

This lecture will be recorded!

Welcome to

CS 3516:
Computer Networks

Prof. Yanhua Li

Time: 9:00am –9:50am M, T, R, and F
Zoom Lecture
Fall 2020 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

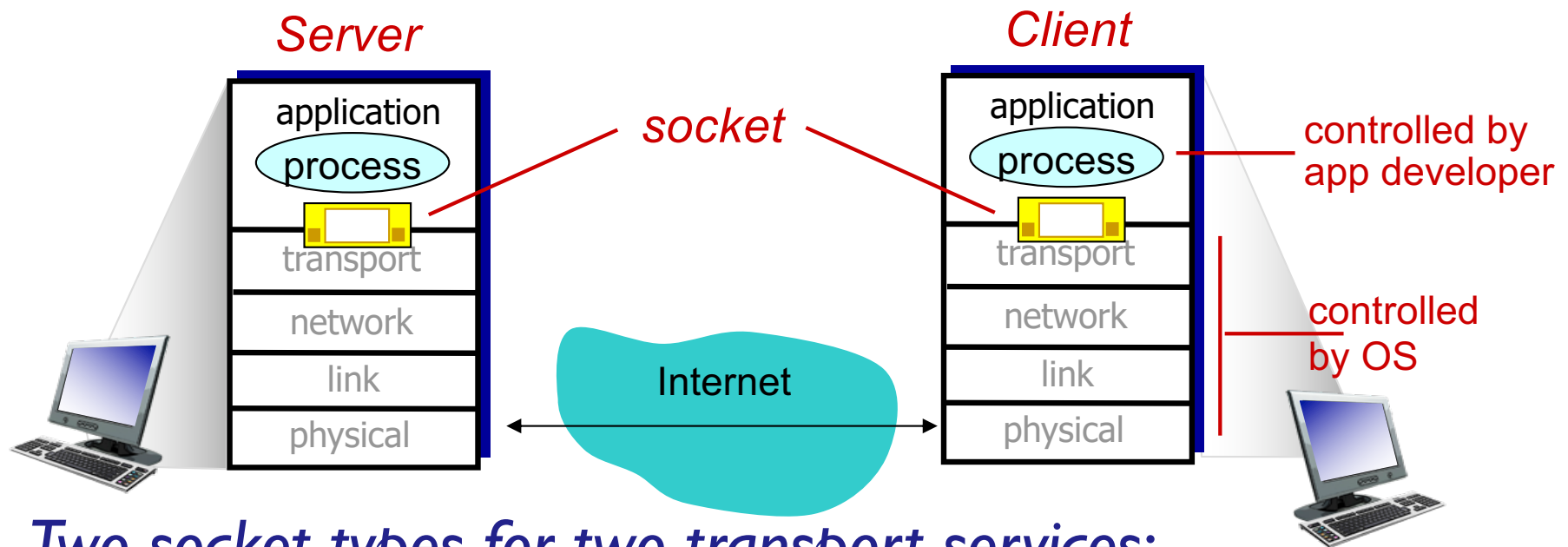
1. Programming project 1 starts today, and is due on 9/17;
2. Lab 1 is due Friday 9/4 (tomorrow).
3. Quiz 1, we will grade it by Friday 9/4.

Socket programming (Project I in C)



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:

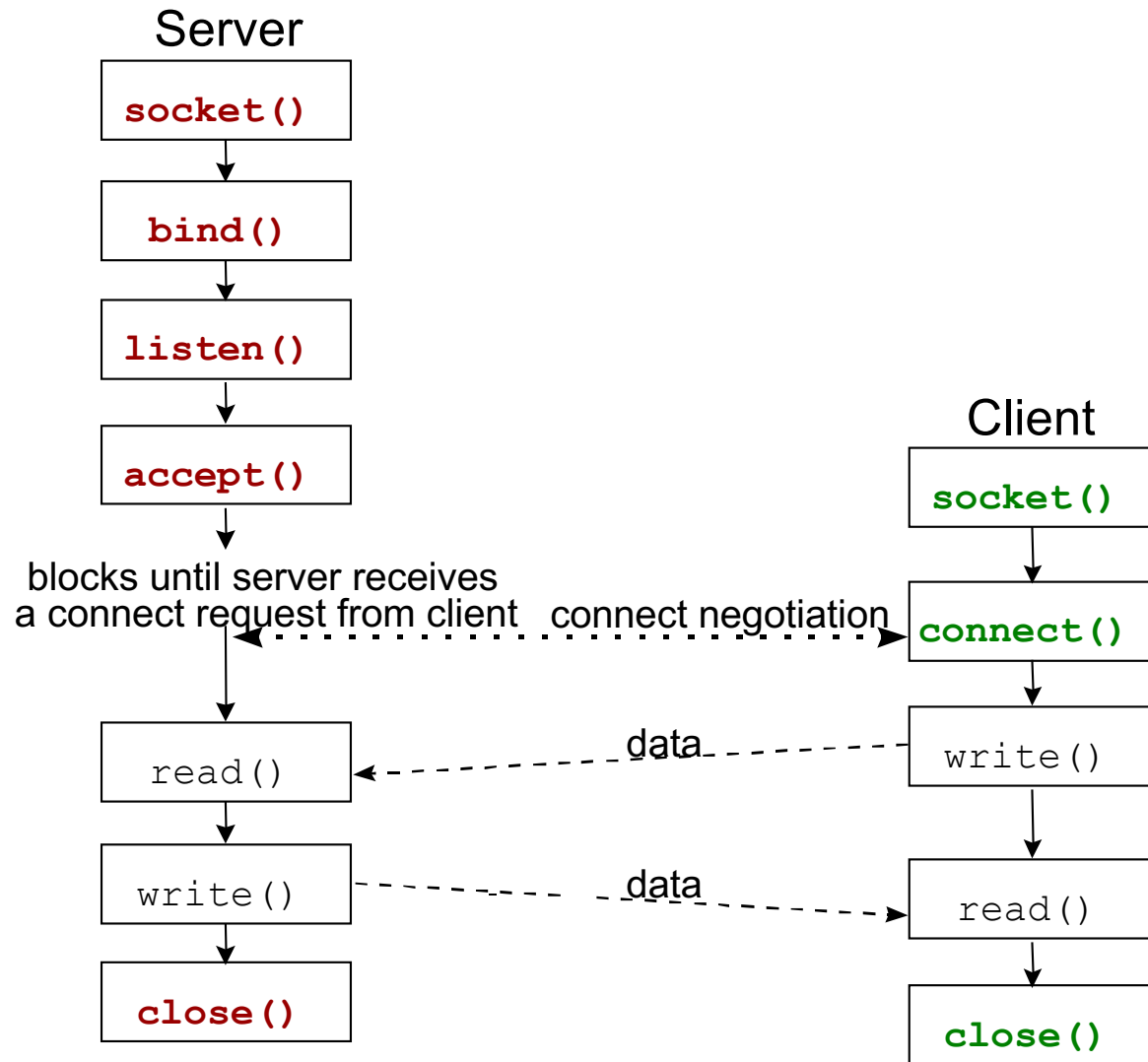
- **UDP:** unreliable datagram
- **TCP:** reliable, byte stream-oriented

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 Bytes) */  
    sa_family_t  sin_family;      /* protocol 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



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 (for Project I)
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SOCK_DGRAM	datagram socket	UDP
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SOCK_RAW	raw socket	
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protocol: set to 0 except for raw sockets

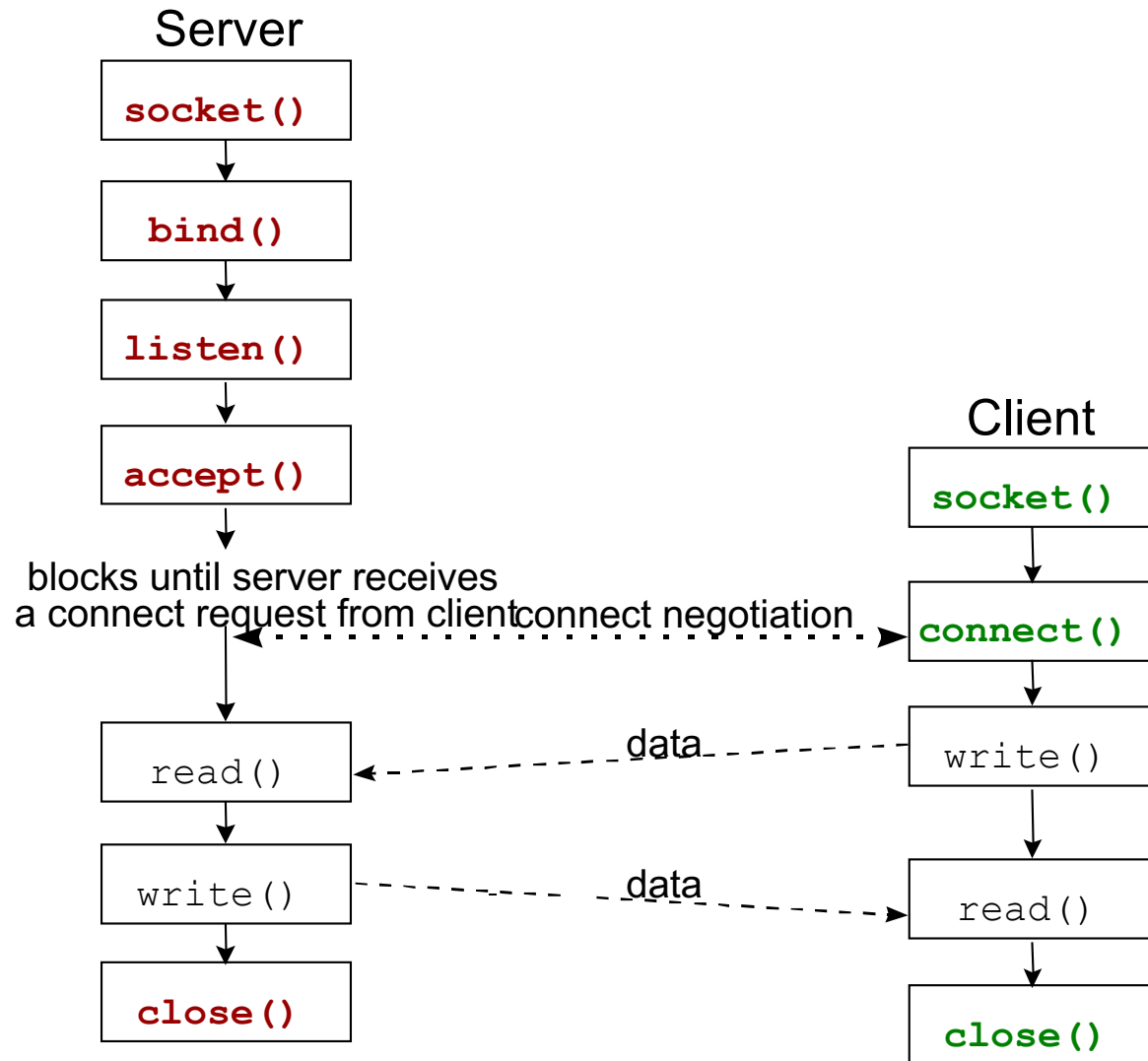
returns on success: **socket descriptor** {a small nonnegative integer}

on error: -1

Example:

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

TCP Socket Calls



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.

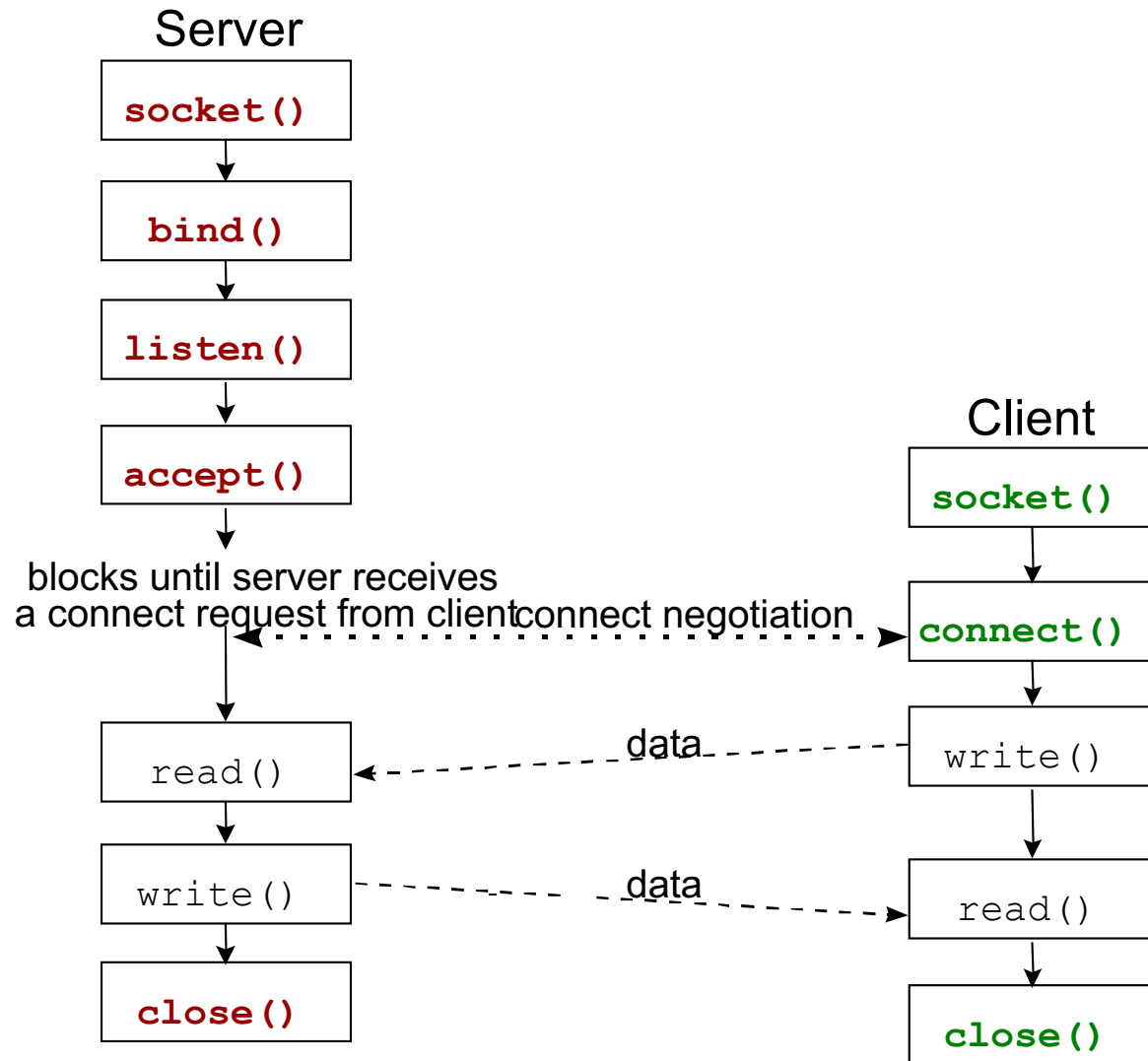
Note – TCP will try to send any data already queued to the other end before the normal connection termination sequence.

Returns **on success:** 0
on error: -1

Example:

```
close (sfd);
```

TCP Socket Calls





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.

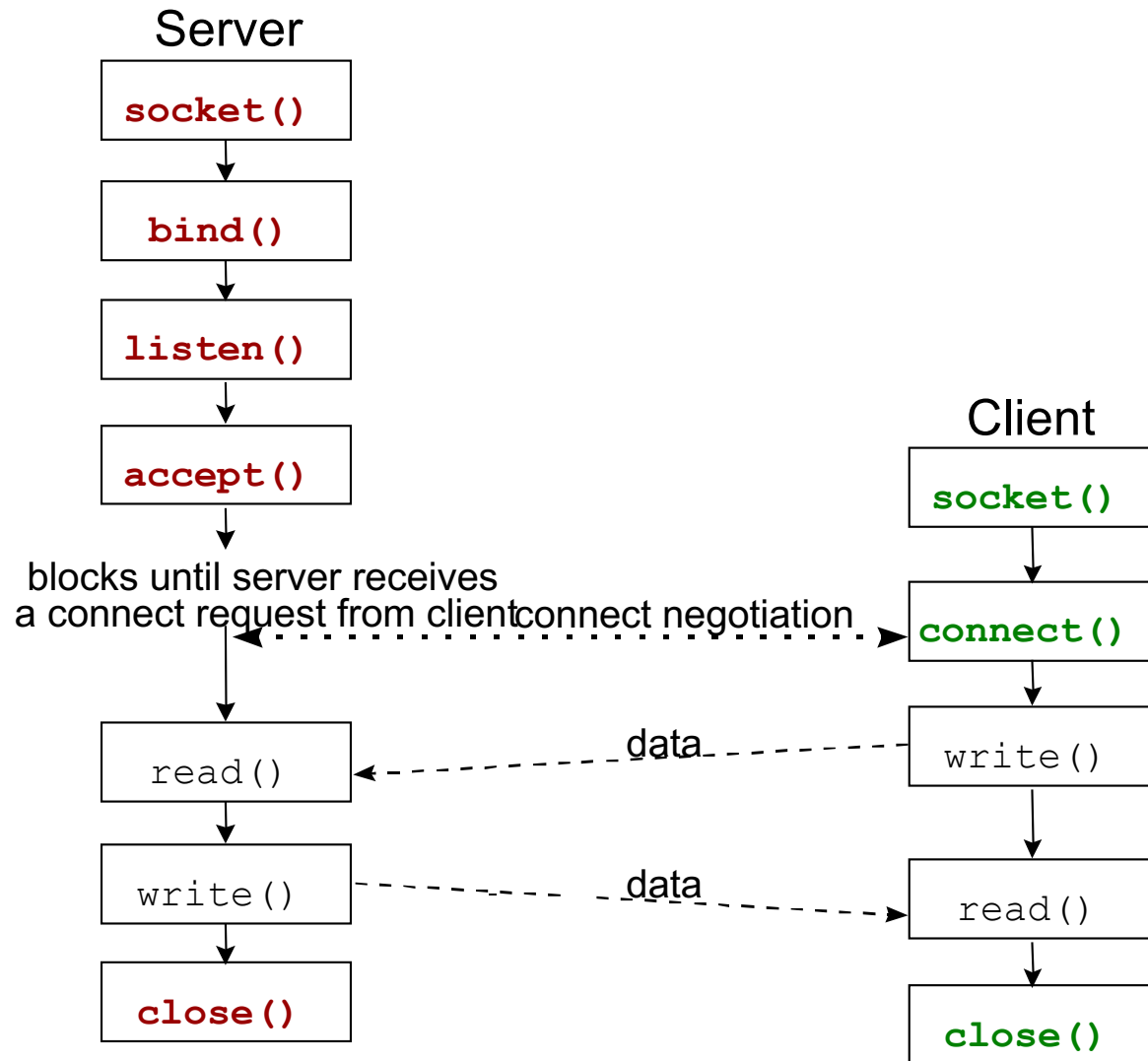
Servers **bind** their “well-known port” when they start.

returns on success: 0
on error: -1

Example:

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

TCP Socket Calls



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.

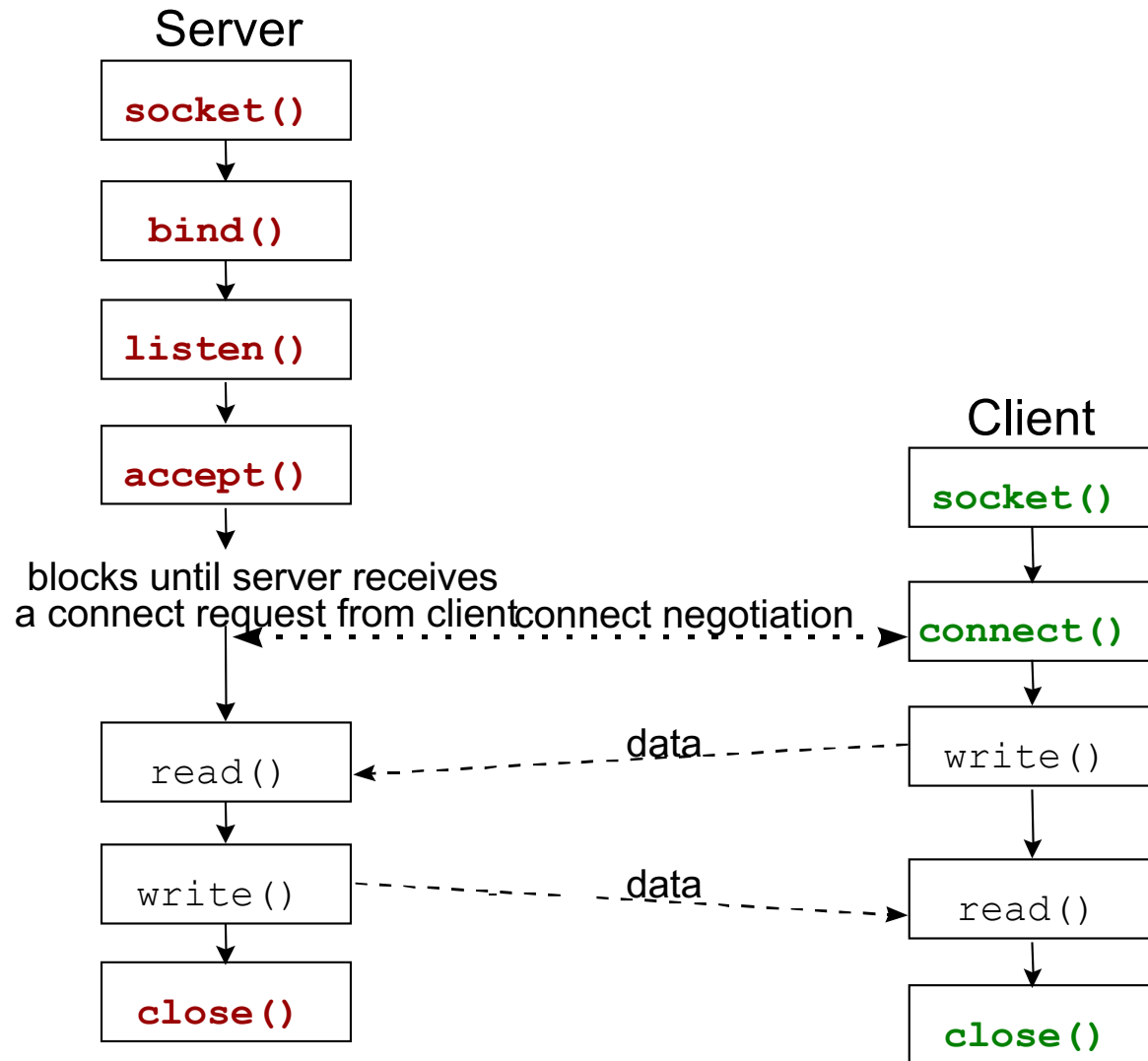
listen is normally called before the **accept** function.

returns on success: 0
on error: -1

Example:

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

TCP Socket Calls



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.

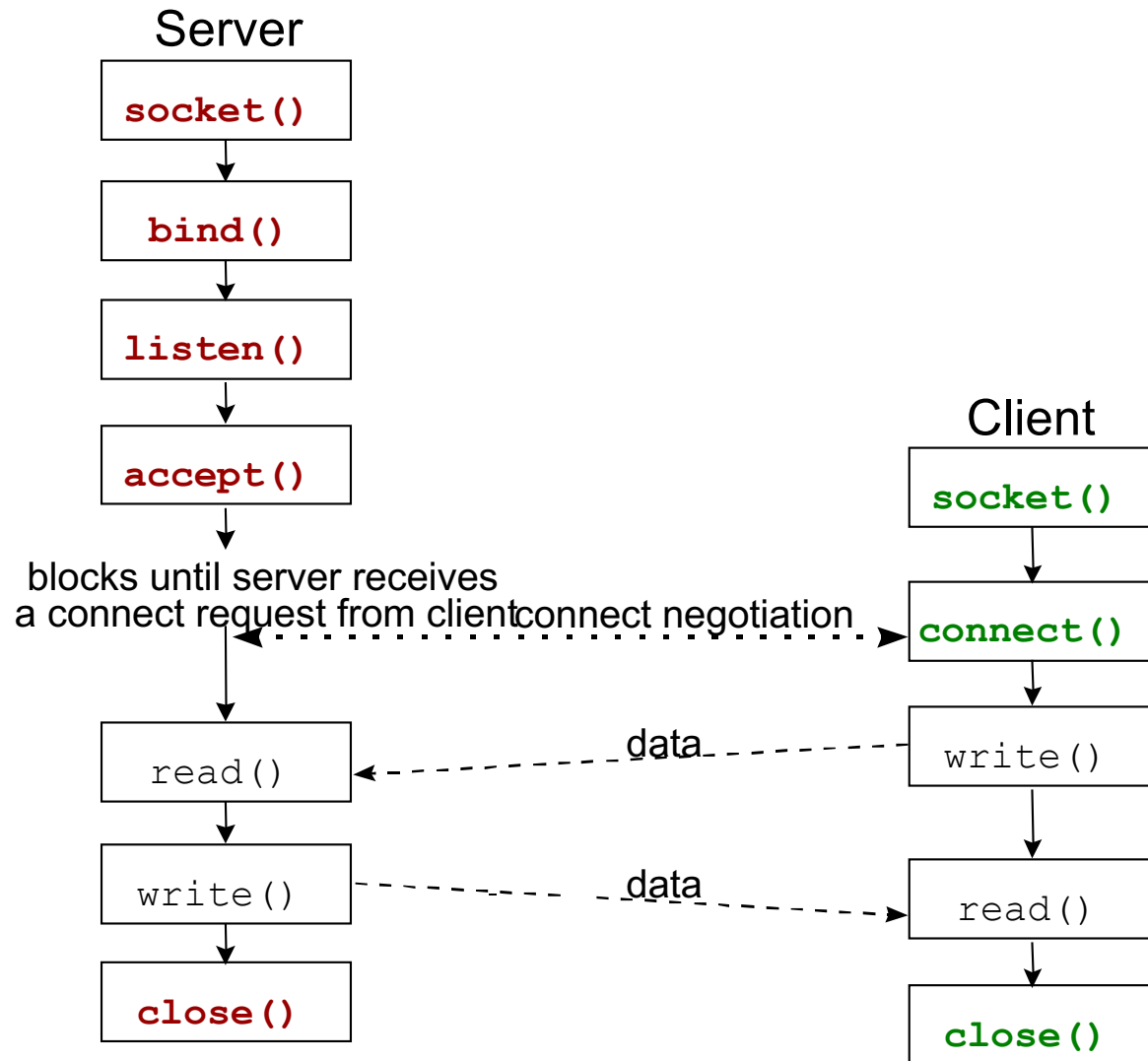
When the server is finished with a client, the connected socket must be closed.

Example:



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


TCP Socket Calls



Suggestions for Labs/Projects

Labs:

Zoom Office hours

Email to Prof Li and TAs

Discussion forum

Piazza

Socket Programming Projects:

- Start with the simplest example (See slides below)
- More resources:

- [Beej's Guide to Network Programming using Internet](#)

[Sockets](#) on class website (Schedule page)

<https://users.wpi.edu/~yli15/courses/CS3516Fall20A/BestPaper.html>

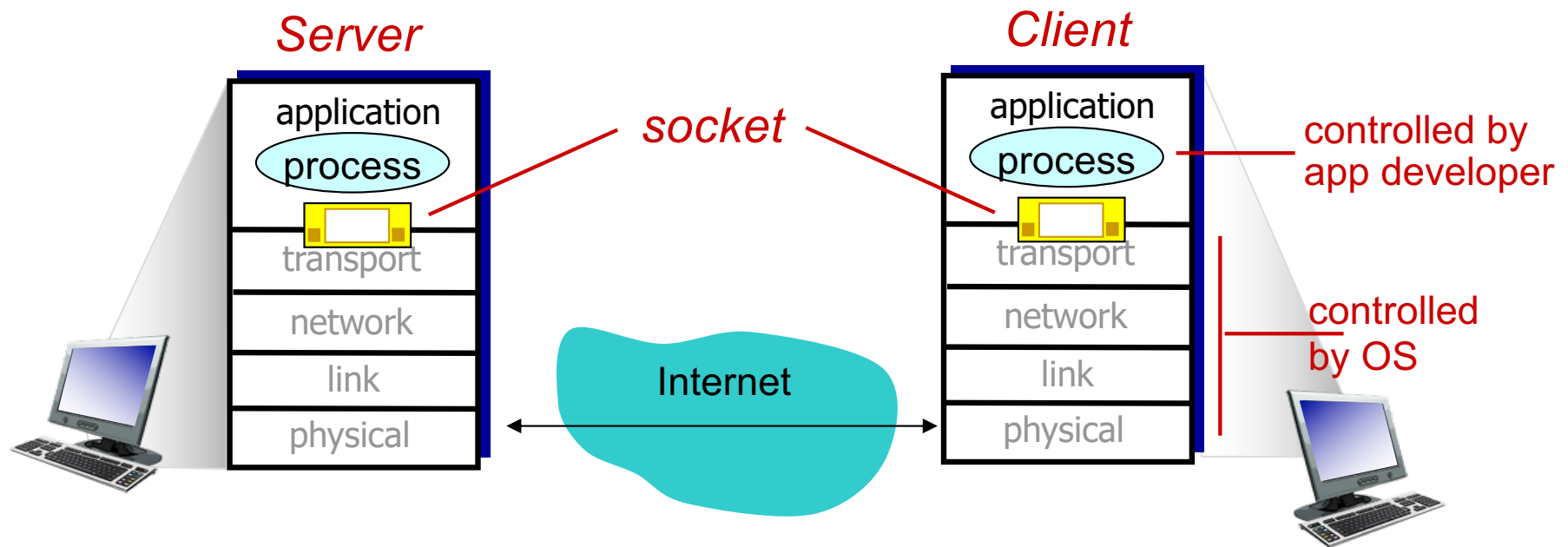
Code example

Echo server



The Client sends a message, e.g., “ABC”

The Server receives a message, and responds simply the same message “ABC” to the client.



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