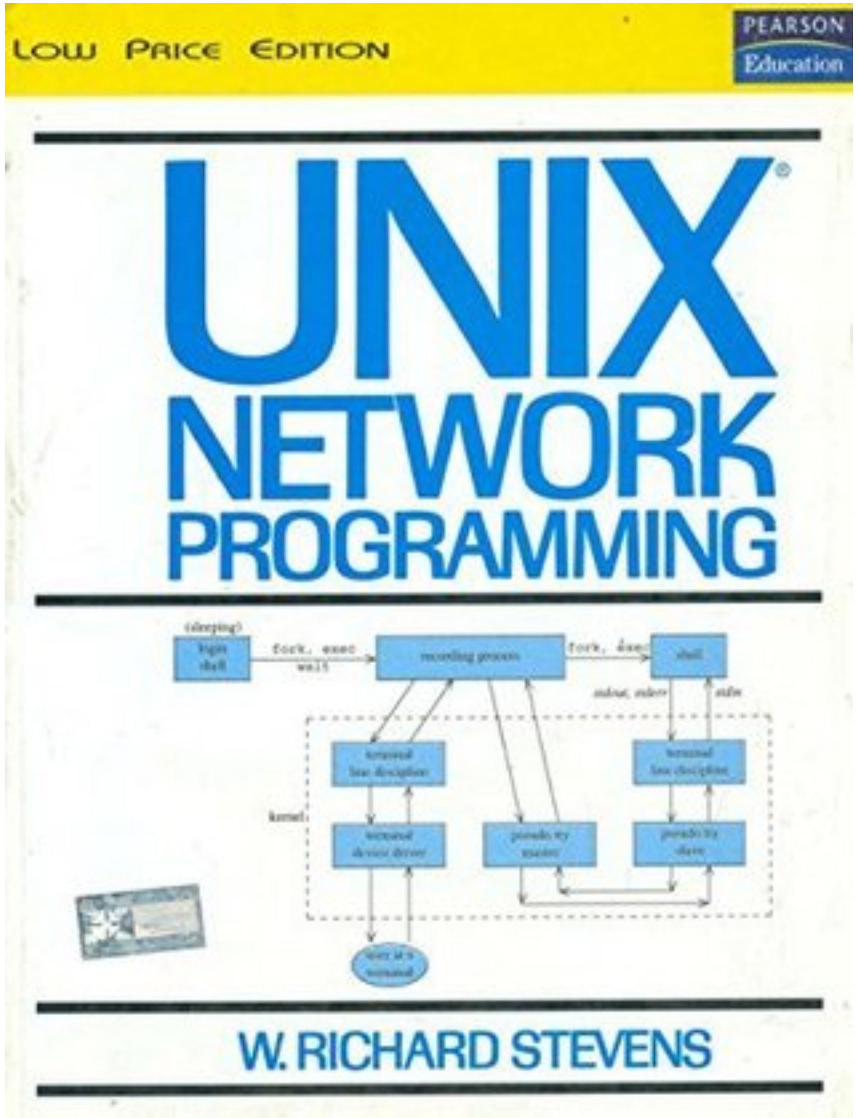
Network Programming



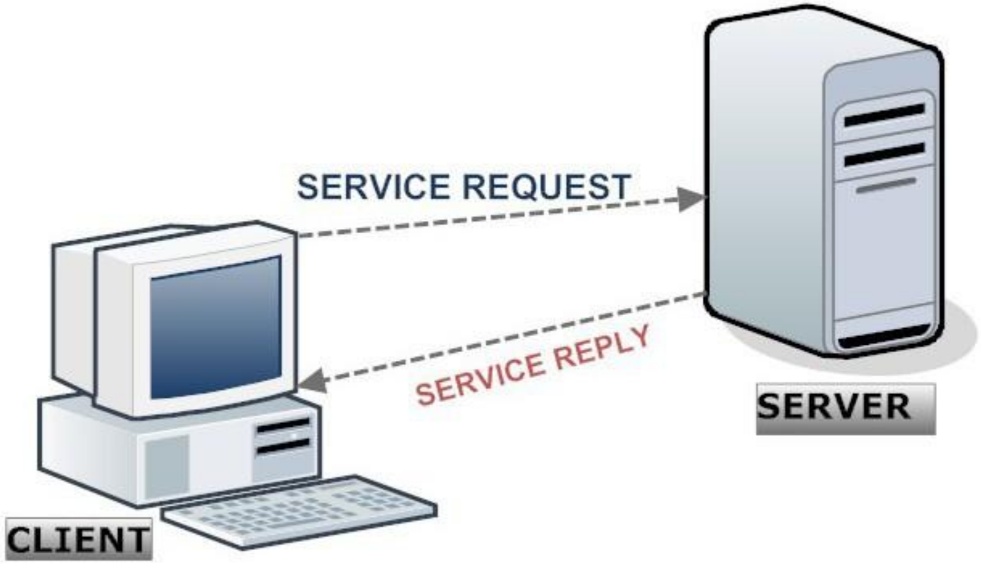
UNIT-1

- **Introduction**: Introduction, Client/server communication, OSI Model, BSD Networking history, Test Networks and Hosts, Unix Standards, 64-bit architectures.
- **Transport Layer:** TCP, UDP and SCTP, TCP Connection Establishment and Termination.
- **Self learning topics:** TCP/IP Protocols in nut shell.

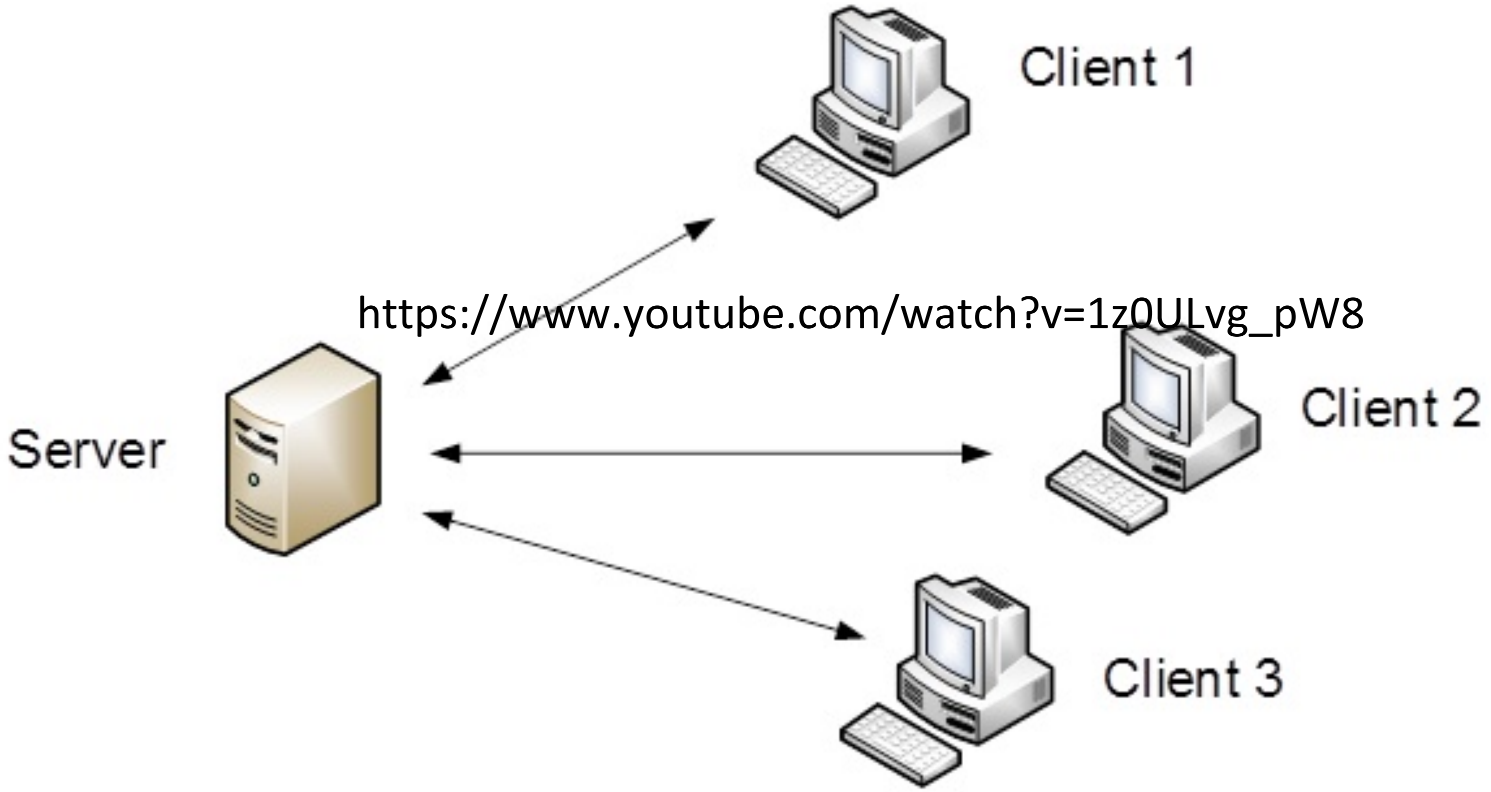
Network programming involves writing programs to communicate with processes either on the same or on other machines on the network using standard Protocols…

High-level decision must be made as to which program would initiate the communication first and when responses are expected…

WebServer program waits for clients to send request and only after the request is received it responds with a reply…

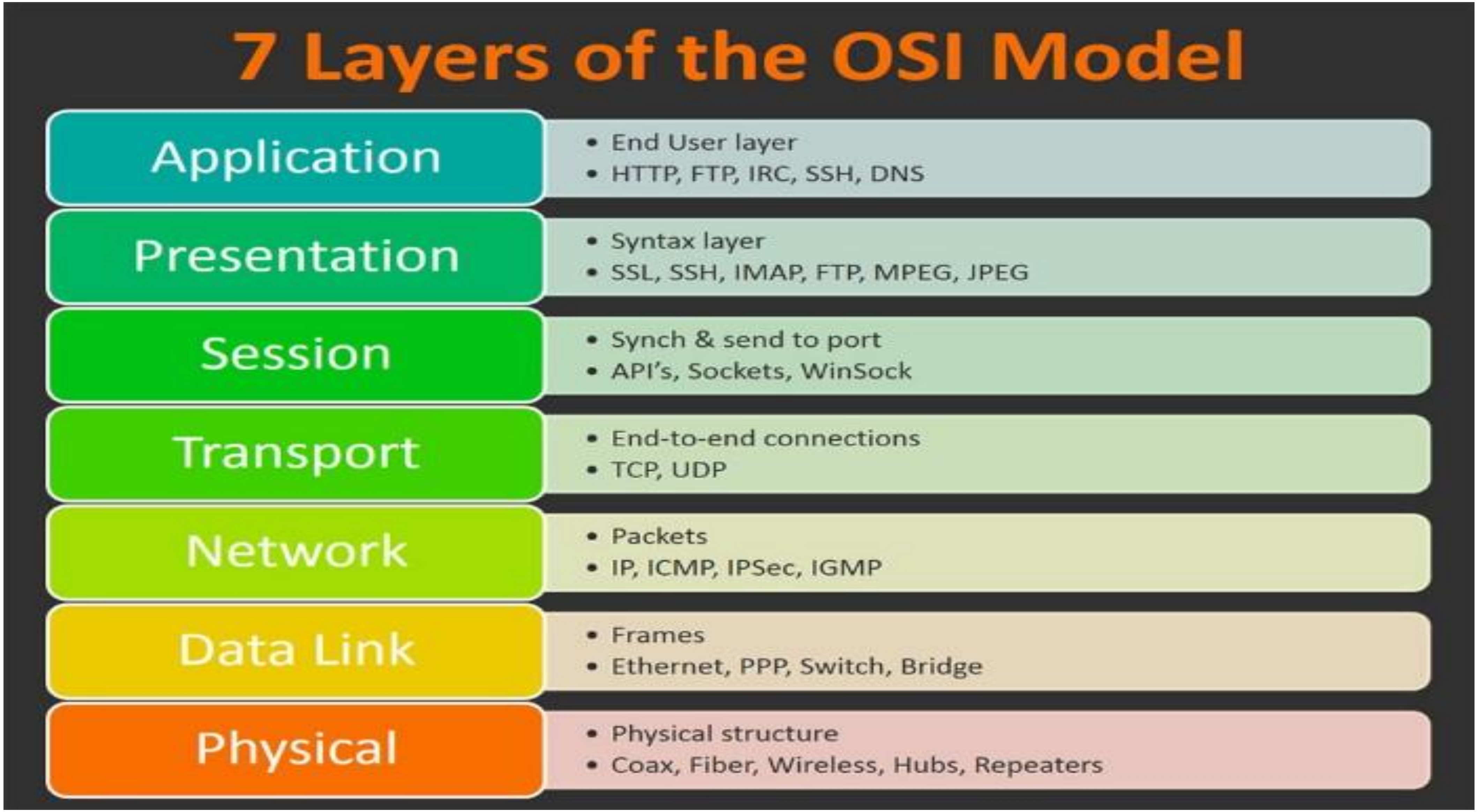


Single Server – Serving multiple Clients

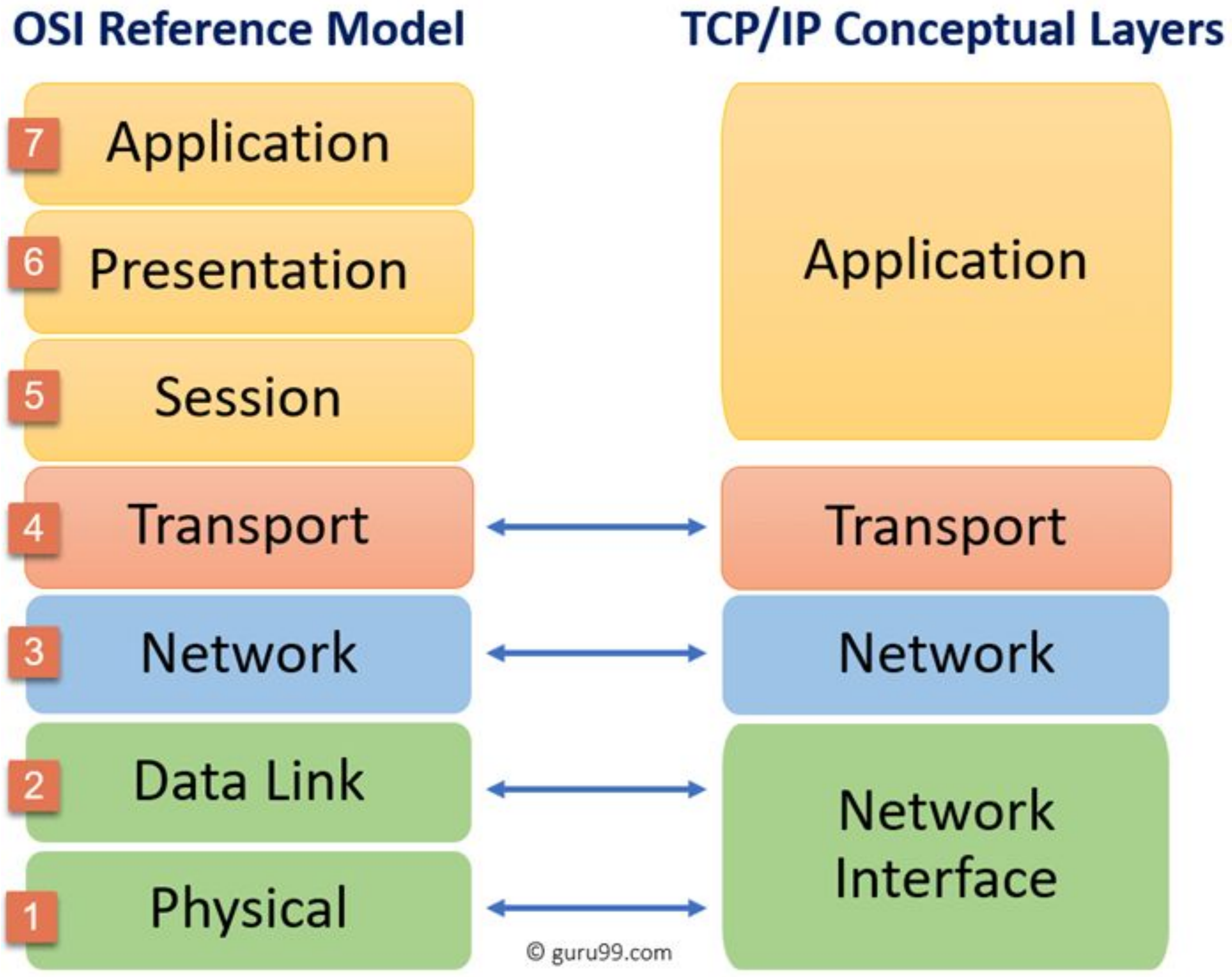


https://www.youtube.com/watch?v=1z0ULvg_pW8

OSI - Model


7 Layers of the OSI Model
Application
• End User layer
• HTTP, FTP, IRC, SSH, DNS
Presentation
• Syntax layer
• SSL, SSH, IMAP, FTP, MPEG, JPEG
Session
• Synch & send to port
• API's, Sockets, WinSock
Transport
• End-to-end connections
• TCP, UDP
Network
• Packets
• IP, ICMP, IPSec, IGMP
Data Link
• Frames
• Ethernet, PPP, Switch, Bridge
Physical
• Physical structure
• Coax, Fiber, Wireless, Hubs, Repeaters

TCP/IP Model



OSI Reference Model
TCP/IP Conceptual Layers
7 Application
6 Presentation
5 Session
4 Transport
3 Network
2 Data Link
1 Physical
Application
Transport
Network
Network Interface
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BSD

BSD

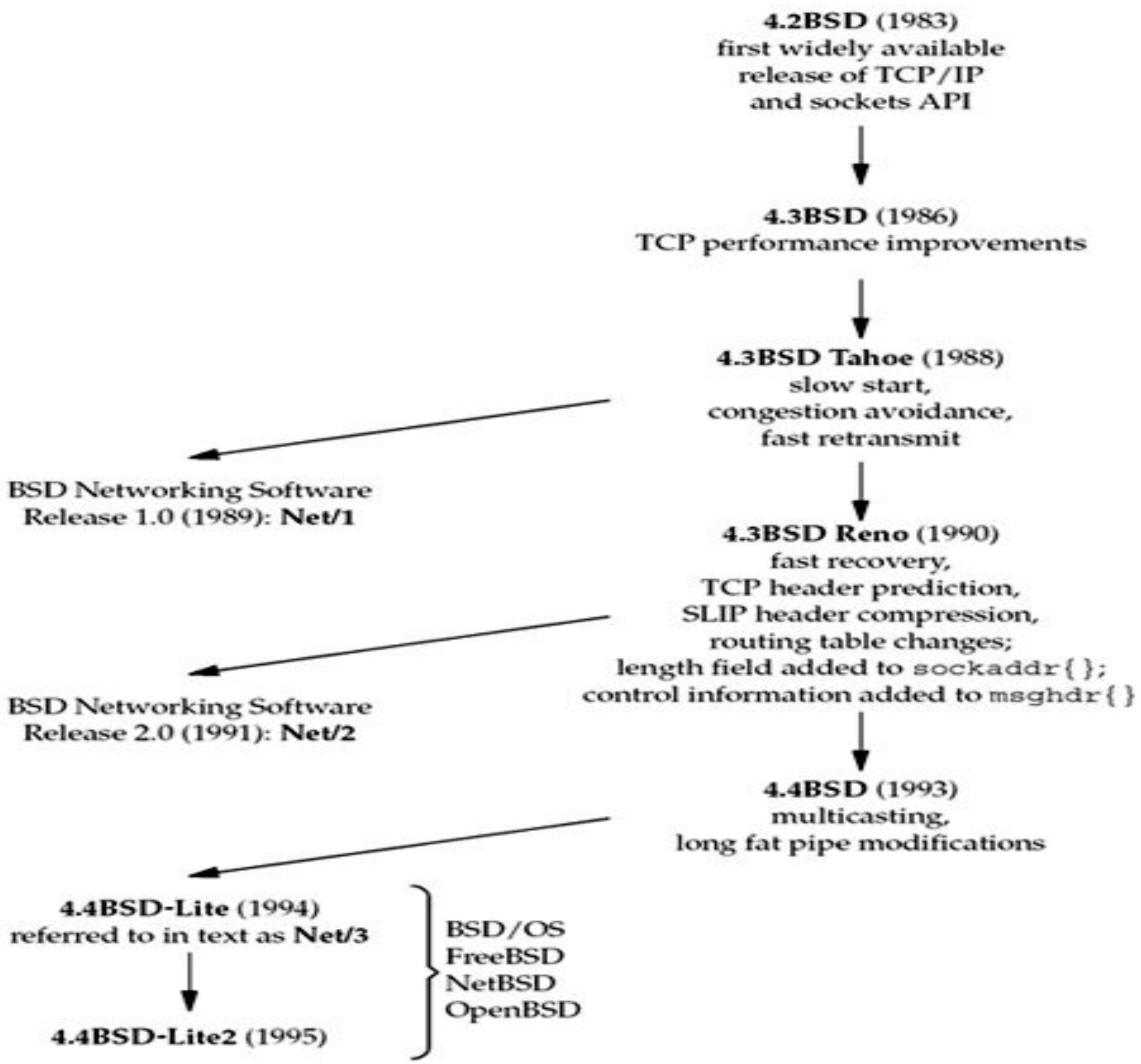
Berkeley Software Distribution (BSD, sometimes called Berkeley Unix) is the UNIX operating system derivative developed and distributed by the Computer Systems Research Group (CSRG) of the University of California, Berkeley, from 1977 to 1995.

BSD

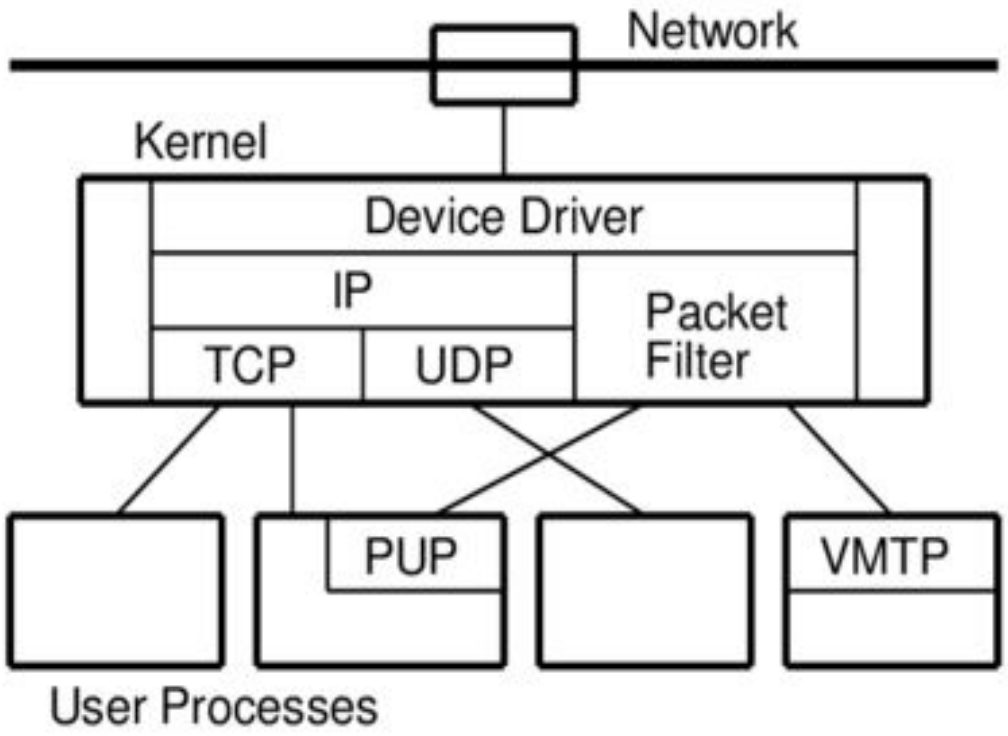
The History of BSD

- 1977 - Bill Joy puts together 1st Berkeley Software Distribution (Version 1)
- mid-1978 - 2BSD released with improved Pascal, termcap, vi (about 75 shipped)
- 1978 - Berkeley obtains a VAX-11/780
- A copy of AT&T 32/V UNIX is installed - does not take advantage of virtual memory

BSD History


4.2BSD (1983)
first widely available
release of TCP/IP
and sockets API
4.3BSD (1986)
TCP performance improvements
4.3BSD Tahoe (1988)
slow start,
congestion avoidance,
fast retransmit
BSD Networking Software
Release 1.0 (1989): **Net/1**
4.3BSD Reno (1990)
fast recovery,
TCP header prediction,
SLIP header compression,
routing table changes;
length field added to sockaddr{};
control information added to msghdr{}
BSD Networking Software
Release 2.0 (1991): **Net/2**
4.4BSD (1993)
multicasting,
long fat pipe modifications
4.4BSD-Lite (1994)
referred to in text as **Net/3**
4.4BSD-Lite2 (1995)
BSD/OS
FreeBSD
NetBSD
OpenBSD

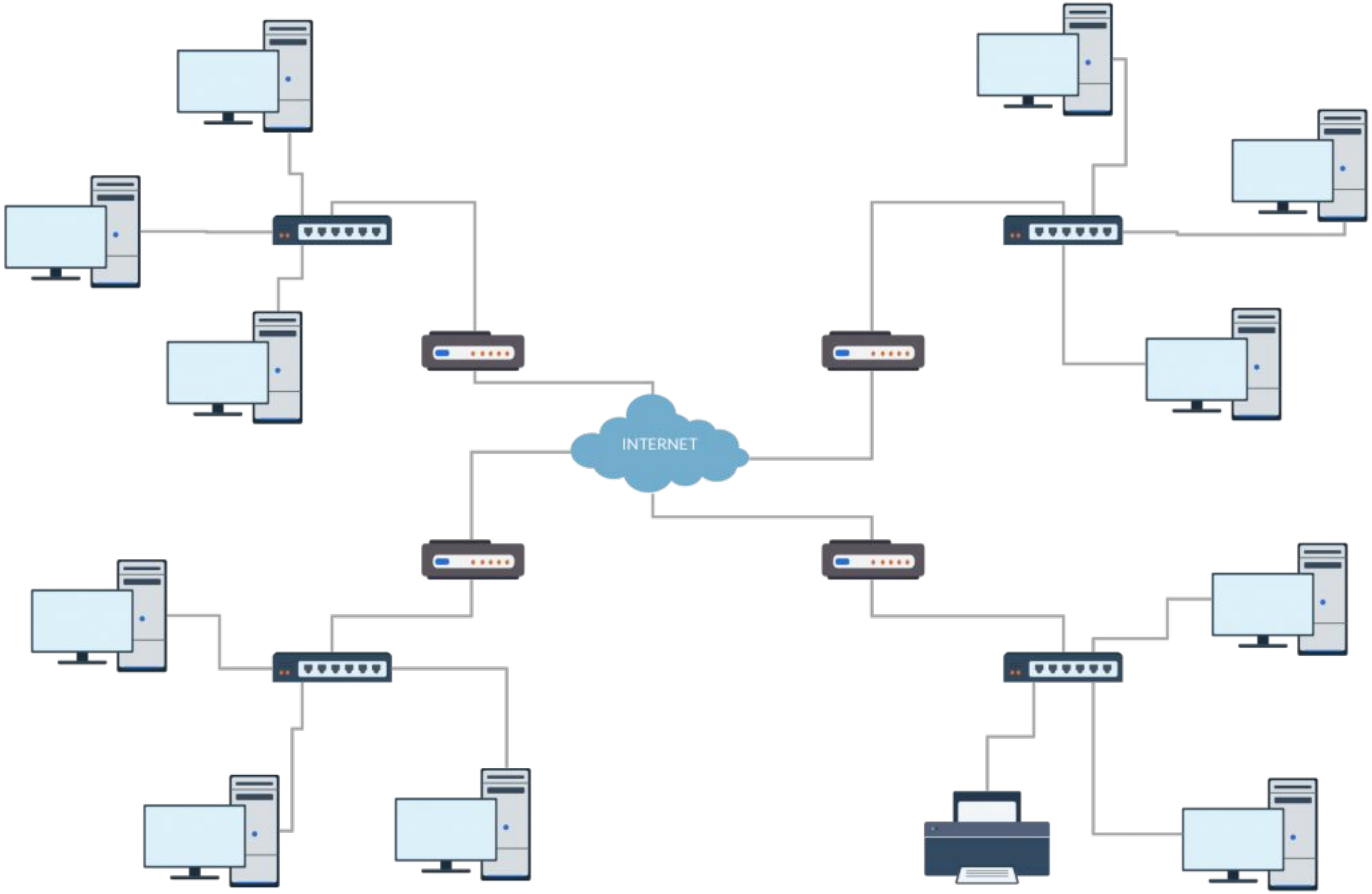
BSD Network



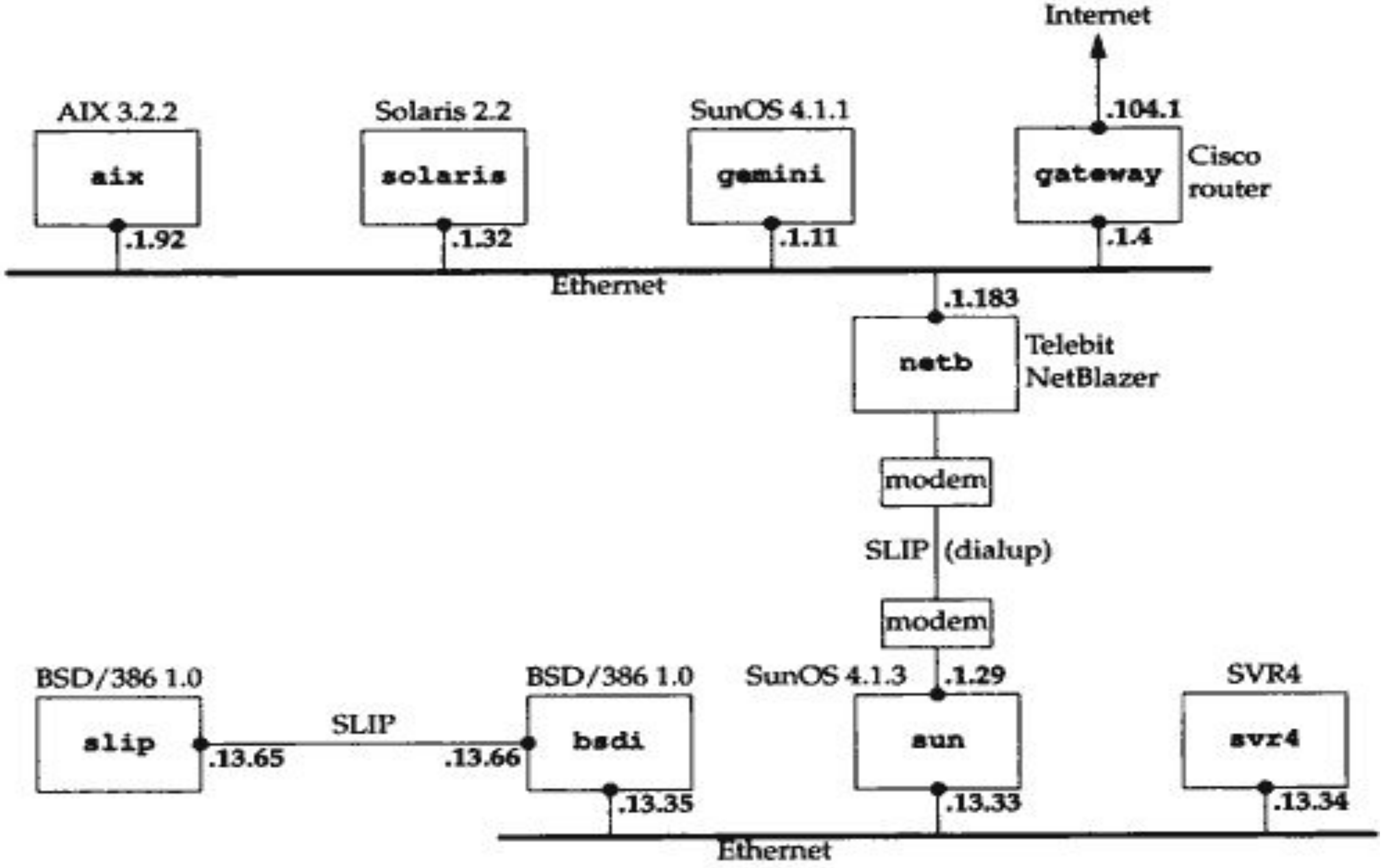
Potentially Unwanted Applications

Versatile Message Transaction Protocol

Test Network and Hosts



Test Network and Hosts



Communication over LAN

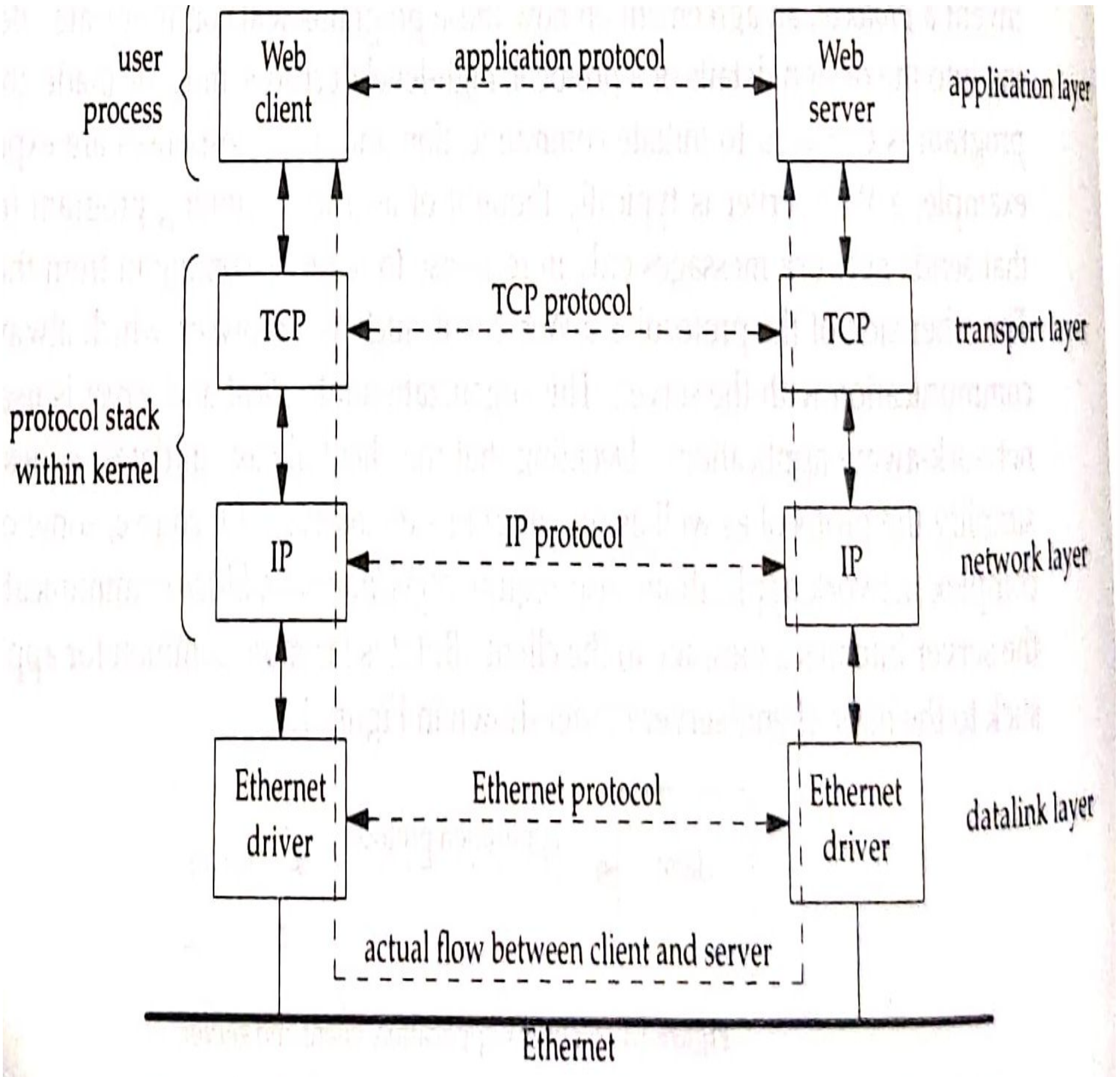
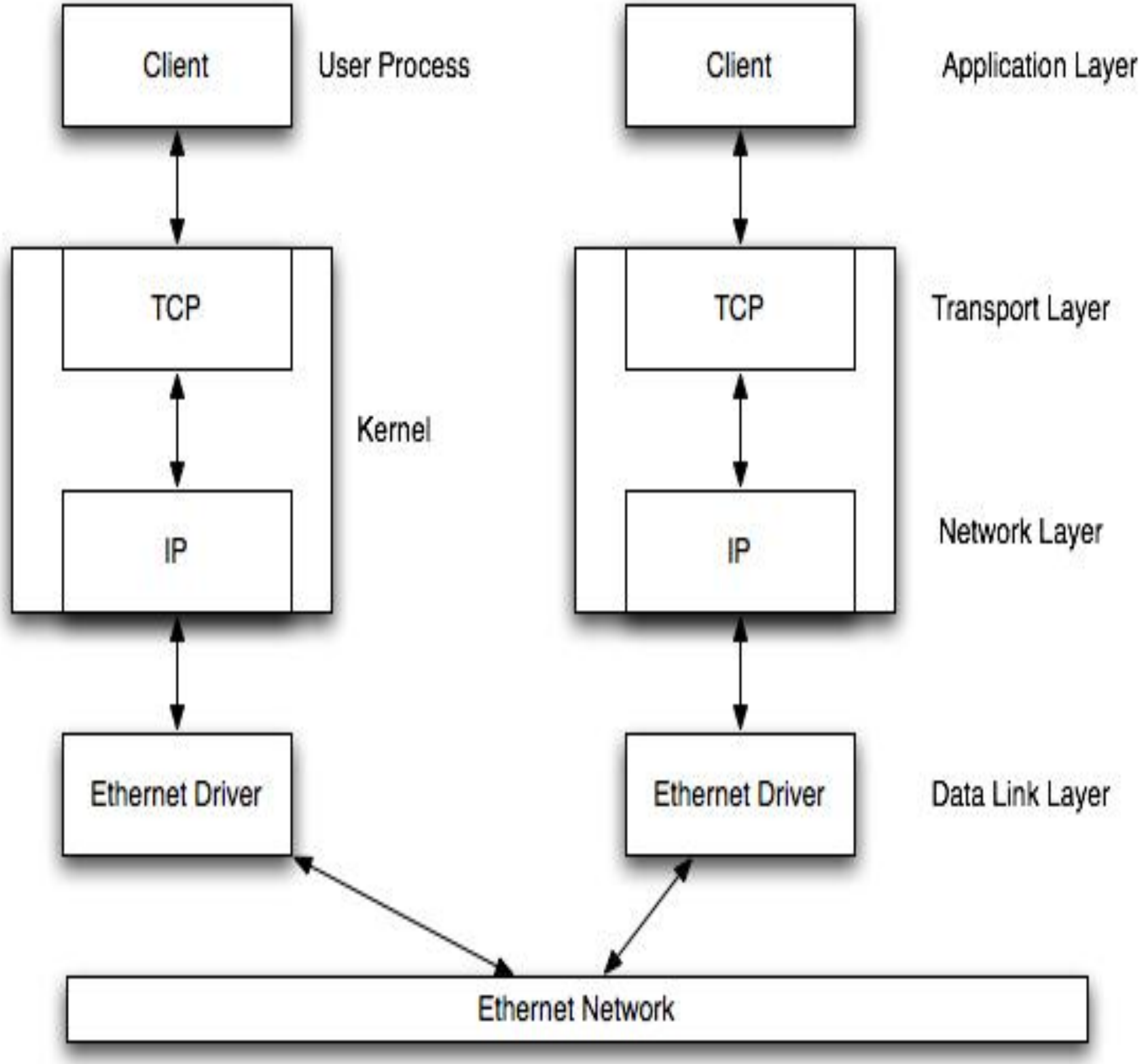
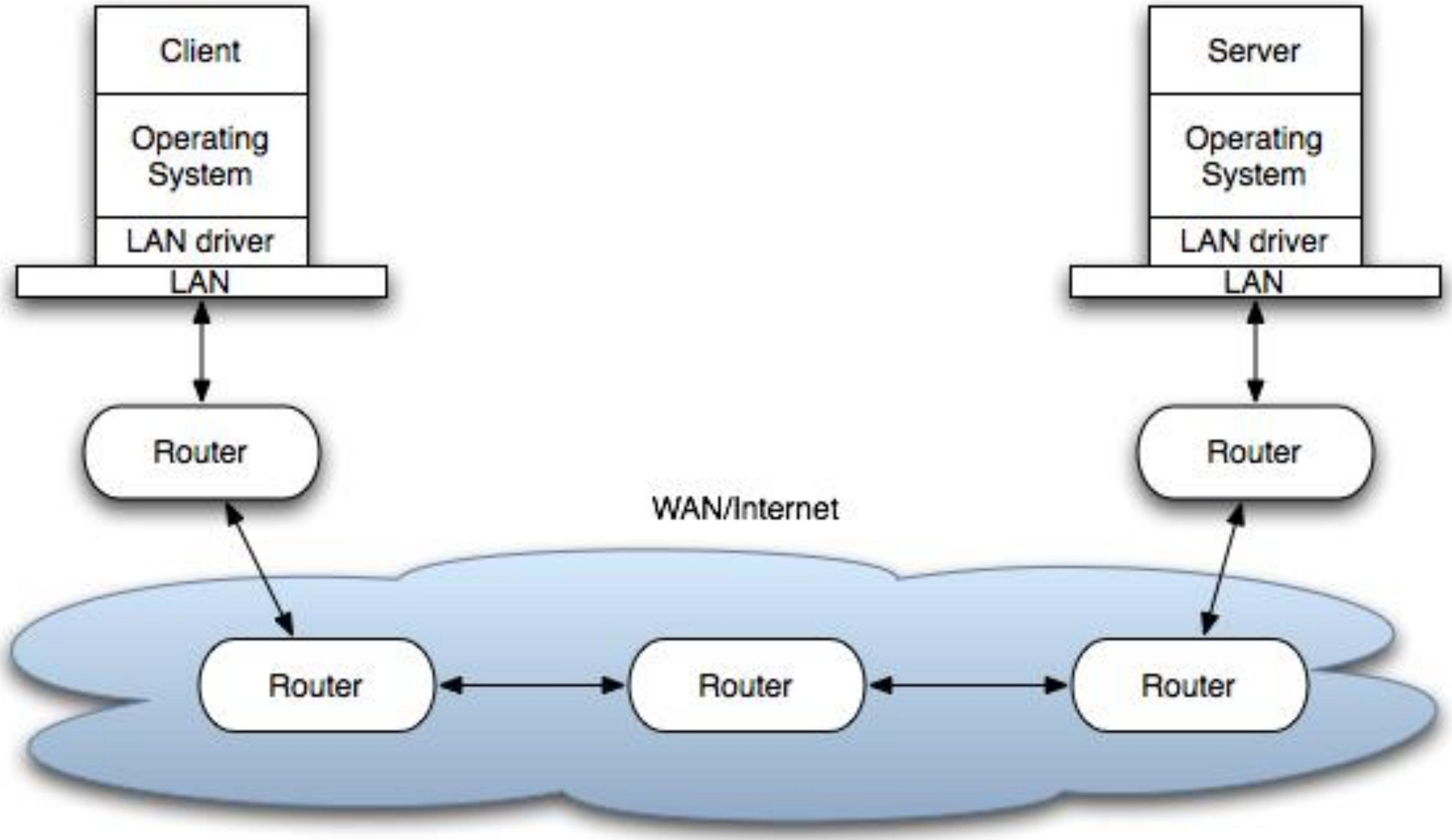


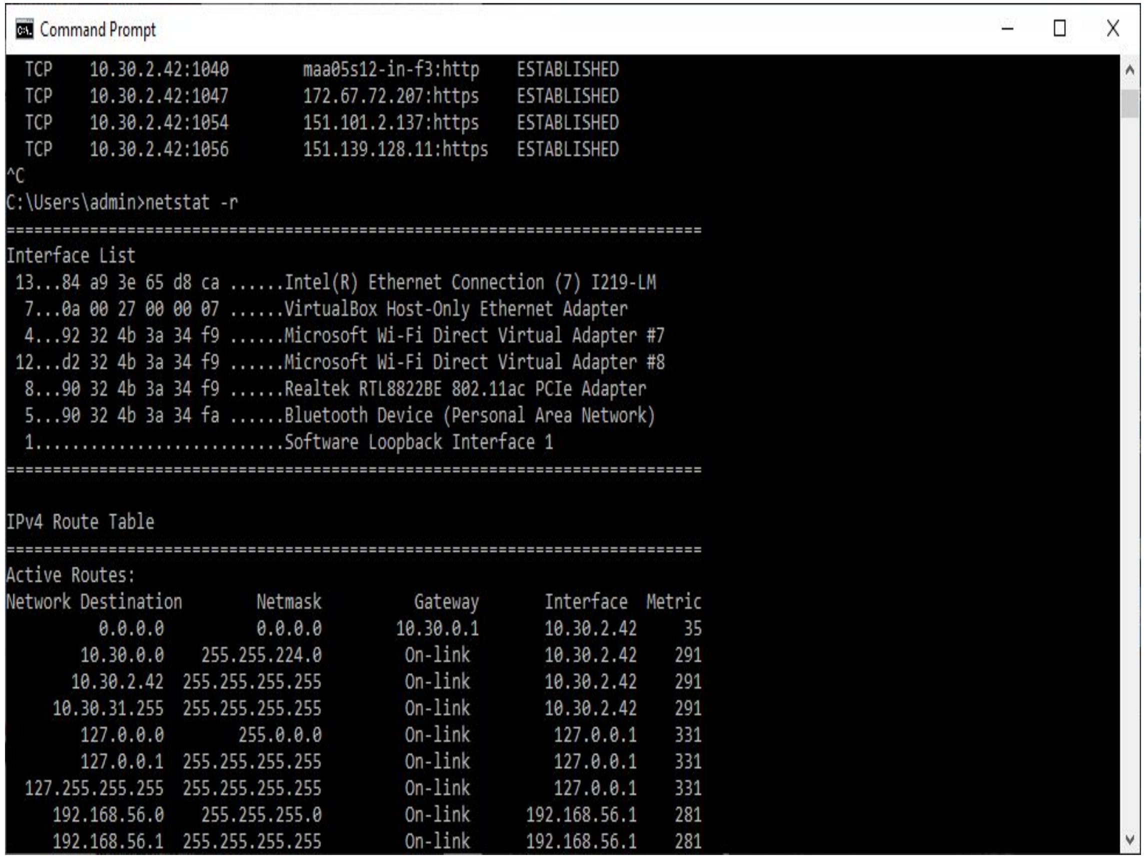
Figure 1.3 Client and server on the same Ethernet communicating using TCP.



Communication over WAN



Discovering Network Topology – netstat –ni and netstat -r



Options	Meaning
-a	All (TCP, UDP, SCTP, ICMP)
-n	Numeric addresses
-b	Display executables
-o	Process id
-f	Fully Qualified domain name
-p proto	Specific protocols
-r	Routing table
-s	Protocol statistics
-t	Current connection network status

Unix Standard - POSIX

THE POSIX STANDARDS

Posix.1 : IEEE 1003.1-1990 adapted by ISO as ISO/IEC 9945:1:1990 standard
***gives standard for base operating system API**

Posix.1b : IEEE 1003.4-1993
*** gives standard APIs for real time operating system interface including interprocess communication**

Posix.1c : Threads and Extensions

Table 1. List of POSIX Base Standards

POSIX.1	System Interface (basic reference standard)[a,b]
POSIX.2	Shell and Utilities[a]
POSIX.3	Methods for Testing Conformance to POSIX[a]
POSIX.4	Real-time Extensions
POSIX.4a	Threads Extensions
POSIX.4b	Additional Real-time Extensions
POSIX.6	Security Extensions
POSIX.7	System Administration
POSIX.8	Transparent File Access
POSIX.12	Protocol Independent Network Interfaces
POSIX.15	Batch Queuing Extensions
POSIX.17	Directory Services

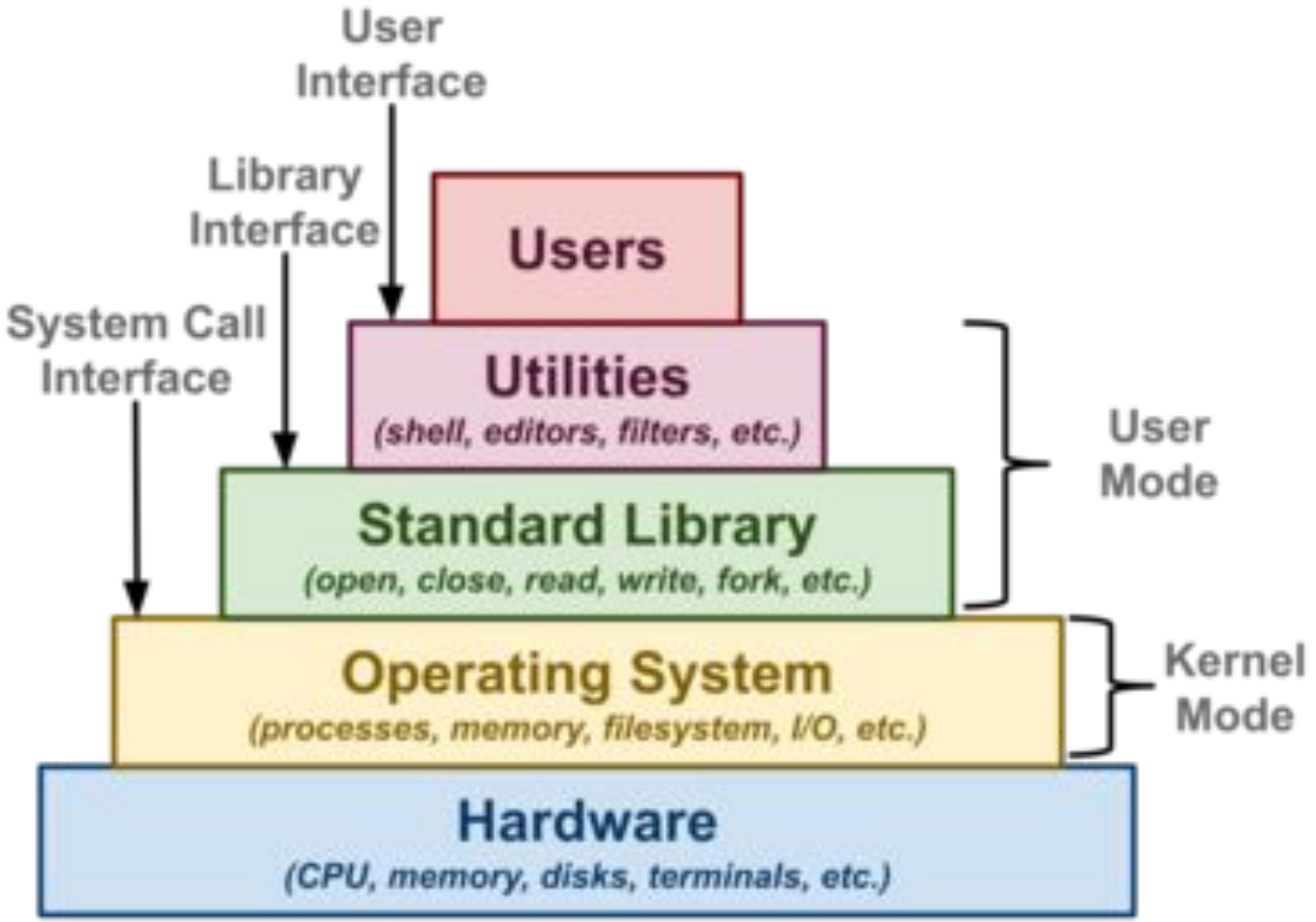
[a] Approved IEEE standards
[b] Approved ISO/IEC standard

Unix Standard - POSIX

What does POSIX mean?

- Portable Operating System Interface for Unix" is the name of a family of related standards specified by the IEEE to define the application programming interface (API), along with shell and utilities interfaces, for software compatible with variants of the UNIX operating system, although the standard can apply to any operating system.

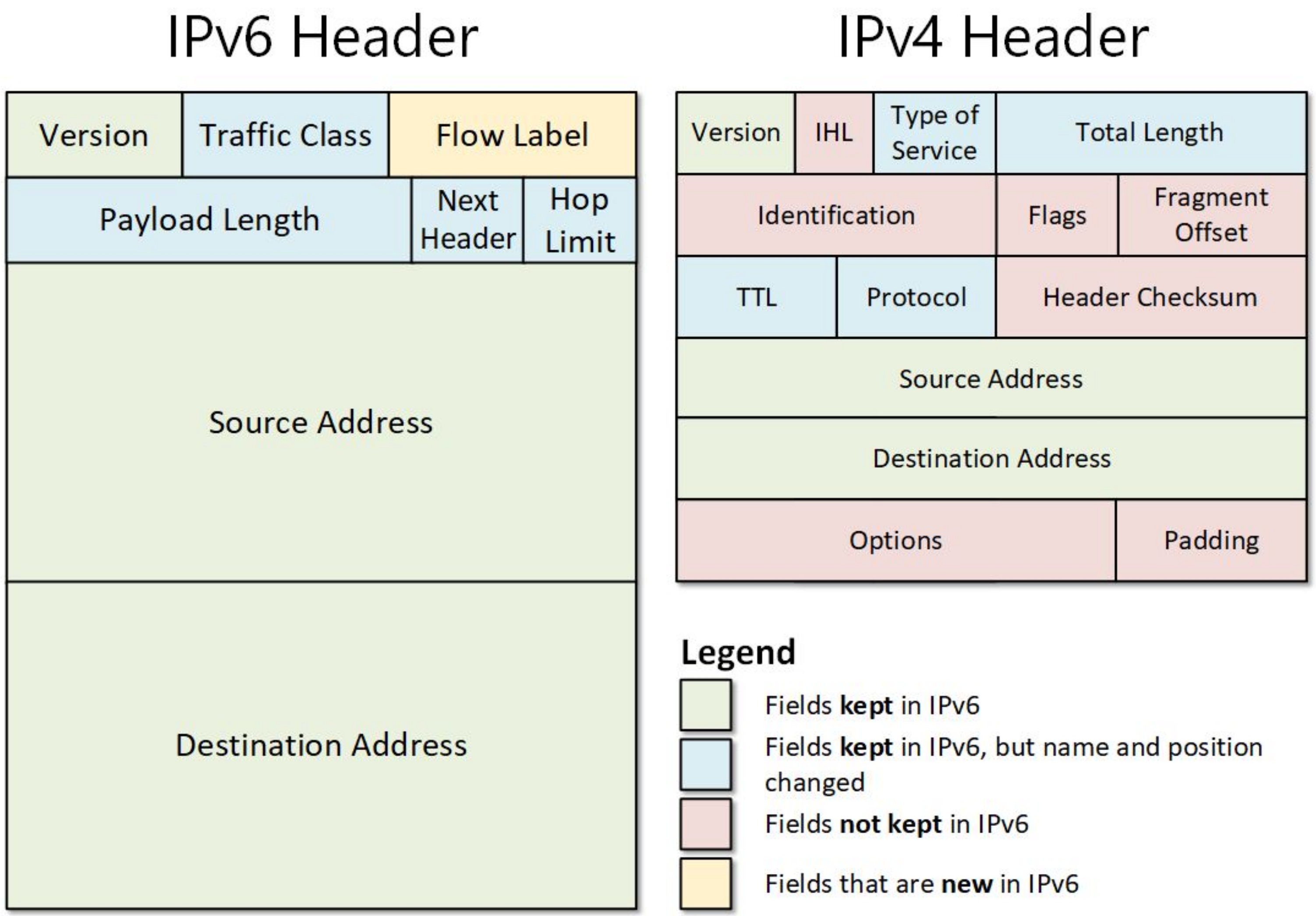
Unix APIs


User
Interface
Library
Interface
System Call
Interface
Users
Utilities
(shell, editors, filters, etc.)
Standard Library
(open, close, read, write, fork, etc.)
Operating System
(processes, memory, filesystem, I/O, etc.)
Hardware
(CPU, memory, disks, terminals, etc.)
User
Mode
Kernel
Mode

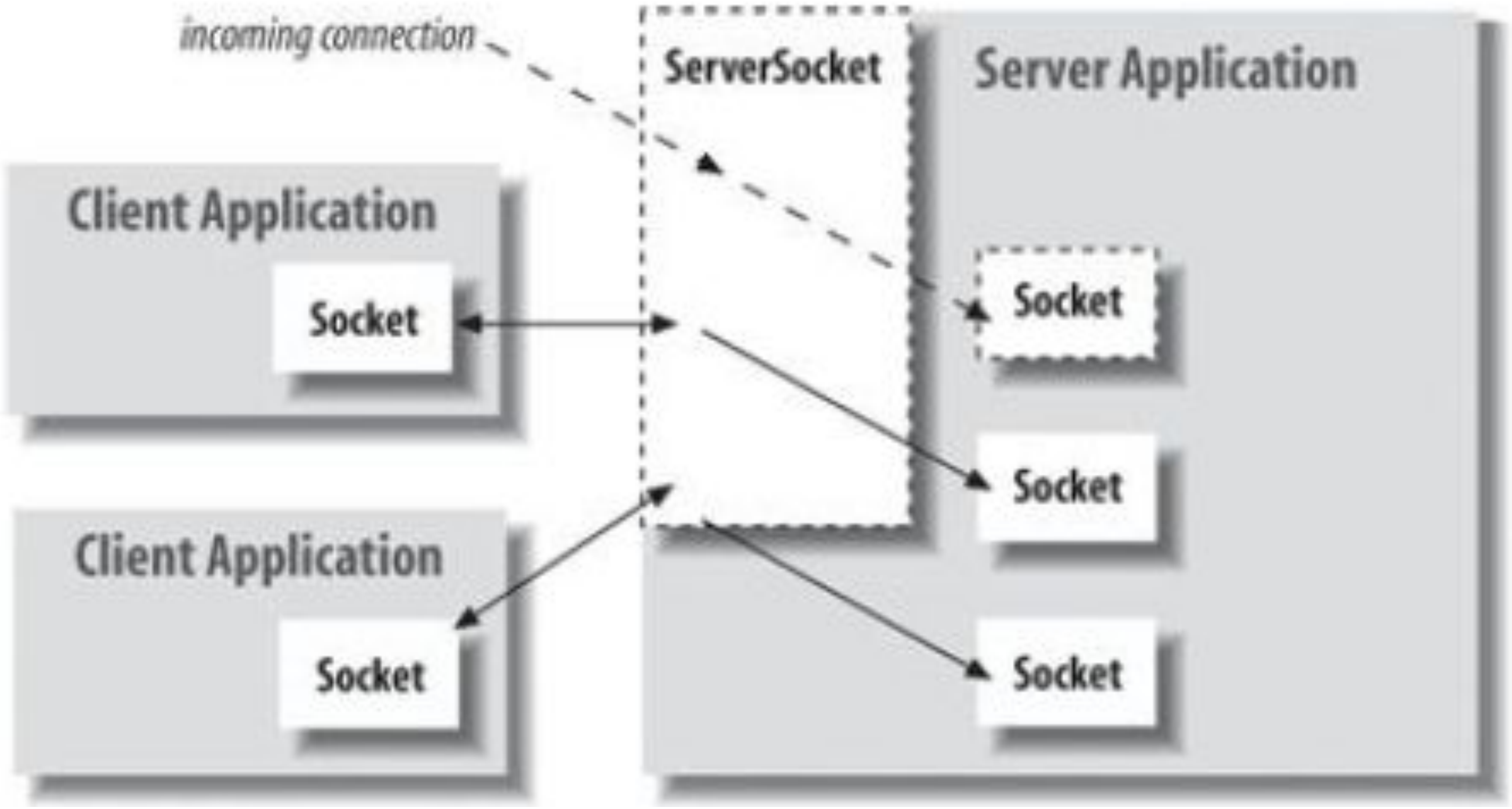
64 Bit Architectures

Datatype	ILP32 model	LP64 model
char	8	8
short	16	16
int	32	32
long	32	64
pointer	32	64

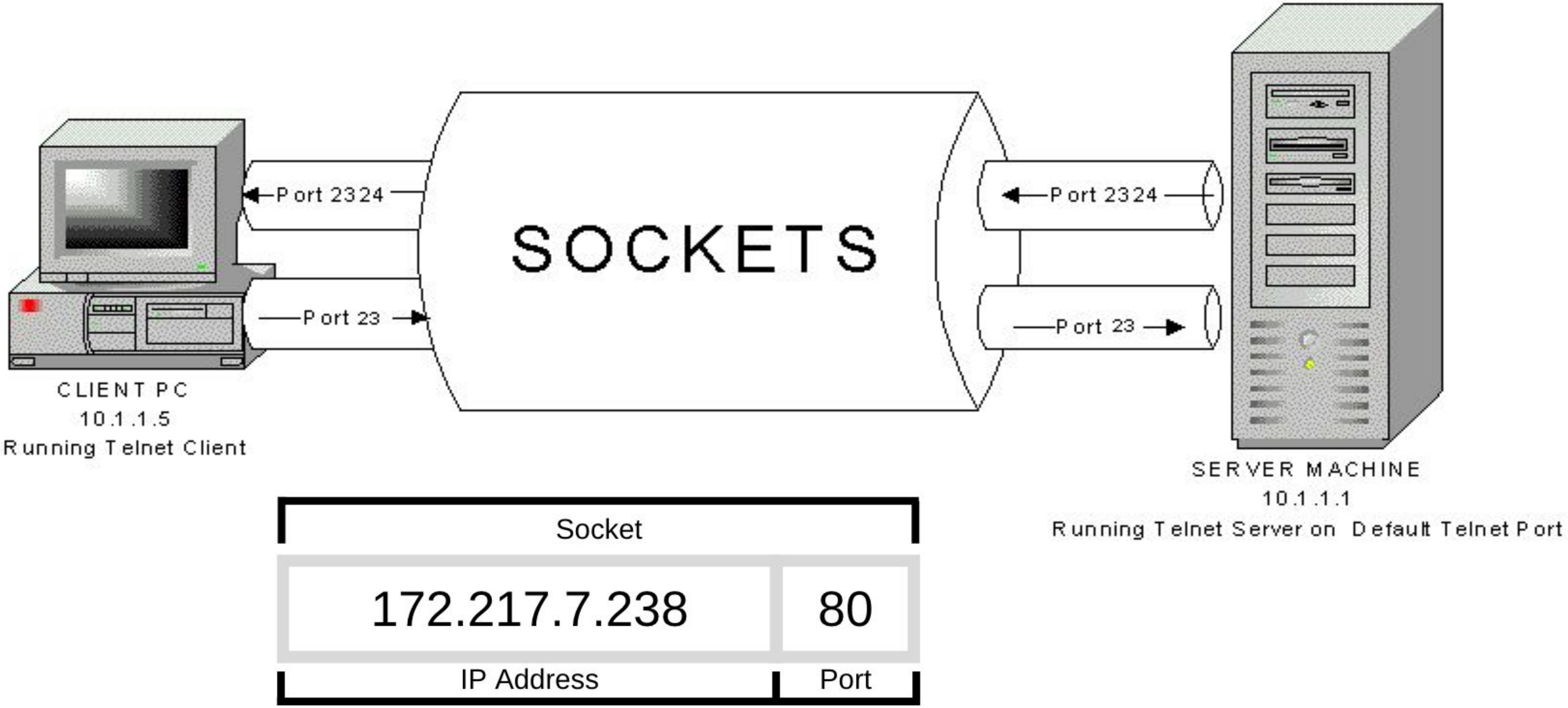
64 Bit Architectures



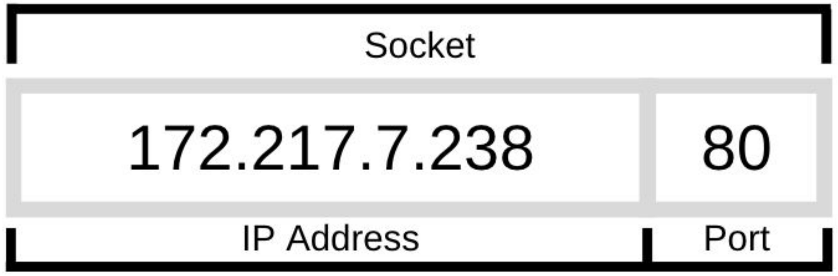
Sockets : An end point for communication between processes across the network



Sockets : An end point for communication between processes across the network



Sockets : An end point for communication between processes across the network



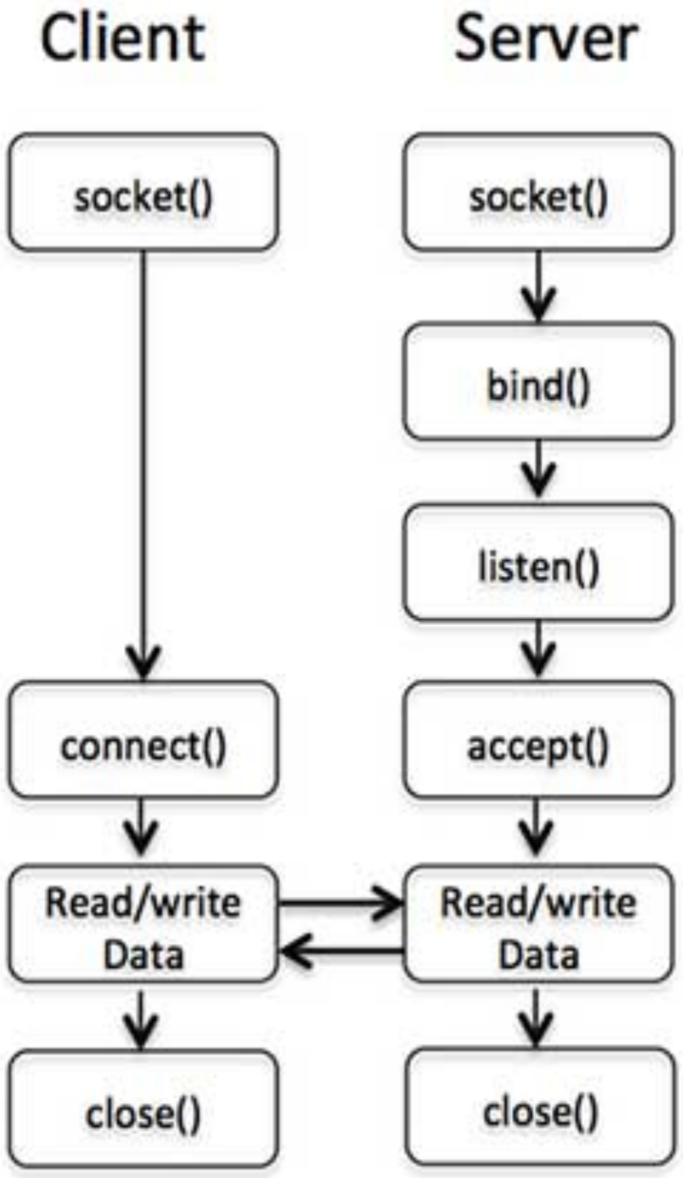

```
struct sockaddr_in s_addr, c_addr;
...
struct sockaddr_in
{                                   AF_INET
   short sin_family;
   u_short sin_port;
   struct in_addr sin_addr;
   char sin_zero[8];                 Not use
}
```

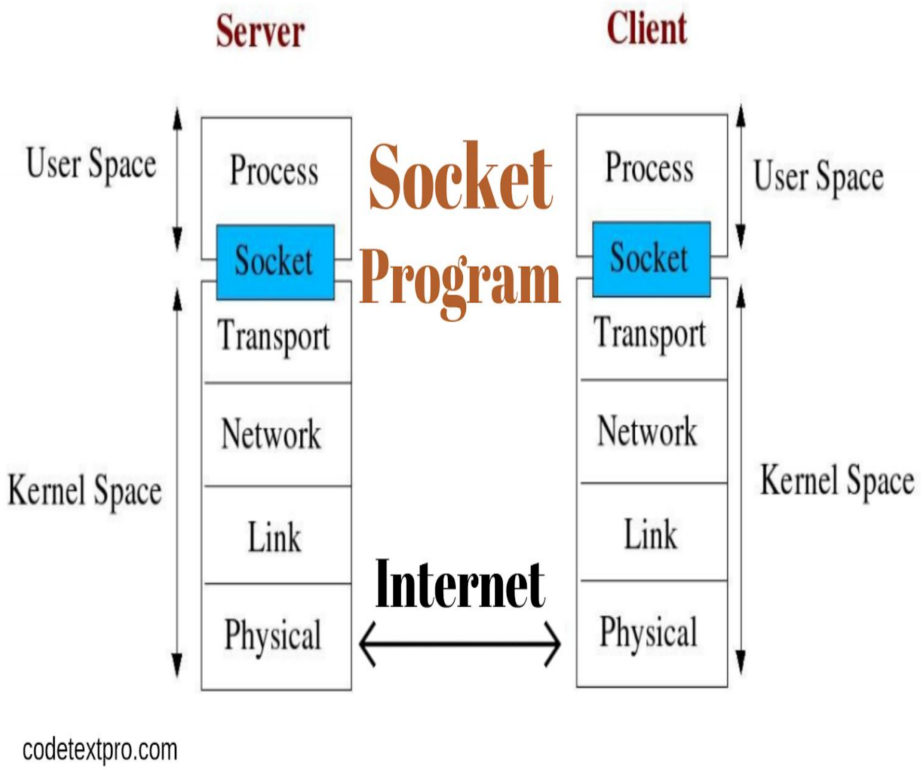
```
struct in_addr { unsigned
long s_addr;
};
```

Day Time Server at port no. 13

Example ::

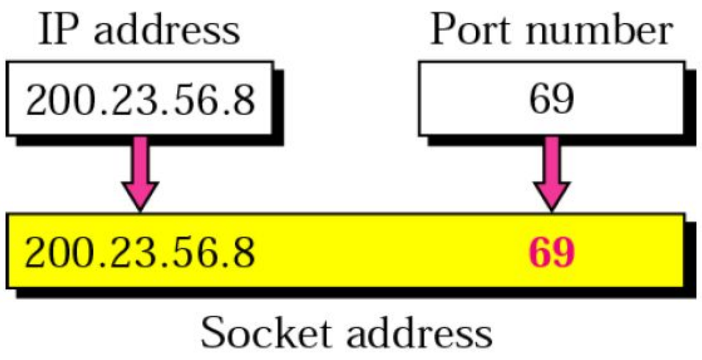
Day Time Client….

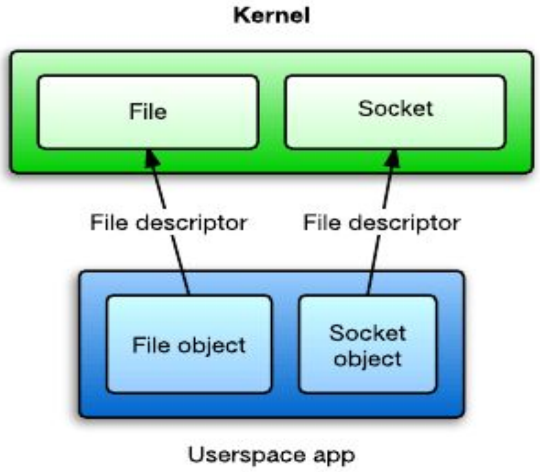




Source Code of Day Time Client

```c
#include <sys/socket.h>
#include <sys/types.h>
#include <netinet/in.h>
#include <netdb.h>
#include <stdio.h>

int main(int argc, char **argv)
{
   int sockfd, n = 0;
   char recvline[1000 + 1];
   struct sockaddr_in servaddr;
      int port = 13;

      if ((sockfd = socket(AF_INET, SOCK_STREAM, 0)) < 0) {
            err(1, "Socket Error");
   }

   bzero(&servaddr, sizeof(servaddr));
   servaddr.sin_family = AF_INET;
   servaddr.sin_port = htons(port);
   inet_pton(AF_INET,argv[1],&servAddress.sin_addr);
   if (connect(sockfd, (struct sockaddr *) &servaddr, sizeof(servaddr)) < 0) {
            err(1, "Connect Error");
   }
```

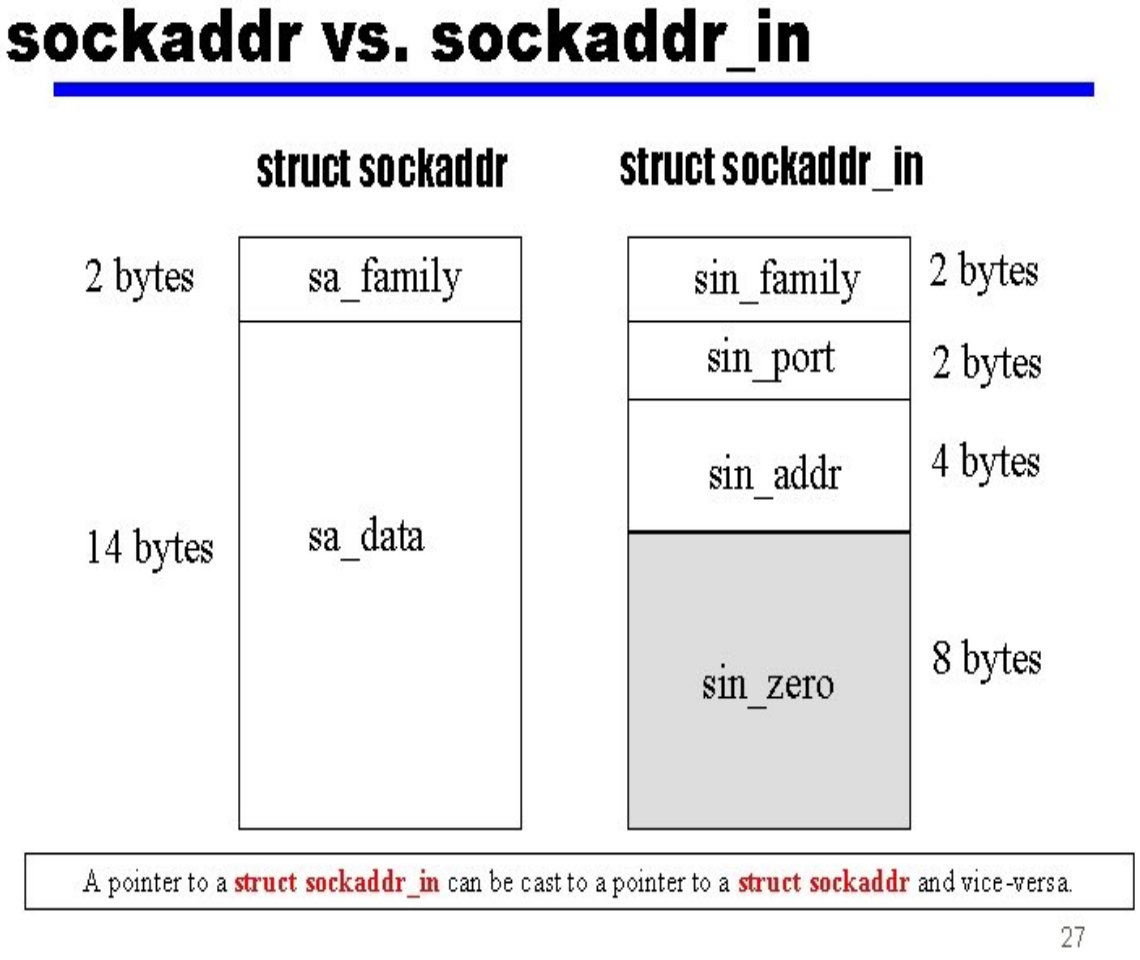




AF_APPLETALK	Apple Computer Inc. Appletalk network
AF_INET	Internet domain
AF_PUP	Xerox Corporation PUP internet
AF_UNIX	Unix file system

127.0.0.1 -- > b'\x7f\x00\x00\x01'

```
while ((n = read(sockfd, recvline, 1000)) > 0) {
        recvline[n] = 0;
        fputs(recvline, stdout);
    }

    return 0;
}
```



```
while ((n = read(sockfd, recvline, 1000)) > 0) {
        recvline[n] = 0;
        fputs(recvline, stdout);
    }

    return 0;
}
```

```
struct sockaddr_in s_addr, c_addr;
...
struct sockaddr_in
{
   short sin_family;
   u_short sin_port;
   struct in_addr sin_addr;
   char sin_zero[8];
}
```

AF_INET

Not use

```
struct in_addr {

unsigned long s_addr;

};
```

DayTime Server…

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

#include <sys/types.h>

#include <netinet/in.h>

#include <netdb.h>

#include <stdio.h>


int main(int argc, char **argv)

{

int listenfd, connfd;

int port = atoi(argv[1]);
```

```
struct sockaddr_in servaddr;

char buff[1000];

time_t ticks;

listenfd = socket(AF_INET, SOCK_STREAM, 0);


bzero(&servaddr, sizeof(servaddr));

servaddr.sin_family = AF_INET;

servaddr.sin_addr.s_addr = htonl(INADDR_ANY);

servaddr.sin_port = htons(port);
```

CREATE A SOCKET

Initialize Socket Address

```c
bind(listenfd, (struct sockaddr *) &servaddr, sizeof(servaddr));

listen(listenfd, 8);

for (;;) {

connfd = accept(listenfd, (struct sockaddr *) NULL, NULL);

ticks = time(NULL);

snprintf(buff, sizeof(buff), "%.24s\r\n", ctime(&ticks));

write(connfd, buff, strlen(buff));

close(connfd);

}

}
```

Bind the SOCKET

Listen on the Port for connections

Accept connection request from Client

Write to socket… { Serve the Client }

Source Code of Day Time Client – IPV6

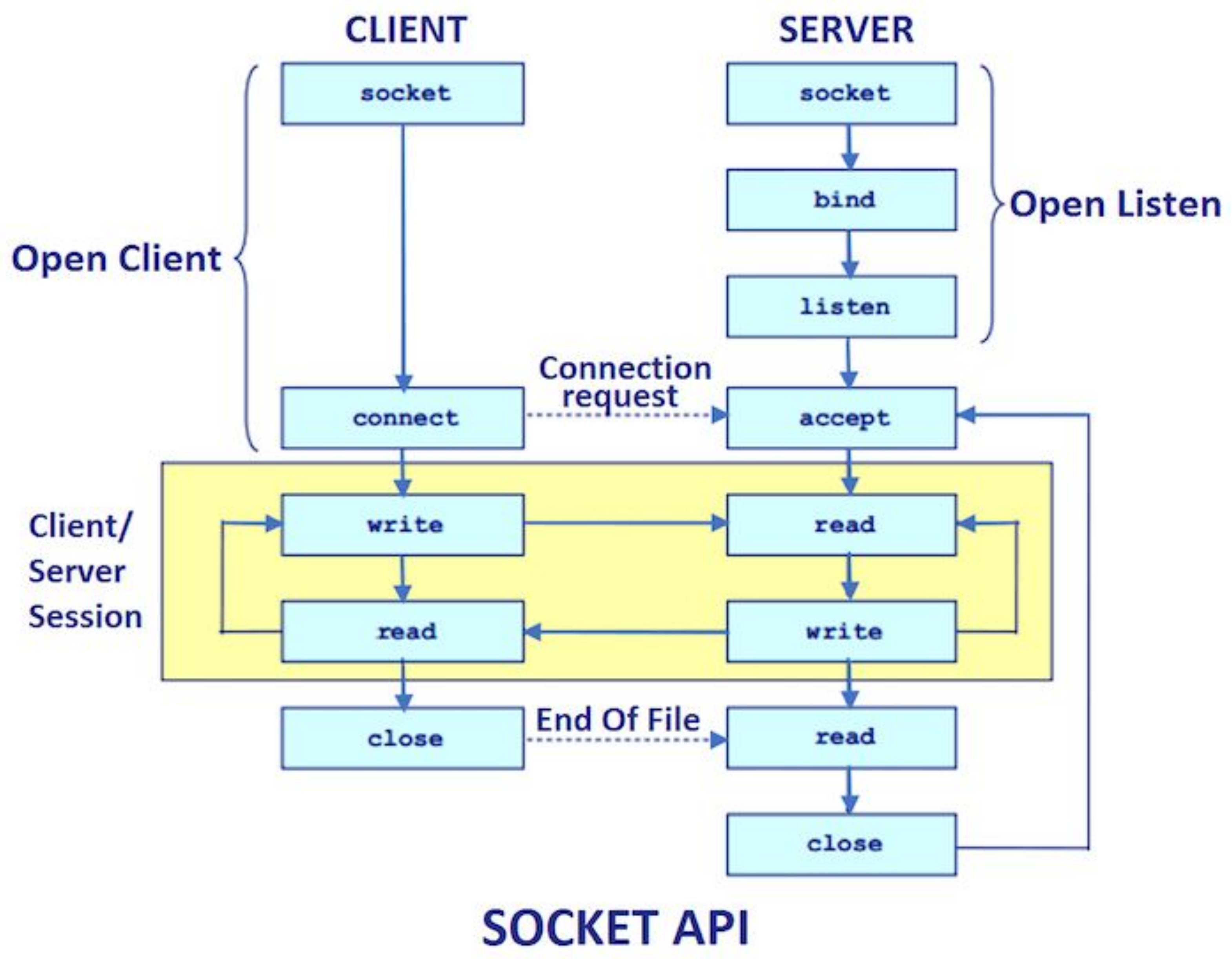
```
int main()
{
int s;
struct sockaddr_in6 addr;

s = socket(AF_INET6, SOCK_STREAM, 0);
addr.sin6_family = AF_INET6;
addr.sin6_port = htons(5000);
inet_pton(AF_INET6, "::1", &addr.sin6_addr);
connect(s, (struct sockaddr *)&addr, sizeof(addr));

while ((n = read(sockfd, recvline, 1000)) > 0) {
        recvline[n] = 0;
        fputs(recvline, stdout);
    }

close(sockfd);
return 0;
}
```

Error Handling and Wrapper functions

In any real-world program, it is essential to check every function call for an error return we check for errors from socket, inet_pton, connect, read, and fputs, and when one occurs, we call our own functions, err_quit and err_sys, to print an error message and terminate the program.

We find that most of the time, this is what we want to do. Occasionally, we want to do something other than terminate when one of these functions returns an error

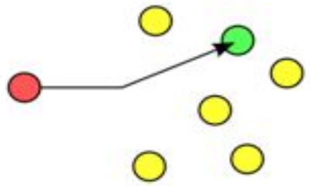
```
int Socket(int family, int type, int  protocol)

{ int n;
if ( (n = socket(family, type, protocol)) < 0)
err_sys("socket error");
return (n);
 }
```


CLIENT
SERVER
socket
socket
bind
listen
Open Listen
Open Client
Connection request
connect
accept
Client/ Server Session
write
read
read
write
close
End Of File
read
close
SOCKET API

TCP AND UDP

TCP

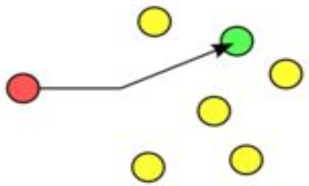
- **Slower but reliable transfers**
- **Typical applications:**
  - Email
  - Web browsing

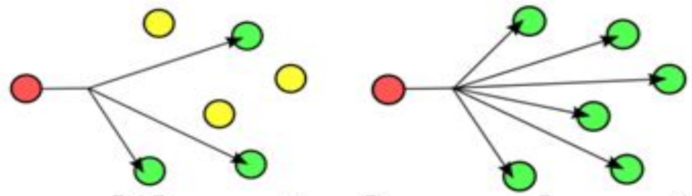


unicast

UDP

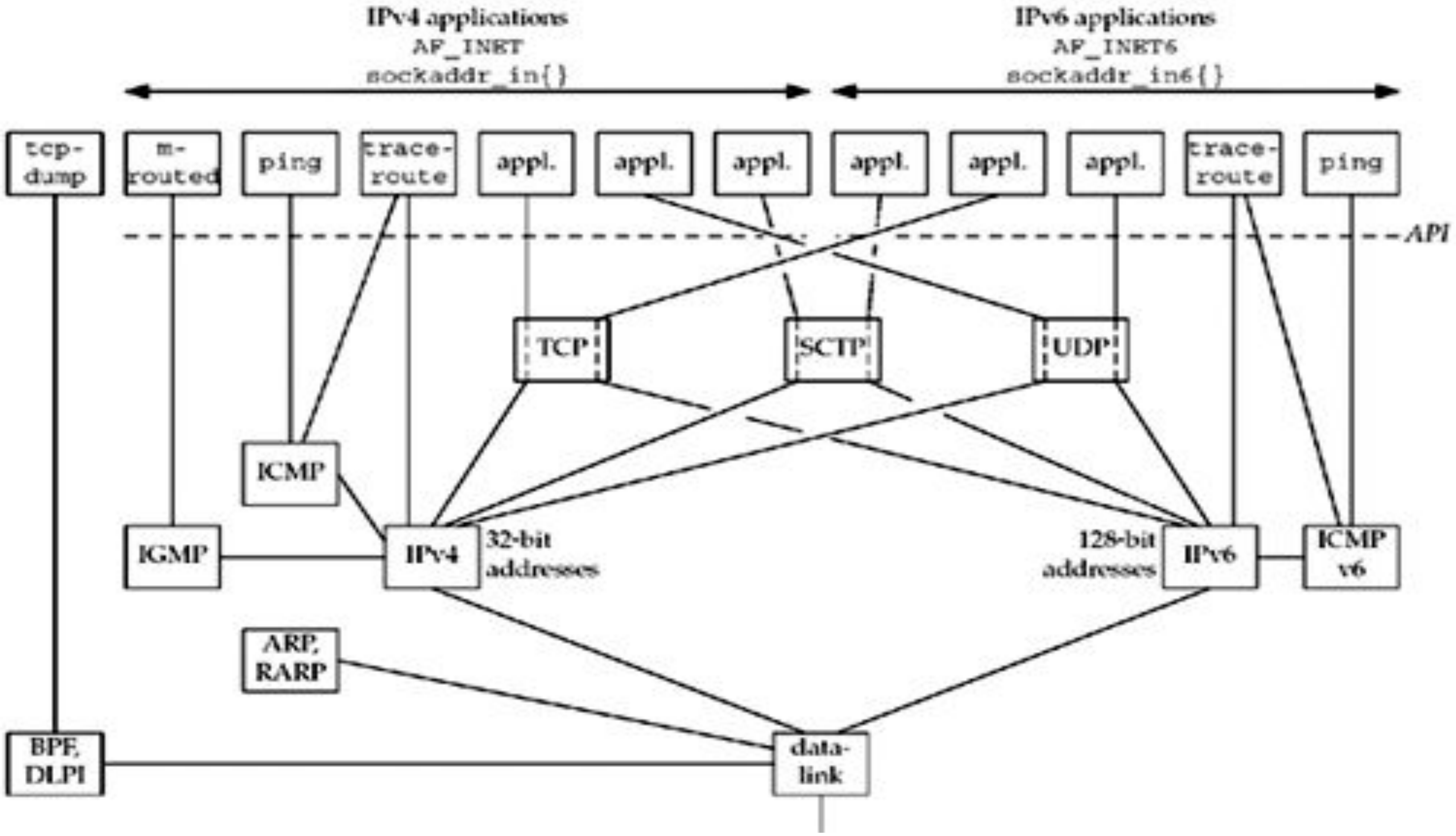
- **Fast but non-guaranteed transfers ("best effort")**
- **Typical applications:**
  - VoIP
  - Music streaming





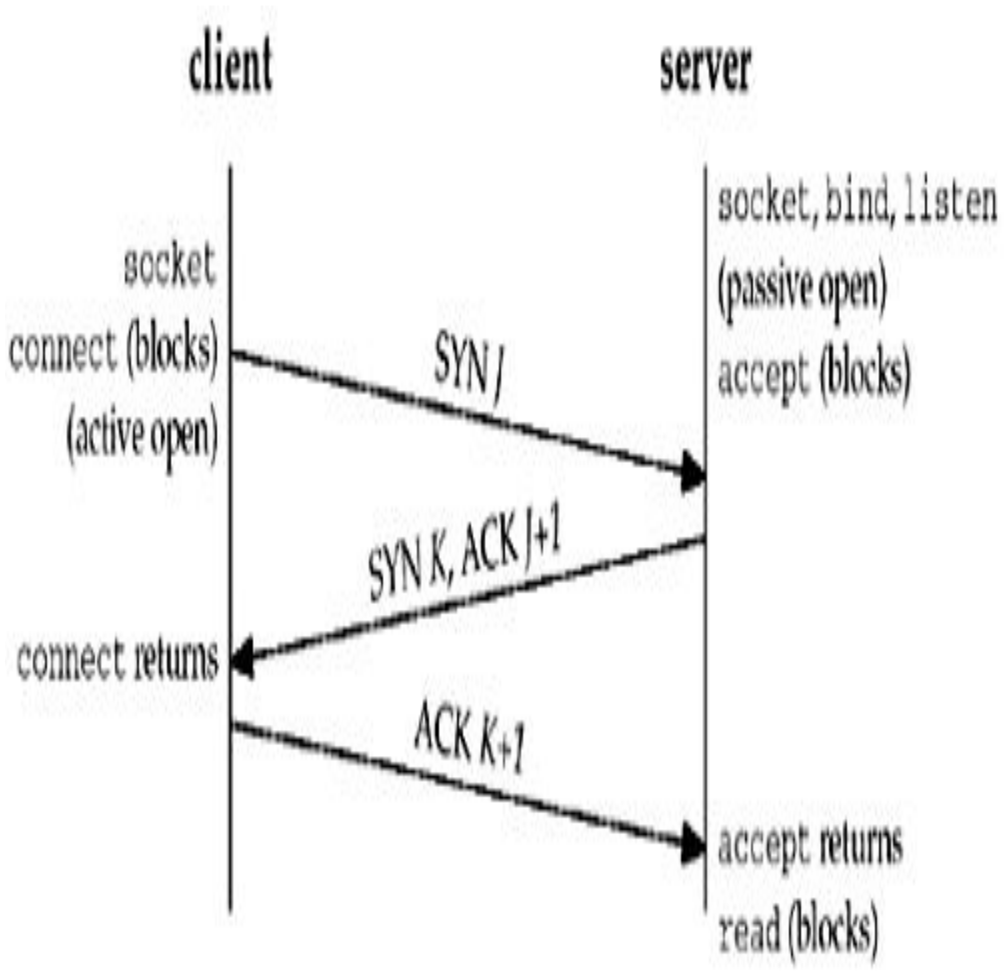
unicast **multicast** **broadcast**

TCP/IP – The Big-picture



TCP Connection Establishment and Termination

Three-Way Handshake



- The following scenario occurs when a TCP connection is established:

1. **The server must be prepared to accept an incoming connection. This is normally done by calling socket, bind, and listen and is called a *passive open.***

2. **The client issues an *active open by calling connect. This causes the client TCP* to send a "synchronize" (SYN) segment, which tells the server the client's initial sequence number for the data that the client will send on the connection. Normally, there is no data sent with the SYN; it just contains an IP header, a TCP header, and possible TCP options**

3. **The server must acknowledge (ACK) the client's SYN and the server must also send its own SYN containing the initial sequence number for the data that the server will send on the connection. The server sends its SYN and the ACK of the client's SYN in a single segment.**

4. **The client must acknowledge the server's SYN.**

- The minimum number of packets required for this exchange is three; hence, this is called TCP's *three-way handshake.*

- **TCP Options**
- Each SYN can contain TCP options. Commonly used options include the following:
- **MSS option**. With this option, the TCP sending the SYN announces its *maximum segment size*
- **Window scale** option. The maximum window that either TCP can advertise to the other TCP is 65,535
- **Timestamp option.** This option is needed for high-speed connections to prevent possible data corruption caused by old, delayed, or duplicated segments..

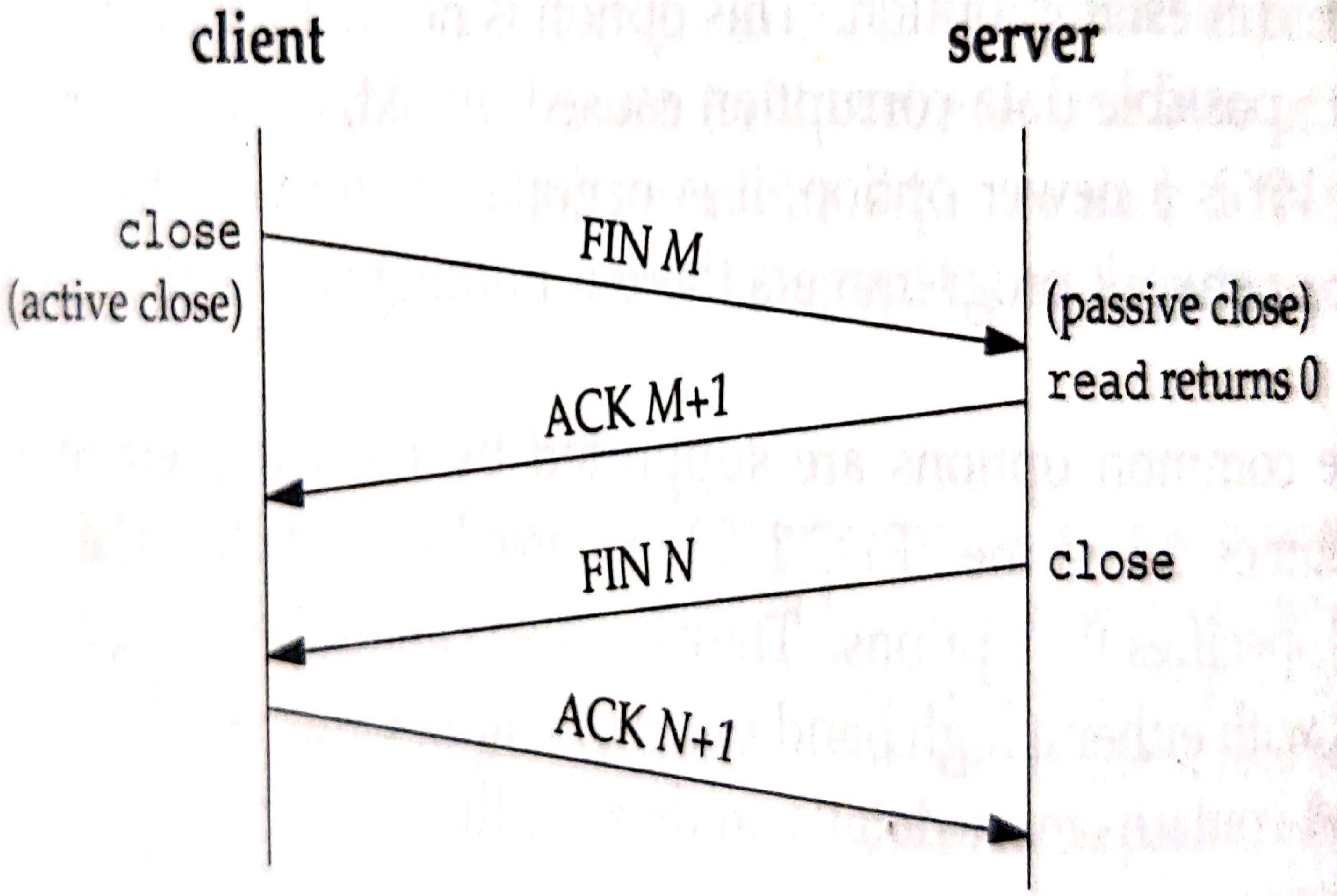


Figure 2.3 Packets exchanged when a TCP connection is closed.

TCP Connection Termination

- While it takes three segments to establish a connection, it takes four to terminate a connection.

1. **One application calls close first, and we say that this end performs the *active close. This end's TCP sends a FIN segment, which means it is finished sending* data.**

2. **The other end that receives the FIN performs the *passive close. The received* FIN is acknowledged by TCP. The receipt of the FIN is also passed to the application as an end-of-file (after any data that may have already been queued for the application to receive), since the receipt of the FIN means the application will not receive any additional data on the connection.**

3. **Sometime later, the application that received the end-of-file will close its socket. This causes its TCP to send a FIN.**

4. **The TCP on the system that receives this final FIN (the end that did the active close) acknowledges the FIN.**

TCP State Transition Diagram

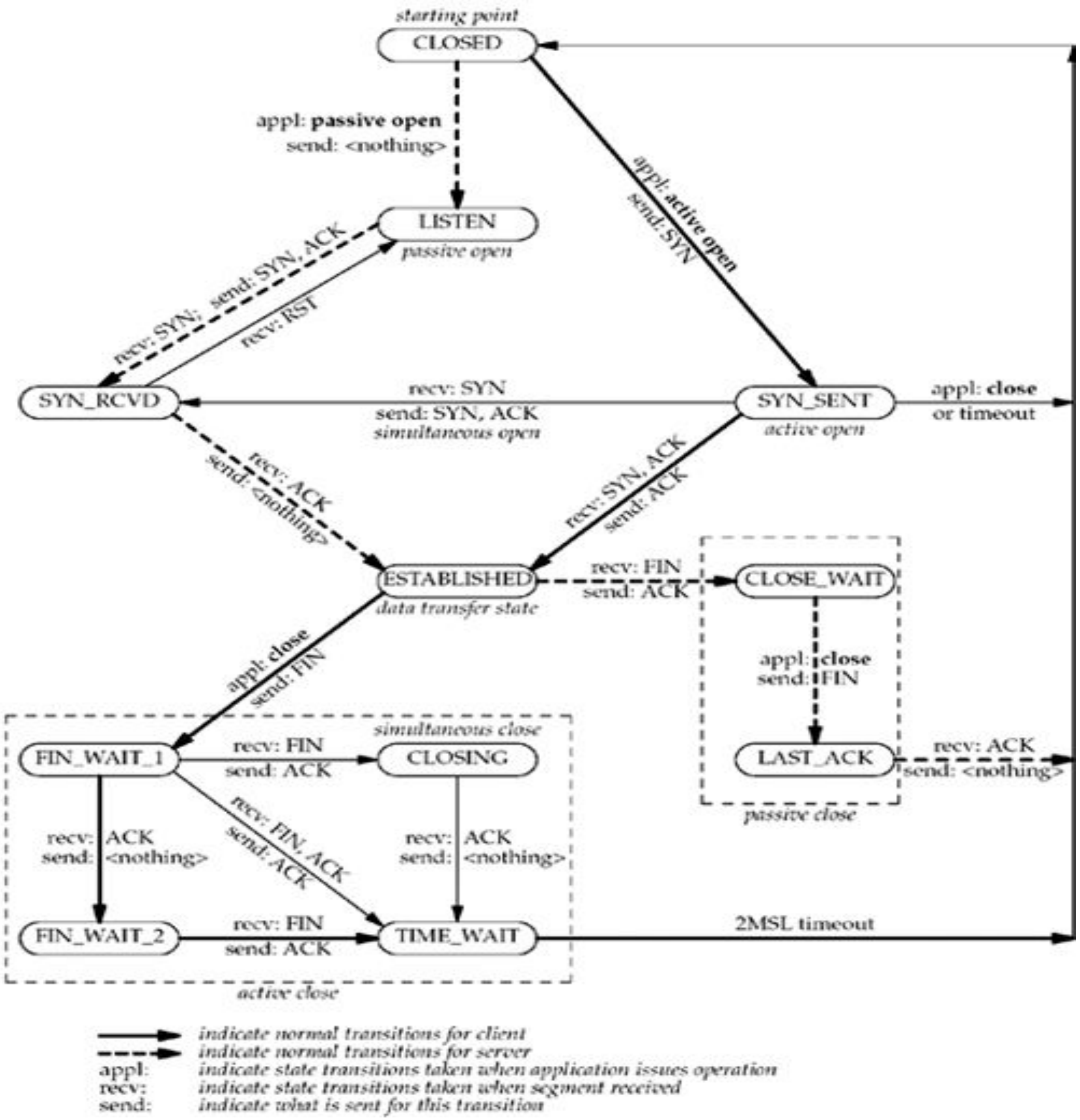
- The operation of TCP with regard to connection establishment and connection termination can be specified with a *state transition diagram.*

- There are 11 different states defined for a connection and the rules of TCP dictate the transitions from one state to another, based on the current state and the segment received in that state.

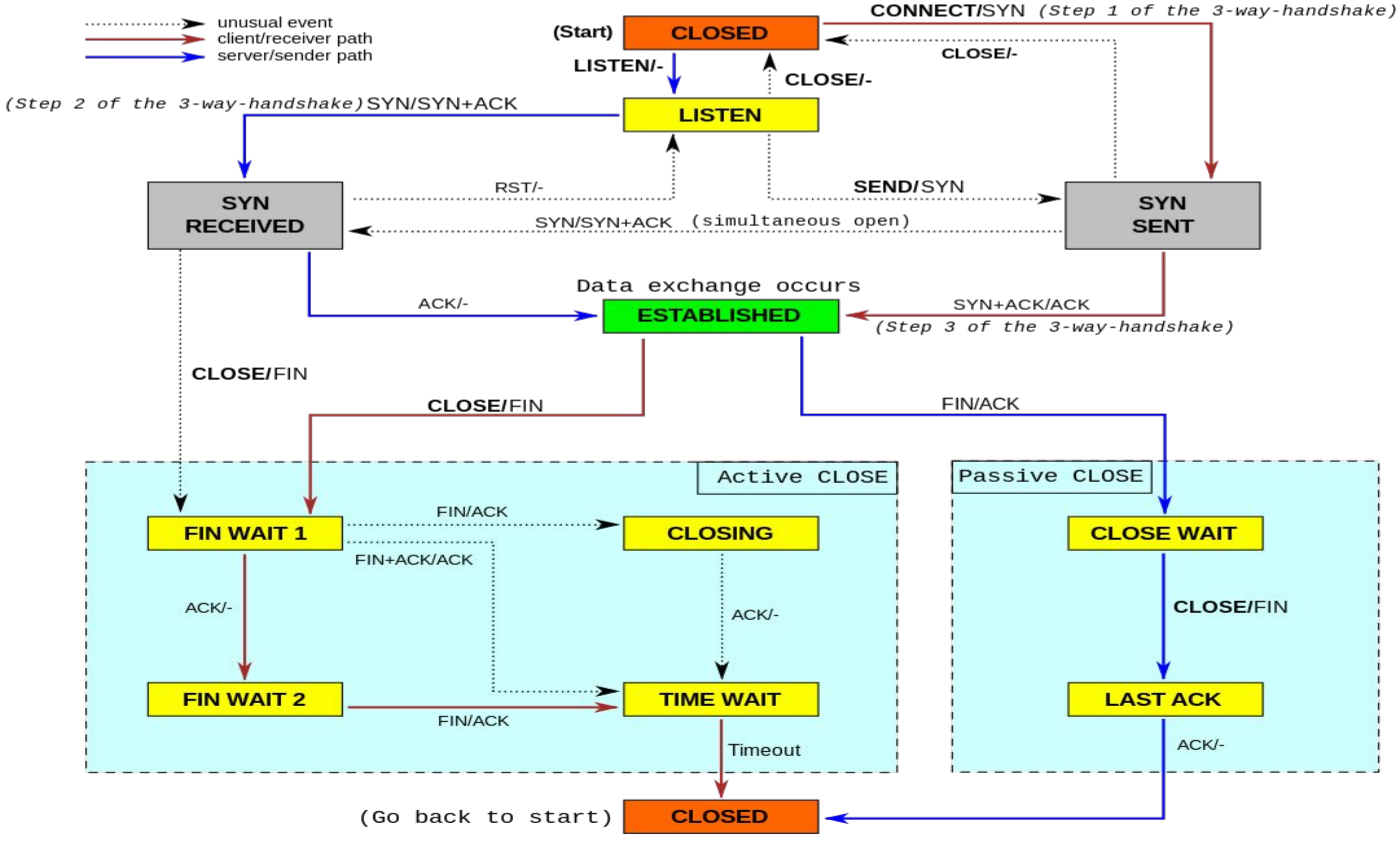
- For example, if an application performs an active open in the CLOSED state, TCP sends a SYN and the new state is SYN_SENT.

- If TCP next receives a SYN with an ACK, it sends an ACK and the new state is ESTABLISHED. This final state is where most data transfer occurs.

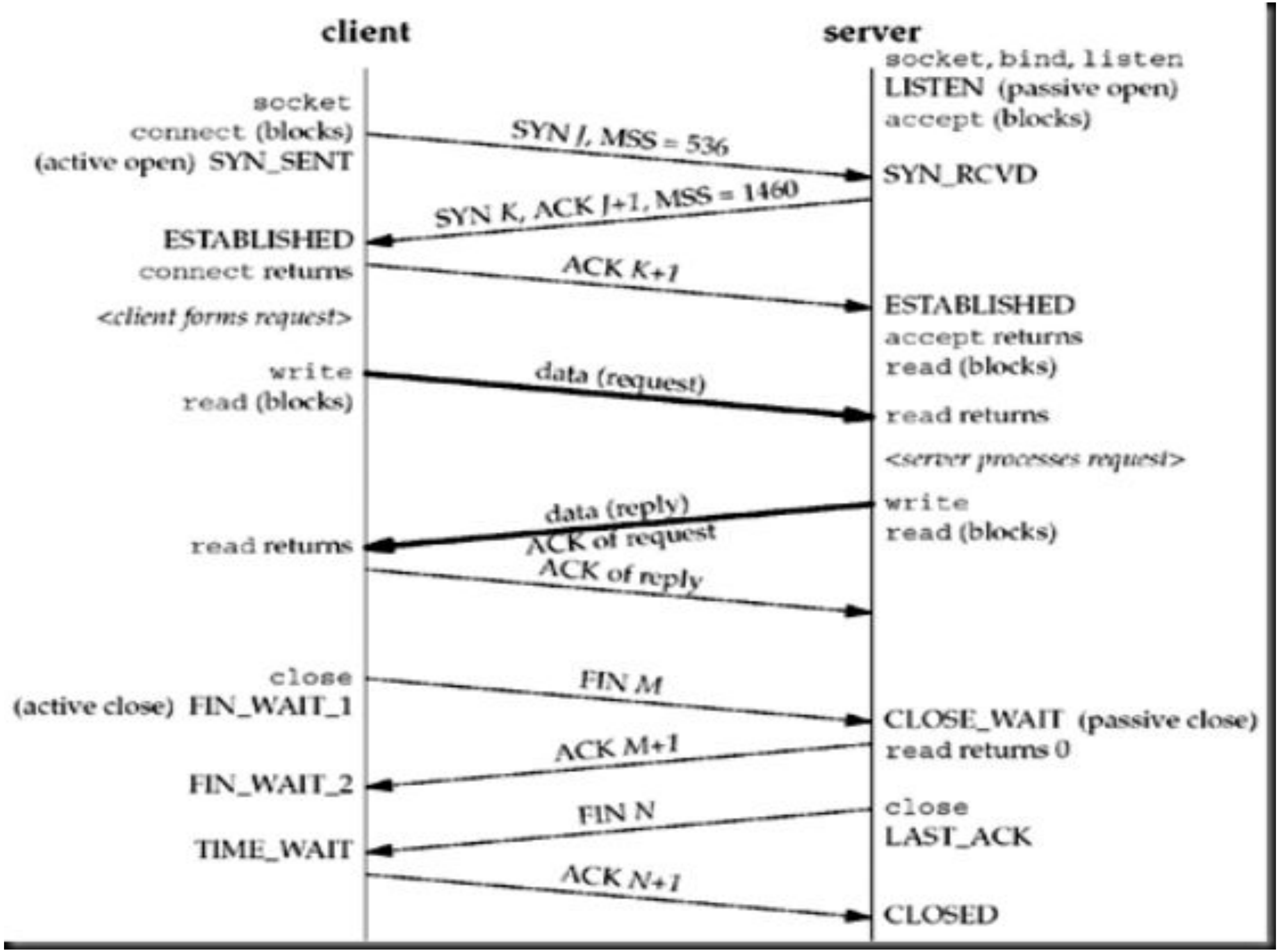
- The two arrows leading from the ESTABLISHED state deal with the termination of a connection.
- If an application calls close before receiving a FIN (an active close), the transition is to the FIN_WAIT_1 state.
- But if an application receives a FIN while in the ESTABLISHED state (a passive close), the transition is to the CLOSE_WAIT state.


starting point
CLOSED
appl: **passive open**
send: <nothing>
appl: **active open**
send: SYN
LISTEN
passive open
recv: SYN; send: SYN, ACK
recv: RST
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
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: ACK
send: <nothing>
recv: FIN, ACK
send: ACK
recv: ACK
send: <nothing>
FIN_WAIT_2
recv: FIN
send: ACK
TIME_WAIT
2MSL timeout
active close
indicate normal transitions for client
indicate normal transitions for server
appl: indicate state transitions taken when application issues operation
recv: indicate state transitions taken when segment received
send: indicate what is sent for this transition

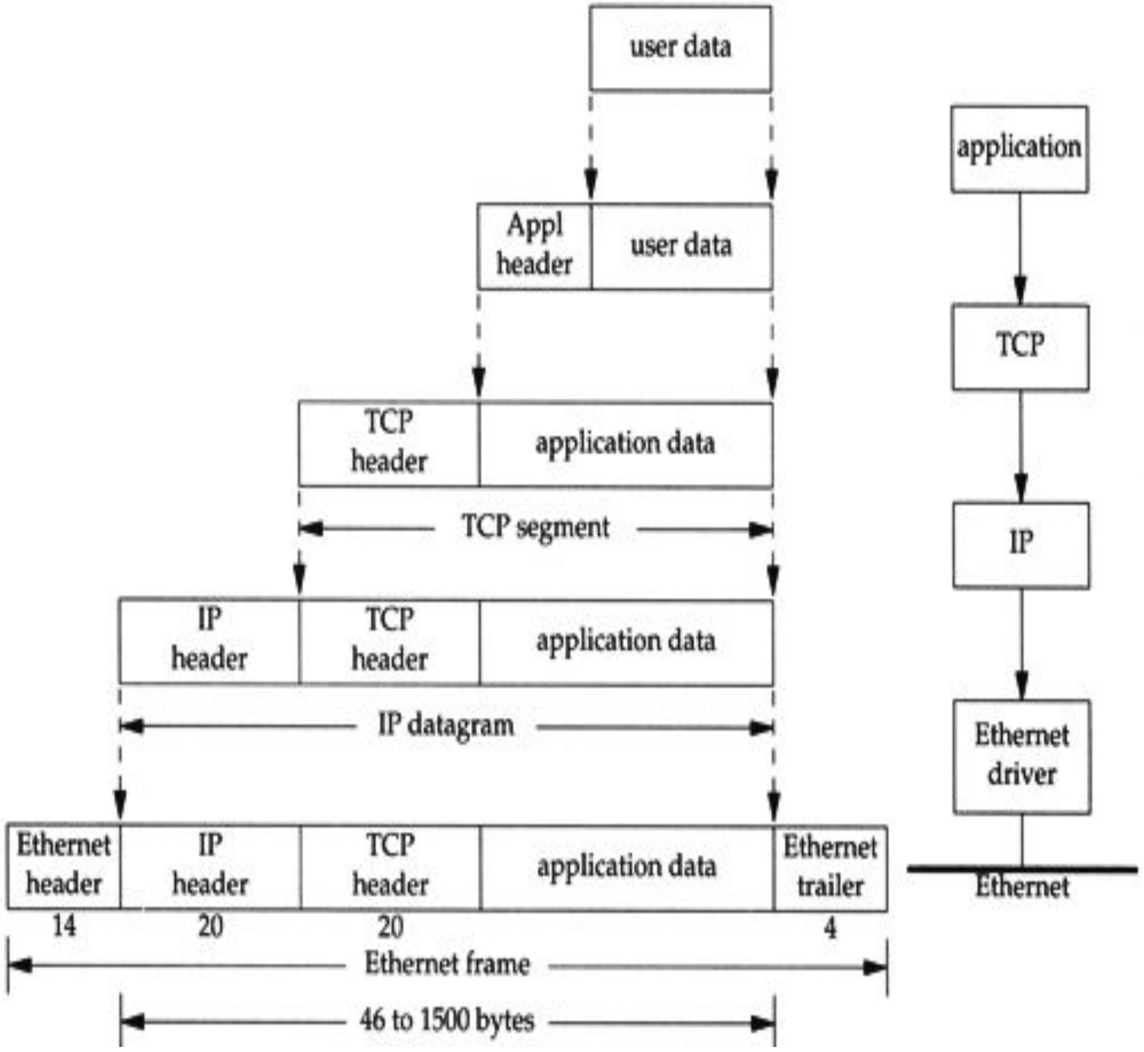
TCP-Connection state diagram

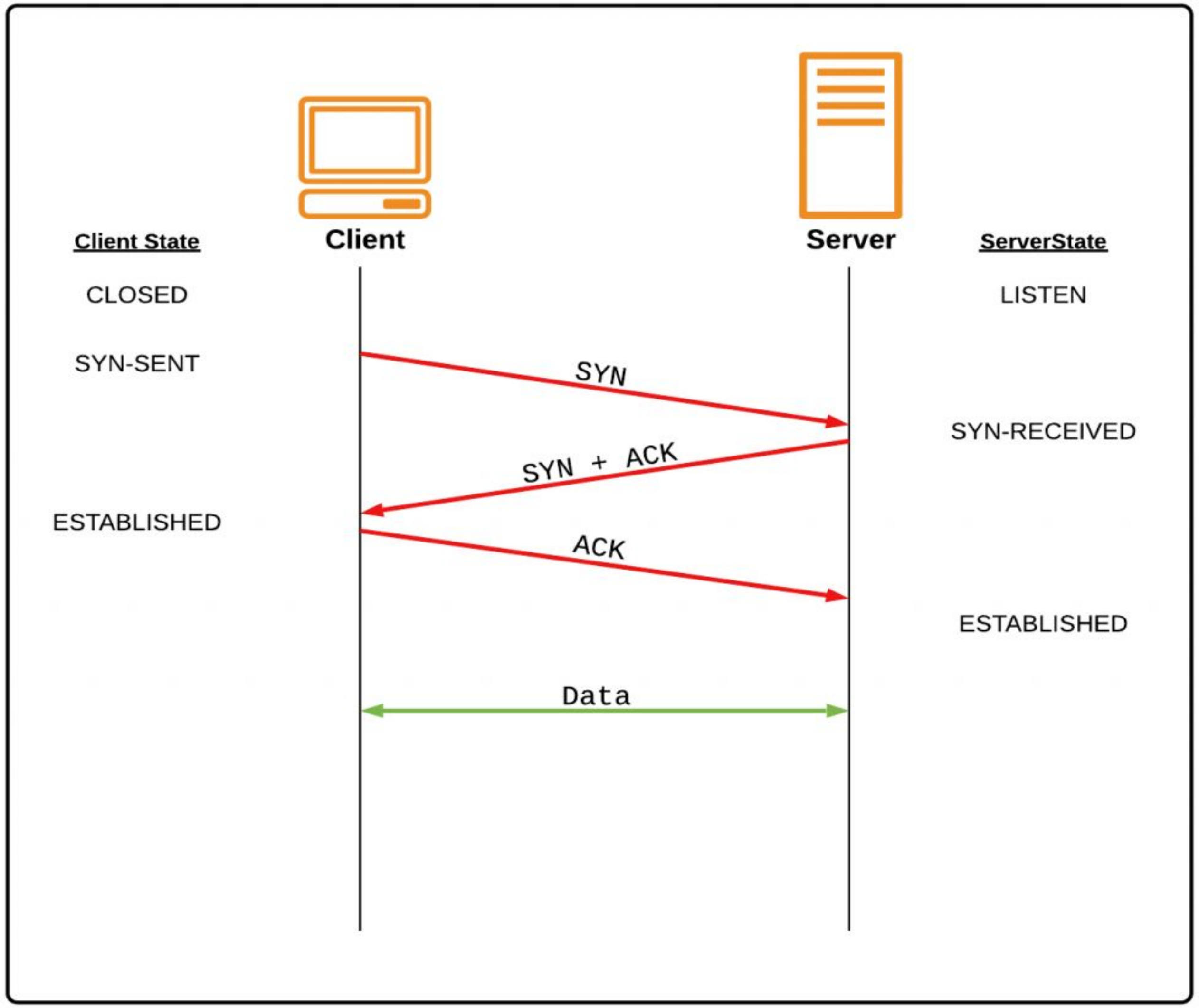


TCP – Connection : Packet Exchange

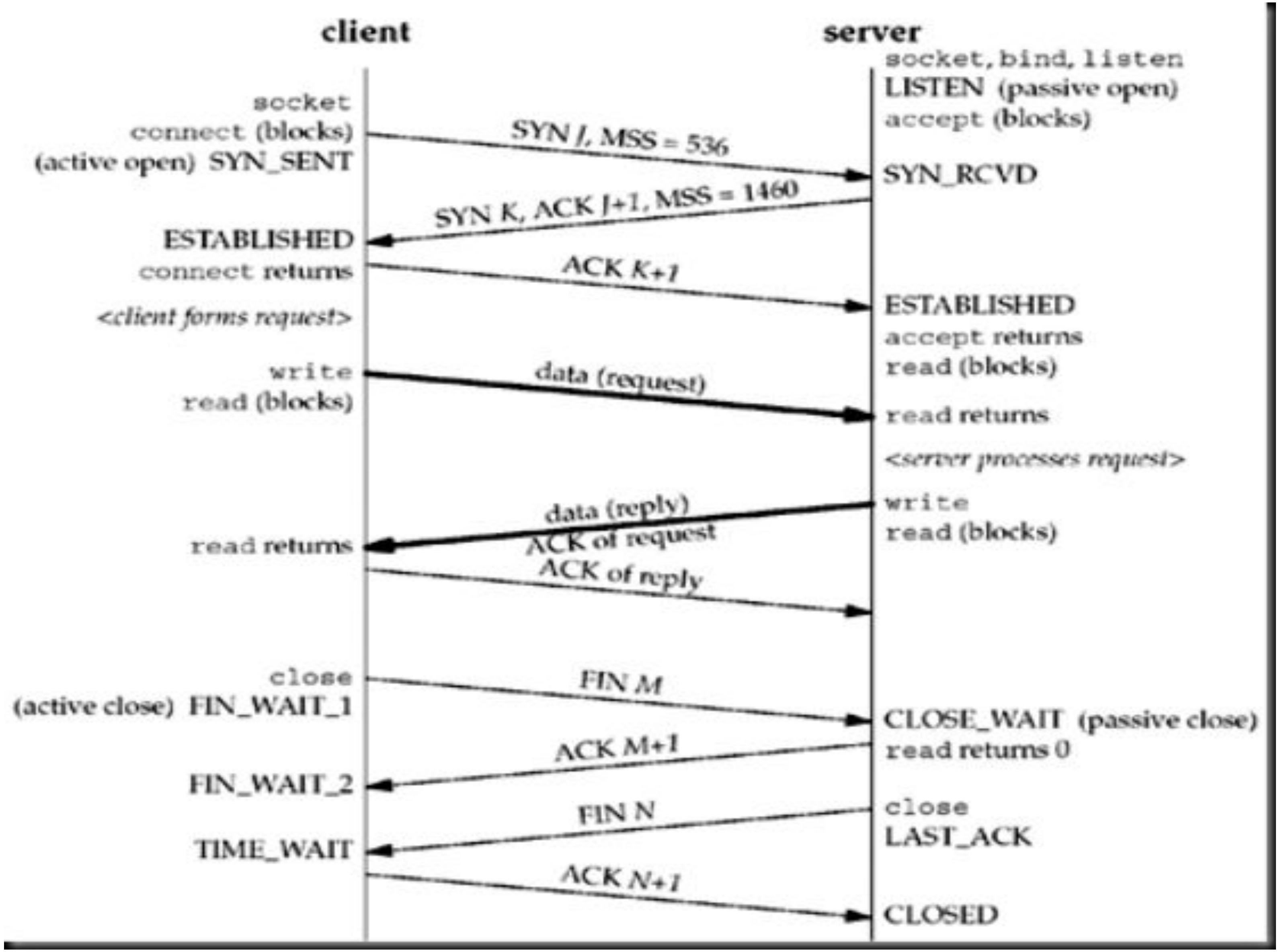


TCP - Connection

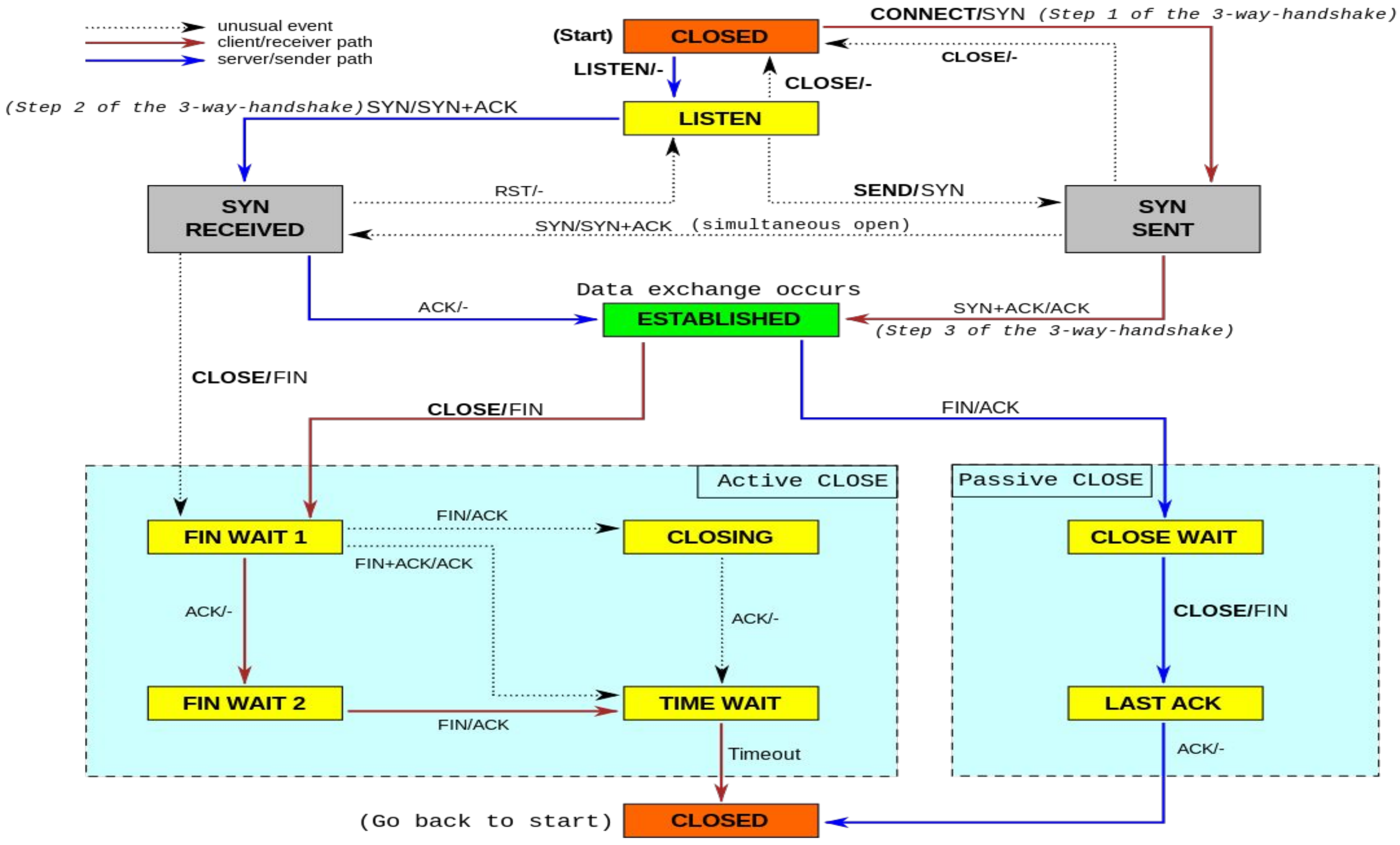




TCP – Connection : Packet Exchange



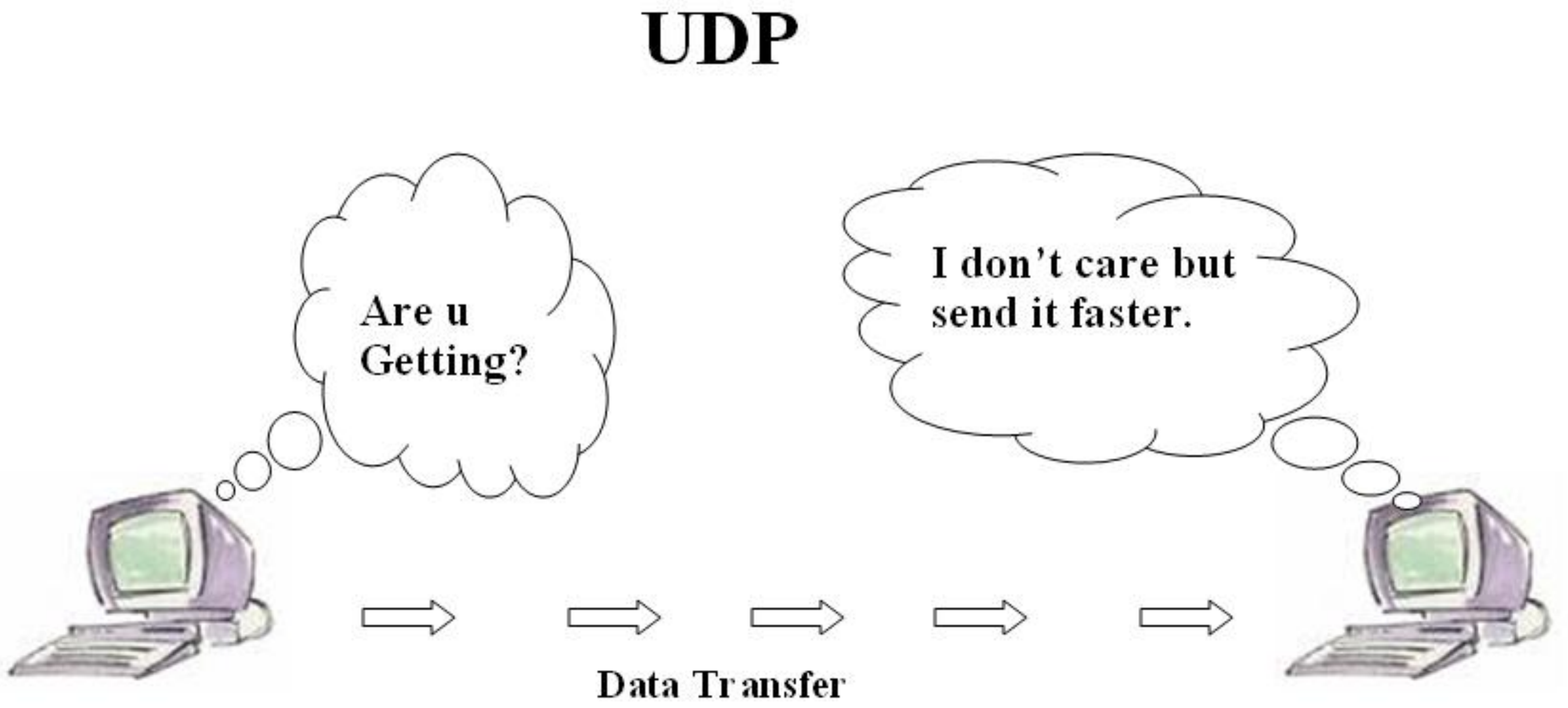
TCP-Connection state diagram



TCP Use cases

Application	Description
DHCP	Dynamic Host Configuration Protocol assigns IP addresses
DNS	Domain Name System translates website names to IP addresses
HTTP	Hypertext Transfer Protocol used to transfer web pages
NBNS	NetBIOS Name Service translates local host names to IP addresses
SMTP	Simple Mail Transfer Protocol sends email messages
SNMP	Simple Network Management Protocol manages network devices
SNTP	Simple Network Time Protocol provides time of day
Telnet	Bi-directional text communication via a terminal application
TFTP	Trivial File Transfer Protocol used to transfer small amounts of data

UDP

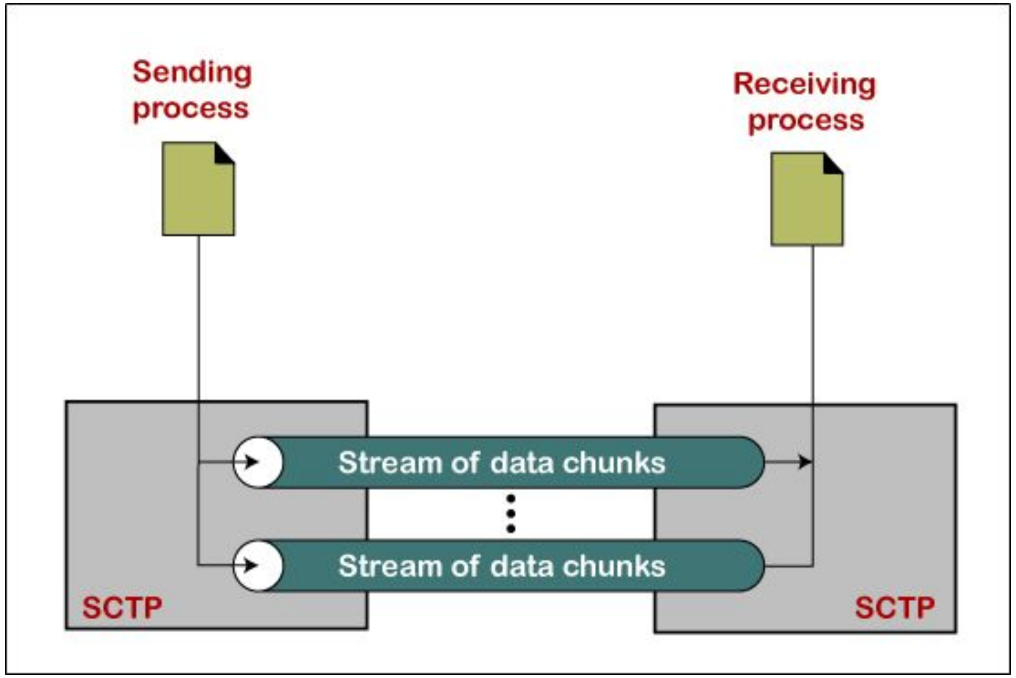

UDP
Are u Getting?
I don't care but send it faster.
Data Transfer

UDP Use cases

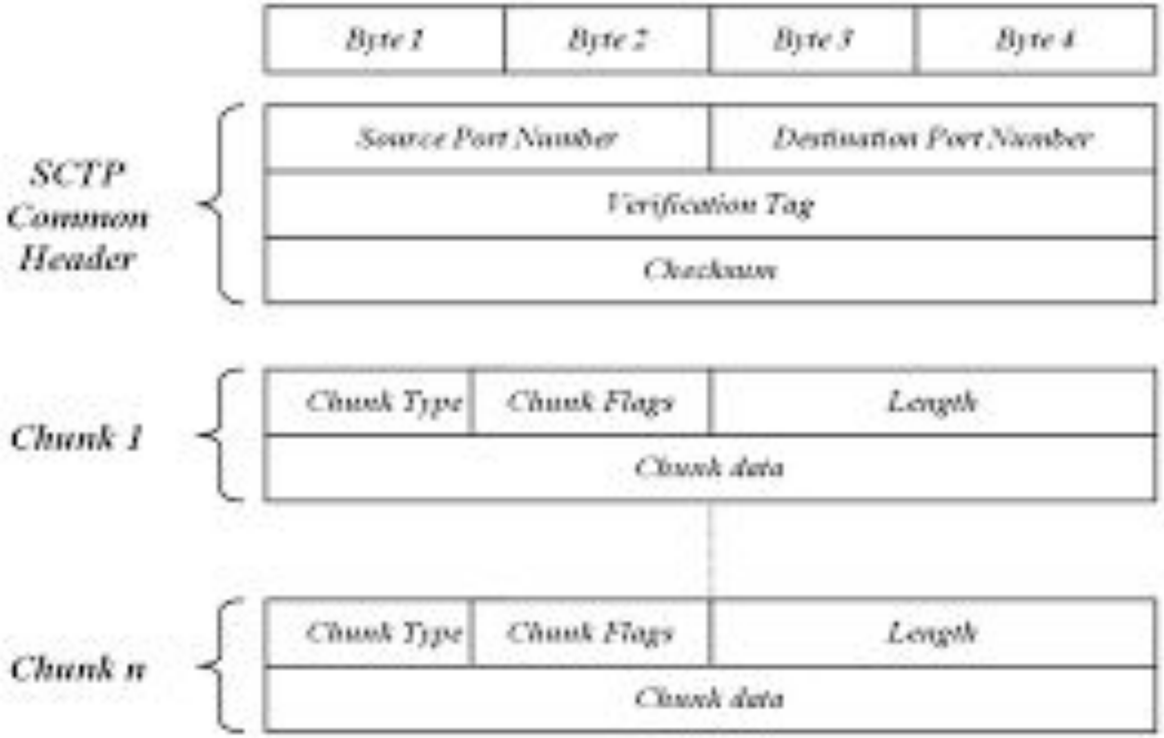
UDP Applications

- Used for applications that can tolerate small amount of packet loss:
  - Multimedia applications,
  - Internet telephony,
  - real-time-video conferencing
  - Domain Name System messages
  - Audio
  - Routing Protocols

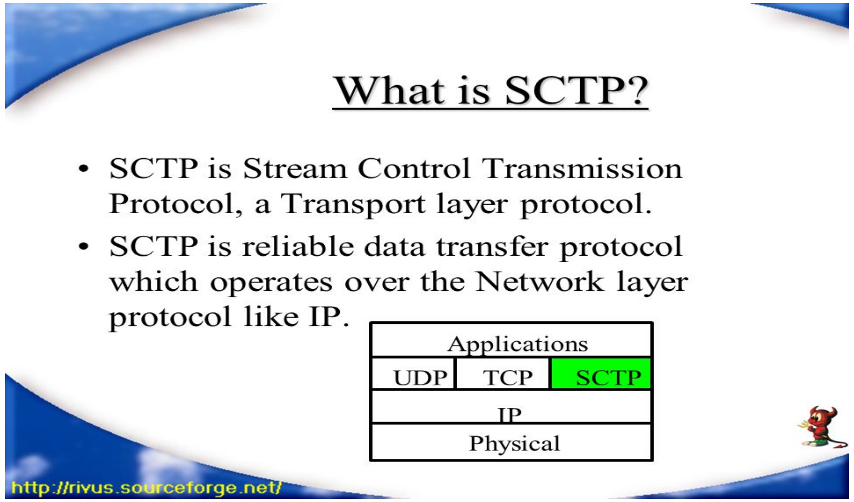
SCTP



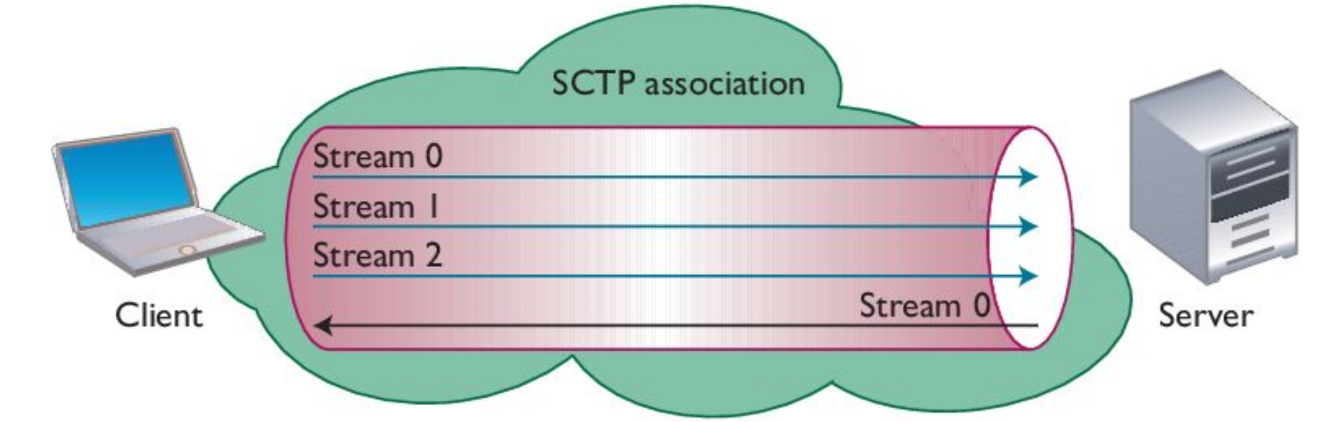
Sending process
Receiving process
Stream of data chunks
Stream of data chunks
SCTP
SCTP



Byte 1
Byte 2
Byte 3
Byte 4
SCTP Common Header
Source Port Number
Destination Port Number
Verification Tag
Checksum
Chunk 1
Chunk Type
Chunk Flags
Length
Chunk data
Chunk n
Chunk Type
Chunk Flags
Length
Chunk data

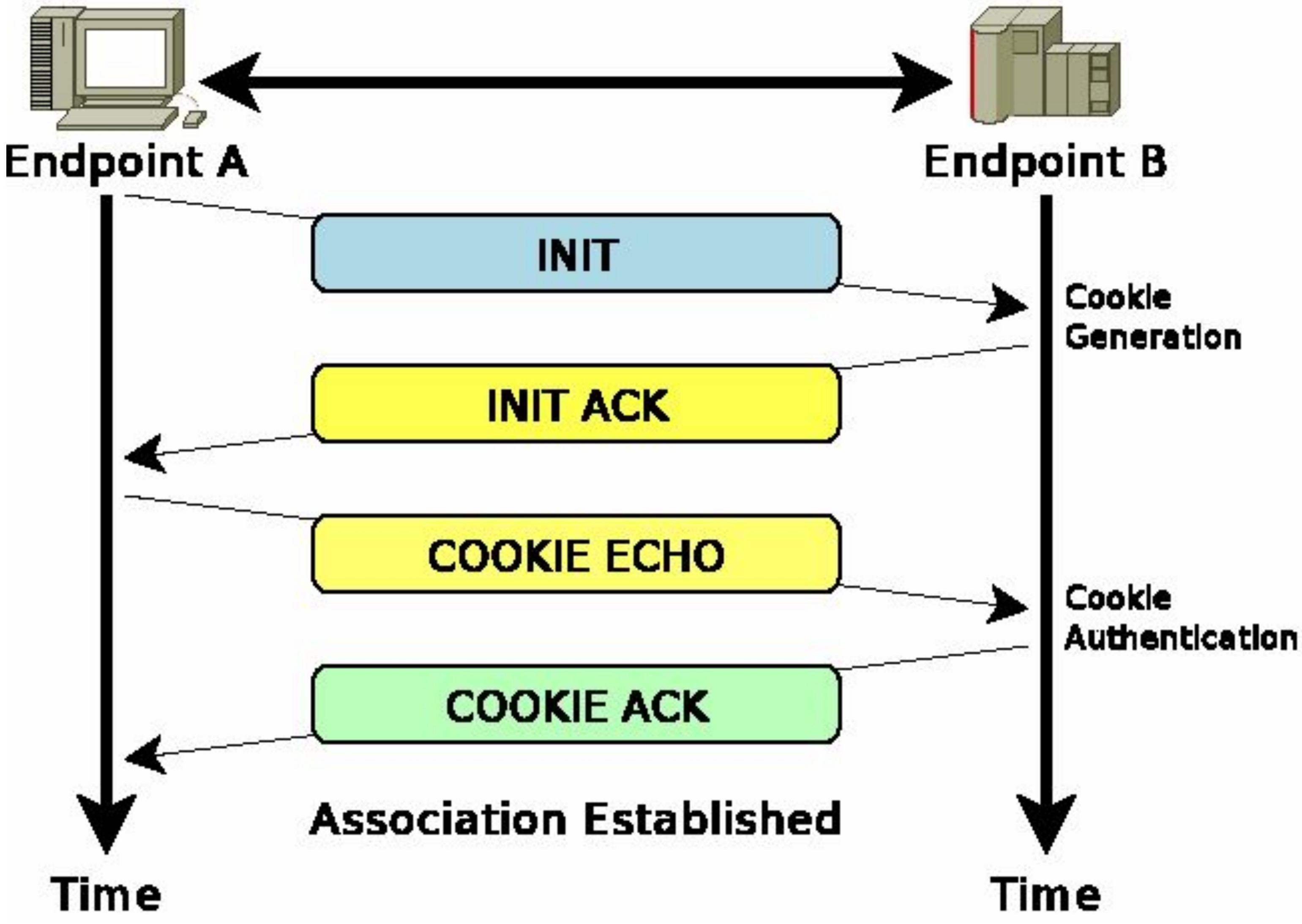


What is SCTP?
• SCTP is Stream Control Transmission Protocol, a Transport layer protocol.
• SCTP is reliable data transfer protocol which operates over the Network layer protocol like IP.
Applications
UDP
TCP
SCTP
IP
Physical
http://rivus.sourceforge.net/

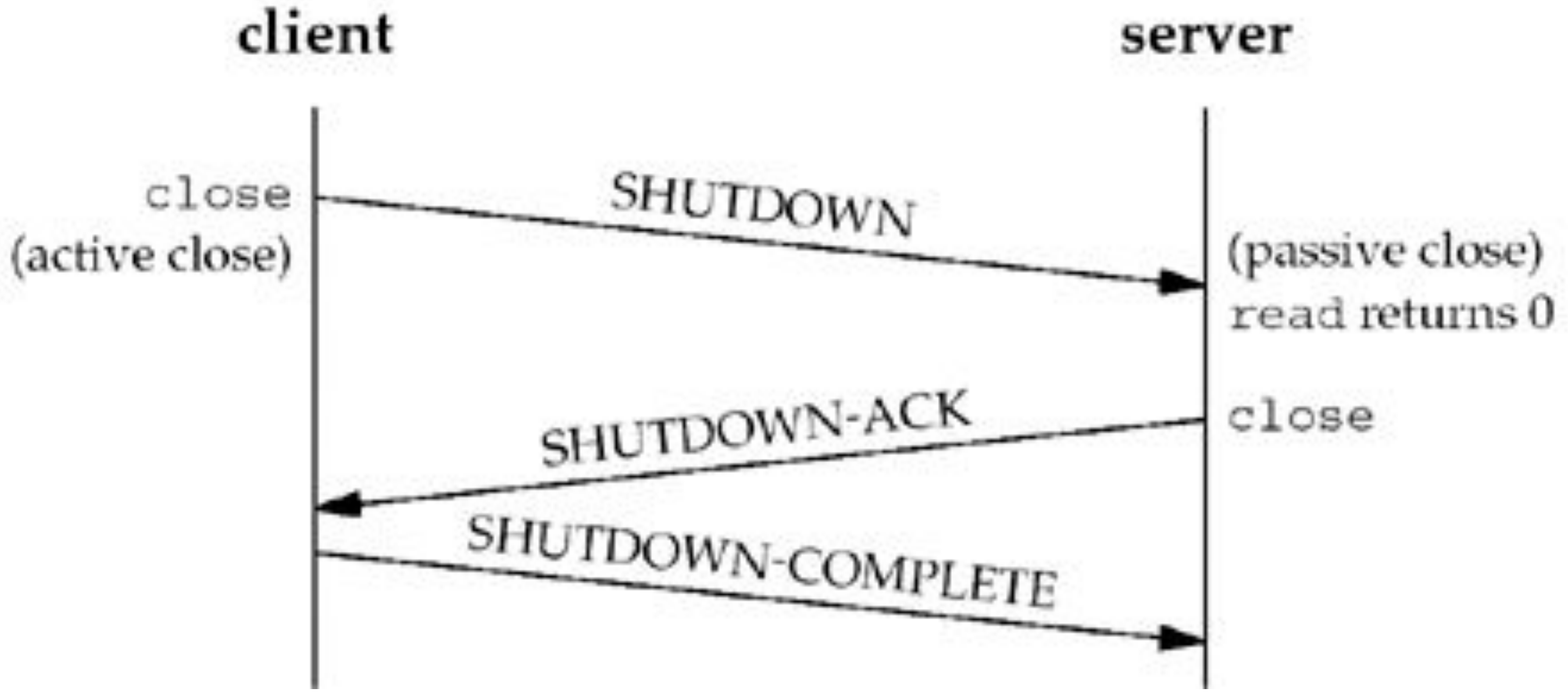


SCTP association
Stream 0
Stream 1
Stream 2
Stream 0
Client
Server

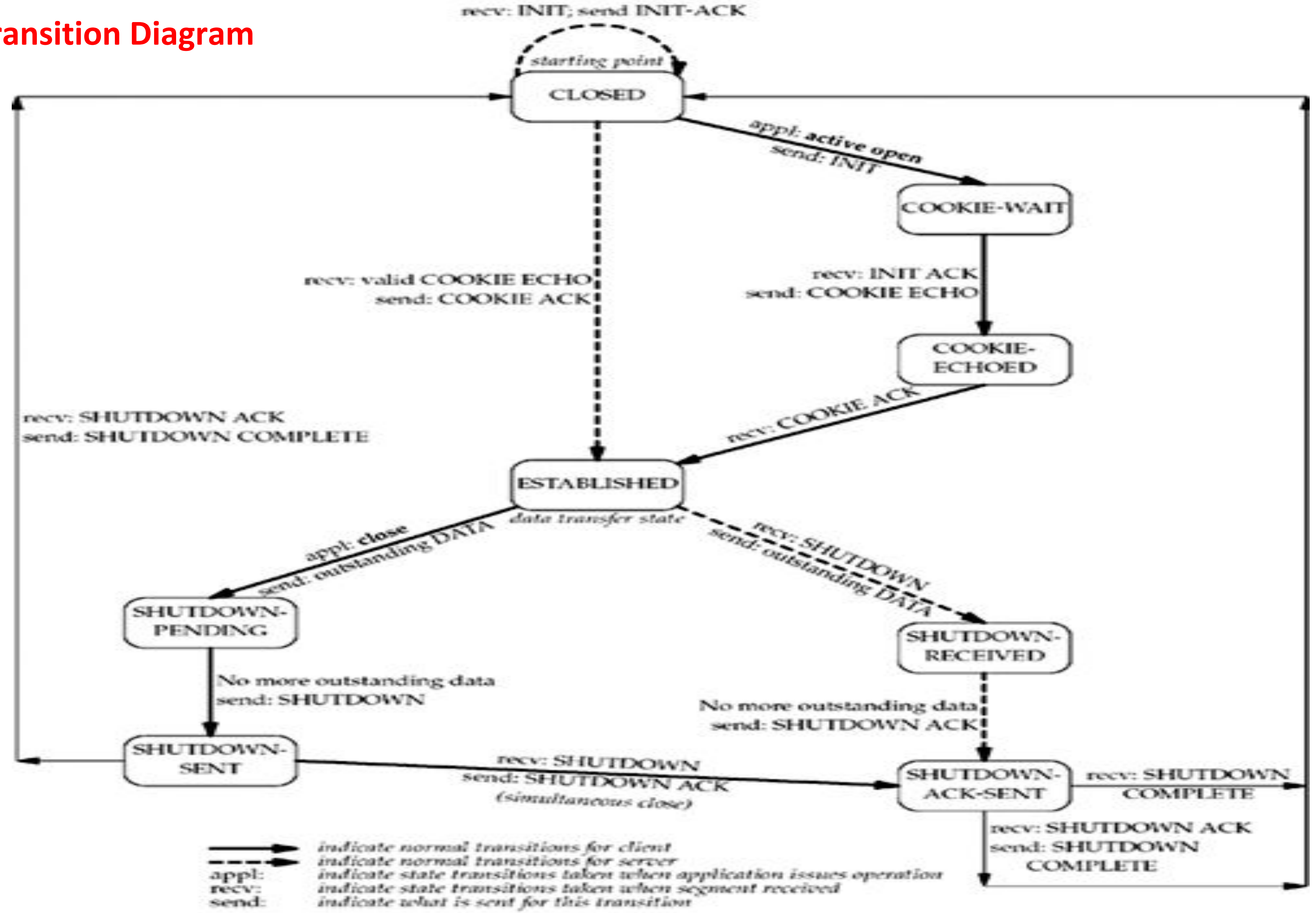
SCTP – 4 way Handshake



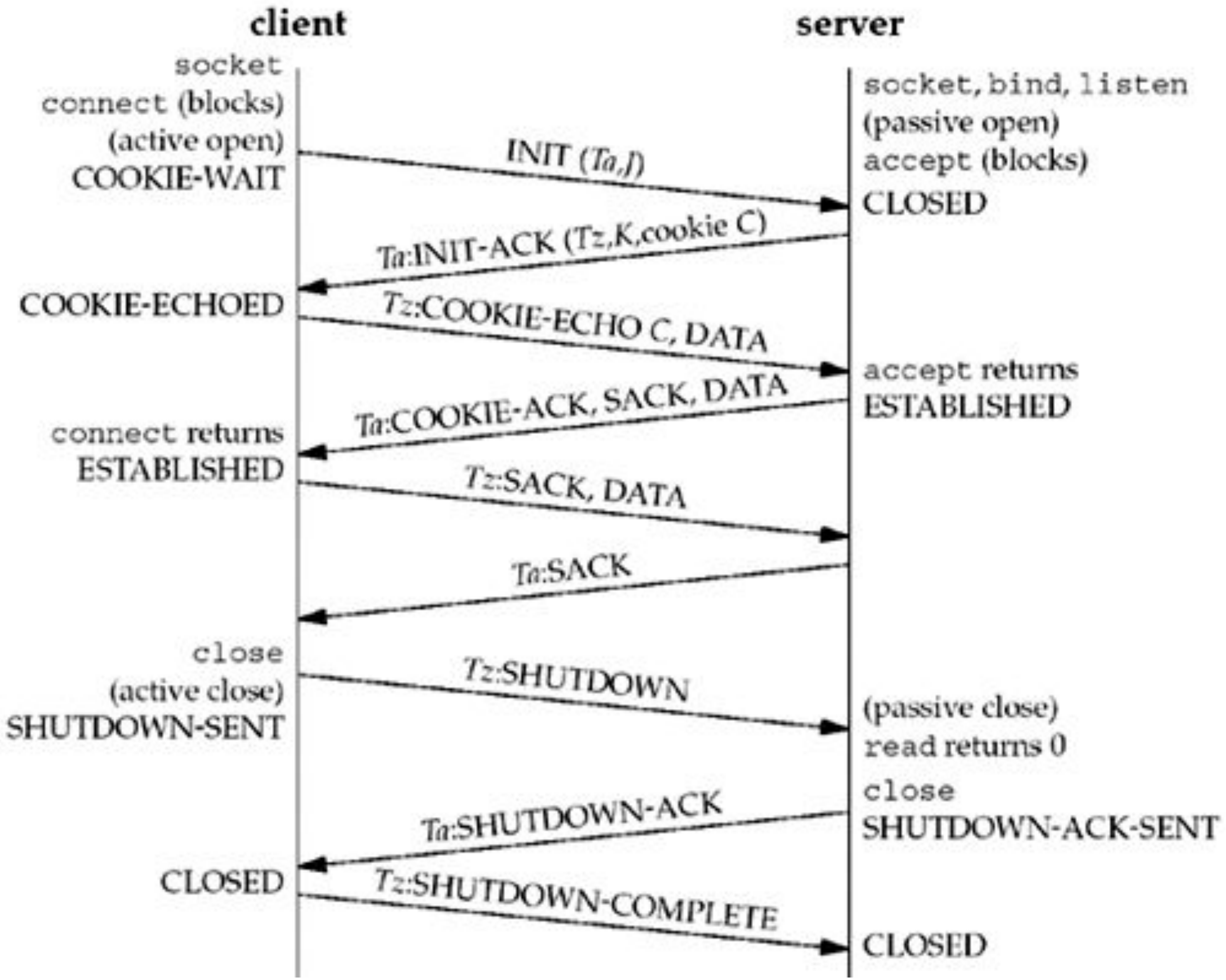
SCTP – Closing



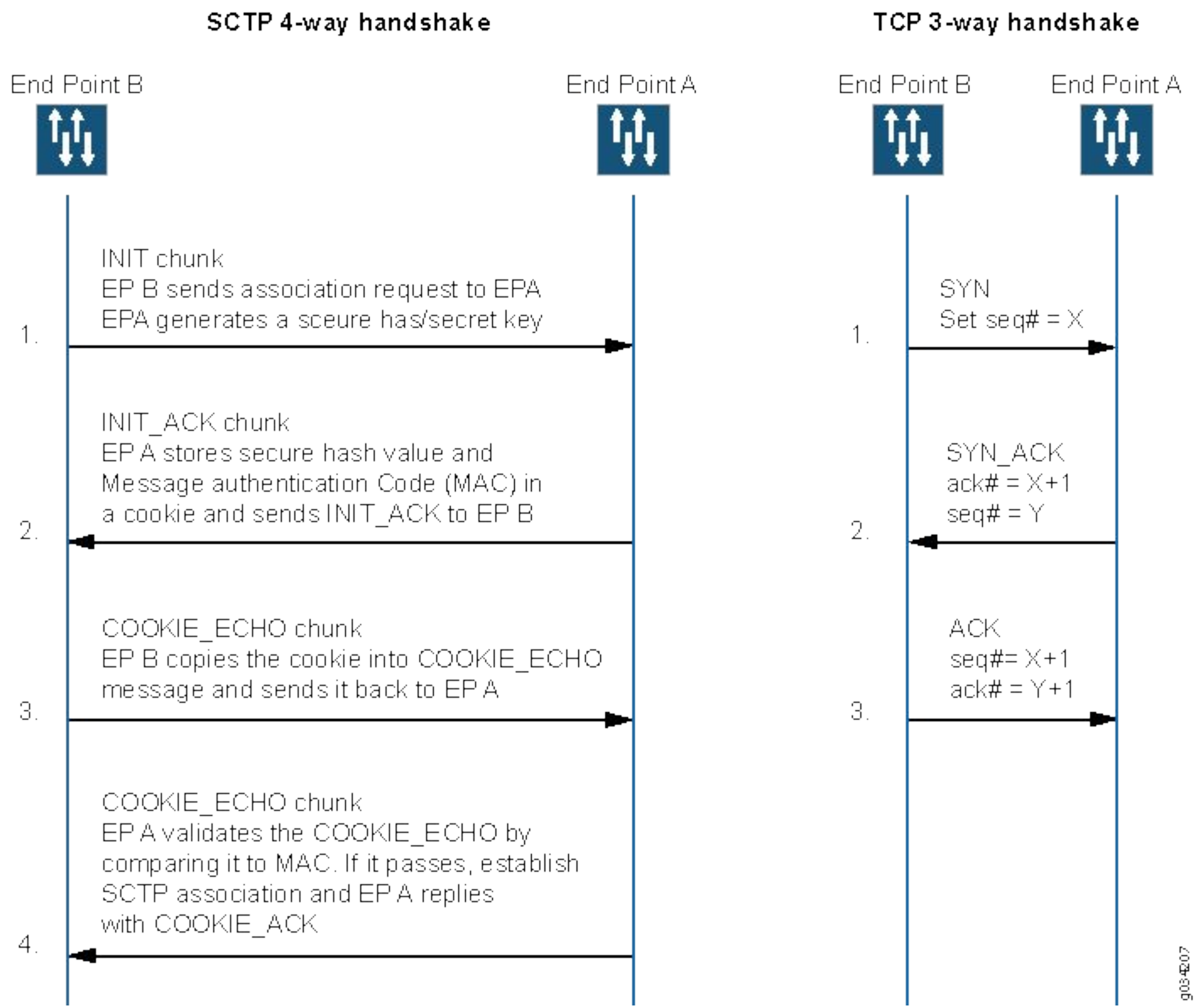
SCTP – State Transition Diagram



SCTP – Packet Exchange



SCTP – 4 way handshake



Comparison

	TCP	UDP	SCTP
Reliability	trustworthy	Unreliable	Trustworthy
Connection type	Connection-oriented	Connectionless	Connection-oriented
Transmission type	Byte-oriented	News-oriented	News-oriented
Transfer sequence	Strictly ordered	Disordered	Partially ordered
Overload control	Yes	No	Yes
Error tolerance	No	No	Yes

Review Questions

1. What is network programming? With neat diagram ,Explain the Client and Server Communication over LAN and WAN
2. Write a program to implement TCP daytime client
3. Write a program to implement TCP daytime client for IPV6
4. Explain the Error Handling using Wrapper functions
5. Write a program to implement TCP daytime Server
6. Explain the layers in the OSI model and Internet Protocol suite
7. Write a brief note on BSD Networking History
8. Write a short note on various UNIX standards
9. With the neat diagram give the overview of TCP/IP Protocol
10. Write a short note on i) TCP ii) UDP iii) SCTP protocols

11. Explain in detail, TCP Connection Establishment and Termination
12. Explain TCP state Transition Diagram
13. With neat diagram, explain Packet Exchange for TCP connection
14. Explain Sockaddr_in structure and its parts.
15. Give the comparison on TCP, UDP and SCTP protocols