Network Programming

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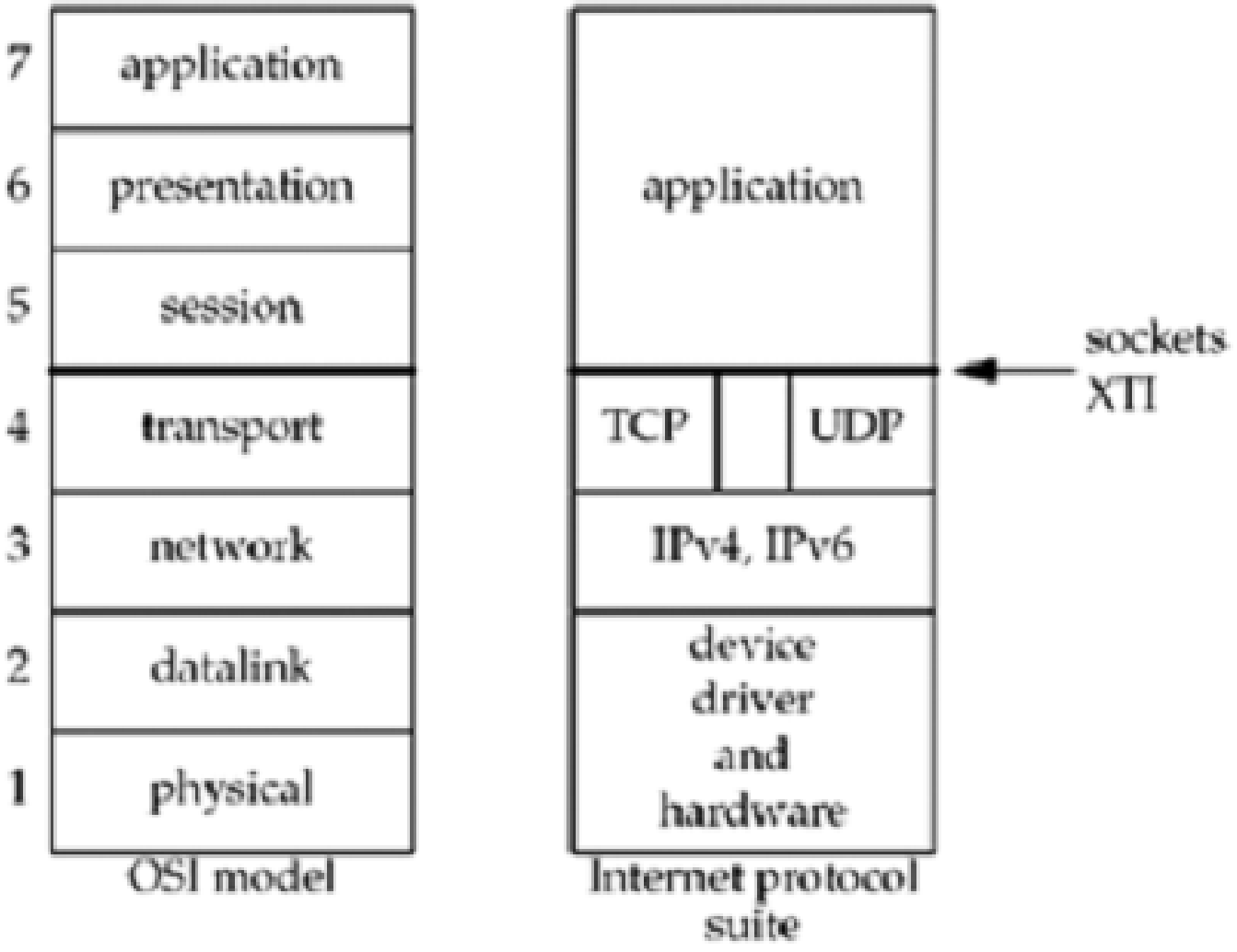
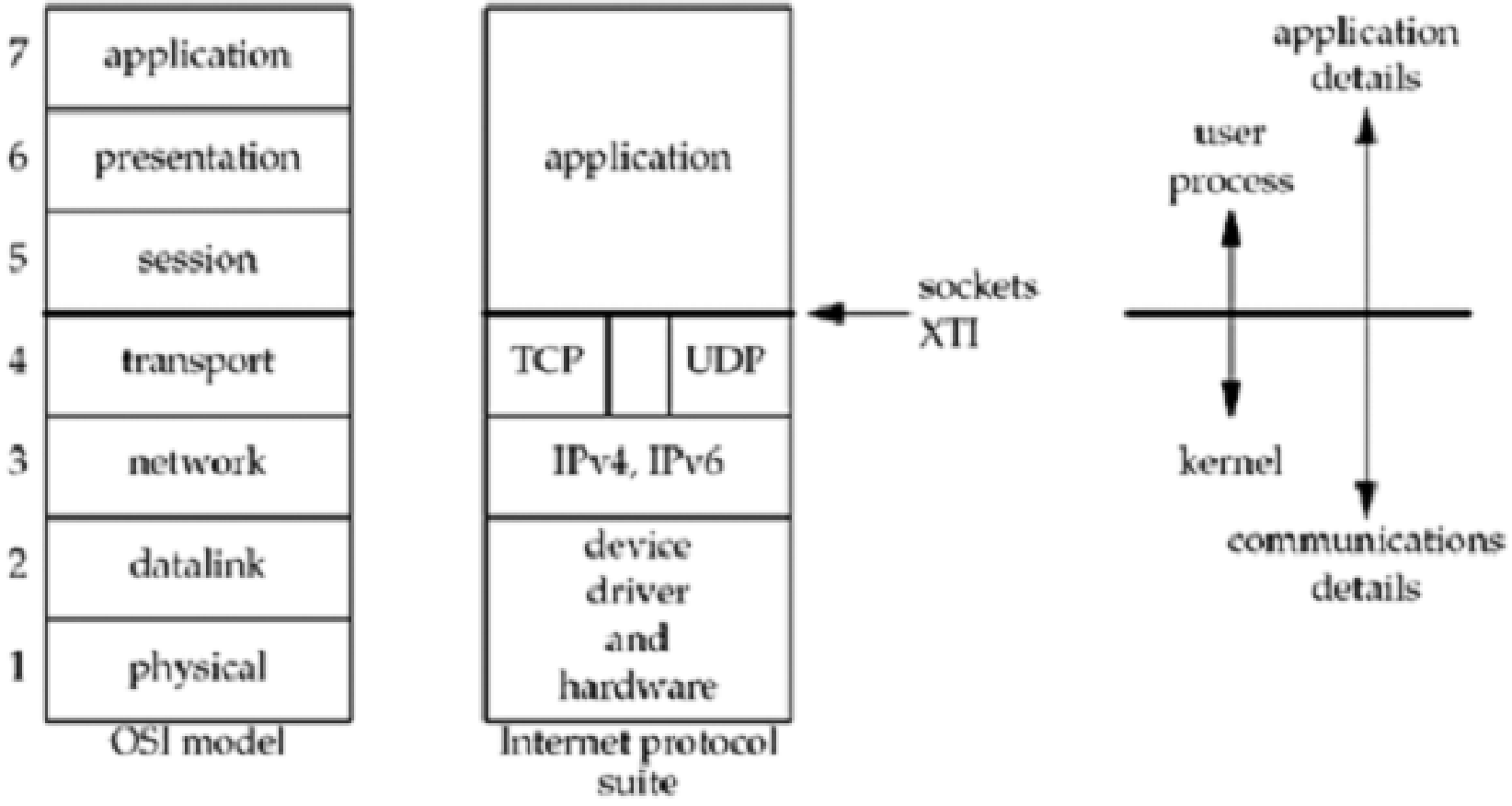
TCP/IP

OSI & Internet protocol suite



TCP/IP


7
application
6
presentation
5
session
4
transport
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network
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datalink
1
physical
OSI model
application
TCP
UDP
IPv4, IPv6
device driver and hardware
Internet protocol suite
sockets XTI
application details
user process
kernel
communications details

TCP or UDP

- At the internet layer, a destination address identifies a host computer; no further distinction is made regarding which process will receive the datagram
- TCP or UDP add a mechanism that distinguishes among destinations within a given host, allowing multiple processes to send and receive datagrams independently

Why process is not the destination for a message?

- Processes are created and destroyed dynamically
- A process can be repalced with a new process without informing all senders
- Identify a destination by the function rather than the process which implements it
- A process can handle multiple functions, so there should a way to specify which one sender desires

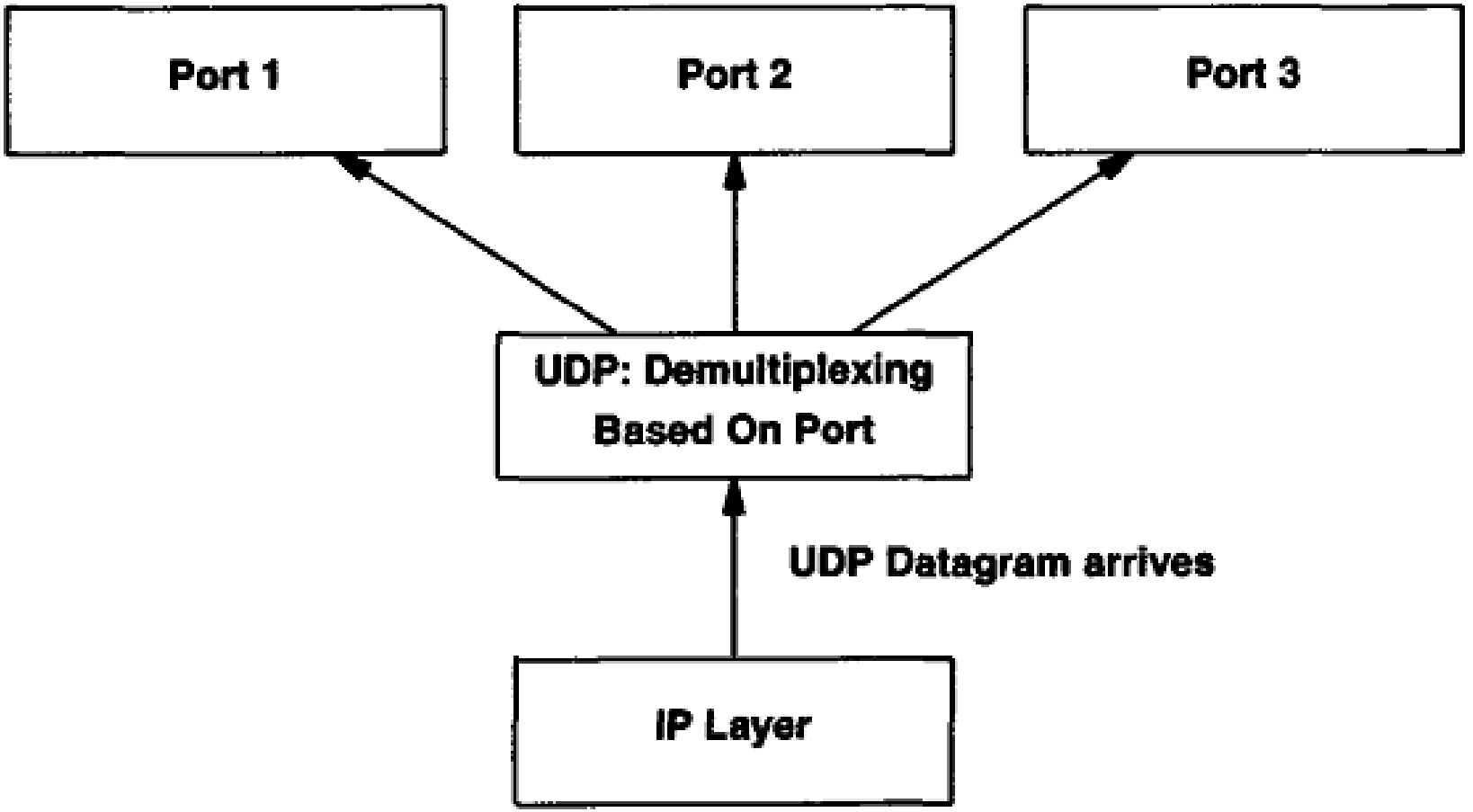
Protocol Ports

- Instead of thinking process as ultimate destination, imagine that each machine contains a set of abstract destination points called protocol ports
- Each protocol port is identified by a positive integer
- Operating systems provide some mechanism that processes use, to specify a port.

Port Numbers

- The port numbers are divided into three ranges by Internet Assigned Numbers Authority
- The well-known ports: 0 through 1023. These port numbers are controlled and assigned by the IANA.
- The registered ports: 1024 through 49151. These are not controlled by the IANA, but the IANA registers and lists the uses of these ports as a convenience to the community.
- The dynamic or private ports, 49152 through 65535. The IANA says nothing about these ports. These are what we call ephemeral ports. (49152 is three-fourths of 65536.)

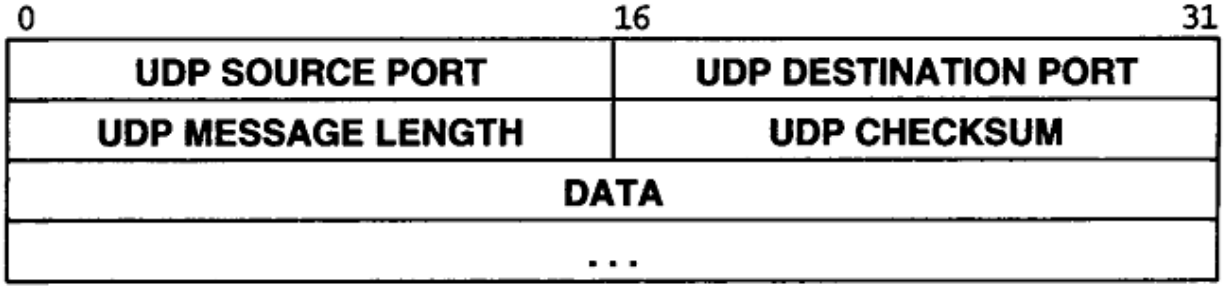
Ports


Port 1
Port 2
Port 3
UDP: Demultiplexing Based On Port
UDP Datagram arrives
IP Layer

UDP (User Datagram Protocol)

- UDP provides an unreliable connectionless delivery service
- UDP uses IP to deliver datagrams to the right host.
- UDP uses *ports* to provide communication services to individual processes.

UDP header



- Header size is 8 bytes
- Lack of reliability:
  - checksum detects an error
  - the datagram is dropped in the network
- If we want to be certain that a datagram reaches its destination, we can build lots of features into our application: acknowledgments from the other end, timeouts, retransmissions, and the like.

Some standard UDP based services and their ports

Decimal	Keyword	UNIX Keyword	Description
0	-	-	Reserved
7	ECHO	echo	Echo
9	DISCARD	discard	Discard
11	USERS	systat	Active Users
13	DAYTIME	daytime	Daytime
15	-	netstat	Network status program
17	QUOTE	qotd	Quote of the Day
19	CHARGEN	chargen	Character Generator
37	TIME	time	Time
42	NAMESERVER	name	Host Name Server
43	NICNAME	whois	Who Is
53	DOMAIN	nameserver	Domain Name Server
67	BOOTPS	bootps	BOOTP or DHCP Server
68	BOOTPC	bootpc	BOOTP or DHCP Client
69	TFTP	tftp	Trivial File Transfer
88	KERBEROS	kerberos	Kerberos Security Service
111	SUNRPC	sunrpc	Sun Remote Procedure Call
123	NTP	ntp	Network Time Protocol

TCP
Transmission Control Protocol

- TCP provides connections between clients and servers.
- TCP uses the connection, not the protocol port, as its fundamental abstraction.
- Connections are identified by a pair of endpoints.
  - Endpoint means (ip, port)
- TCP provides:
  - Connection-oriented
  - Reliable
  - Full-duplex
  - Byte-Stream

Connection-Oriented

- *Connection oriented* means that a virtual connection is established before any user data is transferred.
- A TCP client establishes a connection with a given server, exchanges data with that server across the connection, and then terminates the connection.
- If the connection cannot be established - the user program is notified.
- If the connection is ever interrupted - the user program(s) is notified.

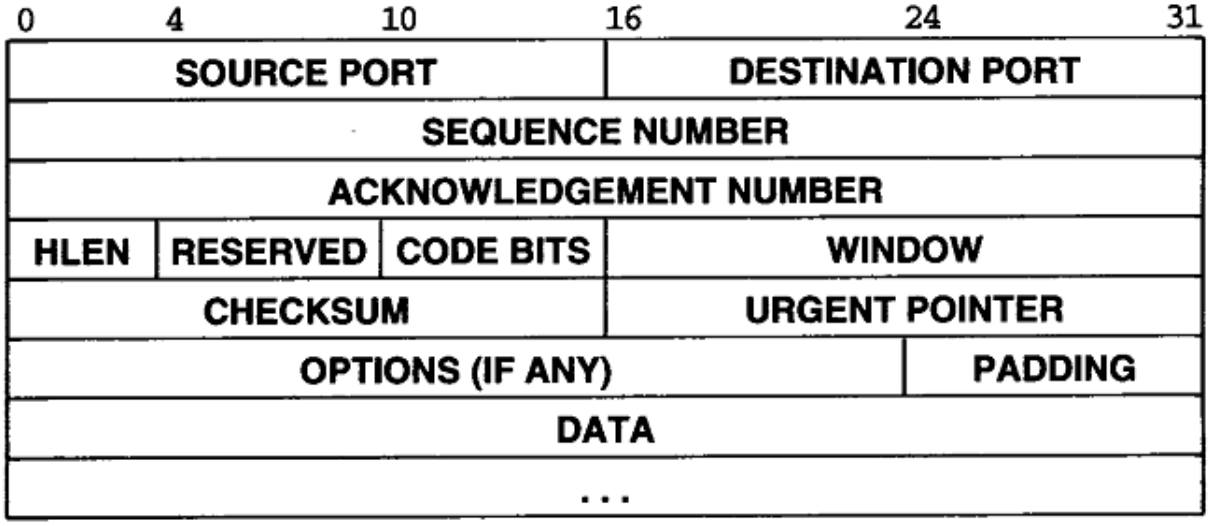
TCP Ports

- Interprocess communication via TCP is achieved with the use of ports (just like UDP).
- UDP ports have no relation to TCP ports (different name spaces).

TCP Segments

- TCP views the data stream as a sequence of bytes that it divides into segments for transmission. Segments carry varying sizes of data.
- The chunk of data that TCP asks IP to deliver is called a *TCP segment*.
- Each segment contains:
  - data bytes from the byte stream
  - control information that identifies the data bytes

TCP Segment Format



Bit (left to right)	Meaning if bit set to 1
URG	Urgent pointer field is valid
ACK	Acknowledgement field is valid
PSH	This segment requests a push
RST	Reset the connection
SYN	Synchronize sequence numbers
FIN	Sender has reached end of its byte stream

TCP Segments

- Segments are exchanged to establish connections, transfer data, send acknowledgements, advertise window sizes, and close connections.
- Because TCP uses piggybacking, acknowledgement can be sent along with data
- TCP advertises how much data it is willing to accept every time it sends segment by specifying its buffer size in the WINDOW field

TCP Connection Establishment

- Three-way handshake
- It accomplishes two important functions.
  - It guarantees that both sides are ready to transfer data (and that they know they are both ready)
  - it allows both sides to agree on initial sequence numbers.
- Sequence numbers are sent and acknowledged during the handshake. Each machine must choose an initial sequence number at random that it will use to identify bytes in the stream it is sending.

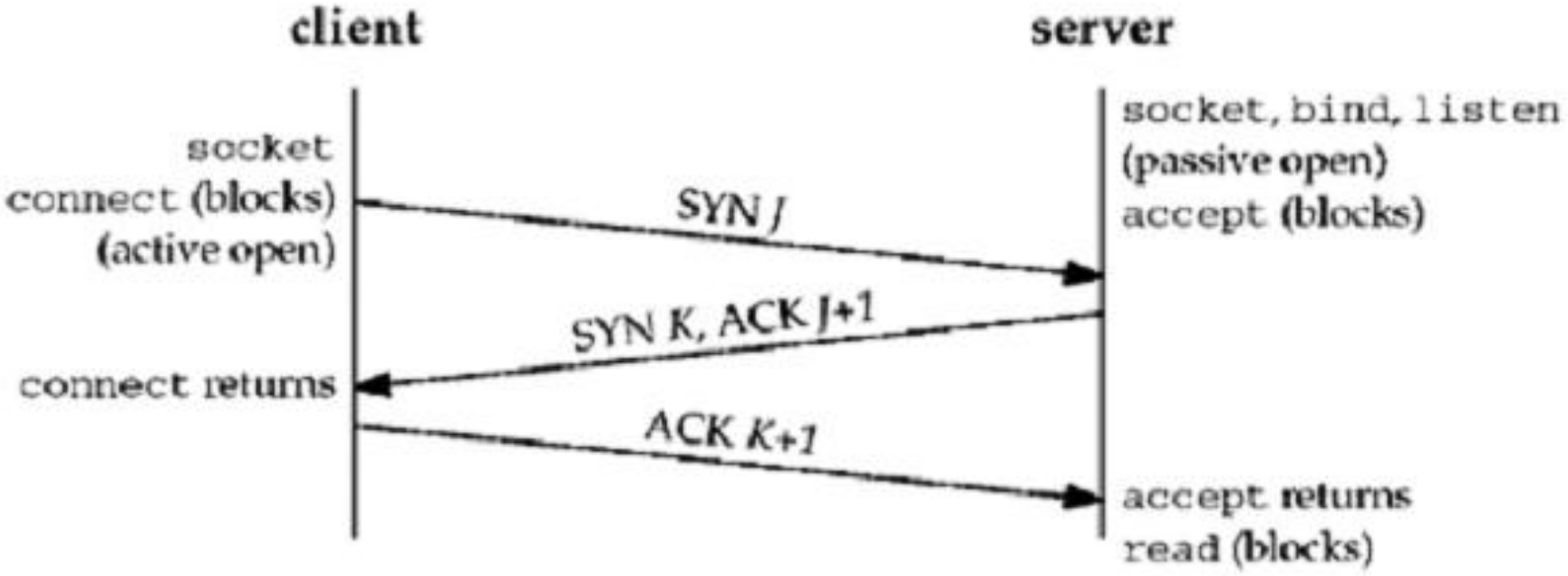
TCP Connection Establishment

- When a client requests a connection, it sends a “SYN” segment (a special TCP segment) to the server port.
- SYN stands for synchronize. The SYN message includes the client’s ISN.
- ISN is Initial Sequence Number.
- Every TCP segment includes a Sequence Number that refers to the first byte of data included in the segment.
- Every TCP segment includes a Request Number (Acknowledgement Number) that indicates the byte number of the next data that is expected to be received.
  - All bytes up through this number have already been received.

TCP Connection Establishment

- A server accepts a connection.
  - Must be looking for new connections!
- A client requests a connection.
  - Must know where the server is!
- A client starts by sending a SYN segment with the following information:
  - Client's ISN (generated pseudo-randomly)
  - Maximum Receive Window for client.
  - Optionally (but usually) MSS (largest datagram accepted).
  - No payload! (Only TCP headers)
- When a waiting server sees a new connection request, the server sends back a SYN segment with:
  - Server's ISN (generated pseudo-randomly)
  - Request Number is Client ISN+1
  - Maximum Receive Window for server.
  - Optionally (but usually) MSS
  - No payload! (Only TCP headers)

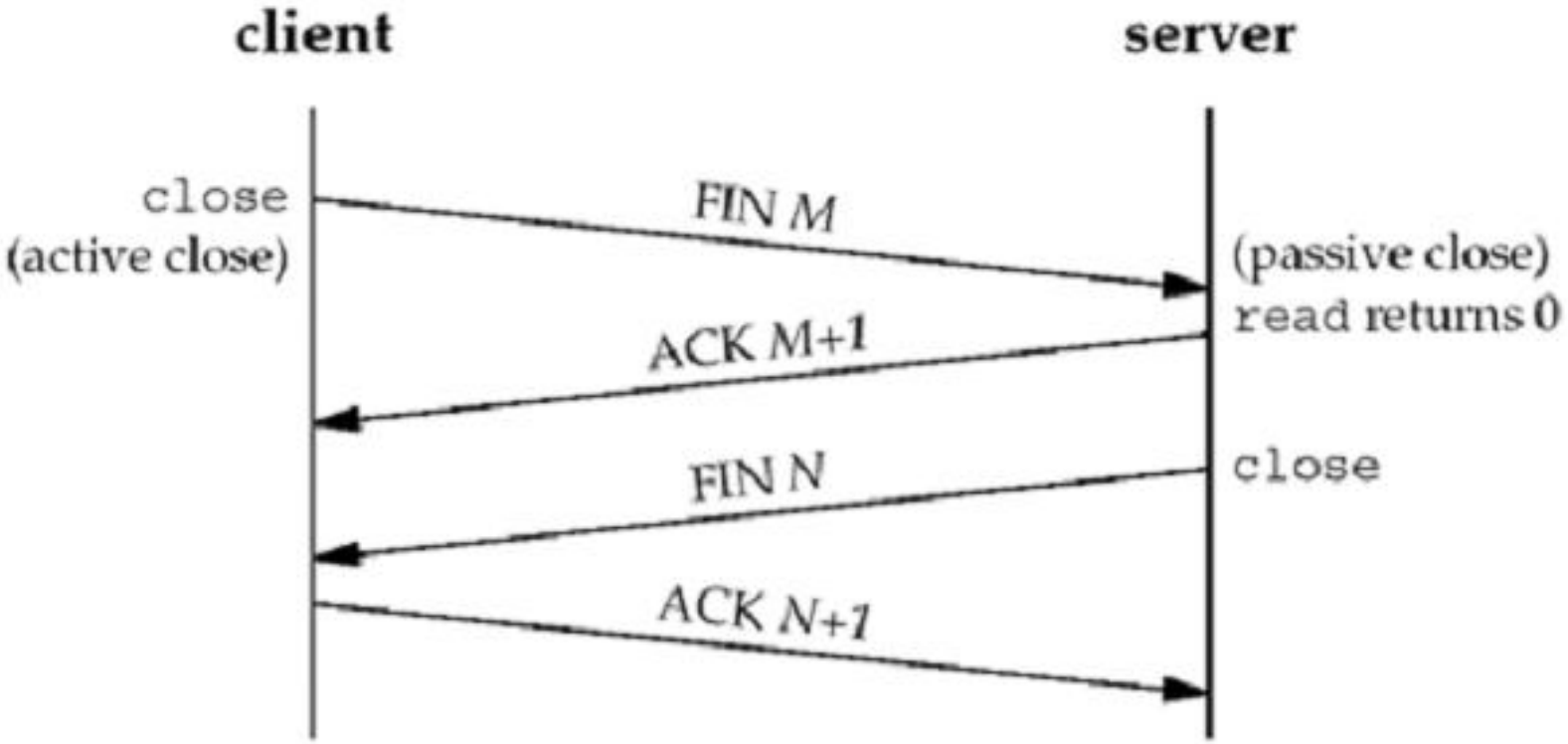
TCP Connection Establishment



Connection Termination

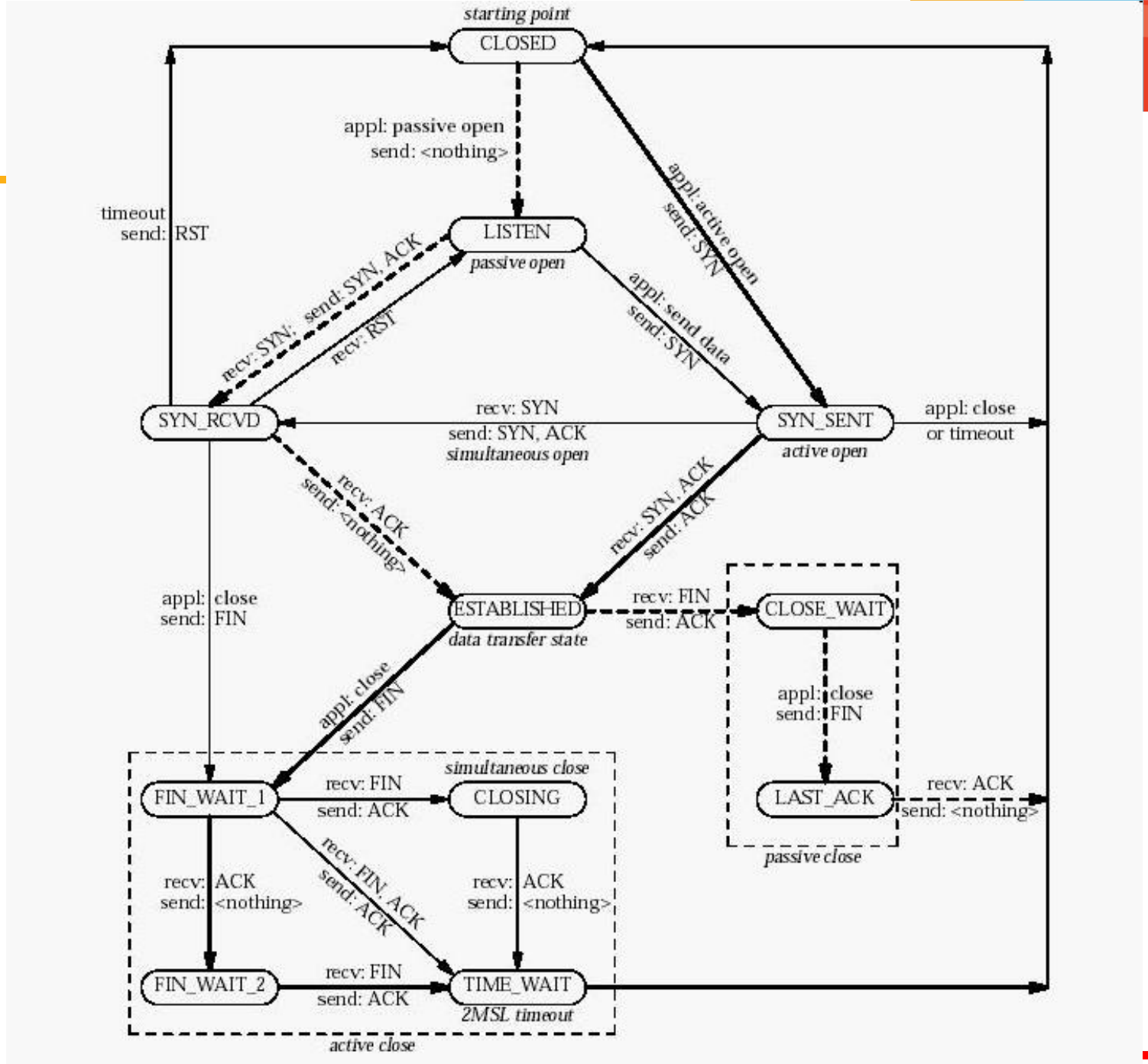
- The TCP layer can send a RST segment that terminates a connection if something is wrong.
- Usually the application tells TCP to terminate the connection gracefully with a FIN segment.
- Either end of the connection can initiate termination.
- A FIN is sent, which means the application is done sending data.
- The FIN is ACK'd.
- The other end must now send a FIN.
- That FIN must be ACK'd.

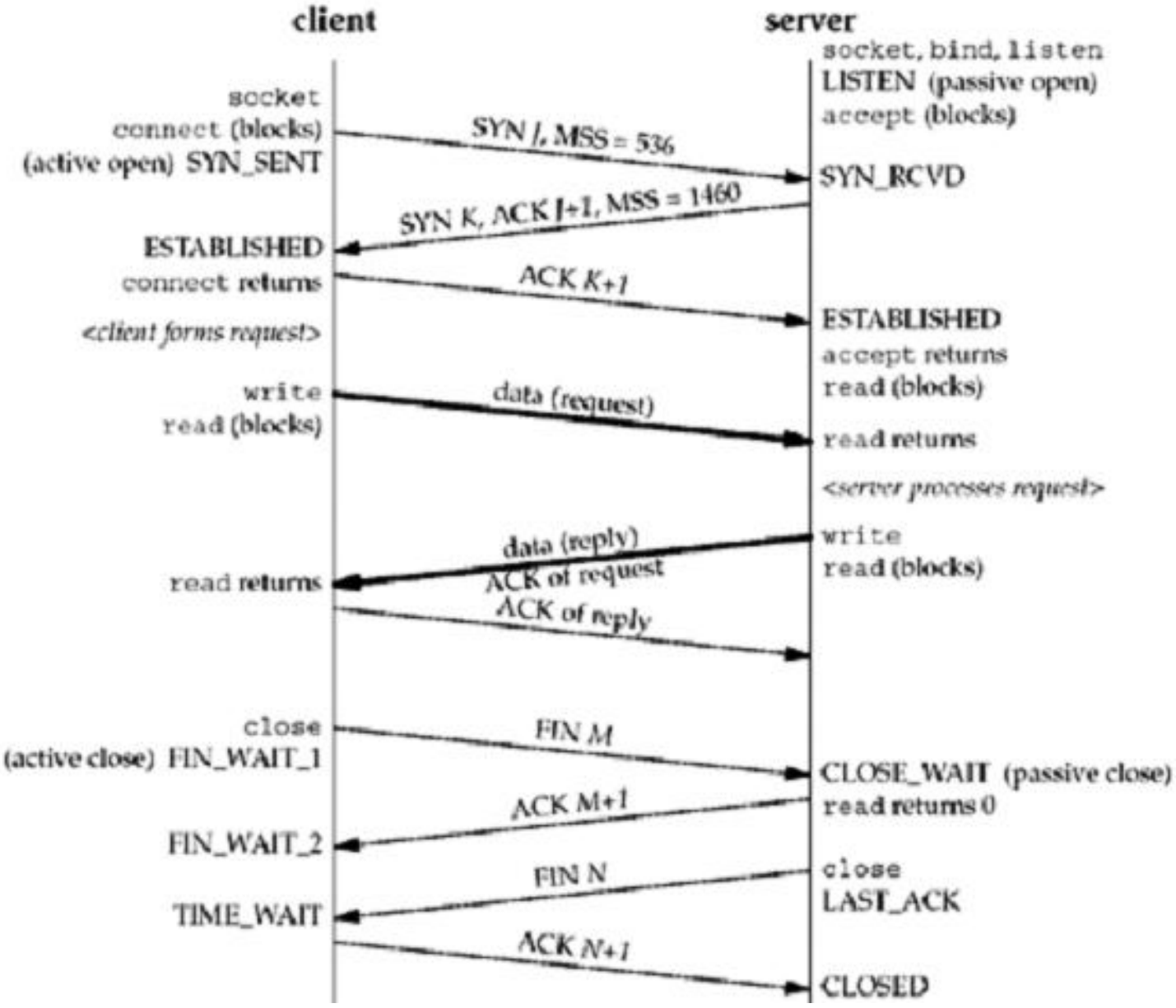
Connection Termination



TCP Connection State Diagram

- There are 11 different states defined for a connection
  - based on the current state and the segment received in that state.
- One reason for showing the state transition diagram is to show the 11 TCP states with their names. These states are displayed by netstat, which is a useful tool when debugging client/server applications


starting point
CLOSED
appl: passive open
send: <nothing>
appl: active open
send: SYN
timeout
send: RST
LISTEN
passive open
recv: SYN; send: SYN, ACK
recv: RST
appl: send data
send: SYN
SYN_RCVD
recv: SYN
send: SYN, ACK
simultaneous open
SYN_SENT
active open
appl: close
or timeout
recv: ACK
send: <nothing>
recv: SYN, ACK
send: ACK
appl: close
send: FIN
ESTABLISHED
data transfer state
recv: FIN
send: ACK
CLOSE_WAIT
appl: close
send: FIN
LAST_ACK
recv: ACK
send: <nothing>
passive close
appl: close
send: FIN
simultaneous close
FIN_WAIT_1
recv: FIN
send: ACK
CLOSING
recv: FIN, ACK
send: ACK
recv: ACK
send: <nothing>
recv: ACK
send: <nothing>
FIN_WAIT_2
recv: FIN
send: ACK
TIME_WAIT
2MSL timeout
active close


client
server
socket, bind, listen
LISTEN (passive open)
accept (blocks)
socket
connect (blocks)
(active open) SYN_SENT
SYN J, MSS = 536
SYN_RCVD
SYN K, ACK J+1, MSS = 1460
ESTABLISHED
connect returns
ACK K+1
<client forms request>
ESTABLISHED
accept returns
read (blocks)
write
read (blocks)
data (request)
read returns
<server processes request>
write
read (blocks)
data (reply)
ACK of request
read returns
ACK of reply
close
(active close) FIN_WAIT_1
FIN M
CLOSE_WAIT (passive close)
read returns 0
ACK M+1
FIN_WAIT_2
FIN N
close
LAST_ACK
TIME_WAIT
ACK N+1
CLOSED

What is the purpose of TIME_WAIT?

- Once a TCP connection has been terminated (the last ACK sent) there is some unfinished business:
  - What if the ACK is lost? The last FIN will be resent and it must be ACK'd.
  - What if there are lost or duplicated segments that finally reach the incarnation of the previous connection after a long delay?
- The MSL is the maximum amount of time that any given IP datagram can live in a network

Outline

- Sockets
- TCP Client Server

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Sockets

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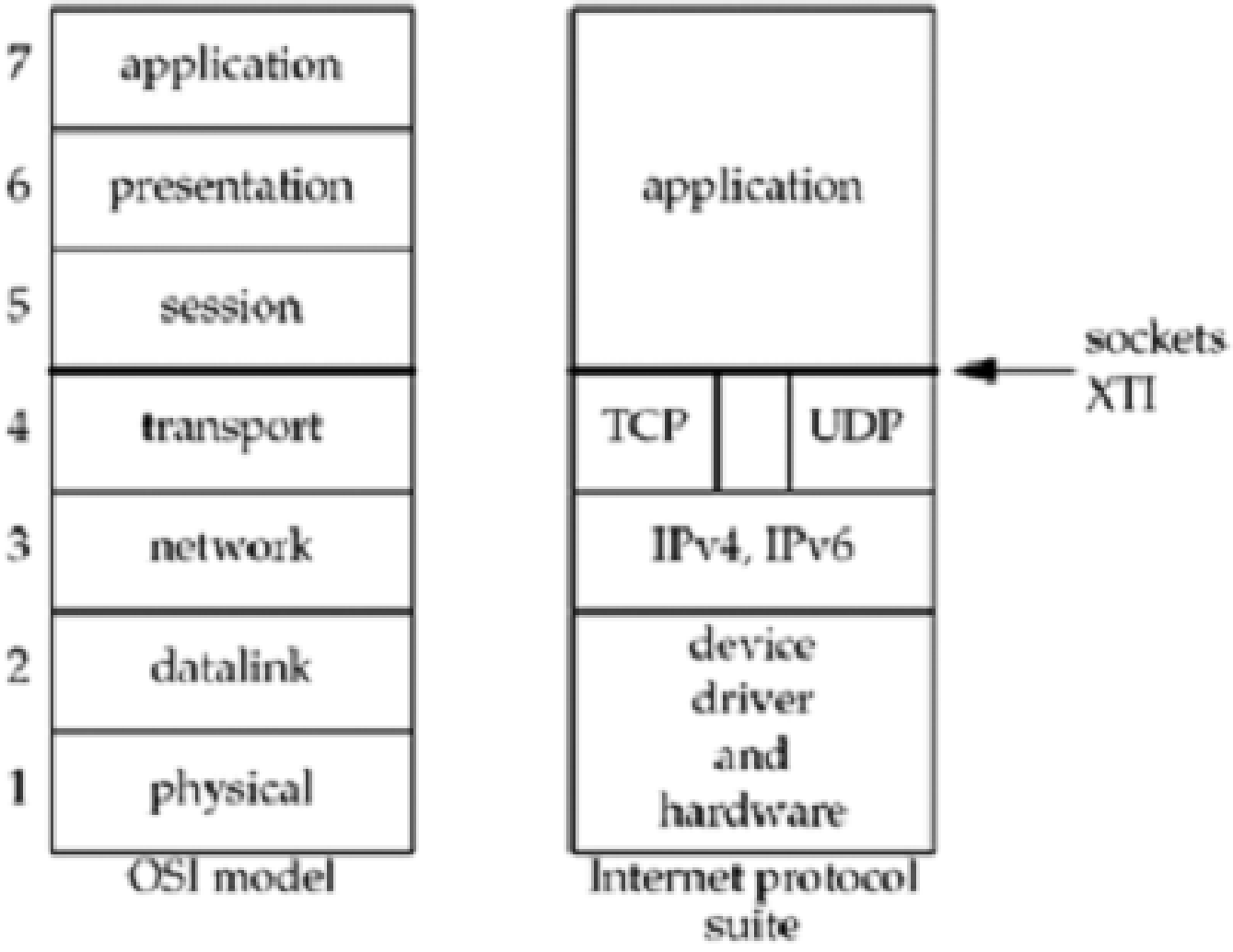


TCP/IP & Sockets API

- TCP/IP does not include an API definition.
- There are a variety of APIs for use with TCP/IP:
  - Sockets
  - TLI, XTI
  - Winsock
  - MacTCP
- API should have the following functionalities
  - Specify local and remote communication endpoints
  - Initiate a connection
  - Wait for incoming connection
  - Send and receive data
  - Terminate a connection gracefully
  - Error handling

Berkeley Sockets API

- First appeared in 42. BSD in 1983.
  - Supported on every UNIX variant.
  - WinSock API also follows socket API.
- Generic API:
  - support for multiple communication domains which differ in addressing methods.

Domain	Communication performed	Communication between applications	Address format	Address structure
AF_UNIX	within kernel	on same host	pathname	*sockaddr_un*
AF_INET	via IPv4	on hosts connected via an IPv4 network	32-bit IPv4 address + 16-bit port number	*sockaddr_in*
AF_INET6	via IPv6	on hosts connected via an IPv6 network	128-bit IPv6 address + 16-bit port number	*sockaddr_in6*

- Uses existing I/O programming interface as much as possible.
  - Socket API is similar to file I/O

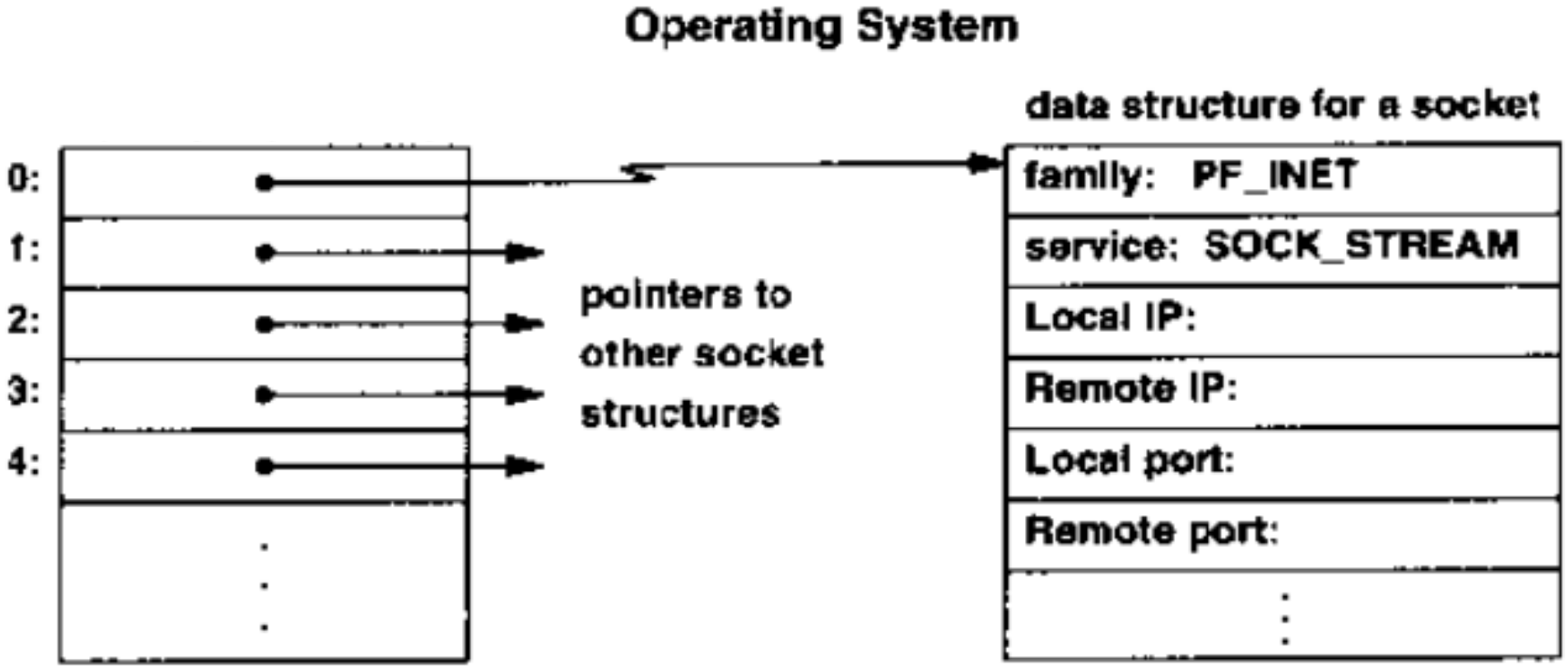
Socket

- A socket is an abstract representation of a communication endpoint.
- Sockets work with Unix I/O services just like files, pipes & FIFOs.
  - read(), write() and close() sys calls work on sockets also
- Sockets have special needs over files:
  - establishing a connection.
  - specifying communication endpoint addresses.

Socket Types

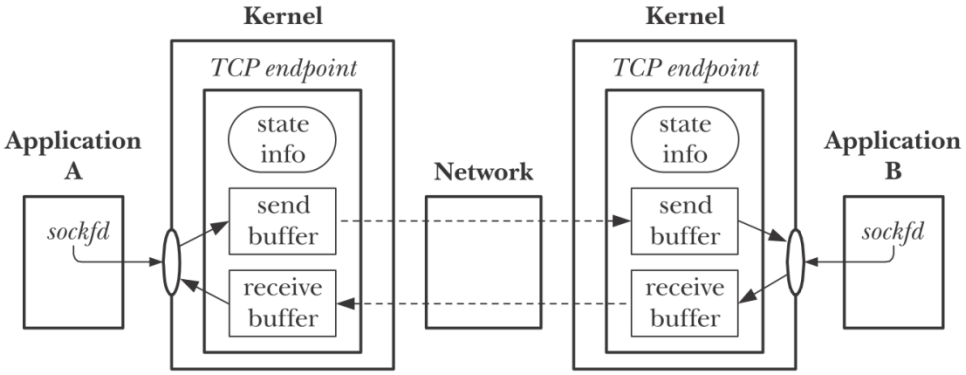
- Two types of sockets
  - Stream Sockets
    - Reliable
    - Bidirectional
    - Byte-stream
    - Connection-oriented
    - Stream sockets operate in connected pairs. (local end point, remote end point)
    - Internet Domain: TCP Socket
  - Datagram Sockets
    - Message boundaries are preserved.
    - No reliability support: out of order, duplicates, or lost datagrams
    - Connectionless socket: no need to be connected to another socket.
    - Internet Domain: UDP Socket

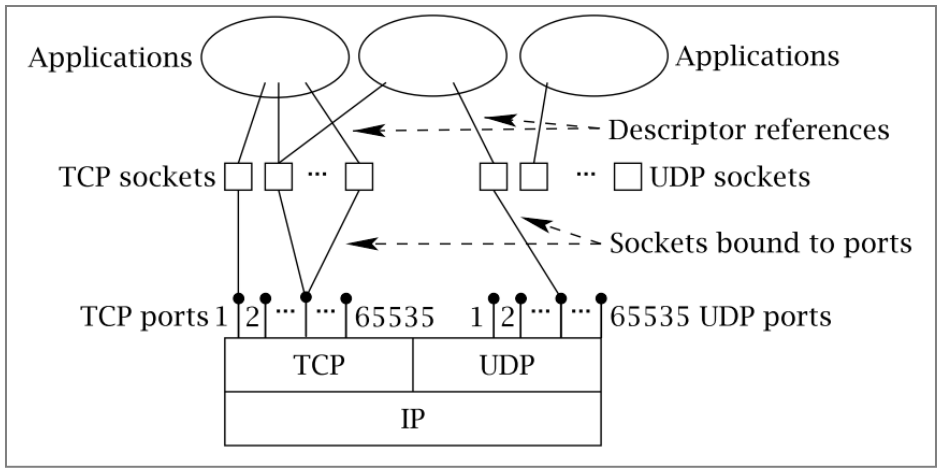
Socket Descriptor Data Structure



Internet Domain & Sockets

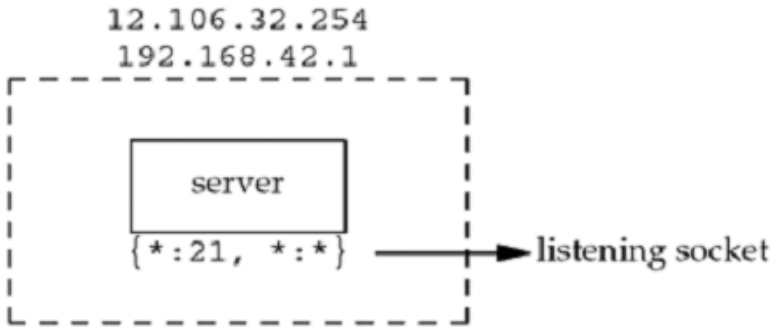
- Endpoint is identified by ip address and port number.
  - A socket needs to be bound to endpoints local and remote.





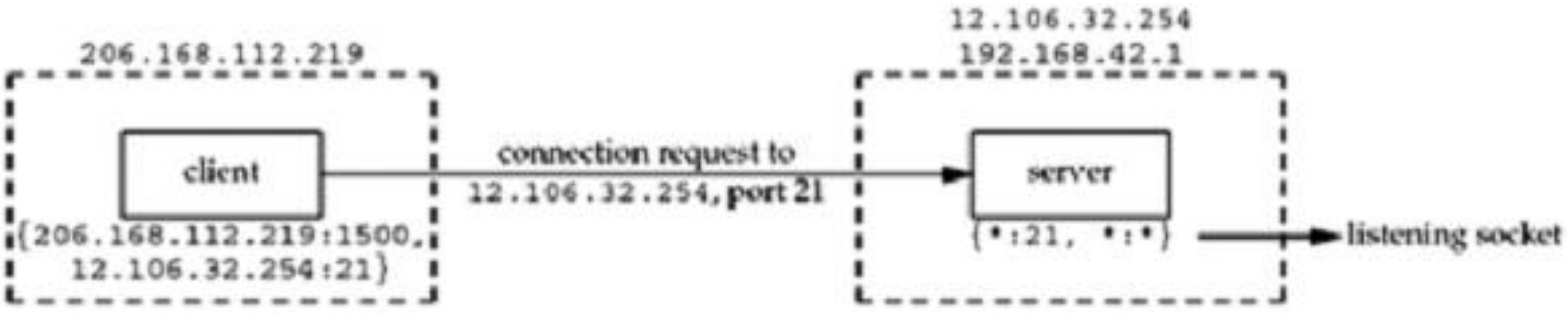
Socket Pair

- The socket pair for a TCP connection is the four-tuple that defines the two endpoints of the connection:
  - the local IP address, local port, foreign IP address, and foreign port.
- A socket pair uniquely identifies every TCP connection on a network.
- We can extend the concept of a socket pair to UDP, even though UDP is connectionless.
- TCP connection for a ftp server:
  - Server has two IP interfaces. * indicates any ip address/any port.

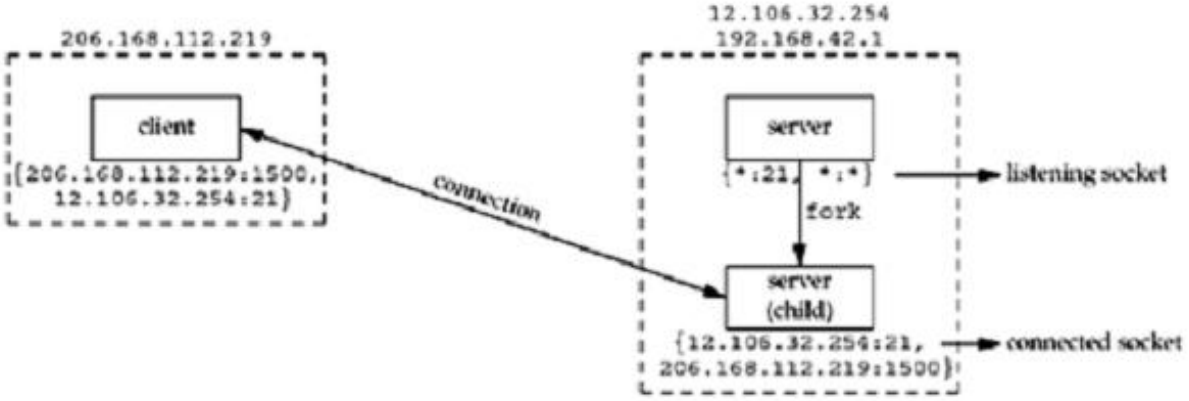


TCP Connection

- A client 206.168.112.219 connects to 12.106.32.254 at port 21.



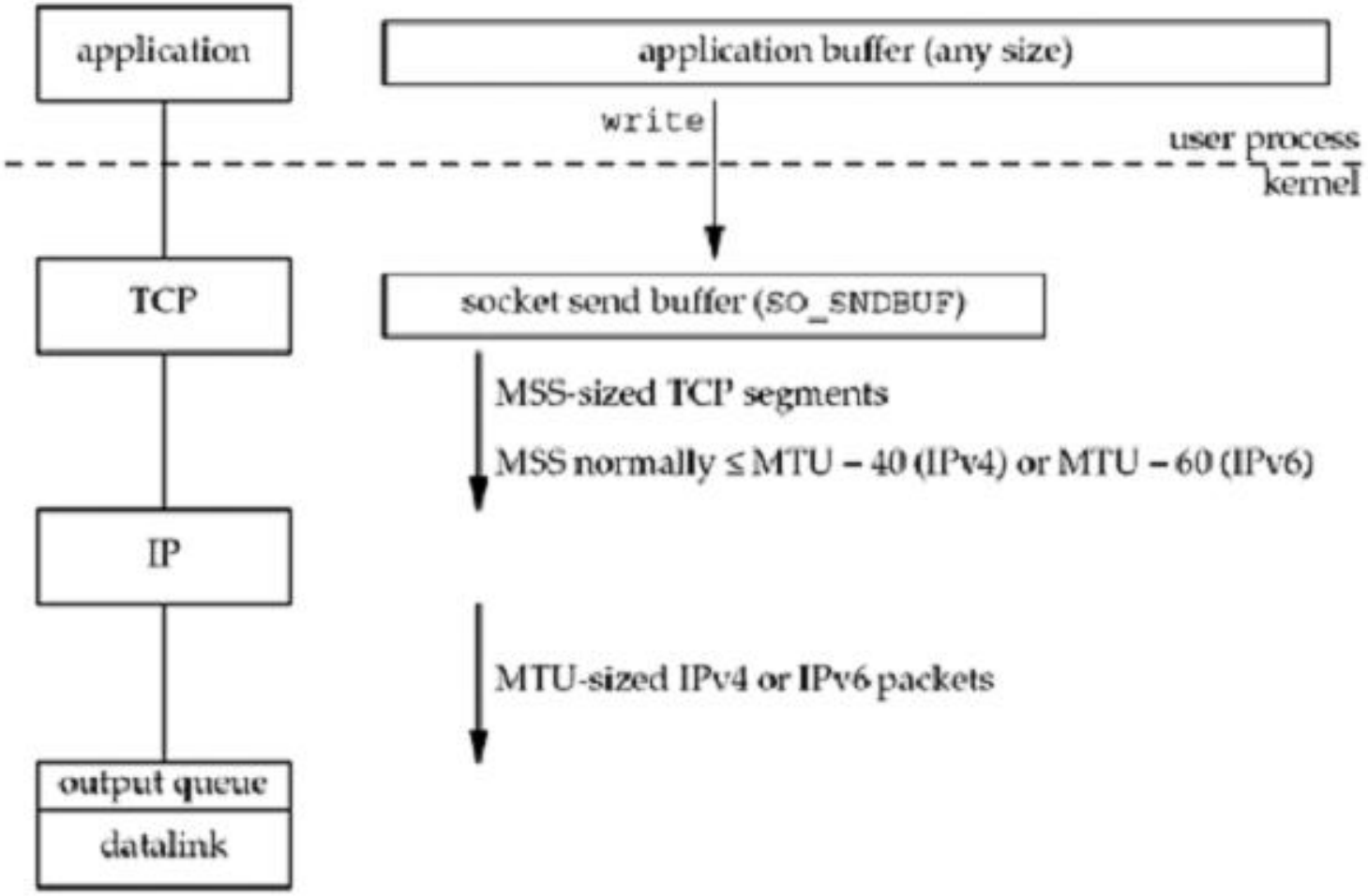
- Server creates a child to handle new cleint.
  - See the new TCP connection pair on server.



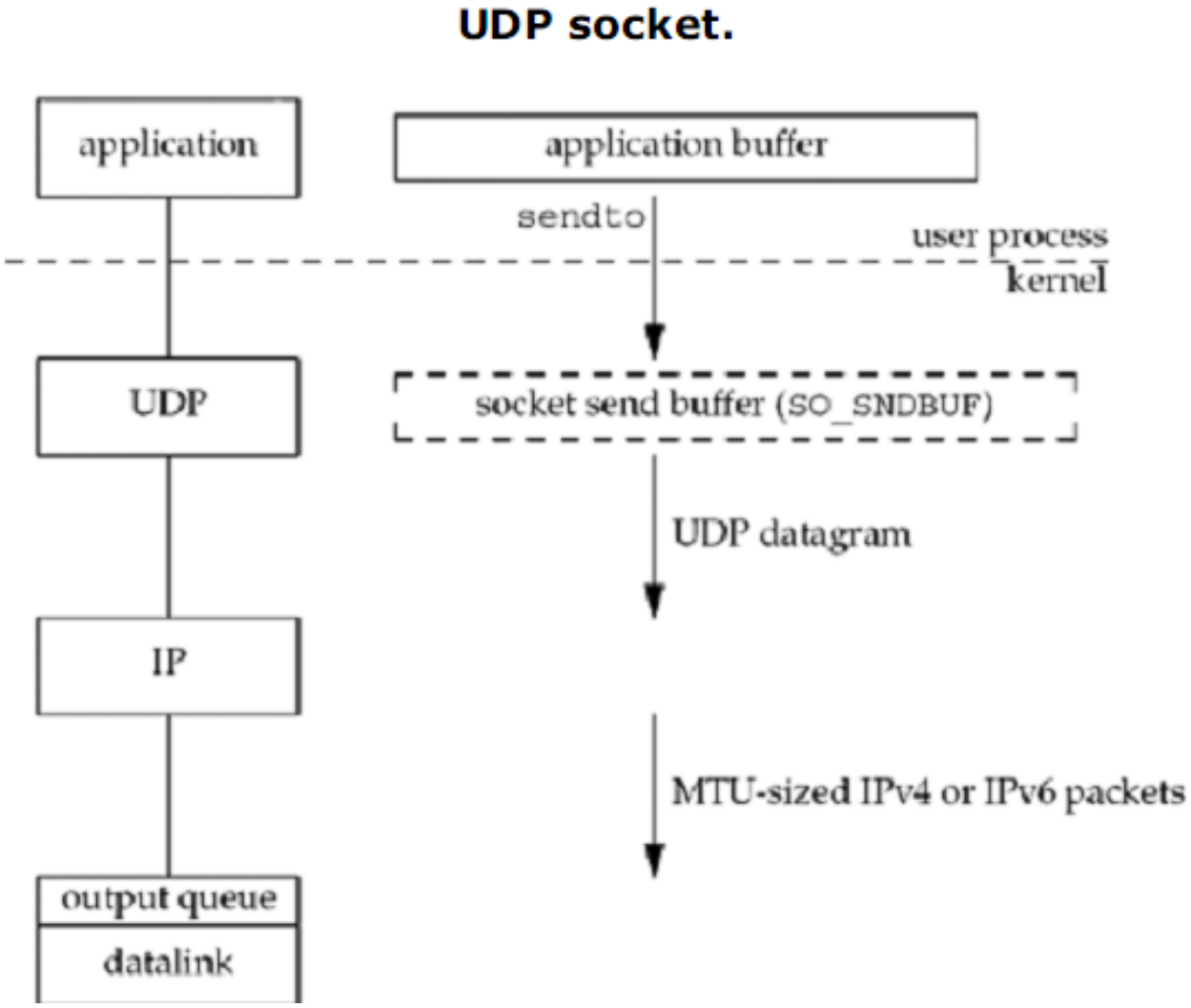
TCP Connection

- Client opens one more connection to the same server. What makes it a different TCP connection?

Writing to TCP Socket



Writing to UDP Socket



Creating a Socket


```
1  #include <sys/socket.h>
2  int socket(int  domain , int  type , int  protocol );
3  //Returns file descriptor on success, or -1 on error
```

- Domain argument specifies the communication domain.
- Type argument specifies the socket type
- Protocol is usually 0. Its value is automatically from first two arguments.
  - But for raw sockets, protocol value can be specified.
- The **`socket()`** system call returns a socket descriptor (small integer) or -1 on error.
- **`socket()`** allocates resources needed for a communication endpoint - but it does not deal with endpoint addressing.

Specifying an Endpoint Address

- Remember that the sockets API is generic.
- There must be a generic way to specify endpoint addresses.
- Internet Domain requires an IP address and a port number for each endpoint address.
- Other domains (families) may use other schemes.
- Data types for specifying address structure

```
1   sa_family_t //address family
2   socklen_t   //length of struct
3   in_addr_t   //IPv4 address
4   in_port_t   //IP port number
```

Generic Socket Address Structure

- General socket address structure acts as template.
- All sys calls take this as the input.

```
1  struct sockaddr {
2      sa_family_t sa_family;  /* Address family (AF_* constant) */
3      char        sa_data[14];/* Socket address (size varies
4                                according to socket domain) */
5  };
```

- For IPv4 domain, socket address structure is

```
1  struct sockaddr_in {
2      sa_family_t     sin_family;
3      in_port_t       sin_port;
4      struct in_addr  sin_addr;
5      char            sin_zero[8];
6  };
```

```
1  sa_family_t //address family
2  socklen_t   //length of struct
3  in_addr_t   //IPv4 address
4  in_port_t   //IP port number
```

```
2  struct in_addr {
3      in_addr_t       s_addr;
4  };
5
```

Specifying End Point Address

- Bind call binds an address to a socket

```
1  #include <sys/socket.h>
2  int bind(int  sockfd , const struct sockaddr * addr ,
3  socklen_t  addrlen );
4  //Returns 0 on success, or -1 on error
```

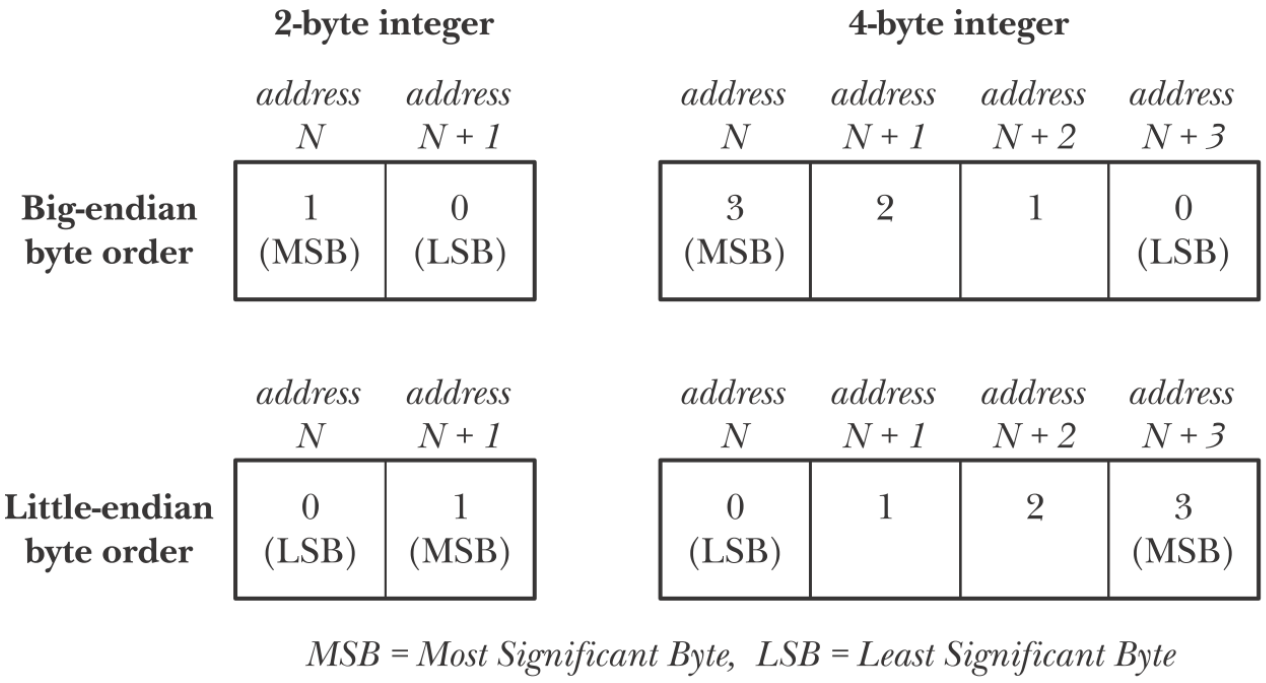
- Bind is used to bind the socket to a local end point.
  - *addr* is the pointer to an address structure that contains the endpoint address.

process specifies		result
IP address	**port**	
Wildcard	0	kernel chooses IP addr and port
Wild card	nonzero	kernel chooses IP, process specifies port
local IP addr	0	process specifies IP, kernel chooses port
local IP addr	nonzero	process specifies IP and port

Wildcard specified as INADDR_ANY

Byte Order

- Different hardware architectures in the network. Passing integers across the network needs to be in standard format: Network Byte Order (NBO): bigendian byte order.



Network Byte Order Functions

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```
1  #include <arpa/inet.h>
2  uint16_t htons(uint16_t  host_uint16 );
3  //Returns host_uint16 converted to network byte order
4  uint32_t htonl(uint32_t  host_uint32 );
5  //Returns host_uint32 converted to network byte order
6  /uint16_t ntohs(uint16_t  net_uint16 );
7  //Returns net_uint16 converted to host byte order
8  uint32_t ntohl(uint32_t  net_uint32 );
9  //Returns net_uint32 converted to host byte order
```

'**h**' : host byte order
'**n**' : network byte order
'**s**' : short (16bit)
'**l**' : long (32bit)

bind() Example

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```
1  int mysock,err;
2  struct sockaddr_in myaddr;
3
4  mysock = socket(PF_INET,SOCK_STREAM,0);
5  myaddr.sin_family = AF_INET;
6  myaddr.sin_port = htons( portnum );
7  myaddr.sin_addr = htonl( ipaddress);
8
9  err=bind(mysock, (sockaddr *) &myaddr, sizeof(myaddr));
```

- Note the usage of byte conversion.
- Nit the casting internet domain address to generic address structure.
- There are a number of uses for **`bind()`**:
  - Server would like to bind to a well known address (port number).
  - Client can bind to a specific port.
  - Client can ask the O.S. to assign *any available* port number.

IPv4 Address Conversion

- The inet_pton() and inet_ntop() functions allow conversion of both IPv4 and IPv6 addresses between binary form and dotted-decimal or hex-string notation.
- The p in the names of these functions stands for “presentation,” and the n stands for “network.” The presentation form is a human-readable string.

```
1  #include <arpa/inet.h>
2  int inet_pton(int  domain , const char * src_str , void * addrptr );
3  //Returns 1 on successful conversion, 0 if src_str is not in
4  //presentation format, or -1 on error
5  const char *inet_ntop(int  domain , const void * addrptr ,
6  char * dst_str , size_t  len );
7  //Returns pointer to dst_str on success, or  NULL  on error
```

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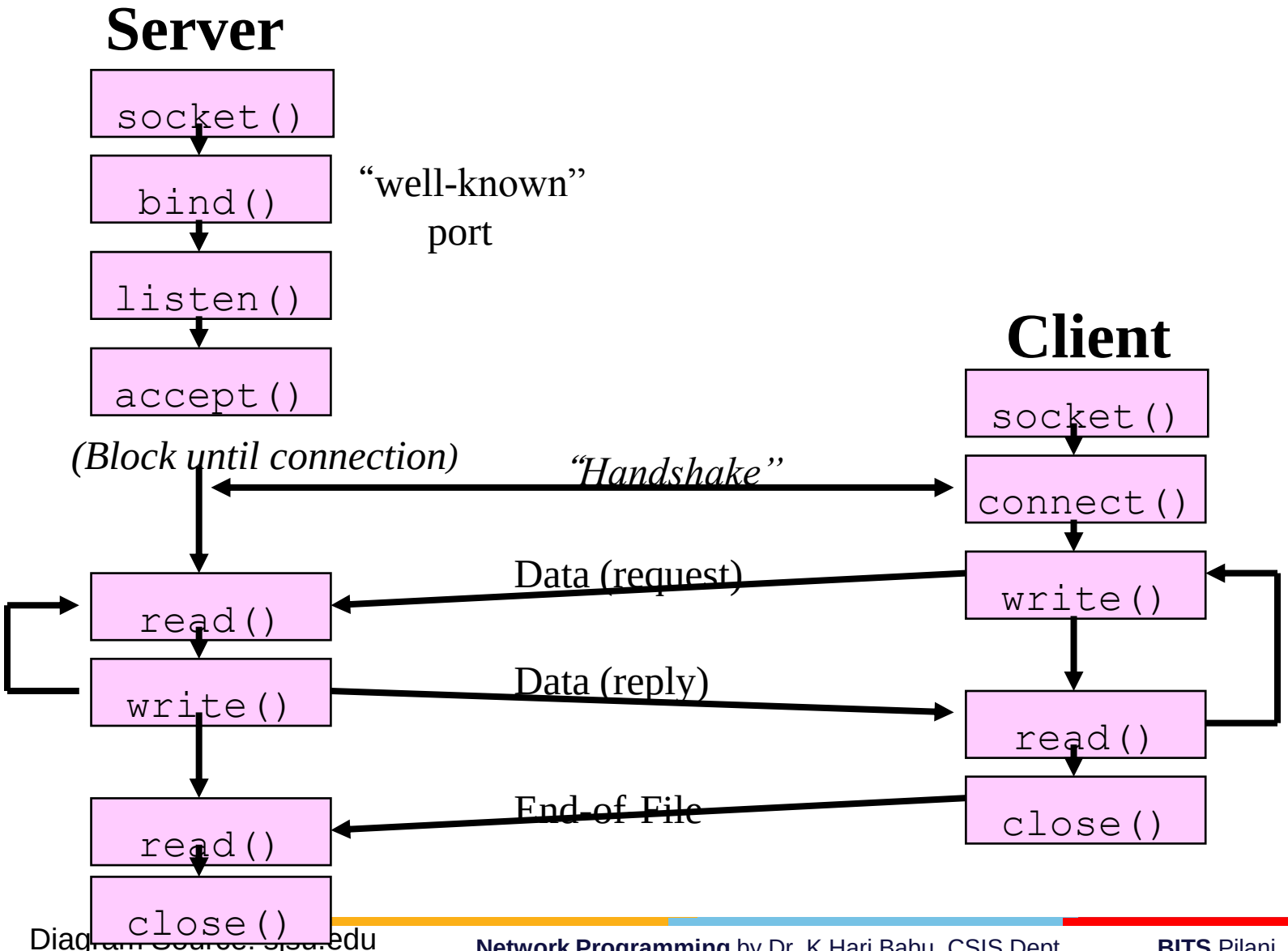
Client Server Programming

Active & Passive Sockets

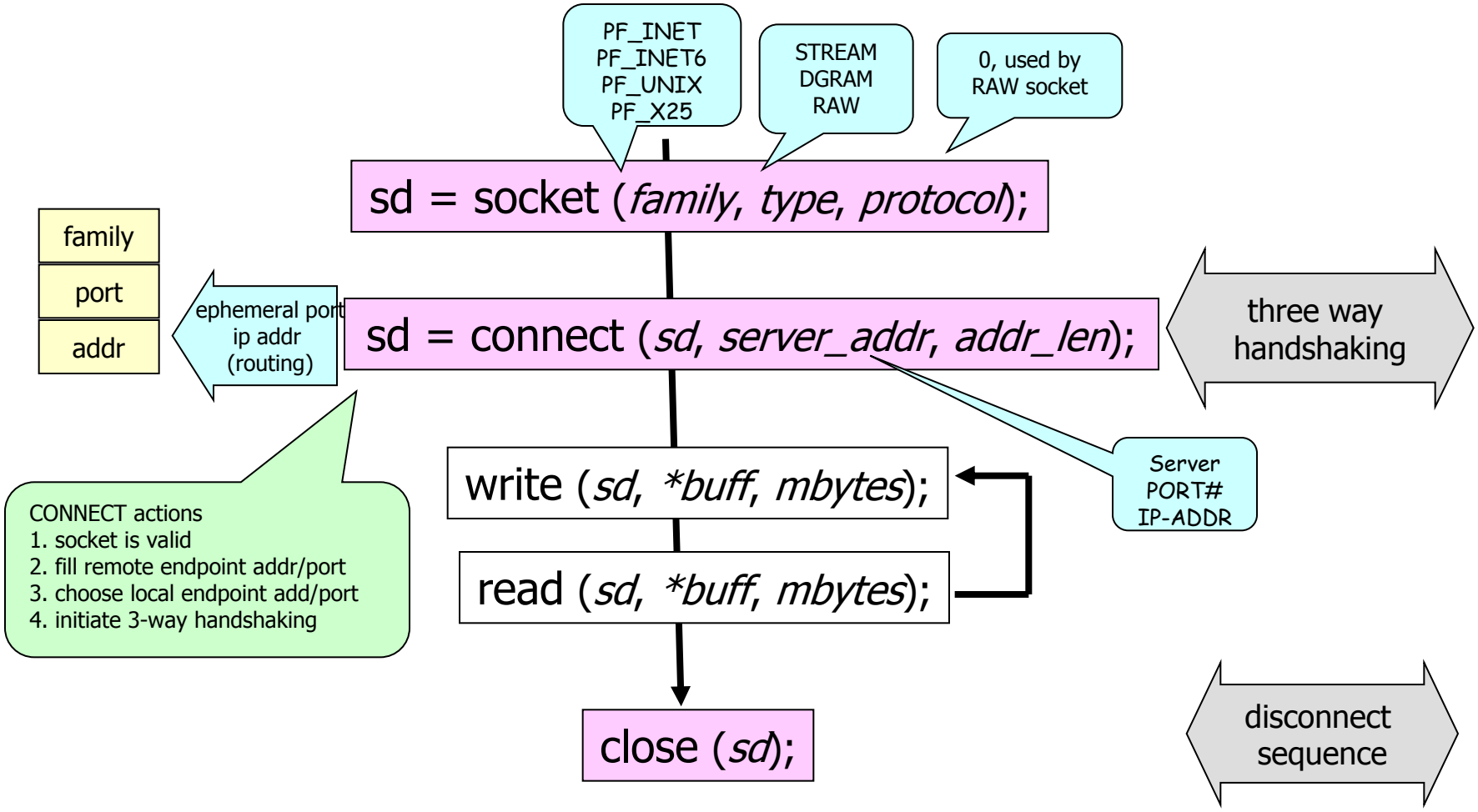
- By default, a socket that has been created using socket() is active.
  - An active socket can be used in a connect() call to establish a connection to a passive socket.
  - This is referred to as performing an active open.
- A passive socket (also called a listening socket) is one that has been marked to allow incoming connections by calling listen().
  - Accepting an incoming connection is referred to as performing a passive open.
- client:
  - which does active socket open
- Server:
  - which does passive socket open.

TCP Client Server



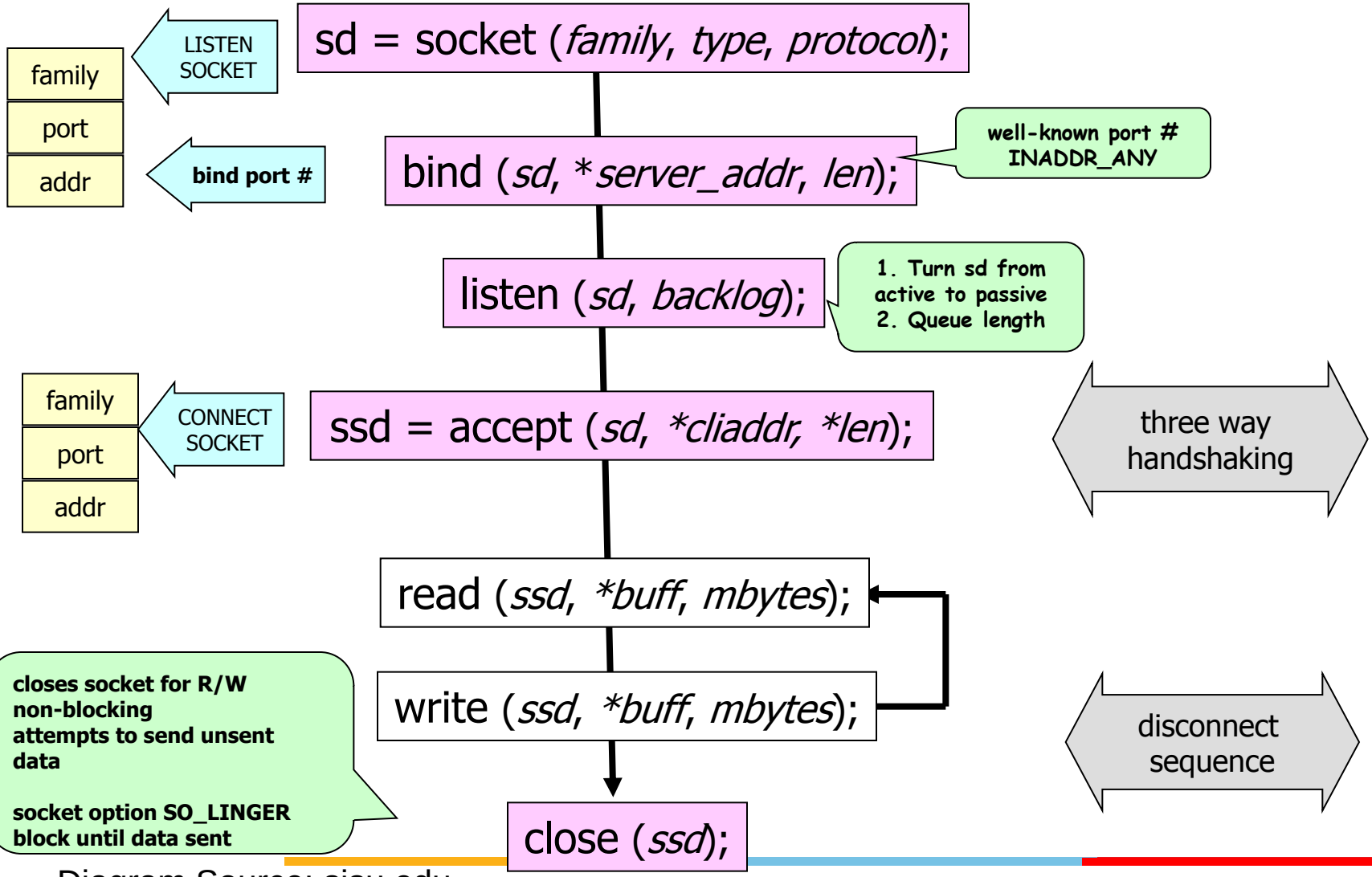
- Diagram Source: sjsu.edu

TCP Client



- Diagram Source: sjsu.edu

TCP Server



- Diagram Source: sjsu.edu

connect() - connect to server

- The connect() system call connects the active socket referred to by the file descriptor sockfd to the listening socket whose address is specified by addr and addrlen.

```
1  #include <sys/socket.h>
2  int connect(int  sockfd , const struct sockaddr * addr,
3  socklen_t  addrlen );
4  //Returns 0 on success, or -1 on error
```

  - *sockfd* is socket descriptor from `socket()`
  - *servaddr* is a pointer to a structure with:
    - *port number* and *IP address*
    - must be specified (unlike `bind()`)
  - *addrlen* is length of structure
  - client doesn't need `bind()`
    - OS will pick ephemeral port
  - returns socket descriptor if ok, -1 on error

connect() - connect to server

- Errors
  - If the server's TCP response to client TCP's SYN segment is RST, then there is no process is waiting for incoming connections.
    - Hard error
  - Three conditions that generate RST are
    - when a SYN arrives for a port that has no listening server
    - when TCP wants to abort an existing connection
    - when TCP receives a segment for a connection that does not exist
  - If client's SYN request elicits ICMP "destination unreachable" message, kernal saves the message but keeps on sending the SYN segment.
    - Soft error

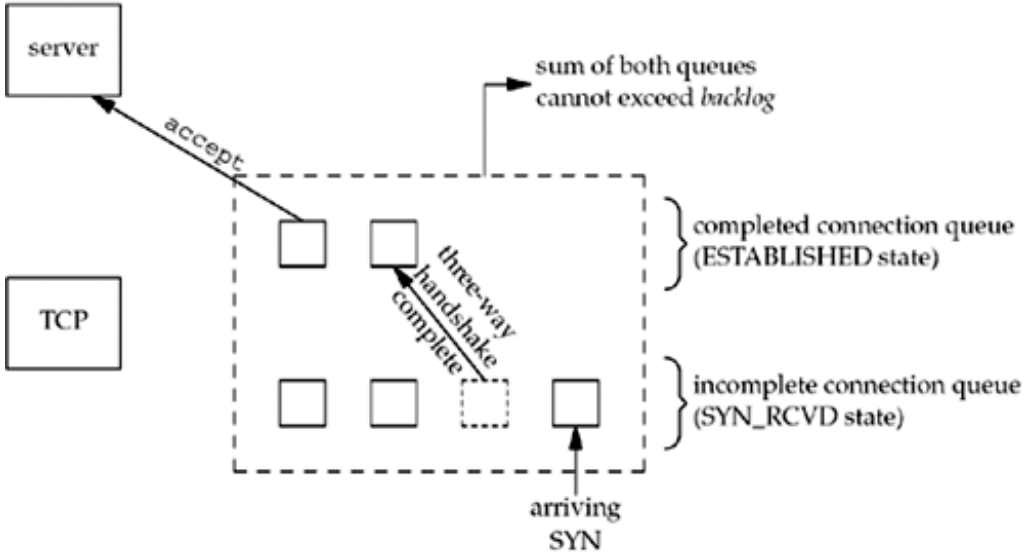
listen() - change socket state to passive

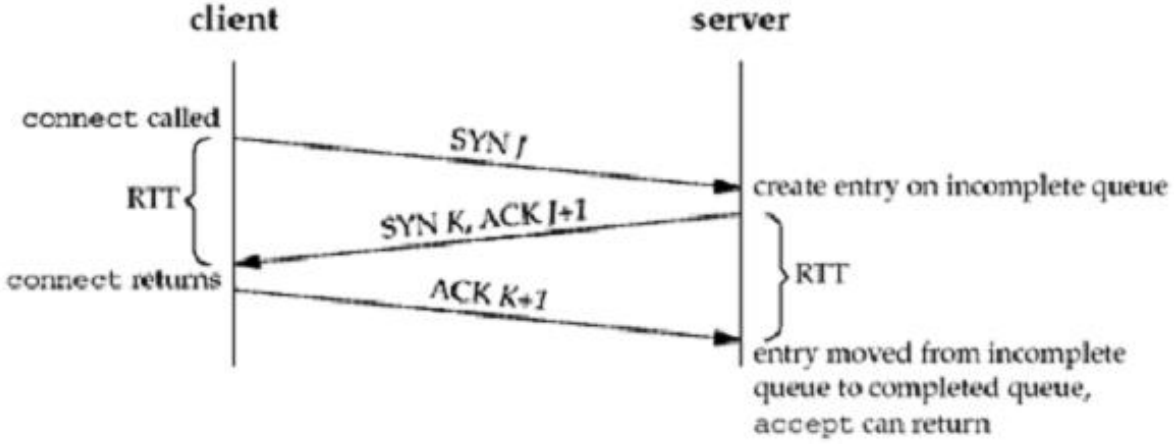
- The listen() system call marks the stream socket referred to by the file descriptor sockfd as passive.
  - The socket will subsequently be used to accept connections from other (active) sockets.

```
1  #include <sys/socket.h>
2  int listen(int  sockfd , int  backlog );
3  //Returns 0 on success, or -1 on error
```

- *sockfd* is socket descriptor from `socket()`
- *backlog* is maximum number of connections that the server should queue for this socket
  - historically 5
  - rarely above 15 on a even moderate Web server!

listen()


server
accept
sum of both queues
cannot exceed backlog
TCP
three-way handshake complete
completed connection queue
(ESTABLISHED state)
incomplete connection queue
(SYN_RCVD state)
arriving SYN


client
server
connect called
SYN J
RTT
create entry on incomplete queue
SYN K, ACK J+1
RTT
connect returns
ACK K+1
entry moved from incomplete
queue to completed queue,
accept can return

accept() - return next completed connection

- The accept() system call accepts an incoming connection on the listening stream socket referred to by the file descriptor sockfd.
  - If there are no pending connections when accept() is called, the call blocks until a connection request arrives.

```
1  #include <sys/socket.h>
2  int accept(int  sockfd , struct sockaddr * addr,
3  socklen_t * addrlen );
4  //Returns file descriptor on success, or -1 on error
```

- *sockfd* is socket descriptor from `socket()`
- *cliaddr* and *addrlen* return protocol address from client
- returns brand new descriptor, created by OS
  - if used with `fork()`, can create concurrent server

close() - close socket fd

- *sockfd* is socket descriptor from `socket()`
- closes socket for reading/writing
  - returns (doesn't block)
  - attempts to send any unsent data
  - socket option SO_LINGER
    - block until data sent
    - or discard any remaining data
  - Returns -1 if error

Descriptor Reference Counts

- For every socket a reference count is maintained, as to how many processes are accessing that socket
- When close() is called on socket descriptor reference count is decreased by 1
- When close() is called on socket descriptor, TCP 4 packet termination sequence will be initiated only if the reference count goes to zero.

getsockname() and getpeername() Functions

- getsockname return the local endpoint address associated with a socket
- getpeername return the foreign protocol address associated with a socket

```
1  #include <sys/socket.h>
2   int getsockname(int sockfd, struct sockaddr *localaddr,
3   socklen_t *addrlen);
4   int getpeername(int sockfd, struct sockaddr *peeraddr,
5   socklen_t *addrlen);
```

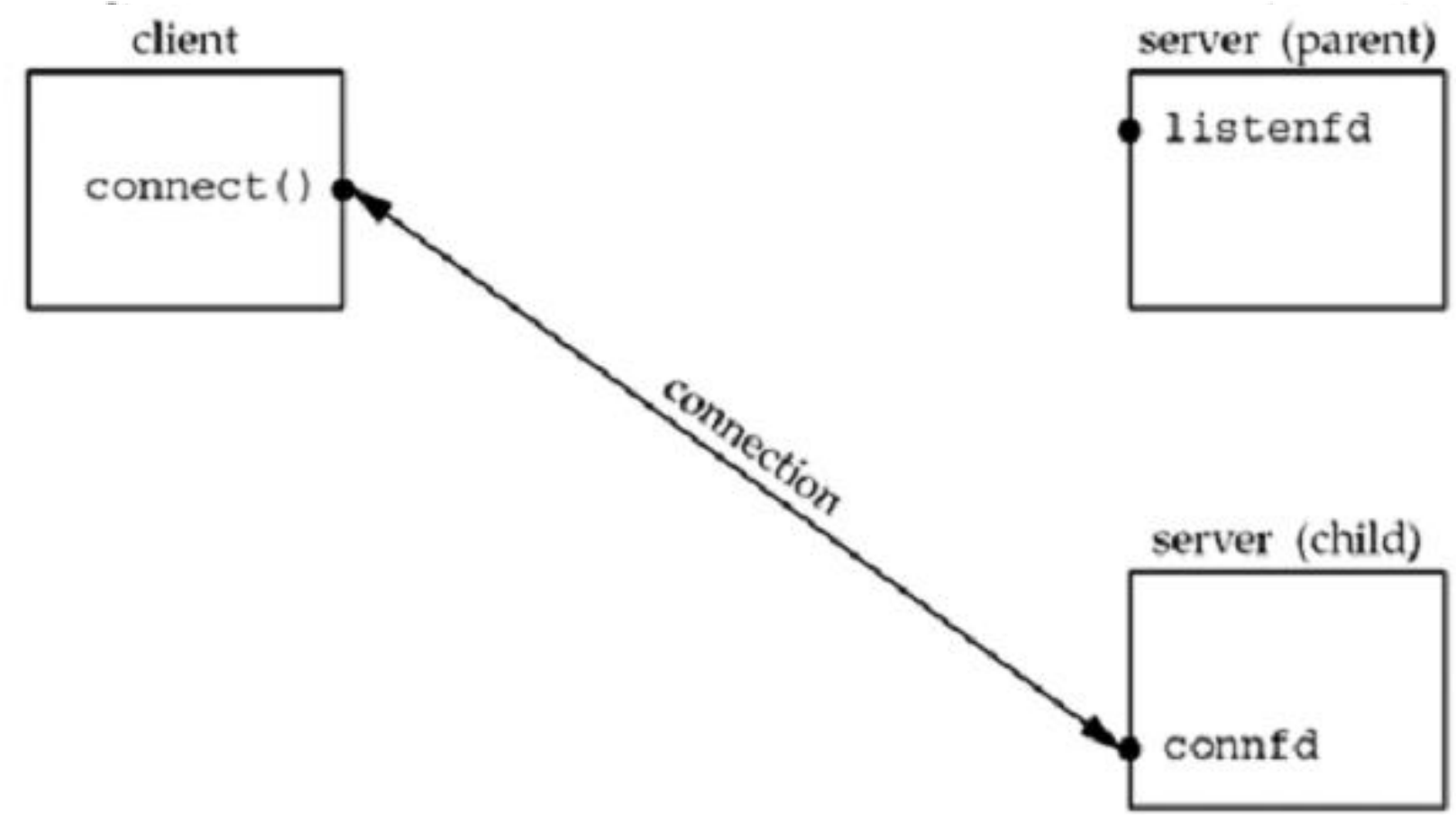
TCP Echo Client

- TCP client and server using echo protocol

```
 1  int main(int argc, char **argv)
 2  {
 3   int     sockfd;
 4   struct sockaddr_in servaddr;
 5   if (argc != 2)
 6      err_quit("usage: tcpcli <IPaddress>");
 7   sockfd = Socket(PF_INET, SOCK_STREAM, 0);
 8   bzero(&servaddr, sizeof(servaddr));
 9   servaddr.sin_family = AF_INET;
10   servaddr.sin_port = htons(SERV_PORT);
11   inet_pton(AF_INET, argv[1], &servaddr.sin_addr);
12   connect(sockfd, (SA *) &servaddr, sizeof(servaddr));
13   str_cli(stdin, sockfd);
```

```
17  void str_cli(FILE *fp, int sockfd)
18  {
19      char sendline[MAXLINE], recvline[MAXLINE];
20      while (Fgets(sendline, MAXLINE, fp) != NULL) {
21       write(sockfd, sendline, strlen (sendline));
22       if (wead(sockfd, recvline, MAXLINE) == 0)
23           err_quit("str_cli: server terminated prematurely");
24       wputs(recvline, stdout);
25  }}
```

TCP Concurrent Server



TCP Concurrent Server


```
1  int main(int argc, char **argv)
2  {  int     listenfd, connfd;
3   pid_t   childpid;
4    socklen_t clilen;
5    struct sockaddr_in cliaddr, servaddr;
6   listenfd = Socket (AF_INET, SOCK_STREAM, 0);
7   bzero(&servaddr, sizeof(servaddr));
8   servaddr.sin_family = AF_INET;
9   servaddr.sin_addr.s_addr = htonl (INADDR_ANY);
10  servaddr.sin_port = htons (SERV_PORT);
11  bind(listenfd, (SA *) &servaddr, sizeof(servaddr));
12  listen(listenfd, LISTENQ);
13   for ( ; ; )  {
14   clilen = sizeof(cliaddr);
15   connfd = accept(listenfd, (struct sokaddr *) &cliaddr, &clilen);
16   if ( (childpid = fork()) == 0) { /* child process */
17       close(listenfd);    /* close listening socket */
18   str_echo(connfd);   /* process the request */
19   exit (0);
20   }
21  close(connfd);          /* parent closes connected socket */
22  }
23  }
```

str_echo function

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```
1   void  str_echo(int sockfd)
2     {
3         ssize_t n;
4         char    buf[MAXLINE];
5       again:
6         while ( (n = read(sockfd, buf, MAXLINE)) > 0)
7             Write(sockfd, buf, n);
8         if (n < 0 && errno == EINTR)
9             goto again;
10        else if (n < 0)
11            err_sys("str_echo: read error");
12    }
```

TCP Concurrent Server

- Handling zombies
  - while ((pid = waitpid(-1, &stat, WNOHANG)) > 0) in SIGCHLD signal handler
- Handling interrupted system calls
  - when writing network programs that catch signals, we must be cognizant of interrupted system calls, and we must handle them
  - Slow system call is any system call that can block forever

Handling interrupted system calls


```
for ( ; ; ) {
clilen = sizeof (cliaddr);
if ( (connfd = accept (listenfd, (SA *)
  &cliaddr, &clilen)) < 0) {
    if (errno == EINTR)
    continue;              /* back to for () */
    else
            err_sys ("accept error");
        }
```

- Another option:
  - Use sigaction() with SA_RESTART flag.

Termination of Server Process

- FIN is sent to client
- Client tcp sends ACK to server
- What if client application doesn't take not of it, and sends data to server?

SIGPIPE Signal

- When a process writes to a socket that has received an RST, the SIGPIPE signal is sent to the process.
- The default action of this signal is to terminate the process, so the process must catch the signal to avoid being involuntarily terminated.

Crashing of Server Host

- Nothing is sent to client
- Client will try to reach the host, but will get errors such as ETIMEDOUT, EHOSTUNREACH, ENETWORKUNREACH

Crashing and Rebooting of Server Host

- When client sends packets, server will respond with RST

Shutdown of Server Host

- Init sends SIGTERM to all processes
- Then sends SIG KILL to all processes
- Fin is sent to the client

Exercise

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- Write a TCP client and server that fulfills the following requirements.
- Server.c:
  - server should take port number on command-line and listen on that port.
  - server should create a child to handle a new client.
  - When a client sends a command such as 'ps', server should execute the command and send the output to the client.
  - it should take care of zombies.
- Client.c:
  - client takes ip address and port number of the server on command-line.
  - client sets up a connection to the server.
  - client takes a command from the user and sends it to the server.
  - client waits for the reply and prints the reply on the standard output.

```
1  if ((servSock = socket(PF_INET, SOCK_STREAM, IPPROTO_TCP)) < 0)
2  printf("socket() failed");
3  memset(&echoServAddr, 0, sizeof(echoServAddr));
4  echoServAddr.sin_family = AF_INET;
5  echoServAddr.sin_addr.s_addr = htonl(INADDR_ANY);
6  echoServAddr.sin_port = htons(echoServPort);
7  if (bind
8  (servSock, (struct sockaddr *) &echoServAddr,
9   sizeof(echoServAddr)) < 0)
10 printf("bind() failed");
11 if (listen(servSock, MAXPENDING) < 0)
12 printf("listen() failed");
```

```
14      for (;;) {
15      clntLen = sizeof(echoClntAddr);
16      if ((clntSock = accept(servSock, (struct sockaddr *) &echoClntAddr,
17                      &clntLen)) < 0)//2M
18      printf ("accept() failed");
19      printf("Handling client %s\n", inet_ntoa(echoClntAddr.sin_addr));
20      ret=fork(); //3M
21          if(ret==0){
22              close(listenfd);
23              read(clntSock, buff, size);
24              int p[2];
25              pipe(p);
26              ret=fork();
27              if(ret==0)
28              {   close(1);
29                  dup(p[1]);
30                  execv(buff);
31                  }
32              read(p[0],buff,size);
33              write(clntSock,buff,size);
34              }
35      close(clntSock);
36  }
```

```
1  //Step 1: Set up Address Structure
2  bzero(&Server_Address, sizeof(Server_Address));
3  Server_Address.sin_family = AF_INET;
4  Server_Address.sin_port = htons(port);
5  temp = inet_addr(Address);
6  if (temp != INADDR_NONE){
7      Server_Address.sin_addr.s_addr = temp;
8  }else{
9      printf ("Invalid IP Address.");
10 }
11 //Step 2: Create a Socket
12 mysocket = socket(PF_INET, SOCK_STREAM, 0);
13 if (mysocket == -1) printf ("socket()");
14
15 //Step 3: Connect to Server
16 result = connect(mysocket, (struct sockaddr *) &Server_Address,
17 sizeof(Server_Address) );
18 if (result == -1) printf ("connect()");
19 while(1){
20 scanf("%s", cmd);
21 if(strcmp(cmd,"exit")==0)
22     exit(0);
23 write(mysocket, cmd,(strlen(cmd));
24 read(mysocket,buff,size);
25 printf("%s", buff);}}
```

Acknowledgements

Q&A

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Thank You