

ELEMENTARY SOCKETS

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Content

- `socket()`
- UDP Socket APIs
- TCP Socket APIs
- Iterative TCP Server
- Design application protocol

socket ()

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

- Creates an endpoint for communication
- [IN] `domain`: `AF_INET`, `AF_INET6`, or `AF_UNSPEC`, ...
- [IN] `type` argument can be:
 - `SOCK_STREAM`: Provides sequenced, reliable, two-way, connection-based byte streams
 - `SOCK_DGRAM`: Supports datagrams
 - `SOCK_RAW`: Provides raw network protocol access
- [IN] `protocol` is usually 0
- Returns value
 - A new socket descriptor that you can use to do sockety things with
 - If error occurs, return -1 (remember **errno**)

bind()

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

- Associate a socket with an IP address and port number
- Where
 - [IN] `sockfd` : socket descriptor
 - [IN] `addr` : pointer to a `sockaddr` structure assigned to `sockfd`
 - [IN] `addrlen` : specifies the size, in bytes of address structure pointed to by `addr`
- Return value
 - Returns 0 if no error occurs.
 - Otherwise, return -1 (and **errno** will be set accordingly)

shutdown ()

```
#include <sys/socket.h>
int shutdown(int socket, int how);
```

- Shut down socket send and receive operations
- Where
 - [IN] sockfd: a descriptor identifying a socket.
 - [IN] how: SHUT_RD, SHUT_WR, SHUT_RDWR
- Return value
 - Returns 0 if no error occurs.
 - Otherwise, return -1 (and **errno** will be set accordingly)

close()

```
#include <unistd.h>
int close(int sockfd);
```

- Close a socket descriptor
- [IN] `sockfd`: a descriptor identifying a socket.
- Return value
 - Returns 0 if no error occurs.
 - Otherwise, return -1 (and **errno** will be set accordingly)
- `close()` VS `shutdown()`
 - `close()` tries to complete this transmission before closing, frees the socket descriptor
 - `shutdown()`: immediately stops receiving and transmitting data, don't releases the socket descriptor

Socket options

```
#include <sys/socket.h>
int setsockopt (int sockfd, int level, int optname,
               void *optval, int optlen);
```

- Set the options that control the transferring data on a socket
- Parameters:
 - [IN] `sockfd`: refer to an open socket descriptor
 - [IN] `level`: specifies the protocol level at which the option resides
 - [IN] `optname`: specifies a single option to set
 - [IN] `optval`: points to the setted option value
 - [IN] `optlen`: the size of option value pointed by `optval`
- Return:
 - Returns 0 if no error occurs.
 - Otherwise, return -1 (and **errno** will be set accordingly)

Socket options(cont)

```
#include <sys/socket.h>
int getsockopt (int sockfd, int level, int optname,
               void *optval, int *optlen);
```

- Get the options that control the transferring data on a socket
- Parameters:
 - [IN] `sockfd`: refer to an open socket descriptor
 - [IN] `level`: specifies the protocol level at which the option resides
 - [IN] `optname`: specifies a single option to set
 - [OUT] `optval`: points to the setted option value
 - [IN, OUT] `optlen`: the size of option value pointed by `optval`
- Return:
 - Returns 0 if no error occurs.
 - Otherwise, return -1 (and **errno** will be set accordingly)

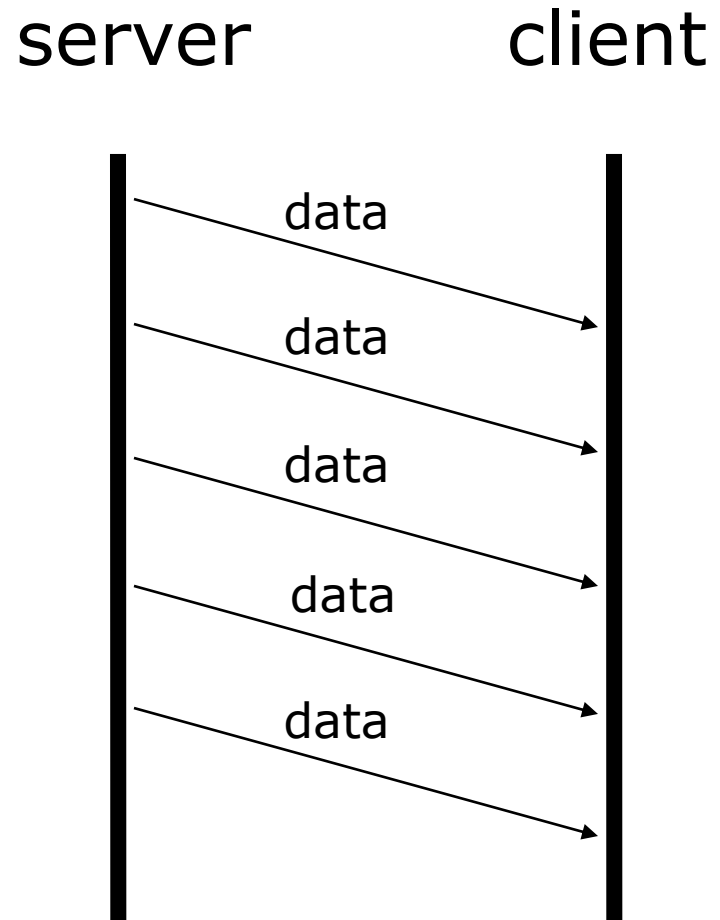
level = SOL_SOCKET

Value name	Type	Description
SO_BROADCAST	int	Configures a socket for sending broadcast data.(Only UDP socket)
SO_DONTROUTE	int	Sets whether outgoing data should be sent on interface the socket is bound to and not a routed on some other interface
SO_KEEPALIVE	int	TCP automatically sends a keep-alive probe to the peer
SO_LINGER	linger	specifies how the close function operates for a connection-oriented protocol
SO_REUSEADDR	int	Allows the socket to be bound to an address that is already in use
SO_RCVTIMEO	timeval	Sets the timeout for blocking receive calls
SO_SNDTIMEO	timeval	Sets the timeout for blocking send calls

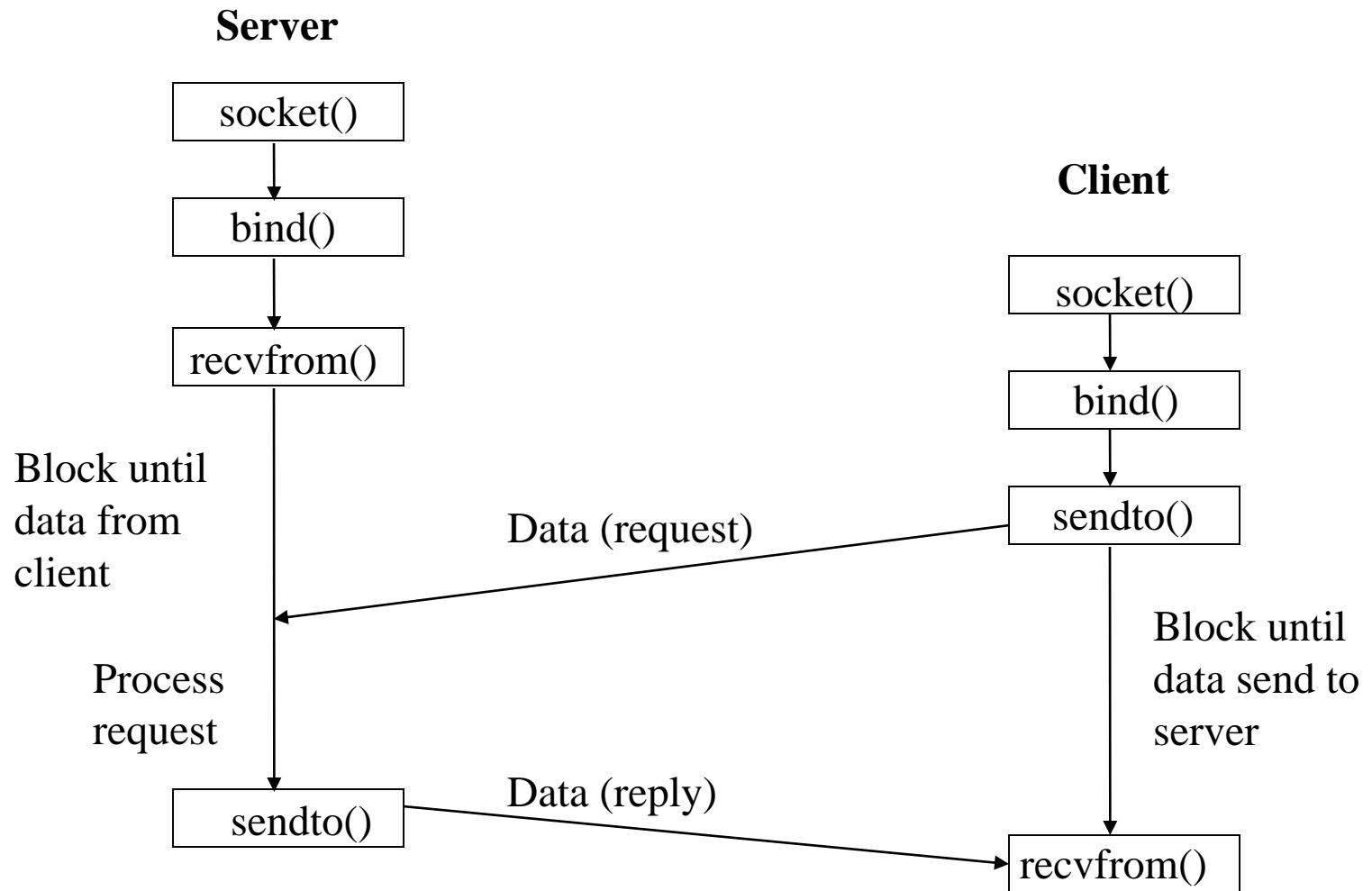
UDP SOCKET

UDP (User Datagram Protocol)

- No reliable
- No flow control
- Familiar example
 - DNS
 - Streaming
- Image
 - Postcard exchange



UDP client/server



recvfrom()

```
ssize_t recvfrom(int sockfd, void *buf, size_t len,  
int flags, struct sockaddr *from, socklen_t *fromlen );
```

- Received data from a socket
- Parameters:
 - [IN] `sockfd`: the socket file descriptor
 - [OUT] `buf`: the buffer where the message should be stored
 - [IN] `len`: the size of the buffer
 - [IN] `flags`: how to control `recvfrom` function work
 - [OUT] `from`: the address of the sender
 - [OUT] `fromlen`: the size of sender's address
- Return:
 - Success: return the length of the received data in bytes. If the incoming message is too long to fit in the supplied buffer, the excess bytes shall be discarded.
 - Error: `-1` and set **`errno`** to indicate the error.

recvfrom() - Flags

- MSG_PEEK: Peeks at an incoming message. The data is treated as unread and the next *recvfrom()* or similar function shall still return this data.
- MSG_OOB: Requests out-of-band data. The significance and semantics of out-of-band data are protocol-specific.
- MSG_WAITALL: On SOCK_STREAM sockets this requests that the function block until the full amount of data can be returned, excepting:
 - the connection is terminated
 - MSG_PEEK was specified
 - an error is pending for the socket
 - a signal is caught
- Use bitwise OR operator (|) to combine more than one flag

sendto ()

```
ssize_t sendto(int sockfd, void *buf, size_t len, int flags,  
               struct sockaddr *to, socklen_t *tolen );
```

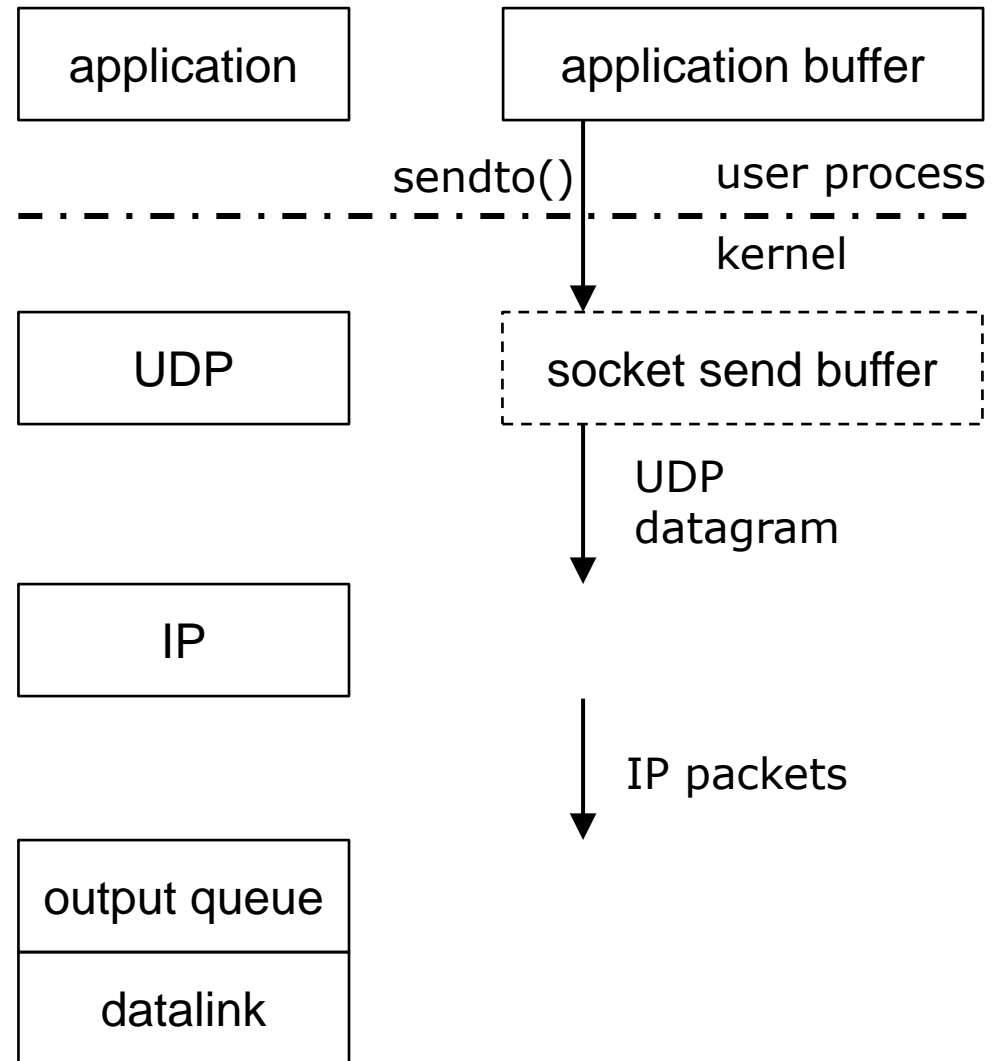
- Sends data on the socket
- Parameters:
 - [IN] `sockfd`: the socket file descriptor
 - [IN] `buf`: points to a buffer containing the message to be sent
 - [IN] `len`: the size of the message
 - [IN] `flags`: how to control `sendto` function work
 - [IN] `to`: the address of the receiver
 - [IN] `tolen`: the length of the `sockaddr` structure pointed to by the `to` argument
- Return:
 - Success: shall return the length of the sent message in bytes
 - Error: `-1` and set **`errno`** to indicate the error.

sendto () - Flags

- MSG_OOB: Sends out-of-band data on sockets that support out-of-band data.
- MSG_DONTROUTE: Don't use a gateway to send out the packet, only send to hosts on directly connected networks
- Use bitwise OR operator (|) to combine more than one flag

sendto()

- UDP socket buffer doesn't really exist
- UDP socket buffer has a send buffer size
- If an application writes a datagram larger than the socket send buffer size, EMSGSIZE is returned



Example

- A simple UDP client and server
 - Server receives data from client
 - Server sends back data to client
 - It present in udpserv01.c and dg_echo.c



Example – UDP Echo Server

```
int sockfd, rcvBytes, sendBytes;
socklen_t len;
char buff[BUFF_SIZE+1];
struct sockaddr_in servaddr, cliaddr;

//Step 1: Construct socket
if((sockfd = socket(AF_INET, SOCK_DGRAM, 0)) < 0){
    perror("Error: ");
    return 0;
}

//Step 2: Bind address to socket
bzero(&servaddr, sizeof(servaddr));
servaddr.sin_family = AF_INET;
servaddr.sin_addr.s_addr = htonl(INADDR_ANY);
servaddr.sin_port = htons(SERV_PORT);
if(bind(sockfd, (struct sockaddr *) &servaddr, sizeof(servaddr))){
    perror("Error: ");
    return 0;
}

printf("Server started.");
```

Example – UDP Echo Server(cont)

```
//Step 3: Communicate with client
for ( ; ; ) {
    len = sizeof(cliaddr);
    rcvBytes = recvfrom(sockfd, buff, BUFF_SIZE, 0,
                        (struct sockaddr *) &cliaddr, &len);

    if(rcvBytes < 0){
        perror("Error: ");
        return 0;
    }
    buff[rcvBytes] = '\0';
    printf("[%s:%d]: %s", inet_ntoa(cliaddr.sin_addr),
            ntohs(cliaddr.sin_port), mesg);

    sendBytes = sendto(sockfd, buff, rcvBytes, 0,
                       (struct sockaddr *) &cliaddr, len);

    if(sendBytes < 0){
        perror("Error: ");
        return 0;
    }
}
```

Example – UDP Echo Client

```
int sockfd, rcvBytes, sendBytes;
socklen_t len;
char buff[BUFF_SIZE+1];
struct sockaddr_in servaddr;

//Step 1: Construct socket
if((sockfd = socket(AF_INET, SOCK_DGRAM, 0)) < 0){
    perror("Error: ");
    return 0;
}

//Step 2: Define the address of the server
bzero(&servaddr, sizeof(servaddr));
servaddr.sin_family = AF_INET;
servaddr.sin_addr = inet_aton(SERV_ADDR, &servaddr.sin_addr);
servaddr.sin_port = htons(SERV_PORT);
```

Example – UDP Echo Client(cont)

```
//Step 3: Communicate with server
printf("Send to server: ");
gets_s(buff, BUFF_SIZE);

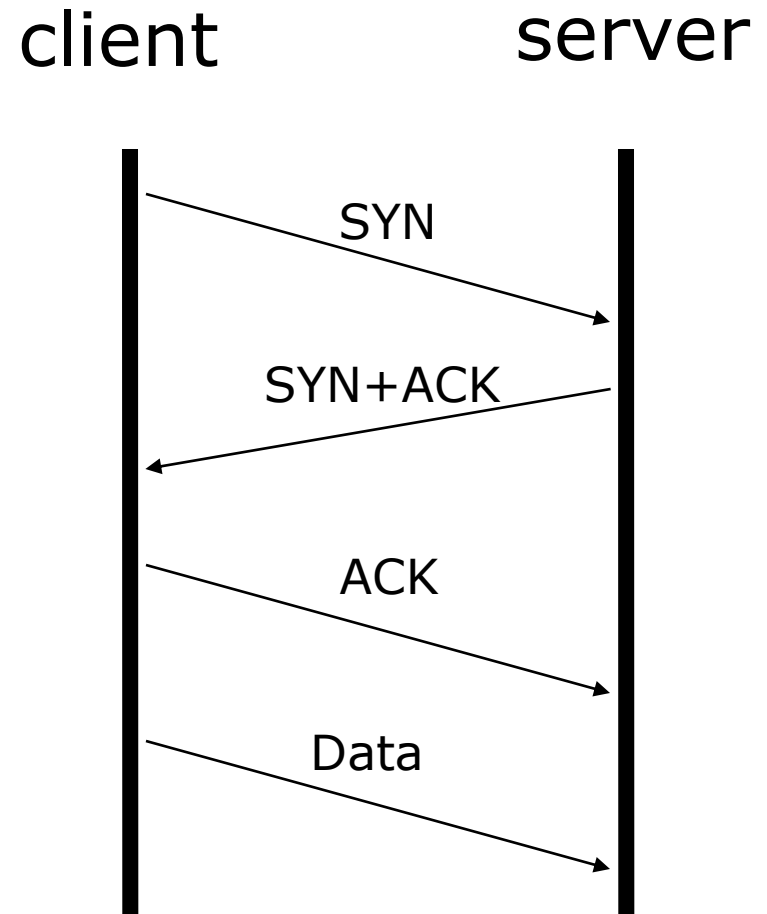
len = sizeof(servaddr);
sendBytes = sendto(sockfd, buff, strlen(buff), 0,
                  (struct sockaddr *) &seraddr, len);
if(sendBytes < 0){
    perror("Error: ");
    return 0;
}

rcvBytes = recvfrom(sockfd, buff, BUFF_SIZE, 0,
                   (struct sockaddr *) &seraddr, &len);
if(rcvBytes < 0){
    perror("Error: ");
    return 0;
}
buff[rcvBytes] = '\0';
printf("Reply from server: %s", buff);
```

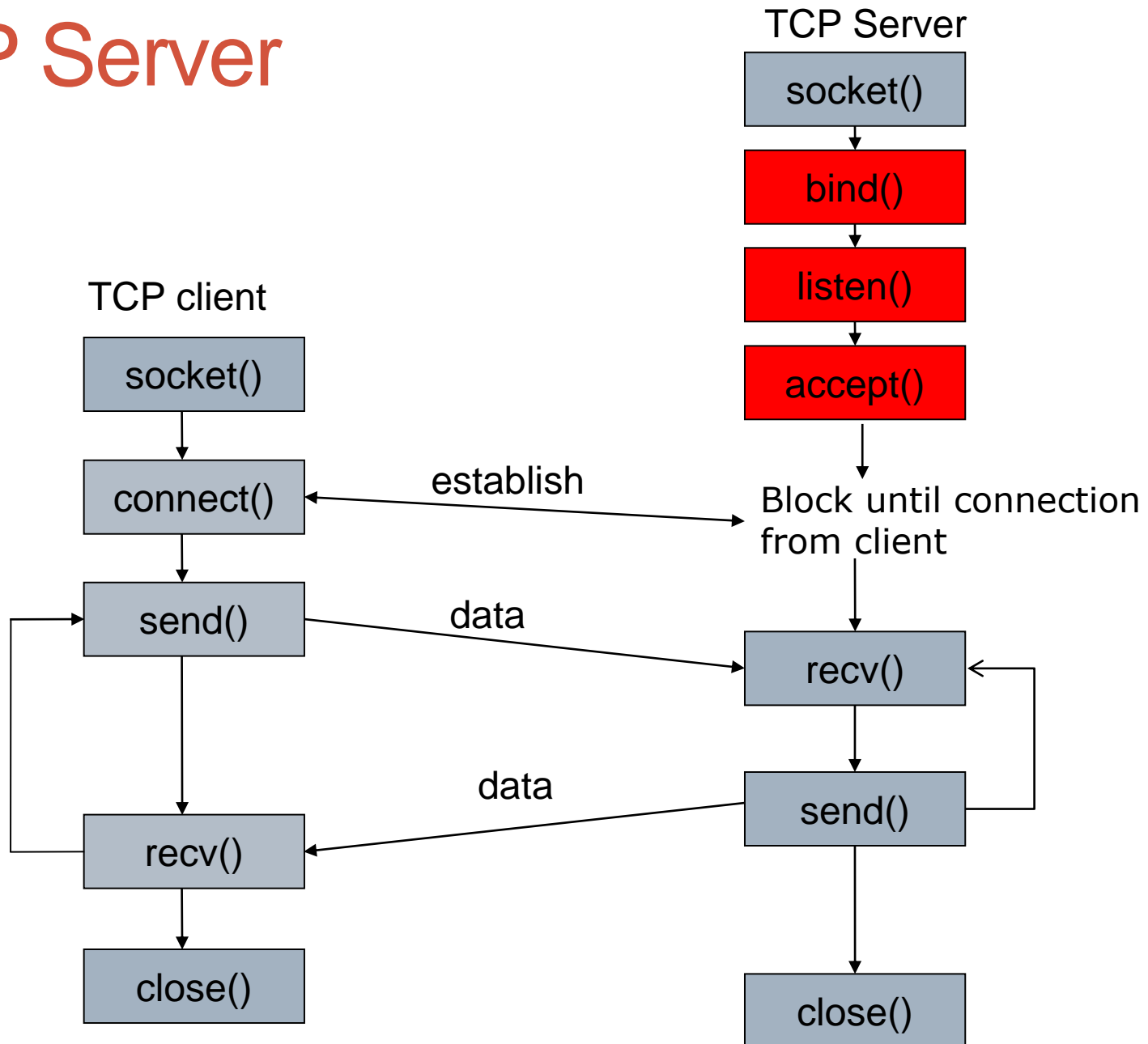
TCP SOCKET

TCP (Transmission Control Protocol)


- Provide reliable communication
- Data rate control
- Example
 - Mail
 - WEB
 - Image



TCP Server



TCP server side

1. Create a socket – `socket()`.
 2. Bind the socket – `bind()`.
 3. Listen on the socket – `listen()`.
 4. Accept a connection – `accept()`.
 5. Send and receive data – `recv()`, `send()`.
 6. Disconnect connection– `close()`
 7. Close LISTENING socket
- 
- repeatedly

listen()

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

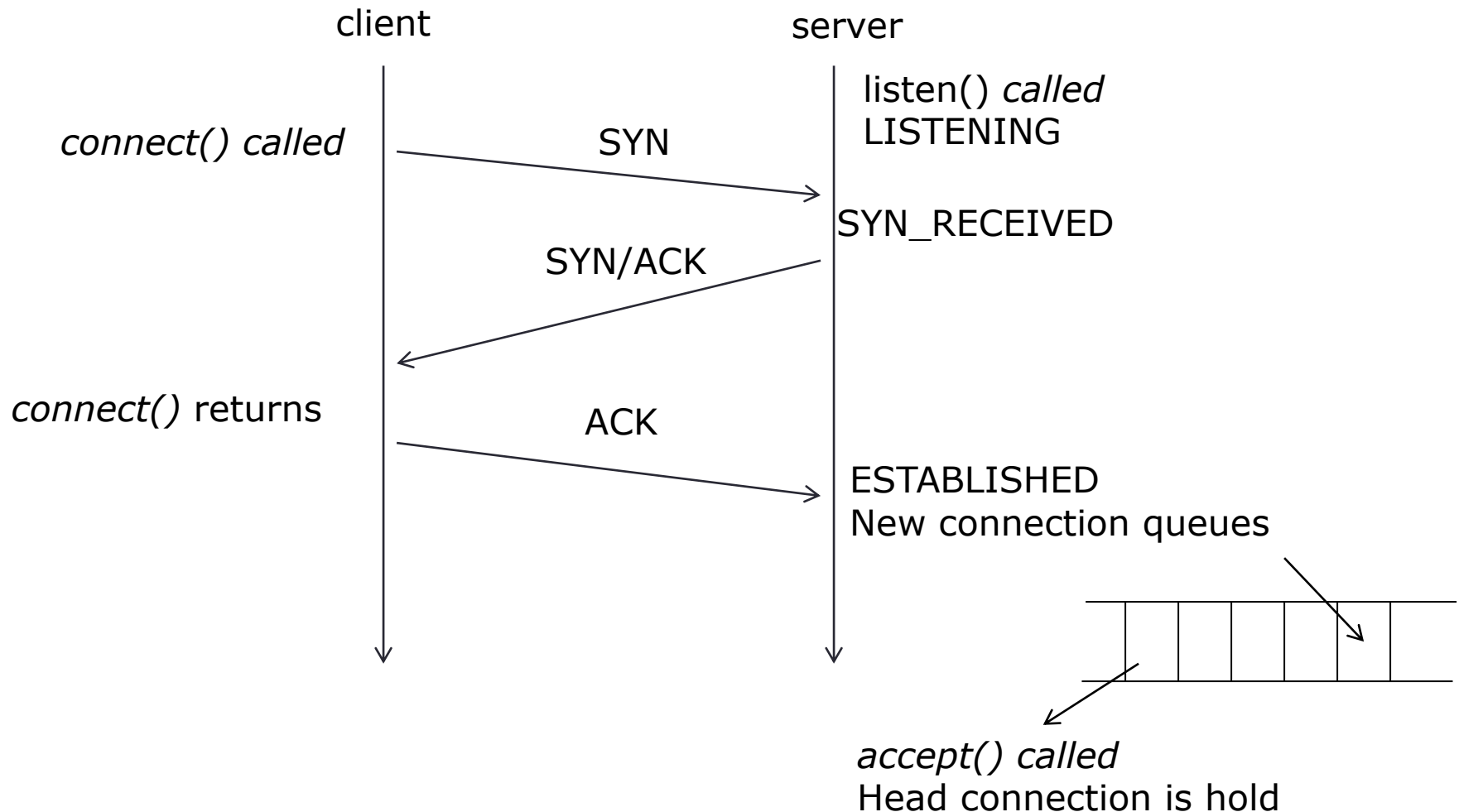
- Establish a socket to LISTENING for incoming connection.
- Parameters:
 - [IN] `sockfd`: a descriptor identifying a bound, unconnected socket
 - [IN] `backlog`: the queue length for *completely* established sockets waiting to be accepted
- Return value
 - On success, 0 is returned
 - On error, -1 is returned, and `errno` is set appropriately

accept()

```
#include <sys/types.h>
#include <sys/socket.h>
int accept(int sockfd, struct sockaddr *addr, socklen_t *addrlen);
```

- Accept an incoming connection on a LISTENING socket
- Parameters:
 - [IN] `sockfd`: A descriptor identifying a socket which is listening for connections after a `listen()`.
 - [OUT] `addr`: pointer to a `sockaddr` structure filled in with the address of the peer socket
 - [IN, OUT] `addrlen`: the caller must initialize it to contain the size (in bytes) of the structure pointed to by `addr`; on return it will contain the actual size of the peer address.
- Return value
 - Newly connected socket descriptor if no errors
 - -1 if has errors

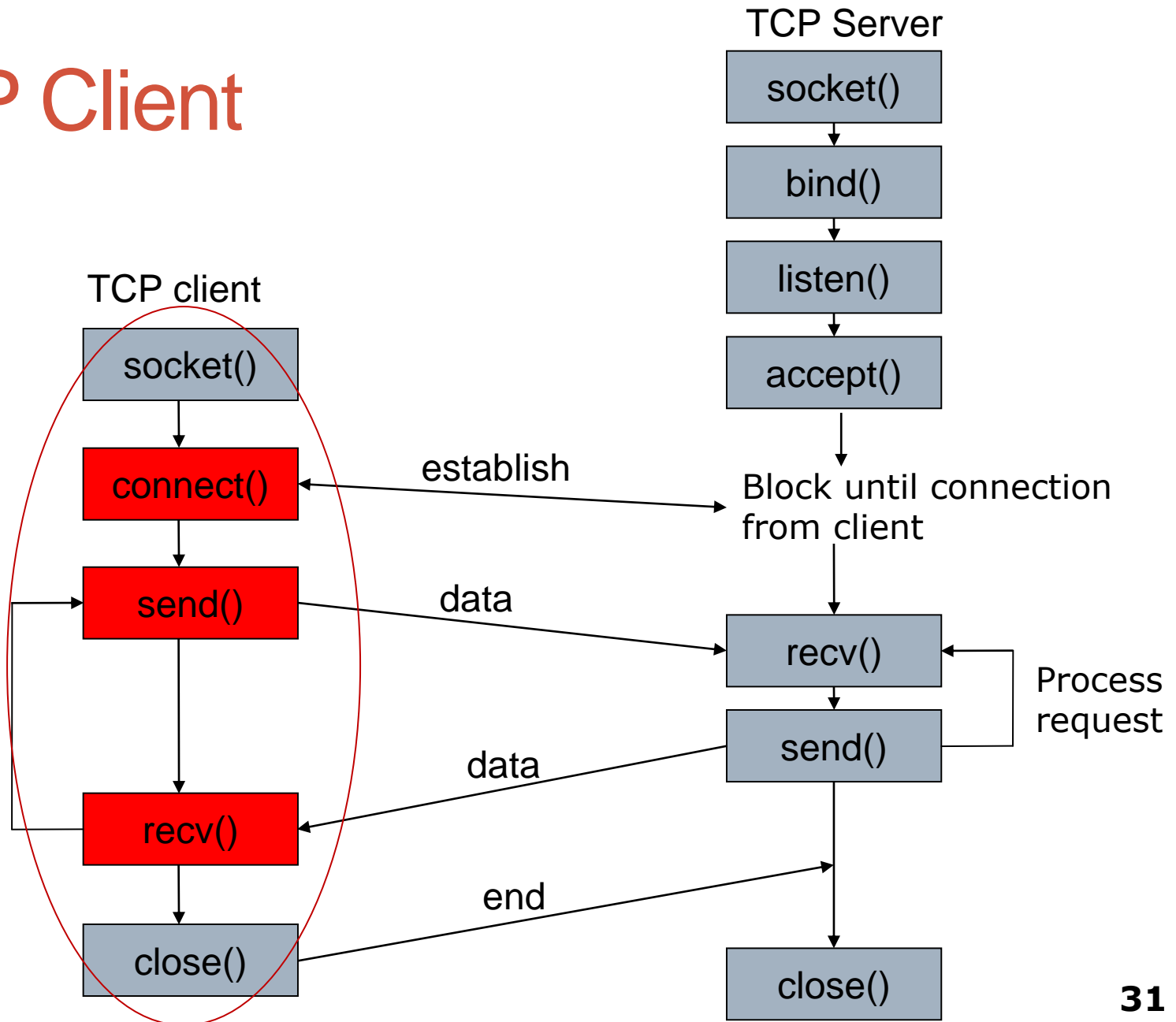
Process connections



Socket Mode

- Types of server sockets
 - *Iterating server*. Only one socket is opened at a time.
 - *Concurrent server*. After an accept, a child process/thread is spawned to handle the connection.
 - *Multiplexing server*. use select to simultaneously wait on all open socketIds, and waking up the process only when new data arrives

TCP Client



TCP client side

- The typical TCP client's communication involves four basic steps:
 - Create a TCP socket using `socket()`.
 - Establish a connection to the server using `connect()`.
 - Communicate using `send()` and `recv()`.
 - Close the connection with `close()`.
- Why “clients” doesn't need `bind()` ?

connect ()

```
#include <sys/types.h>
#include <sys/socket.h>
int connect(int sockfd, const struct sockaddr *serv_addr,
            socklen_t addrlen);
```

- Connect a socket to a server
- Parameters:
 - [IN] sockfd: A descriptor identifying an unconnected socket.
 - [IN] serv_addr: The address of the server to which the socket is to be connected.
 - [IN] addrlen: The length of the name.
- Return value
 - If no error occurs, returns 0.
 - Otherwise, it returns -1

send()

```
#include <sys/types.h>
#include <sys/socket.h>
ssize_t send(int sockfd, const void *buf, size_t len,
             int flags);
```

- Send data on a connected socket
- Parameter:
 - [IN] `sockfd`: a descriptor identifying a connected socket.
 - [IN] `buf`: points to the buffer containing the message to send.
 - [IN] `len`: specifies the length of the message
 - [IN] `flags`: specifies the type of message transmission, usually 0
- Return value:
 - If no error occurs, `send()` returns the total number of characters sent
 - Otherwise, return -1

send () - Flags

- `MSG_OOB`: Send as “out of band” data. The receiver will receive the signal `SIGURG` and it can then receive this data without first receiving all the rest of the normal data in the queue.
- `MSG_DONTROUTE`: Don't send this data over a router, just keep it local.
- `MSG_DONTWAIT`: If **`send()`** would block because outbound traffic is clogged, have it return `EAGAIN`. This is like a “enable non-blocking just for this send.”
- `MSG_NOSIGNAL`: If you **`send()`** to a remote host which is no longer **`recv()`**, you'll typically get the signal `SIGPIPE`. Adding this flag prevents that signal from being raised.

send () – Data size is greater buffer's

```
char sendBuff[2048];
int  dataLength, nLeft, idx;

// Fill sendbuff with 2048 bytes of data
nLeft = dataLength;
idx = 0;

while (nLeft > 0){
    // Assume s is a valid, connected stream socket
    ret = send(s, &sendBuff[idx], nLeft, 0);
    if (ret == -1)
    {
        // Error handler
    }
    nLeft -= ret;
    idx += ret;
}
```

recv()

```
#include <sys/types.h>
#include <sys/socket.h>
ssize_t recv(int sockfd, void *buf, size_t len, int flags);
```

- Receive data on a socket
- Parameter:
 - [IN] `sockfd`: a descriptor identifying a connected socket.
 - [IN, OUT] `buf`: points to a buffer where the message should be stored
 - [IN] `len`: specifies the length in bytes of the buffer
 - [IN] `flags`: specifies the type of message reception, usually 0
- Return value:
 - If no error occurs, returns the length of received message in bytes
 - If peer has performed an orderly shutdown, return 0
 - Otherwise, return -1

recv() - Flags

- MSG_PEEK: Peeks at an incoming message. The data is treated as unread and the next *recvfrom()* or similar function shall still return this data.
- MSG_OOB: Requests out-of-band data. The significance and semantics of out-of-band data are protocol-specific.
- MSG_WAITALL: On SOCK_STREAM sockets this requests that the function block until the full amount of data can be returned, excepting:
 - the connection is terminated
 - MSG_PEEK was specified
 - an error is pending for the socket
 - a signal is caught
- Use bitwise OR operator (|) to combine more than one flag

Example – TCP Echo Server

```
int listenfd, connfd;
char buff[BUFF_SIZE+1];
struct sockaddr_in servAddr;

//Step 1: Construct socket
listenfd = socket(AF_INET, SOCK_STREAM, 0);

//Step 2: Bind address to socket
bzero(&servaddr, sizeof(servaddr));
servaddr.sin_family = AF_INET;
servaddr.sin_addr.s_addr = htonl(INADDR_ANY);
servaddr.sin_port = htons(SERV_PORT);
if(bind(listenfd, (struct sockaddr *) &servAddr,
        sizeof(servAddr))) {
    perror("Error: ");
    return 0;
}
```

Example – TCP Echo Server(cont)

```
//Step 3: Listen request from client
if(listen(listenfd, 10)){
    perror("Error! Cannot listen.");
    return 0;
}
printf("Server started!");

//Step 4: Communicate with client
sockaddr_in clientAddr;
int rcvBytes, sendBytes, clientAddrLen = sizeof(clientAddr);
while(1){
    //accept request
    connfd = accept(listenfd, (sockaddr *) & clientAddr,
                    &clientAddrLen);
```


Example – TCP Echo Server(cont)

```
//receive message from client
rcvBytes = recv(connfd, buff, BUFF_SIZE, 0);
if(rcvBytes < 0){
    perror("Error :");
}
else{
    buff[rcvBytes] = '\\0';
    printf("Receive from client[%s:%d] %s\\n",
           inet_ntoa(clientAddr.sin_addr),
           ntohs(clientAddr.sin_port), buff);
    //Echo to client
    sendBytes = send(connfd, buff, strlen(buff), 0);
    if(sendBytes < 0)
        perror("Error: ",);
}
closesocket(connfd);
} //end while
```

Example – TCP Echo Client

```
int clientfd;
char buff[BUFF_SIZE+1];
struct sockaddr_in servaddr;

//Step 1: Construct socket
clientfd = socket(AF_INET, SOCK_STREAM, 0);

//Step 2: Specify server's address
bzero(&servaddr, sizeof(servaddr));
servaddr.sin_family = AF_INET;
servaddr.sin_addr.s_addr = htonl(SERV_ADDR);
servaddr.sin_port = htons(SERV_PORT);

//Step 4: Connect server
if(connect(clientfd, (sockaddr *) &serverAddr,
           sizeof(serverAddr))) {
    perror("Error: ");
    return 0;
}
```

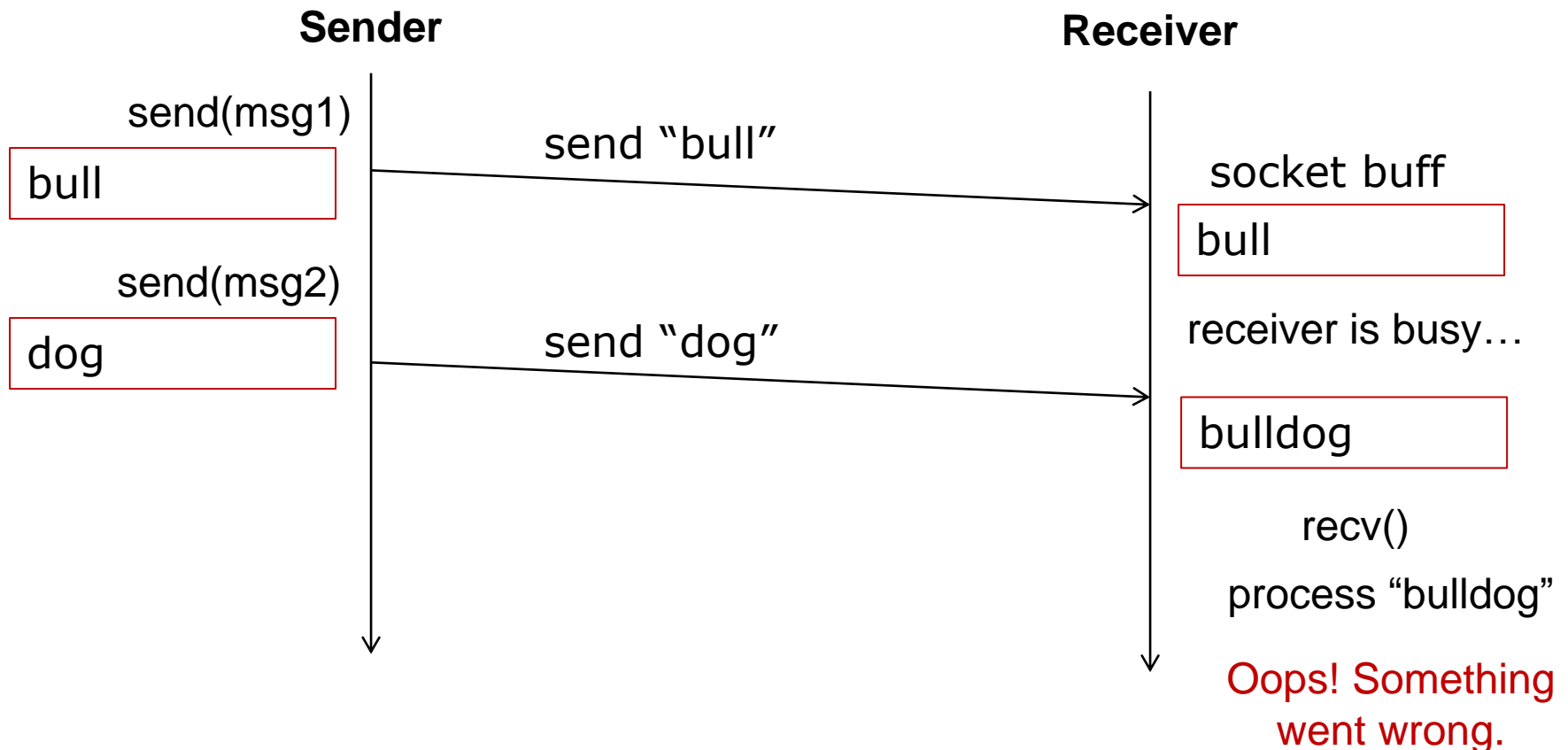
Example – TCP Echo Client(cont)

```
//Step 5: Communicate with server
char buff[BUFF_SIZE];
int ret;
//Send message
printf("Send to server: ");
gets_s(buff, BUFF_SIZE);
ret = send(clientfd, buff, strlen(buff), 0);
if(ret < 0){
    perror("Error: ");
    return 0;
}
//Receive echo message
ret = recv(clientfd, buff, BUFF_SIZE, 0);
if(ret < 0){
    perror("Error: ");
    return 0;
}
printf("Receive from server: %s\n", buff);
close(clientfd);
return 0;
```

Byte stream problem

TCP does not operate on *packets* of data.

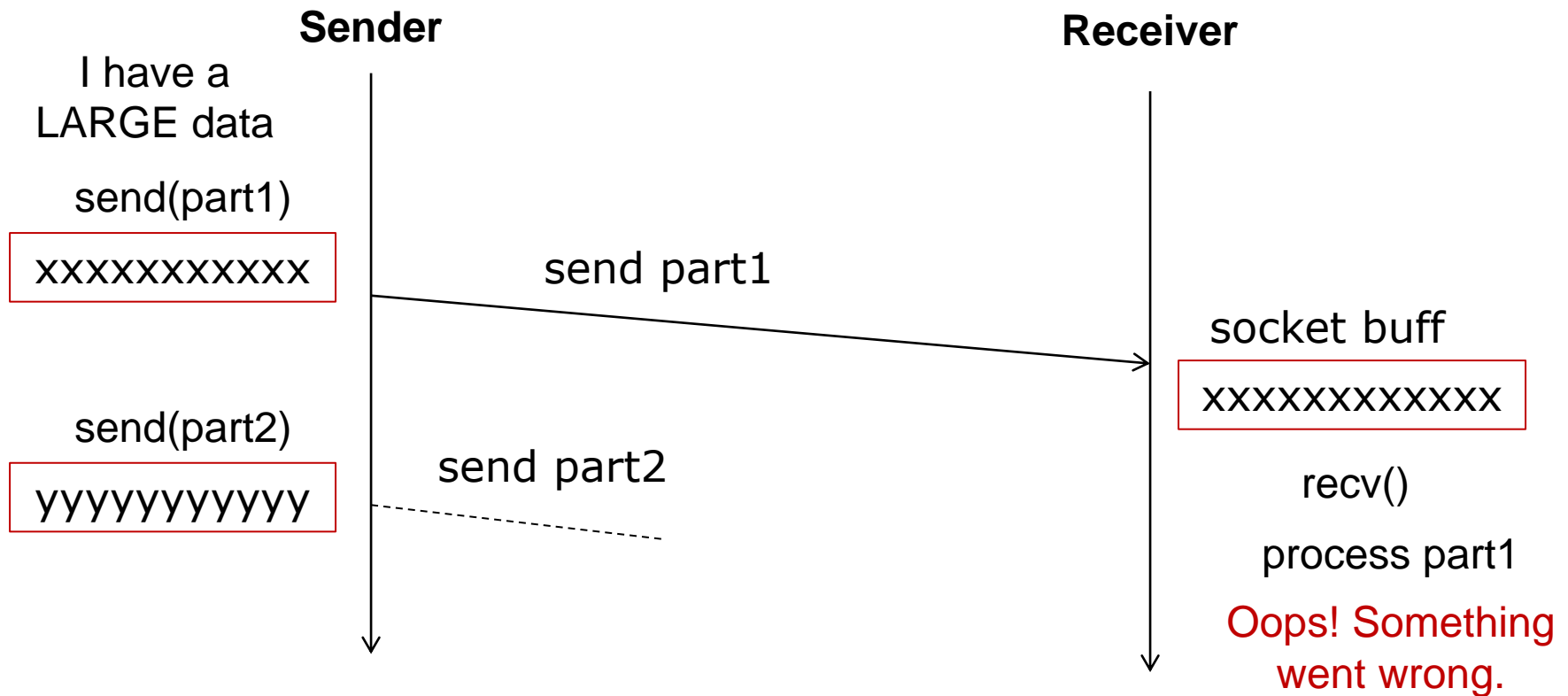
TCP operates on *streams* of data.



Byte stream problem(cont)

TCP does not operate on *packets* of data.

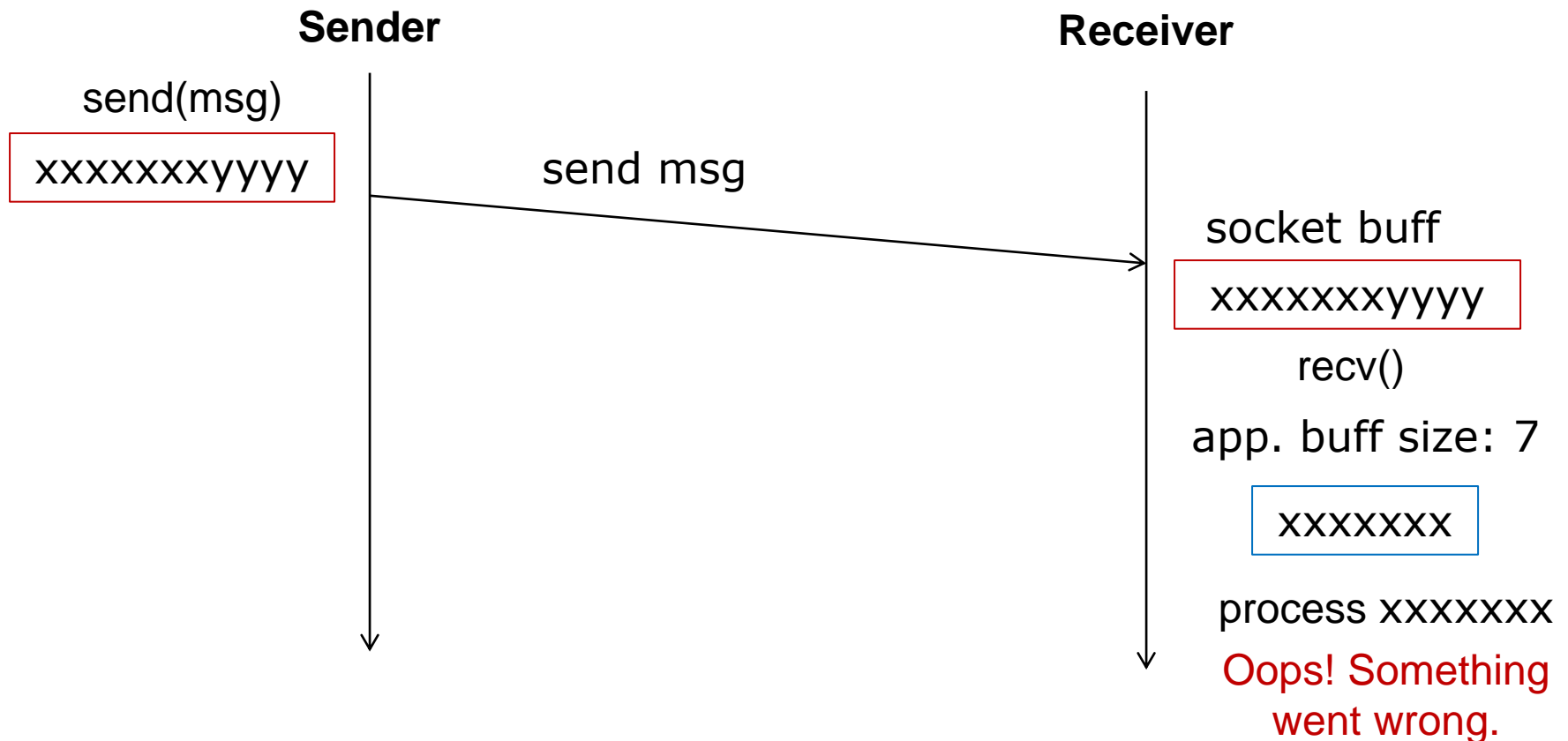
TCP operates on *streams* of data.



Byte stream problem(cont)

TCP does not operate on *packets* of data.

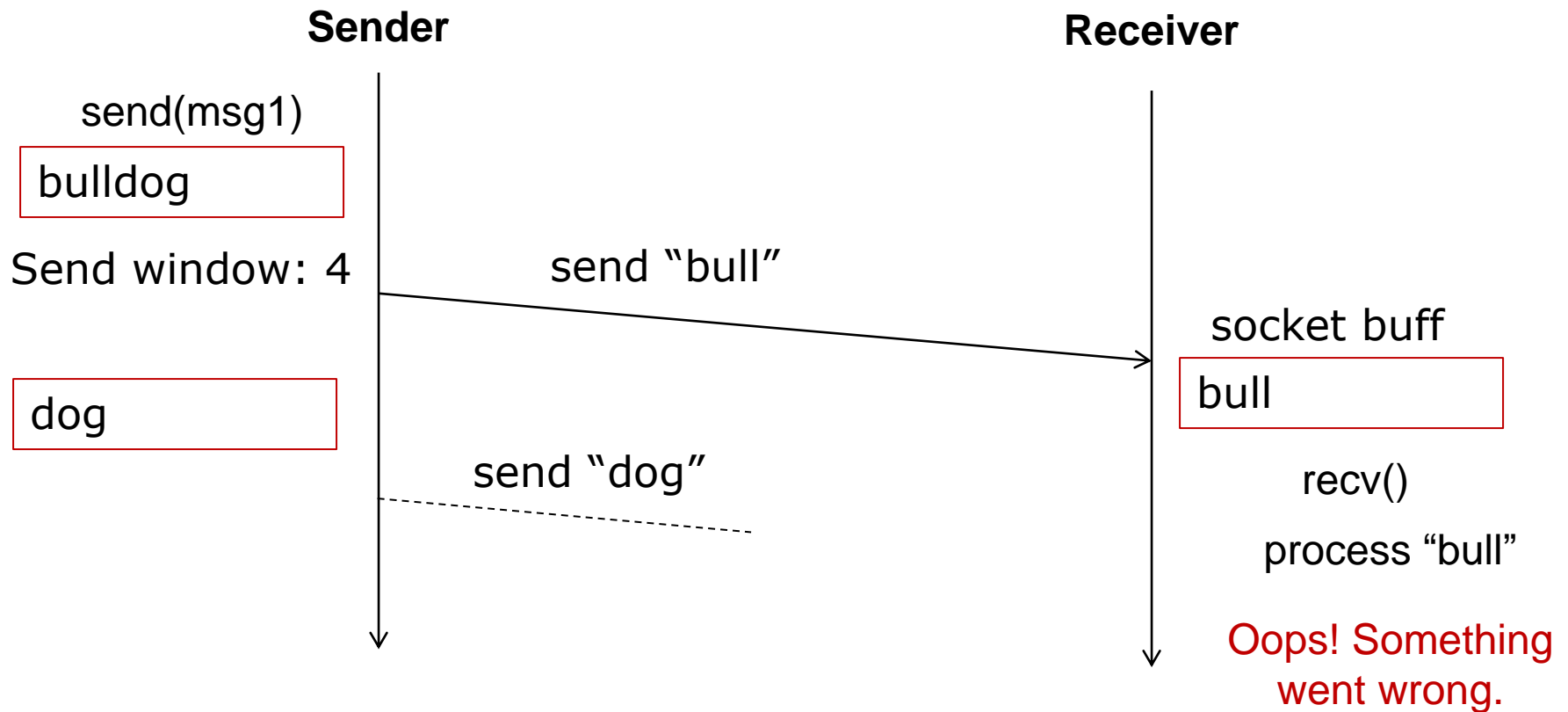
TCP operates on *streams* of data.



Byte stream problem(cont)

TCP does not operate on *packets* of data.

TCP operates on *streams* of data.



Byte stream problem(cont)

- Receiver doesn't know the size of message that sender has sent

- Solution 1: Fixed-length message

- What length? How to pad?

- Solution 2: Delimiters



- But message also can contain delimiters
 - Complex!

- Solution 3: Length prefixing



- Send message with its length
 - Receiver:
 - `recv(..., n, MSG_WAITALL)` returns the length of the message
 - Receives data (next slide)

Byte stream problem(cont)

```
char    recvBuff[BUFF_SIZE], *data;
int     ret, nLeft;
nLeft = msgLength; //length of the data needs to be received
data = (char *) malloc(msgLength);
memset(data, 0, msgLength)
idx = 0;

while (nLeft > 0)
{
    ret = recv(s, &recvBuff, BUFF_SIZE, 0);
    if (ret == -1){
        // Error handler
        break;
    }
    idx += ret;
    memcpy(data + idx, recvBuff, ret)
    nLeft -= ret;
}
```

connect () with UDP

- If server isn't running, the client blocks forever in the call to `recvfrom()` → asynchronous error
- Use `connect()` for a UDP socket
 - But it's different from calling `connect()` on a TCP socket
 - Calling `connect()` on a UDP socket doesn't create a connection
 - The kernel just checks for any immediate errors and returns immediately to the calling process
- We do not use `sendto()`, but `write()` or `send()` instead
- We do not need to use `recvfrom()` to learn the sender of a datagram, but `read()`, `recv()` instead
- Asynchronous errors are returned to the process for connected UDP sockets

Example

```
int n;
char sendline[MAXLINE], recvline[MAXLINE + 1];
struct sockaddr_in servaddr;
connect(sockfd, (struct sockaddr *) &servaddr, servlen);
while (fgets(sendline, MAXLINE, fp) != NULL) {
    send(sockfd, sendline, strlen(sendline));
    n = recv(sockfd, recvline, MAXLINE);
    recvline[n] = 0;  /* null terminate */
    printf("%s", recvline);
}
```

APPLICATION PROTOCOL DESIGN

Protocol

- Set of rules:
 - Message format
 - Message sequence
 - Process message
- Goals
 - Everyone must know
 - Everyone must agree
 - Unambiguous
 - Complete

Example: POP session

```
C: <client connects to service port 110>
S: +OK POP3 server ready <1896.6971@mailgate.dobbs.org>
C: USER bob
S: +OK bob
C: PASS redqueen
S: +OK bob's maildrop has 2 messages (320 octets)
C: LIST
S: +OK 2 messages (320 octets)
S: 1 120
S: 2 200
S: .
C: QUIT
S: +OK dewey POP3 server signing off (maildrop empty)
C: <client hangs u>
```

Example: FTP authentication

```
> ftp 202.191.56.65
C: Connected to 202.91.56.65
S: 220 Servers identifying string
User: vantv (C: USER vantv)
S: 331 Password required for vantv
Password: (C: PASS)
S: 530 Login incorrect
C: ls
S: 530 Please login with USER and PASS
C: USER vantv
S: 331 Password required for vantv
Password: (C: PASS)
S: 230 User vantv logged in
```

Steps in design

1. Define services
2. Choose application model (client/server, P2P,...)
3. Establish the design goals
4. Design the message structure: format, fields, types of messages, encoding, ...
5. Protocol processing
6. Interaction with environment (DNS, DHCP...)

Design Goals

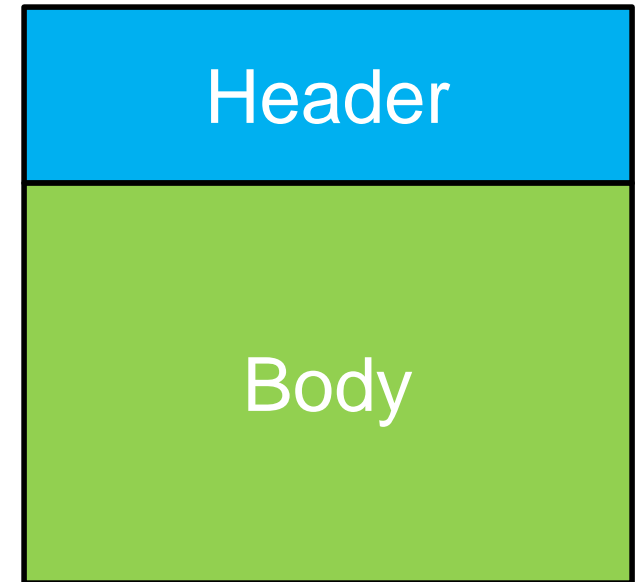
- Do we need reliable exchanges?
- How many types of parties are involved? Can they all communicate to each other?
- Is the authentication of parties needed
- How important is the authentication of parties?
- Is the transferred data confidential? What degree of authorization is needed?
- Do we need complex error handling?

Design Issues

- Is it to be stateful vs stateless?
- Is the transport protocol reliable or unreliable?
- Are replies needed?
 - How to respond to lost replies?
- Is it to be broadcast, multicast or unicast?
 - Broadcast, multicast: must use UDP Socket
- Are there multiple connections?
 - How to synchronize?
- How many types of parties are involved? Can they all communicate to each other?
- Session management
- Security: authentication, authorization, confidential...

Designing the Message

- Header: contains structured fields describing the actual data in the message, such as
 - message type
 - command
 - body size
 - recipient information
 - sequence information
 - retransmission count...
- Body: the actual data to be transmitted:
 - the command parameters
 - the data payload



The simplest formats:

- Type – Length – Value(TLV)
- Type – Value

Control Messages

- Define the stages of the dialogue between the parties
 - Control the dialogue between the parties
- Address various communication aspects:
- communication initiation or ending
 - describe the communication stage (e.g. authentication, status request, data transfer)
 - coordination (e.g. receipt confirmation, retry requests)
 - resource changes (e.g. requests for new communication channels)
- Usual format:

Command	Parameter
---------	-----------
- Command: SHOULD have fixed length or use delimiter
 - Example: USER, PASS, PWD (FTP),

Data transfer

- Messages that carry data over the network
- They are usually sent as a responses to specific commands
- Data is usually fragmented in multiple messages
- Header describe:
 - the type of the binary data format
 - clues for the layout of the structured data (when the structure is flexible/dynamic)
 - data size, offset or sequence information
 - type of the data block: last / intermediary

Message Format

Byte oriented




- The first part of the message is typically a byte to distinguish between message types.
- Further bytes in the message would contain message content according to a pre-defined format
- Advantages: compactness
- Disadvantages: harder to process, debug or test
- Example: DHCP, DNS

Data Format

Text-oriented

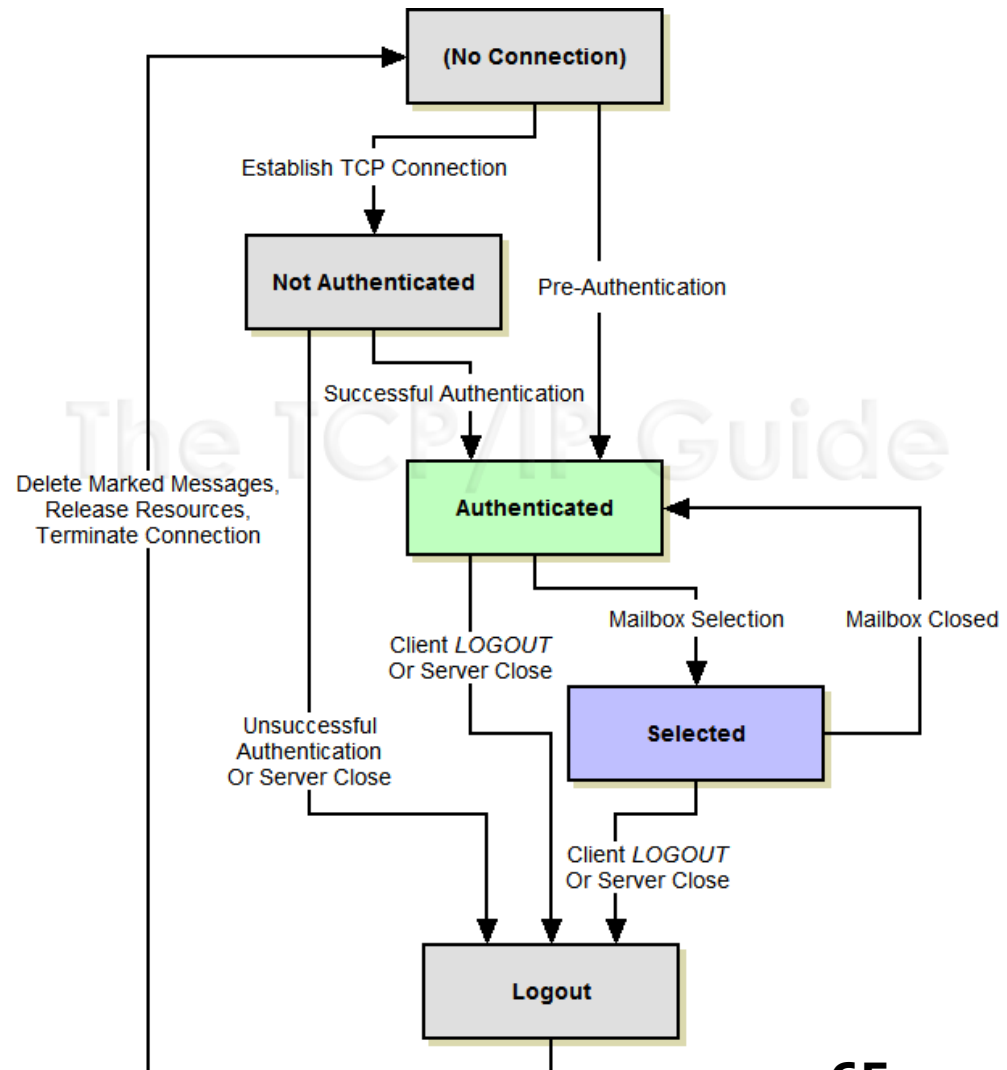
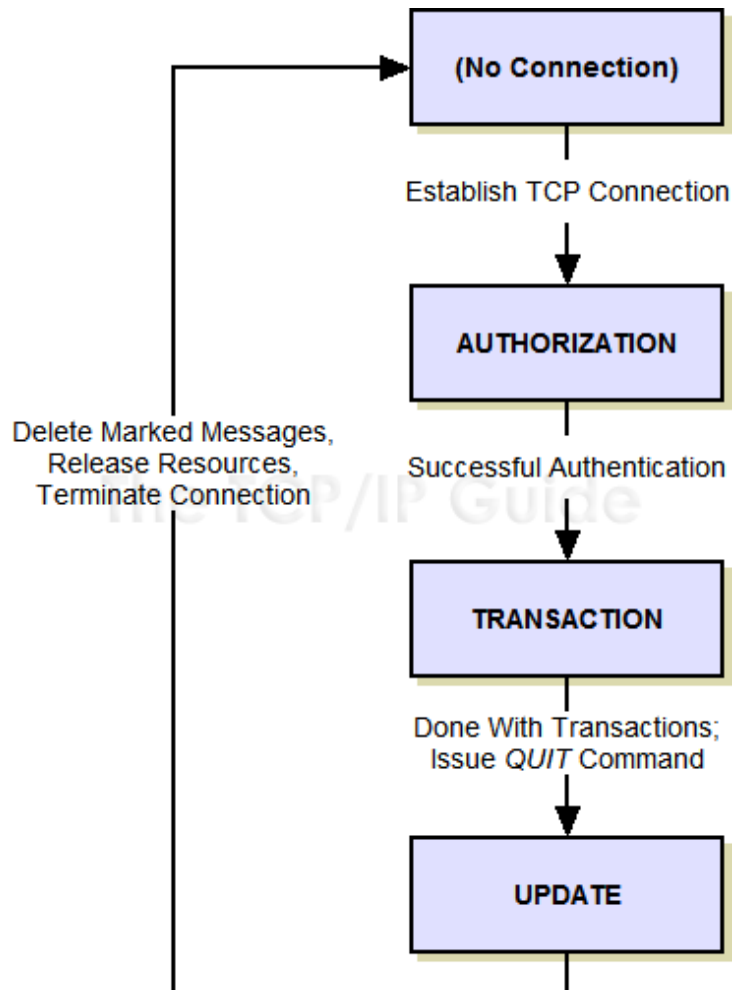
- A message is a sequence of one or more lines
- The start of the first line of the message is typically a word that represents the message type.
- The rest of the first line and successive lines contain the data.
- Advantage:
 - easy to understand, monitor
 - flexible
 - easy to test
- Disadvantage
 - may make the messages unjustifiably large
 - may become complex
- Example: HTTP, FTP, email protocols

Protocol Processing

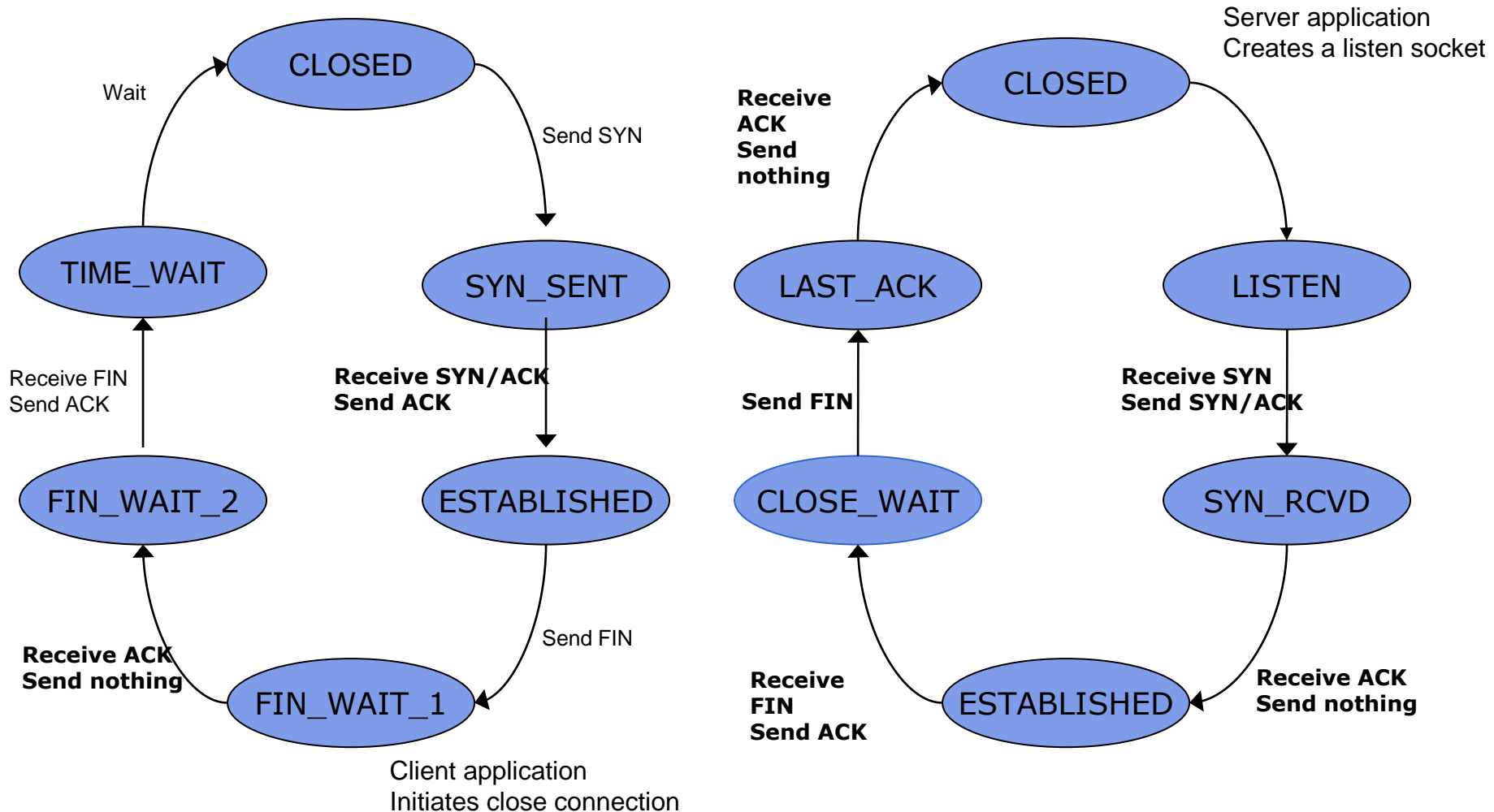
- Describe the sequences of messages, at each and all the stages in the of each communication scenario, for all parties in the system
- Finite State Machine is mandatory:
 - State: 
 - Transaction: 
 - Choose: 
- And/ Or use state Table

Current state	Transcation		Next state
	Receive	Send	

Example: POP3 and IMAP4 session

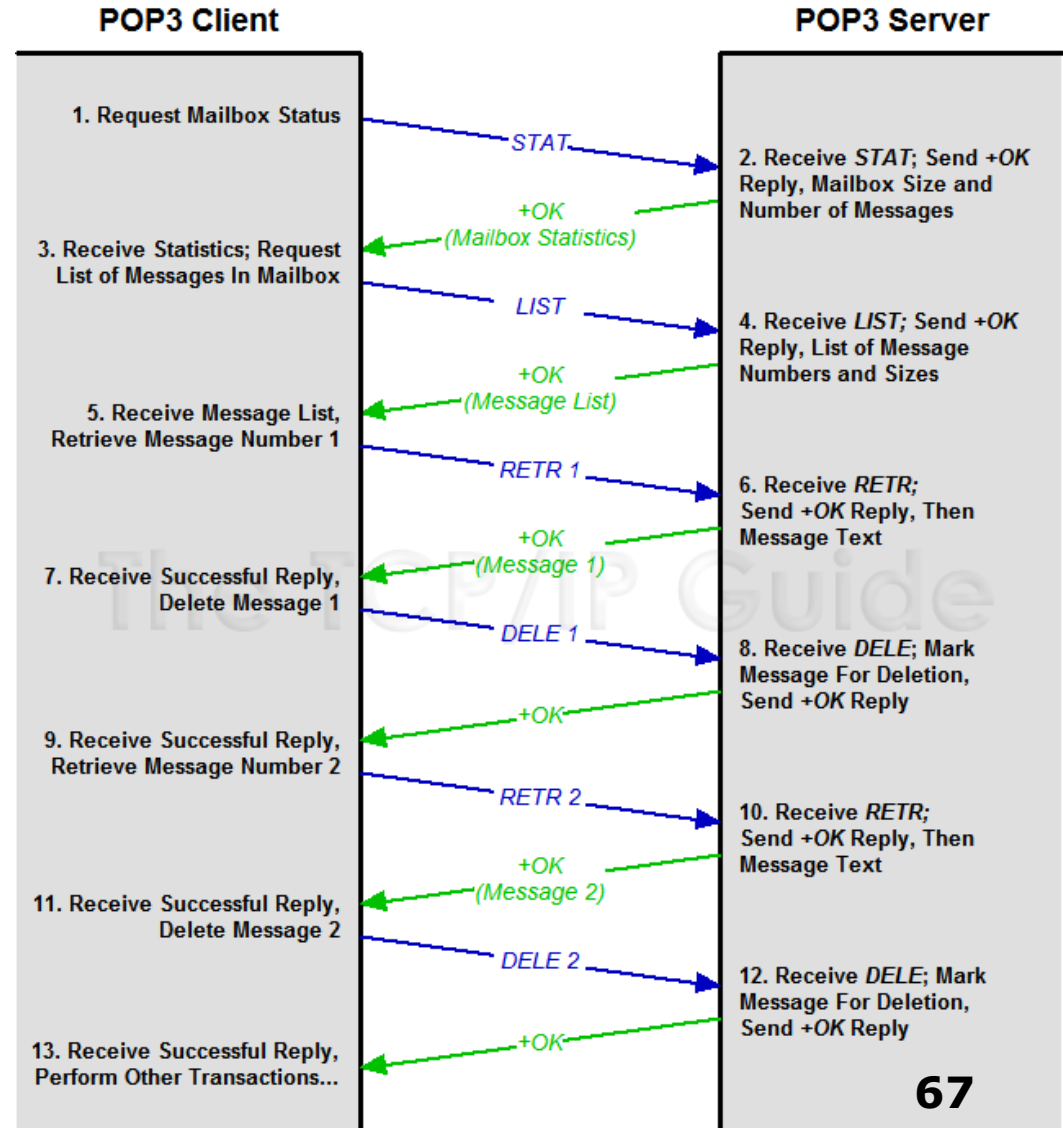


Example: TCP connection



Message Transaction Diagram

- Represents the sequence of message transaction
- Example: POP3



Implementing an Application Protocol

- Type of message

- Use integer: `enum msg_type {...}`
- Use string

- Data structure

- Use struct. Example:

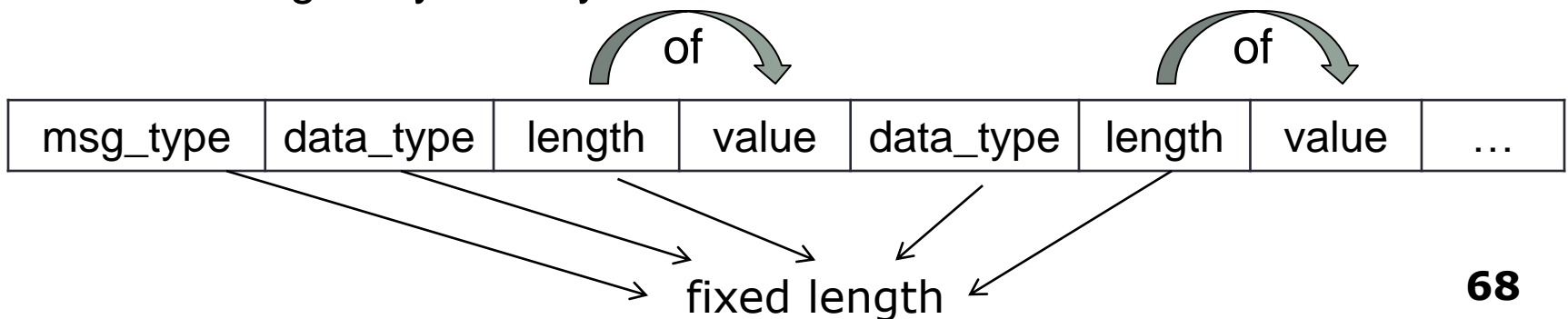
```
struct message{  
    char msg_type[4];  
    char data_type[8];  
    int value;  
}
```

or

```
struct message{  
    msg_type type;  
    struct msg_payload payload;  
};
```

```
struct msg_payload{  
    int id;  
    char fullname[30];  
    int age;  
    //...  
}
```

- Use string or byte array



Implementing an Application Protocol

- Message handler(pseudo code)

```
//handle message
switch (msg_type){
    case MSG_TYPE1:
        {
            //...
        }
    case MGS_TYPE2:
        {
            //...
            if(data_type == DATA_TYPE1)
                //...
        }
    //...
}
```