Welcome to

# *CS 3516:*
# *Computer Networks*

Prof. Yanhua Li

Time: 9:00am –9:50am M, T, R, and F
Location: AK219
Fall 2018 A-term

# So far…

1.1 what is the Internet?

"nuts and bolts" view

service view

1.2 network edge

- end systems, access networks, links

1.3 network core

- packet switching, circuit switching, network structure

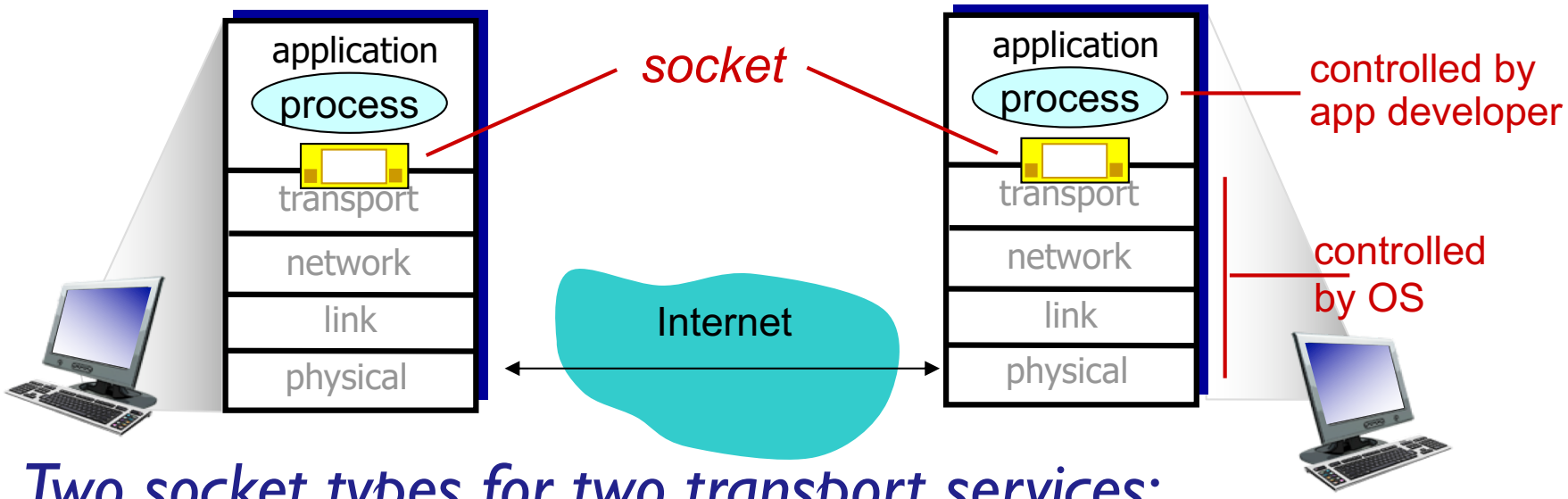
# Reminder

1. Programming project 1 starts today, and is due on 9/11;
2. Lab 1 is due Tue (tomorrow).

# Socket programming

*goal:* learn how to build client/server applications that communicate using sockets

*socket:* door between application process and end-end-transport protocol




*Two socket types for two transport services:*

- *UDP:* unreliable datagram
- *TCP:* reliable, byte stream-oriented

# IPv4 Socket Address Structure

*The Internet socket address structure is named* **sockaddr_in** *and is defined by including <netinet/in.h> header.*

```
struct in_addr {
  in_addr_t   s_addr                 /* 32-bit IP address */
};                                   /* network byte ordered */
struct sockaddr_in {
  uint8_t          sin_len;          /* length of  structure (16) */
  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 */
};
```

# TCP Socket Calls

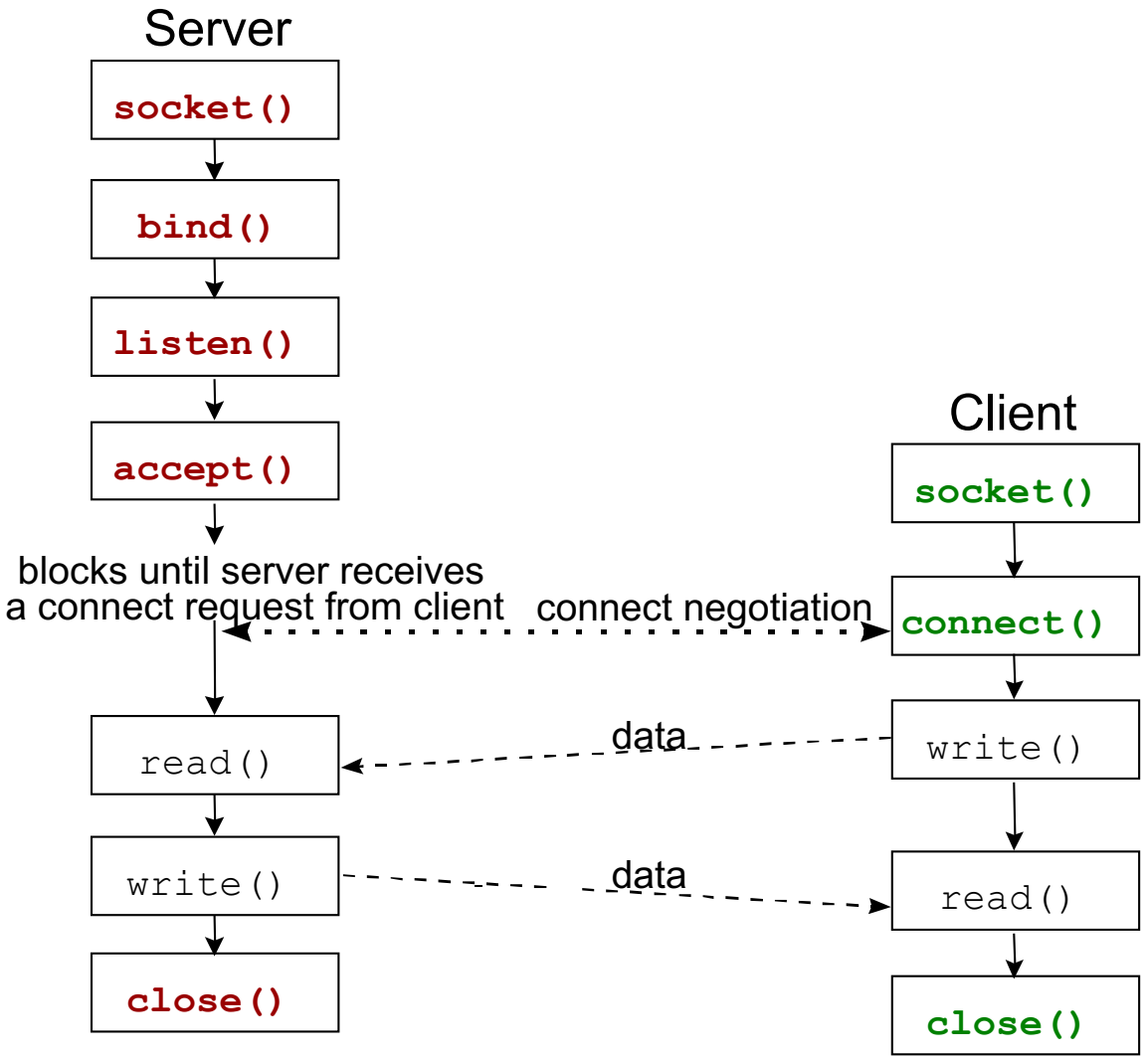





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Figure 2.17

# System Calls for Elementary TCP Sockets

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

**socket Function**

```
int  socket ( int family,  int  type, int protocol );
```

***family***: specifies the protocol family {AF_INET for TCP/IP}

***type***: indicates communications semantics

| | | |
|---|---|---|
| SOCK_STREAM | stream socket | TCP |
| SOCK_DGRAM | datagram socket | UDP |
| SOCK_RAW | raw socket | |

***protocol***: set to 0 except for raw sockets

returns on success: socket descriptor {a small nonnegative integer}

on error: -1

Example:

```
if  (( sd = socket (AF_INET, SOCK_STREAM, 0)) < 0)
                err_sys ("socket call error");
```

# TCP Socket Calls

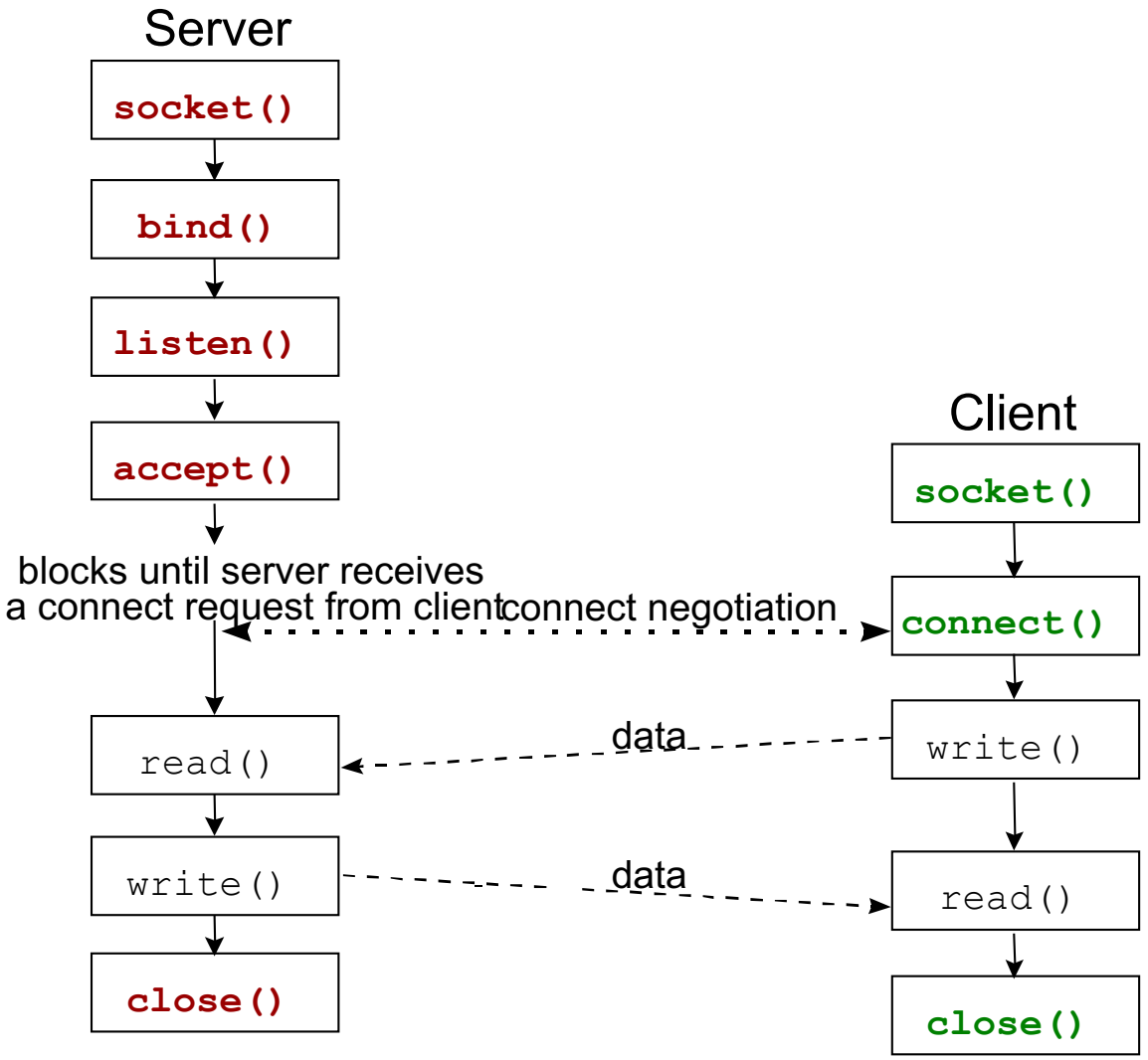




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Figure 2.17

connect Function

int connect (int *sockfd*, const struct sockaddr **servaddr*, socklen_t *addrlen*);

***sockfd***: a socket descriptor returned by the socket function

****servaddr***: a pointer to a socket address structure

***addrlen***: the size of the socket address structure

The socket address structure must contain the **IP address** and the **port number** for the connection wanted.

In TCP **connect** initiates a three-way handshake. **connect** returns only when the connection is established or when an error occurs.

returns on success: 0

on error: -1

Example:

```
if ( connect (sd, (struct sockaddr *) &servaddr, sizeof
    (servaddr)) != 0)
    err_sys("connect call error");
```

## close Function

```
int close (int sockfd);
```

**close** marks the socket as closed and returns to the process immediately.

***sockfd***: This socket descriptor is no longer useable.

Note – TCP will try to send any data already queued to the other end before the normal connection termination sequence.

Returns on success: 0

on error: -1

Example:

```
close (sfd);
```

# TCP Socket Calls

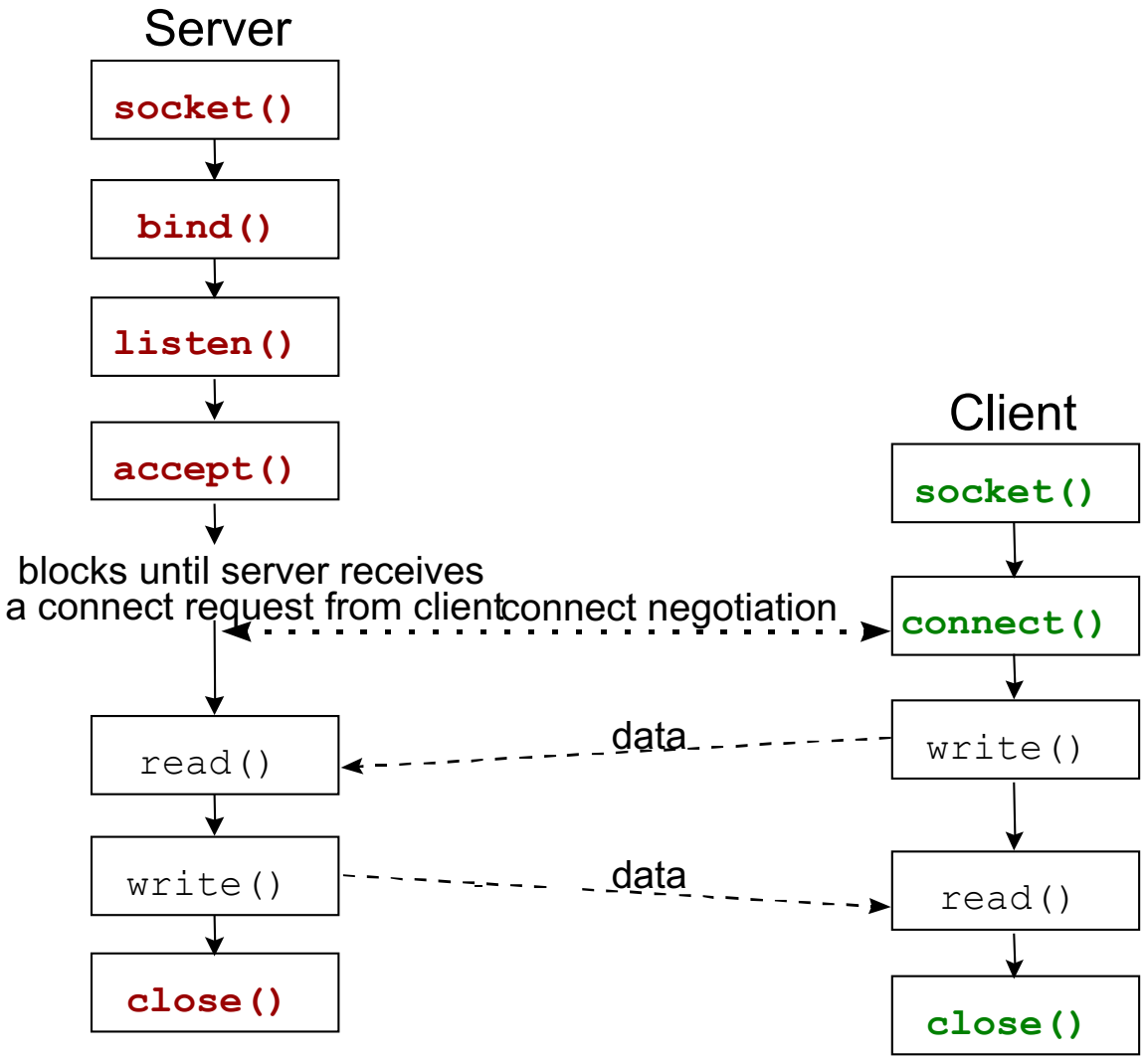




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Figure 2.17

bind Function

int bind (int *sockfd*, const struct sockaddr **myaddr*, socklen_t *addrlen*);

**bind** assigns a local protocol address to a socket.

protocol address: a 32 bit IPv4 address and a 16 bit TCP or UDP port number.

***sockfd***: a socket descriptor returned by the socket function.

****myaddr***: a pointer to a protocol-specific address.

***addrlen***: the size of the socket address structure.

*Servers* **bind** their "well-known port" when they start.

returns on success: 0

on error: -1

Example:

```
if (bind (sd, (struct sockaddr *) &servaddr, sizeof (servaddr))
!= 0)
    errsys ("bind call error");
```

# TCP Socket Calls

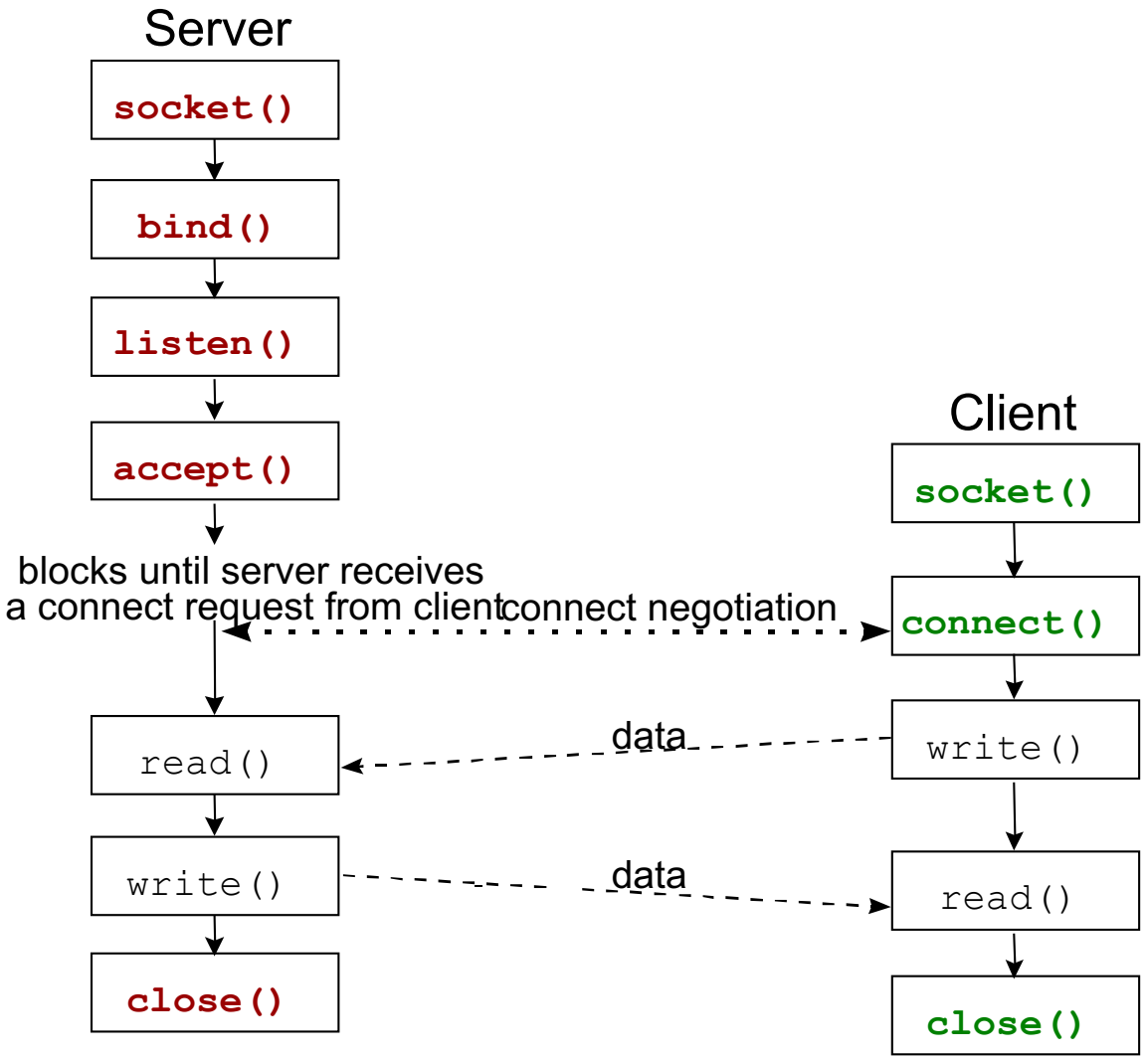




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Figure 2.17

## listen Function

int listen (int *sockfd*, int *backlog*);

**listen** is called **only** by a TCP server and performs two actions:

1. Converts an unconnected socket (*sockfd*) into a passive socket.
2. Specifies the maximum number of connections (*backlog*) that the kernel should queue for this socket.

**listen** is normally called before the **accept** function.

returns on success: 0

on error: -1

Example:

```
if (listen (sd, 2) != 0)
    errsys ("listen call error");
```

# TCP Socket Calls

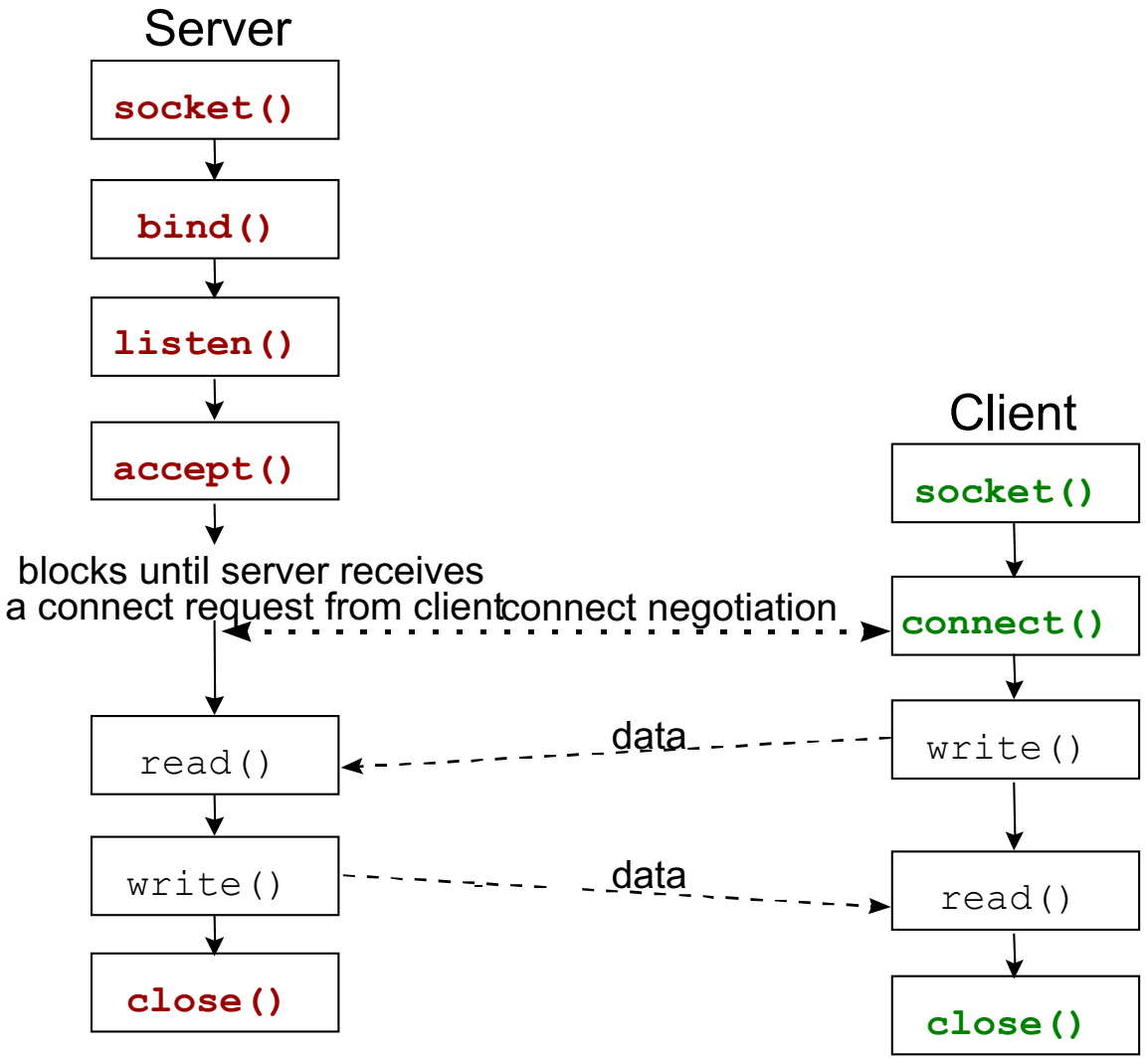




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Figure 2.17

accept Function

int accept (int *sockfd*, struct sockaddr **cliaddr*, socklen_t **addrlen*);

**accept** is called by the TCP server to return the next completed connection from the front of the completed connection queue.

***sockfd***: This is the same socket descriptor as in **listen** call.

***cliaddr**: used to return the protocol address of the connected peer process (i.e., the client process).

***addrlen**: {this is a value-result argument}

*before the accept call:* We set the integer value pointed to by *addrlen to the size of the socket address structure pointed to by *cliaddr;

*on return from the accept call:* This integer value contains the actual number of bytes stored in the socket address structure.

returns on success: a **new** socket descriptor

on error: -1

accept Function (cont.)

int accept (int *sockfd*, struct sockaddr **cliaddr*, socklen_t **addrlen*);

For **accept** the first argument ***sockfd*** is the listening socket

and the returned value is the connected socket.

The server will have one connected socket for each client connection accepted.

When the server is finished with a client, the connected socket must be closed.

Example:

connected socket

```
sfd= accept (sd, NULL, NULL);
if (sfd == -1) err_sys ("accept error");
```

# TCP Socket Calls

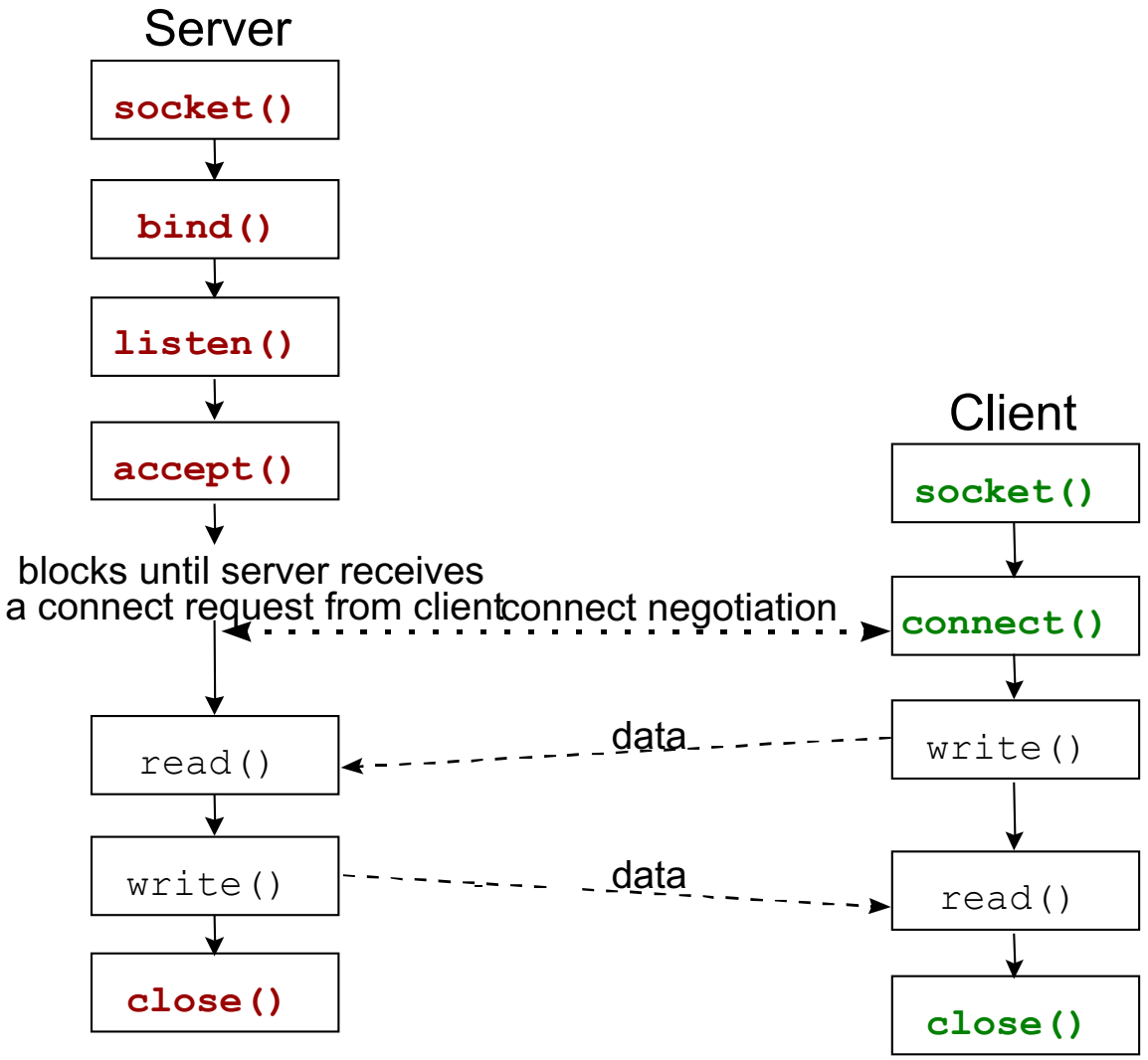




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Figure 2.17

# UDP Socket Calls

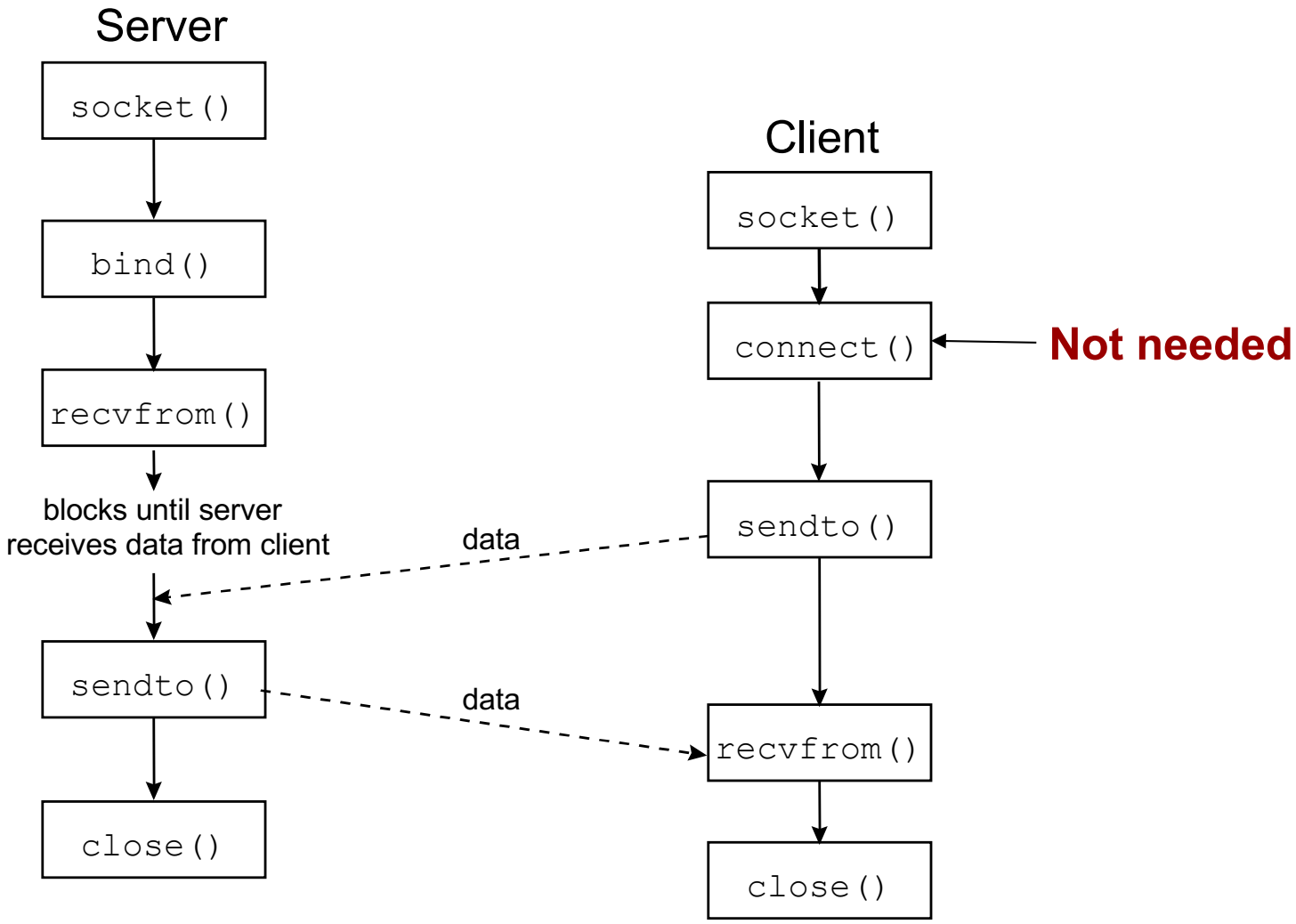




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Figure 2.18

# Suggestions for Labs/Projects

Labs:

Office hour

Email to cs3516-ta@cs.wpi.edu

Discussion forum

Socket Programming Projects:

- Start with the simplest example in the slides

# Code example

# TCP Echo Server

```
#include <stdio.h>          /* for printf() and fprintf() */
#include <sys/socket.h> /* for socket(), bind(), and connect() */
#include <arpa/inet.h>   /* for sockaddr_in and inet_ntoa() */
#include <stdlib.h>       /* for atoi() and exit() */
#include <string.h>       /* for memset() */
#include <unistd.h>      /* for close() */

#define MAXPENDING 5    /* Maximum outstanding connection requests */
void DieWithError(char *errorMessage);  /* Error handling function */
void HandleTCPClient(int clntSocket);   /* TCP client handling function */
```

D&C

```
int main(int argc, char *argv[])
{    int servSock;                  /*Socket descriptor for server */
     int clntSock;                  /* Socket descriptor for client */
     struct sockaddr_in echoServAddr; /* Local address */
     struct sockaddr_in echoClntAddr; /* Client address */
     unsigned short echoServPort;     /* Server port */
     unsigned int clntLen;            /* Length of client address data structure */

     if (argc != 2)     /* Test for correct number of arguments */
    {
          fprintf(stderr, "Usage:  %s <Server Port>\n", argv[0]);
          exit(1);
     }
     echoServPort = atoi(argv[1]);  /* First arg:  local port */

     /* Create socket for incoming connections */
     if ((servSock = socket (PF_INET, SOCK_STREAM, IPPROTO_TCP)) < 0)
          DieWithError("socket() failed");
```

D&C

# TCP Echo Server

```
 /* Construct local address structure */
 memset(&echoServAddr, 0, sizeof(echoServAddr));       /* Zero out structure */
 echoServAddr.sin_family = AF_INET;                    /* Internet address family */
 echoServAddr.sin_addr.s_addr = htonl(INADDR_ANY);     /* Any incoming interface */
 echoServAddr.sin_port = htons(echoServPort);          /* Local port */

 /* Bind to the local address */
if (bind (servSock, (struct sockaddr *) &echoServAddr, sizeof(echoServAddr))<0)
        DieWithError("bind() failed");

 /* Mark the socket so it will listen for incoming connections */
 if (listen (servSock, MAXPENDING) < 0)
        DieWithError("listen() failed");
```

D&C

# TCP Echo Server

```
 for (;;) /* Run forever */
{
    /* Set the size of the in-out parameter */
    clntLen = sizeof(echoClntAddr);        /* Wait for a client to connect */
    if ((clntSock = accept (servSock, (struct sockaddr *) &echoClntAddr, &clntLen)) < 0)
        DieWithError("accept() failed");

    /* clntSock is connected to a client! */
    printf("Handling client %s\n", inet_ntoa(echoClntAddr.sin_addr));
    HandleTCPClient(clntSock);
 }
 /* NOT REACHED */
}
```

D&C

# TCP Echo Client

```
#include <stdio.h>          /* for printf() and fprintf() */
#include <sys/socket.h> /* for socket(), connect(), send(), and recv() */
#include <arpa/inet.h>   /* for sockaddr_in and inet_addr() */
#include <stdlib.h>        /* for atoi() and exit() */
#include <string.h>       /* for memset() */
#include <unistd.h>      /* for close() */

#define RCVBUFSIZE 32   /* Size of receive buffer */

void DieWithError(char *errorMessage);  /* Error handling function */
```

D&C

```
int main(int argc, char *argv[])

{
    int sock;                                   /* Socket descriptor */
    struct sockaddr_in echoServAddr;  /* Echo server address */
    unsigned short echoServPort;        /* Echo server port */
    char *servIP;                               /* Server IP address (dotted quad) */
    char *echoString;                           /* String to send to echo server */
    char echoBuffer[RCVBUFSIZE];  /* Buffer for echo string */
    unsigned int echoStringLen;         /* Length of string to echo */
    int bytesRcvd, totalBytesRcvd;      /* Bytes read in single recv()
                                                    and total bytes read */

    if ((argc < 3) || (argc > 4))    /* Test for correct number of arguments */
    {
      fprintf(stderr, "Usage: %s <Server IP> <Echo Word> [<Echo Port>]\n",
              argv[0]);
      exit(1);
    }
```

D&C

```
servIP = argv[1];           /* First arg: server IP address (dotted quad) */
echoString = argv[2];       /* Second arg: string to echo */

if (argc == 4)
    echoServPort = atoi(argv[3]); /* Use given port, if any */
else
    echoServPort = 7;  /* 7 is the well-known port for the echo service */

/* Create a reliable, stream socket using TCP */
if ((sock = socket (PF_INET, SOCK_STREAM, IPPROTO_TCP)) < 0)
    DieWithError("socket() failed");

/* Construct the server address structure */
memset(&echoServAddr, 0, sizeof(echoServAddr));     /* Zero out structure */
echoServAddr.sin_family      = AF_INET;             /* Internet address family */
echoServAddr.sin_addr.s_addr = inet_addr(servIP);   /* Server IP address */
echoServAddr.sin_port        = htons(echoServPort); /* Server port */
```

D&C

# TCP Echo Client

```
/* Establish the connection to the echo server */
if (connect (sock, (struct sockaddr *) &echoServAddr, sizeof(echoServAddr)) < 0)
        DieWithError("connect() failed");

echoStringLen = strlen(echoString);          /* Determine input length */

/* Send the string to the server */
if (send (sock, echoString, echoStringLen, 0) != echoStringLen)
        DieWithError("send() sent a different number of bytes than expected");

/* Receive the same string back from the server */
totalBytesRcvd = 0;
printf("Received: ");                /* Setup to print the echoed string */
```

D&C

# TCP Echo Client

```
while (totalBytesRcvd < echoStringLen)
{
      /* Receive up to the buffer size (minus 1 to leave space for
                              a null terminator) bytes from the sender */
      if ((bytesRcvd = recv(sock, echoBuffer, RCVBUFSIZE - 1, 0)) <= 0)
       DieWithError("recv() failed or connection closed prematurely");
      totalBytesRcvd += bytesRcvd;   /* Keep tally of total bytes */
      echoBuffer[bytesRcvd] = '\0';  /* Terminate the string! */
      printf("%s", echoBuffer);      /* Print the echo buffer */
}
printf("\n");    /* Print a final linefeed */
close (sock);
exit(0);
}
```

D&C

# BACKUP SLIDES

# The Socket Interface

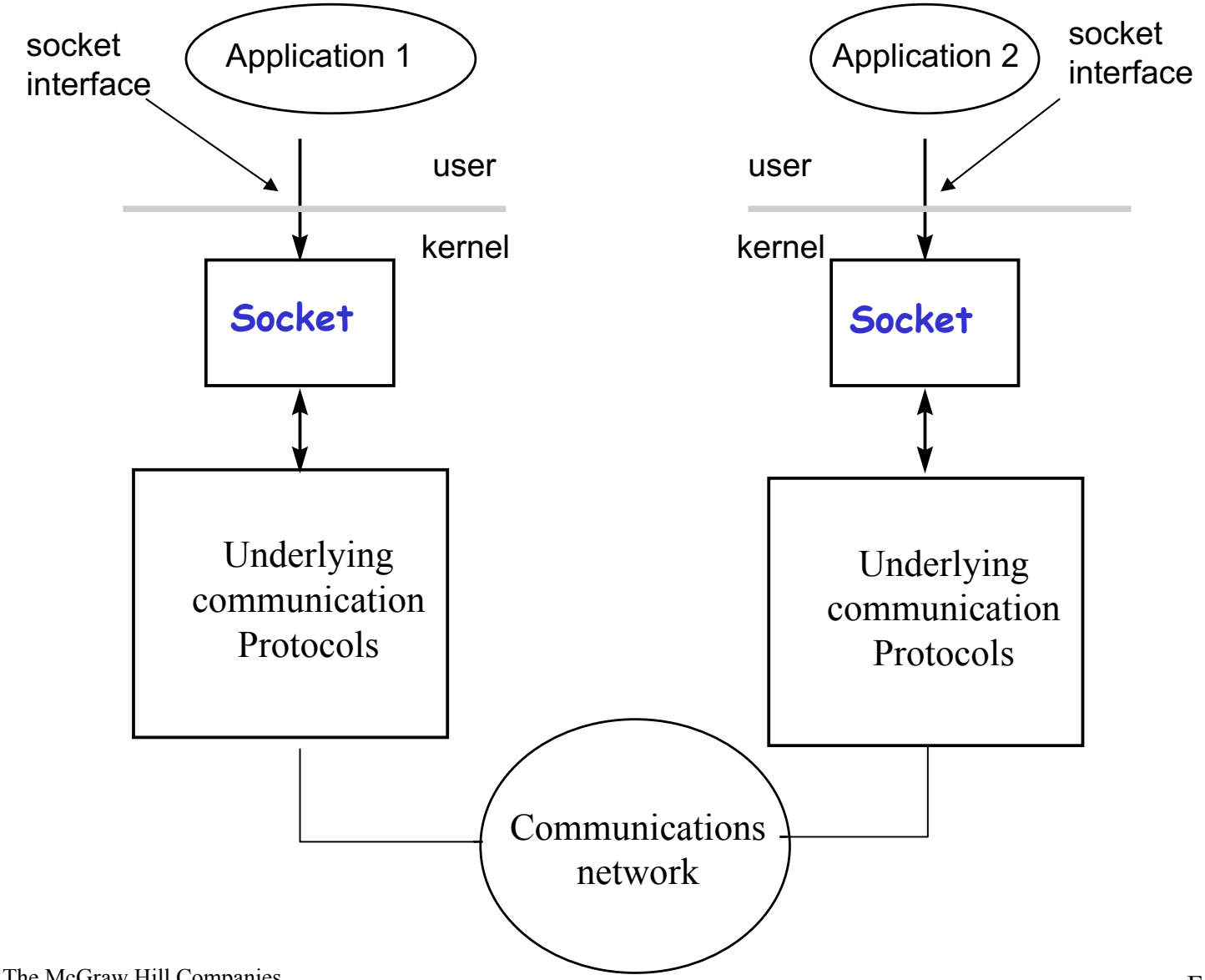






Figure 2.16