Introduction

- Network – Interconnection of a set of device capable of communication.
- Device can be a host (end system) such as large computer, desktop, laptop, workstation, cell phone
- Device can also be router, switch, modem etc.
- Device in a network are connected using wire such as cables.

Local Area Network (LAN):

- LANs are privately owned.
- LAN connects hosts in a office, building or campus.
- Each host in a LAN has an address.

Wide Area Network (WAN):

- WAN is interconnection of device for communication.
- WAN has a wide geographical span through town, state, country or world.
- A WAN interconnects connecting device such as switch, router or modem.
- WAN normally owned by communicat^n companies.
- Two types –
  a. Point to point WAN:
     - It connects two communicat^n device through a cable
     - Refer Fig. 1.2 (Slide 1.8)

  b. Switched WAN:
     - It is a network with more than two ends
     - It is the backbone of global communication.
     - It is a combination of several point to point to WAN.
     - Refer Fig. 1.3 (Slide No 1.9)

Internet:

- When two or more n/w are connected to one another it is called internet or internetwork.
- Fig. 1.4 (Slide 1.10) and Fig. 1.5 (Slide 1.11)

Switching:

- Internet is a switched n/w in which a switch connects atleast 2 links together.
- Switch forward the data from one link to another link.
- Two types:
  1. Circuit Switched Network
  2. Packet " "

(1) Circuit Switched N/w :-

- A connection called circuit is always available between two end system.
- Refer Fig. 1.6 (slide no 1.13)
- Switch is used to make it active or inactive.
- Example :- Telephone n/w in past.
- It has forwarding capability but no storing capability.
- It is efficient if it is working with full capacity and inefficient if working with partial capacity.

(2) Packet Switched Network:

- Communicatn betn two ends is done in blocks of data called packets.
- It has both storing and forwarding capacity.
- Example - Router
- Refer fig. 1.7 (slide no 1.14)
- Router has a queue that can store and forward packets.
- Packet switch n/w is more efficient than circuit switched n/w.
- But packets may encounter some delays.

Accessing Internet:-

- Refer Fig. 1.8 (slide 1.16)
- Internet consist of backbones, provider n/w & customer n/w.

- Backbones are large n/w owned by communication companies.
- Backbone n/w communicate through switching ~~po~~ systems called peering points
- Provider n/w are small n/w that uses the services of backbone n/w.
- Customer n/w uses the services provided by internet by paying to provider n/ws.

Protocol Layering:-

- Protocol is the rules that sender, reciever and intermediate devices follow to carry out communicatⁿ effectively.
- Simple communicatⁿ require a simple protocol.
- Complex communicatⁿ divide the task into different layers.
- Each layer needs different protocol.
- Protocol layering divide a complex task into several smaller and simpler tasks.
- This is called modularity.
- A layer or module is a blackbox with inputs and outputs. without concern how inputs are changed to outputs.
- Advantage of protocol layering is that it allows to separate services from implementation.
- Another advantage of protocol layering is that all layers are not present in all devices.
- Principle of protocol layering
  (1) If we want bidirectional communication we need to make each layer, so that it is able to perform two opposite task, one in each direction.

2. Two object under each layer at both sites should be identical.

- Refer fig. 1.11 (slide no 1.24)
- So there is a logical connection betn each layer.

TCP/IP Protocol Suite:

- It is a set of protocol organized in different layers.
- It is a hierarchical protocol made up interactive modules, each of which provides a specific functionality.
- Upper level protocol is supported by services provided by one or more lower level protocols.
- Refer Fig 1.12 (slide no 1.28
- Layer architecture
  1. Application layer
  2. Transport "
  3. Network "
  4. Datalink "
  5. Physical layer.
- Refer Fig 1.13 (slide no 1.29)
- Hosts involves in all five layers.
- Router " only 3 layers.
- Switch " " 2 layers.
- Fig 1.14 (slide no 1.30)

Application Layer:-

- Logical connection between two application layer is end to end.
- Communicat^n in application layer is bet^n 2 processes.
- Protocols used - HTTP, SMTP, FTP, TELNET, SSH, SNMP, DNS, IGMP.
- Hyper text transfer protocol (HTTP) is vehicle for accessing world wide web (www)
- Simple mail transfer protocol (SMTP) used in email service.
- File transfer protocol (FTP) is used for transferring file from one host to another.
- Terminal network and secure shell is used for accessing the sites remotely.
- DNS ~~used~~ (Domain Name system) used to find the n/w layer address of computer.

Transport Layer:-

- Logical connection at transport layer is end-to-end.
- Transport layer gets the message from application layer.
- It encapsulate the message(M) with a transport layer header (H_T)
- Message (M) and header (H_T) ~~is~~ combinedly called as segment or user datagram.
- Transport layer give services to application layer.
- Transport layer protocols are TCP, UDP, SCTP.
- Transmission control protocol (TCP) is a connect^n oriented protocol.
- TCP provides flow control and congestion control.

- User datagram protocol (UDP) is a connectionless protocol
- UDP does not provide flow, error or congestion control.
- Stream control transmission protocol (SCTP) designed to respond to application of multimedia.

Network Layer:

- Responsible for creating connection betn source and destination.
- Communicatn at n/w layer is host to host.
- Routers in the path chose the best ~~host~~ route
- Packet of n/w layer is called datagram (Segment + HN)
- Protocols of n/w layer are – IP, ICMP, IGMP, DHCP, ARP, RARP.
- Internet protocol (IP) define the format of packet, structure of address used, routing packets.
- IP is connectionless protocol that does not provide flow control, error control or congestion control.
- Internet control message protocol (ICMP) help to report problem when routing packets.
- Dynamic Host configuration Protocol (DHCP) get the n/w layer address for a host.
- Address resolution protocol (ARP) helps to find link layer address of a host.

Datalink Layer

- It is responsible for taking the datagram and moving it across the link.
- link can be wired LAN, wired WAN or switch
- No specific protocol for link layer
- It supports all standard protocols.

- Datalink layer takes datagram and encapsulate it with header of link layer.
- This packet is called as frame.
- link layer provides error detection and correction.

Physical layer:

- Responsible for carry the individual bits in a frame across the link.
- Physical layer contains the hidden layer called transmission media.
- Transmission media can not carry bits. It carries electrical or optical signals.
- So bits should be converted to signal before transmission.

Encapsulation and Decapsulation:-

- Fig. 1.16 (Slide no
- There is no encapsulation or decapsulation in switch.
- Encapsulation occur at source host, ~~destination host~~ and router
- Decapsulation " " destination host and router.

- Encapsulation at source Host
  - The data to be exchanged is called Message in application layer.
  - The message is passed to transport layer.
  - At transport layer, a header is added to the message which contains identifier for source and destination program (port numbers)
  - Header of transport layer also contain information about flow control, error control and congestion control.

- The message of application ~~transport~~ layer along with the header of transport layer is called as segment.
- Segment is passed to n/w layer where a network layer header is added.
- Header of n/w layer contains the address of source and Destinatn host.
- Header of n/w layer also contains information about error checking, fragmentation etc.
- The result of network layer packet is called datagram.
- Datagram is passed to datalink layer where header of datalink layer is added to it.
- Header of link layer contains link layer addresses of the host.
- Result of link layer packet is called as your frame.
- frame is passed to physical layer for transmission.

- Decapsulation at destination host:
  - Each layer decapsulates the packet
  - " " remove the header from payload
  - Deliver the payload to upper layer
  - Finally the message will be delivered to applicatn layer.
  - Refer fig 1.16 (Slide no.

Adressing :-

- Any communication that involves two parties needs two addresses - source address and destination address.
- For communication, we need 4 pair of address, one for each layer.
- Physical layer does not need any address.

- Addresses in TCP/IP protocol suite - Fig. 1.17 (Slide no

Multiplexing and demultiplexing :-

- Refer Fig. 1.18 (Slide no
- Multiplexing in communication means that a protocol at a layer can encapsulate a packet from several next higher layer protocols.
- Demultiplexing means that a protocol can decapsulate and deliver a packet to several next higher layer protocol.

OSI Model :

- ISO standard that covers all aspects of network communications is the Open systems Interconnection (OSI)
- An open system is a set of protocol that allows any two different systems to communicate regardless of their underlaying architecture.
- OSI model is not a protocol, it is a model
- OSI model is designed as a network architecture that is flexible robust and interoperable.
- It consist of seven layers
- Fig. 1.19 (Slide no
- Comparison of TCP/IP & OSI Fig. 1.20 (Slide no
- Reason for Lack of success of OSI model
  1. OSI model was completed TCP/IP already implemented. A Lot of time and money already spent.
  2. Some layers in OSI model are not fully defined.

3. OSI model does not show a high performance enhancement than TCP/IP model.

Delay and Packet Loss:-

- Delay in other words is the time required.
- There are 4 types of delays in n/w
  1. Transmission delay
  2. Propagation delay
  3. Processing "
  4. Queueing "

- Transmission delay: (D_{trans})
  - Host needs to put the bits in the packet one by one in the line.
  - If first bit of packet put at time t1 and last " " " " " " t2, then transmission delay is $(t_2 - t_1)$
  - Transmission Delay = $D_{trans} = \dfrac{\text{Packet length } (L)}{\text{Transmission rate } (R)}$

    $= \dfrac{L}{R}$ second

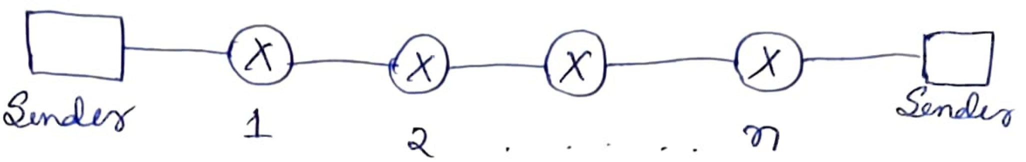
- Propagation Delay: (D_{prop})
  - It is the time required to travel from point A to point B in the transmission media.
  - Dprop depends on propagation speed of medium and distance betn link.
  - $D_{prop} = \dfrac{\text{Distance } (D)}{\text{Propagat}^n \text{ speed } (V)} = \dfrac{D}{V}$

- Processing ~~data~~ delay: (D_{proc})
  - Time required by router or destinatn host to process the packet

- Processing means removing header, checking header delivering packet etc.

- Queuing Delay : (D_{queue})
  - It happens in router
  - Time a packet wait in input queue of router and output queue of router.

- Total delay:



  - If we have n routers, (n+1) links exist betn source and destination.
  - So (n+1) transmission delays. [n routers & 1 source]
  - (n+1) propagation delays [n links)
  - (n+1) processing delays [n routers & 1 destination]
  - n queuing delays [n routers]
  - Total delay $= [(n+1)(D_{trans} + D_{prop} + D_{proc}) + n\, D_{queue}]$

Throughput :-

- Throughput at any point in the n/w is defined as the number of bits passing through the point in a second.
- Fig 1.10 (Slide no 4.20)
- Throughput = Minimum ($R_1, R_2, \dots, R_n$)
  where R = data rate or bandwidth.
- Packet Loss :
  - When router recieves a packet, it is stored in the input queue if router is busy processing another packet.
  - If the input queue is full when a packet arrived, the packet is dropped.

Q-1. Suppose two hosts A & B are separated by 2000 Km. And connected by a direct link of R = 2 Mbps. Suppose propagation speed of the midium is 2.5×10^8 m/s.

a. Calculate D_{prop}.

b. Calculate the maximum number of bits that can be in the link.

c. Consider sending a file of 80000 bits from host A to host B. Calulate the total time taken to send the file.

Solⁿ – a. Distance = D = 2000×10^3 m

Propagation speed = V = 2.5×10^8 m/s

$$D_{prop} = \frac{D}{V} = \frac{2000 \times 10^3}{2.5 \times 10^8} = 8 \times 10^{-3} s$$

b. Maximum number of bits in link = Bandwidth delay product

Bandwidth = R = 2 Mbps = 2×10^6 bps

Delay = D_{prop} = 8×10^{-3} s

Maximum number of bits in link = $R \times D_{prop}$

$= 2 \times 10^6 \times 8 \times 10^{-3}$ bits

$= 16000$ bits

c. File size = L = 80000 bits

No router is there ⇒ $n = 0$

Time taken to send the file =

$$[(n+1)(D_{prop} + D_{trans} + D_{proc}) + n D_{queue}]$$

$= D_{prop} + D_{trans} + D_{proc}$

$= D_{prop} + D_{trans}$

$= 8 \times 10^{-3} + \frac{L}{R} = 8 \times 10^{-3} + \frac{80000}{2 \times 10^6}$ ~~$= 32 \times 10^{-5}$ s~~

$$\text{Total time} = \left(8\times10^{-3} + \frac{80000}{2\times10^{6}}\right) s$$
$$= \left(8\times10^{-3} + 4\times10^{-2}\right) s$$
$$= 48\times10^{-3}\ s = 48\ ms$$

Q-2 - Host A wants to send a large file to host B. Path from host A to host B has two links of rate $R1 = 3$ Mbps and $R2 = 400$ kbps. Find out the throughput for file transfer. If R1 becomes half what is the throughput?

Solⁿ -

Throughput = Minimum (R1, R2)
= Minimum (3Mbps, 400 kbps)
= 400 kbps.

If R1 becomes half = 1.5 Mbps

Throughput = Minimum (1.5 Mbps, 400kbps)
= 400kbps.

Q-3 - Consider a point-to-point link of 50 km length. At what bandwidth would propagation delay equal transmission delay for a 100 Byte packet at a speed of 2×10^{8} m/s.

Solⁿ - Distance = D = 50 km $= 50\times10^{3}$ m

$L = 100$ Byte $= 100\times8$ bits

$V = 2\times10^{8}$ m/s

$$D_{prop} = D_{trans}$$

$$\Rightarrow \frac{D}{V} = \frac{L}{R}$$

$$\Rightarrow R = \frac{L\times V}{D}$$

$$= \frac{100\times8\times2\times10^{8}}{50\times10^{3}} = 32\times10^{5}\ bps$$
$$= 3.2\ Mbps$$

Q-4 – Suppose N packets arrive to a link at which no packets are currently being transmitted or queued. Each packet is of length L bits and link has transmission rate of R bps. What is the average queuing delay for N packets?

Solⁿ – After N packet arrive at link

Delay for 1st packet $= 0$

" " 2nd " $= \frac{L}{R}$

" " 3rd " $= \frac{2L}{R}$

" " Nth " $= (N-1)\frac{L}{R}$

– Total delay $= 0 + \frac{L}{R} + \frac{2L}{R} + \cdots + (N-1)\frac{L}{R}$

$$= \frac{L}{R}\left[1 + 2 + \cdots (N-1)\right]$$

$$= \frac{L}{R}\left[\frac{(N-1)(N-1+1)}{2}\right]$$

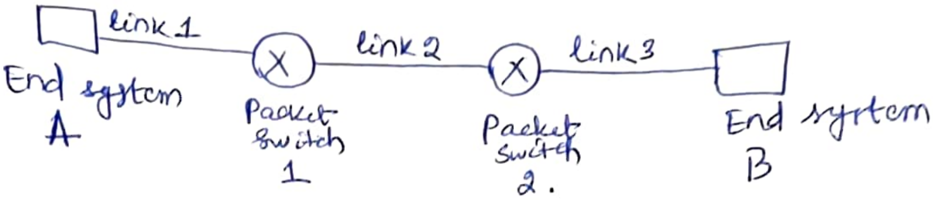
$$= \frac{L}{R}\left[\frac{N(N-1)}{2}\right]$$

– Average Delay $= \frac{\text{Total Delay}}{N}$

$$= \frac{L}{R}\frac{(N-1)}{2}$$

Q-5 – Consider a packet of length 1500 Bytes which begins at end system A and travels over 3 links to a destination end system B. The 3 links are connected by 2 packet switches, the propagation speed on all links is 2.5×10^8 m/s. The transmission rates of all the three links are 2Mbps. The packet switch processing delay is 3m/s. The length of first link is 5000km, the length of second link is 4000km and length of last link is 1000km. What is the end-to-end delay?

Solⁿ -



Propagation speed $= V = 2.5 \times 10^8$ m/s, $L = 1500B = 1500 \times 8$ bit

Data rate $= R = 2$Mbps $= 2 \times 10^6$ bps

Packet switch processing delay $= 3$ms $= 3 \times 10^{-3}$s

Distance of link 1 $= D_1 = 5000$ km $= 5000 \times 10^3$ m

" " " 2 $= D_2 = 4000$ km $= 4000 \times 10^3$ m

" " " 3 $= D_3 = 1000$ km $= 1000 \times 10^3$ m

Number of routers $= n = 2$

- Total transmission delay $= (n+1)\, D_{trans}$

$$= (n+1)\,\frac{L}{R}$$

$$= (2+1)\,\frac{1500 \times 8}{2 \times 10^6}$$

$$= 3 \times 15 \times 4 \times 10^{-4} = 12 \times 10^{-3}\text{s}$$

- Total propagation delay $= (n+1)\, D_{prop} = (n+1)\,\frac{D}{V}$

$$= (2+1)\left(\frac{D_1}{V} + \frac{D_2}{V} + \frac{D_3}{V}\right)$$

$$= \frac{3}{2.5 \times 10^8}\,(5000 + 4000 + 1000) \times 10^3$$

$$= 3 \times 4 \times 10^{-2}$$

$$= 12 \times 10^{-2} = 1.2\text{ms}$$

- Total processing delay $= n \times D_{proc}$

$$= 2 \times 3 \times 10^{-3} = 6 \times 10^{-3}\text{s}$$

- Total end to end delay $= (12 \times 10^{-3} + 1.2 \times 10^{-3} + 6 \times 10^{-3})$ s

$$= 19.2 \times 10^{-3}\text{ s}$$

$$= 19.2\text{ms}$$