addr(const char *strptr);
/* return 32-bit binary network byte ordered IPv4
  address; INADDR_NONE if error, deprecated and
  replaced by inet_aton()  */

char *inet_ntoa(struct in_addr inaddr);
/* returns: pointer to dotted-decimal string */
```

```
/* A simple server in the internet domain
     using TCP */
#include <stdio.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>

int main(int argc, char *argv[])
{
     int sockfd, newsockfd, portno, clilen;
     char buffer[256];
     struct sockaddr_in serv_addr, cli_addr;
     int n;

     ...
     sockfd = socket(PF_INET,
                     SOCK_STREAM, 0);
     bzero((char *)
     &serv_addr,sizeof(serv_addr));
     portno = atoi(argv[1]);
     serv_addr.sin_family = AF_INET;
     serv_addr.sin_addr.s_addr =
     INADDR_ANY;
     serv_addr.sin_port = htons(portno);
     if (bind(sockfd, (struct sockaddr *)
            &serv_addr,
             sizeof(serv_addr)) < 0)
             error("ERROR on binding");

     listen(sockfd,5);
     clilen = sizeof(cli_addr);
     newsockfd = accept(sockfd,
                 (struct sockaddr *) &cli_addr,
                 &clilen);
     bzero(buffer,256);
     n = read(newsockfd,buffer,255);
     printf("Here is the message: %s\n",buffer);
     n = write(newsockfd,"I got your msg",18);
     return 0;
}
```

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

int main(int argc, char *argv[])
{
    int sockfd, portno, n;
    struct sockaddr_in serv_addr;
    struct hostent *server;
    char buffer[256];

    portno = atoi(argv[2]);

    sockfd = socket(PF_INET, SOCK_STREAM,
     0);
    server = gethostbyname(argv[1]);
    bzero((char *) &serv_addr, sizeof(serv_addr));
    serv_addr.sin_family = AF_INET;
    bcopy((char *)server->h_addr,
         (char *)&serv_addr.sin_addr.s_addr,
         server->h_length);
    serv_addr.sin_port = htons(portno);
    if (connect(sockfd,&serv_addr,
                  sizeof(serv_addr)) < 0)
        error("ERROR connecting");
    printf("Please enter the message: ");
    bzero(buffer,256);
    fgets(buffer,255,stdin);
    n = write(sockfd,buffer,strlen(buffer));

    bzero(buffer,256);
    n = read(sockfd,buffer,255);
    printf("%s\n",buffer);

    return 0;
}
```