CSE405
Computer Networks

The Internet: The internet is a global network that connects millions of computers and devices worldwide.

- hosts = end systems
- The connected devices are called hosts. (end systems) and run network applications at the "edge" of the internet.

(2) Packet Switching: Data is transferred over the internet in small units called packets. (chunks of data)

- Routers and switches are responsible for forwarding these packets from one device to another until the reach their destination.

(3) Communication links:

(I) Fiber optics
(II) Copper cables
(III) Radio waves
(IV) Satellite

- **transmission Rate:** bandwi
  The speed of these connections is determined by bandwidth
- **bandwidth:** capacity
  how much data can be transferred per second.

(4) Networks: collection of devices, routers, links managed by an organization.

Example: ISP (Internet Service Providers)

- Internet is a huge system of interconnected ISPs that link different networks together.

Throughput: actual rate of data transfer over a network typically measured in bits per second (bps), Kbps, Mbps, Gbps

"Protocol define the format, order of messages sent and received among network entities and actions taken on message transmission, receipt"

Protocols: Protocols are sets of rules that control how data is sent and received over the internet.

Some key protocols are —

(I) HTTP (Hyper Text Transfer Protocol) → for websites

(II) IP (Internet Protocol) → assign addresses to devices and routes data

(III) TCP (Transmission Control Protocol) → ensures reliable data transfer.

(IV) Wifi, 4G, Ethernet

(V) Streaming video, skype

Internet Standards: ensure compalibility accross device and networks

(I) RFC (Request for Comments) → official documents describing internet protocols.

(II) IETF (Internet Engineering Task Force)

Internet Infrastructure: The internet is an infrastructu that enables various applications and services.

Network edge

- Hosts: Clients and Servers
- Servers often in data centers.

☐ Access networks, physical media: wired, wireless communication link

Hosts: sending function:

- Takes application message, breaks into smaller chunks, known as packets, of length L bits.
- transmit packet into access network at transmission rate R.

Also known as bandwidth rate/link capacity/link transmission rate

$$\therefore \text{Packet Transmission delay} = \frac{L \text{ (bits)}}{R \text{ (bits/sec)}}$$

(time needed to transmit L-bit packet into link)

Links: physical media

This refers to the medium that physically connects a transmitter (sender) and a receiver (destination). The physical link is responsible for carrying signals between there two points.

Or, It ~~is what~~ lies between transmitter & receiver.

- bit: smallest unit of data that propagates between transmitter/receiver pairs.

• guided media: signals propagate in solid media. Ex: copper, fiber, coax	• Unguided media: signals propagate freely Ex: radio

The network edge:

- **end systems (hosts)**

(These devices are like smartphones, computers, tablets and servers. They run applications like web, email, file sharing)

- **client/server model**

Client is a device that requests services from another device (server).
Server is typically always on and provides service or resource to the client.

Ex: Web browser/Server, Email Client/Server.

- **peer-peer model**

It is different from the client server model. Because there is no single server that always provides a service. Instead each peer may act as both a client and a server. Here, devices (peers) communicate directly with one another without any dedicated server. Example: BitTorrent.

There are two types of service:

(i) Connection-oriented service
(ii) Connectionless service

① Connection oriented service (TCP - Transmission Control Protocol)

- Data transfer between end systems
- Reliable, ordered data transfer
- Uses handshaking before data transfer

Handsking - setup / preparation for data transfer.

- Flow control : Prevents sender from overwhelming receiver
- Congestion control: Adjust sending rate when network is busy. Protect internet from entering 'gridlock'.
- Used by applications like - HTTP (Web), File Transfer (FTP), Telnet (remote login), SMTP (email)

② Connectionless Service (UDP - User Datagram Protocol)

- Data transfer between end systems
- No flow control
- Connectionless
- No congestion control
- Unreliable data transfer
- Used by applications that prioritize speed over reliability, such as — streaming media, teleconferencing, DNS, and Internet telephony.

Network Core:

- A mesh of interconnected routers.
- Uses packet switching, where hosts break application layer messages into packets.
- Packets forwarded from one router to the next along a path from source to destination.

Two key Network-core functions:

① Forwarding (Switching)	② Routing
• local action • Moves packets from an input link to appropriate output link within a router. • Uses forwarding table that maps destination adresses to output ports	• global action • Determines the entire path a packet takes from source to destination. • Uses routing algorithms to find best route.

Packet Switching:

① Store and forward: entire packet must arrive at routers before it can be transmitted on next link.

② Queueing: It occurs when work arrives faster than it can be serviced.

③ Resource allocated: end-end resource allocated to, reserved for "call" between source and destination.

④ Dedicated Resource:

When a connection is established between source and

destination, a dedicated communication path (circuit) is reserved for the entire duration of the call. Once a circuit is allocated, it cannot be shared with others.

Example: Traditional telephone system

Types of circuit Switching - (FDM & TDM):

① Frequency Division Multiplexing (FDM)

⇒ Divides frequency spectrum into multiple ~~bands~~. narrow frequency bands.

⇒ each call allocated its own band, can transmit a max rate of that narrow band.

② Time Division Multiplexing (TDM)

⇒ time divided into slots

⇒ each call gets a periodic time slot to transmit at maximum rate of (wider) frequency band (only) during it's time slot.

How do packet delay and loss occur? → cause delays, reduce network performance and retransmission

⇒ When packet queue in router buffers, waiting for turn for transmission, if the arrival rate of packets ~~(links)~~ exceeds output link capacity, the queue length grows. increasing delay. Packet loss: service rate < arrival rate

⇒ Packet loss occur when there is no free buffers. Because Routers have limited buffer memory to store queued packets. If the buffer is full and new packets arrive, the router drops incoming packets causing packet loss.

Packet delay : 4 types

① Processing delay (d_{proc})

② Queueing delay (d_{queue})

③ Transmission delay (d_{trans})

④ Propagation delay (d_{prop})

$\therefore d_{nodal} = (d_{proc} + d_{queue}) + (d_{trans} + d_{prop})$

($d_{proc} + d_{queue}$) → Router/Hardware dependent

($d_{trans} + d_{prop}$) → link dependent

$d_{trans} = \frac{L}{R}$

L = Length of packet (bits) or packet length (bits)

R = link transmission rate

$d_{prop} = \frac{d}{S}$

d = length of physical link

S = propagation speed ($\sim 2 \times 10^8$ m/sec)

Question: ① Types of delay

② Router এর delay গুলো কী?

③ Link " " " "?

Caravan Analogy (Slide page- 28, 29) :-

① Ans: R = 12 sec

S = 100 km/hr

d = 100 km

$d_{trans} = (10 \times 12)\,sec = 120\,sec = 2\,min$

$d_{prop} = \frac{d}{V} = \frac{100\,km}{100\,km/hr} = 1\,hr = 60\,min$

Total delay $= d_{trans} + d_{prop} = (2 + 60)\,min = 62\,min$

(2) Ans:

$\frac{S}{V} = 1000\,km/h$

$d = 100\,km$

$R = 1\,min = 60\,sec$

$d_{trans} = 10\,min$ (for 10 car)

$\therefore d_{trans} = 1\,min$ (for 1 car)

$d_p = \frac{100\,km}{1000\,km/hr} = 0.1\,hour = 6\,min$

Total delay $= 1\,min + 6\,min = 7\,min$

Yes, after 7 min first car arrives at second booth.

Practice Problem:

Suppose two hosts, X and Y, are located 20,000 km apart and are connected through a direct link with a transmission rate of 2 Mbps. The propagation speed along this link is 3×10^8 m/s.

(i) If Host X sends a video file of 1,200,000 bits. The video file is split into 15 packets, each containing 80,000 bits. Assume that it takes 25 milliseconds to check for bit errors on each packet before transmission. Determine the

total time needed to send the entire video file in this packetized format.

Ans: Given, $d = 20,000\ km$

$R = 2\ Mbps$

$V = 3 \times 10^8\ m/s$

Full data length = 12,00,000 bit

Number of packets = 15

Length of each packet = 80,000 bits

processing delay of each packet = 25 ms

$\therefore$ Total processing delay, $d_{proc} = (15 \times 25)\ ms$

$= 375\ ms$

Transmission delay of each packet $= \frac{L}{R}$

$= \frac{80,000\ bits}{2 \times 10^6\ bps} = 0.04 = 40\ ms$

$\therefore$ Total transmission delay, $d_{trans} = (15 \times 40)\ ms$

$= 600\ ms$

Propagation delay $= \frac{d}{V} = \frac{20,000 \times 10^3\ m}{3 \times 10^8\ m/s}$

$= 0.0667\ s$

$= 66.67\ ms$

$\therefore$ Total delay $= (375 + 600 + 66.67)\ ms$

$= 1041.67\ ms$

What do "real" Internet delay & loss looks like?

Traceroute: Traceroute is a network diagnostic tool that tracks the path packets take from source to destination, identifying delays and connection issues. It uses the time-to-live (TTL) field in packets to map the route to a destination. Traceroute identifes distance, time, delays, congestion etc. (path, route, IP address সম্পর্কে acknowledge করে)

TTL: (Time-to-Live) TTL is a field in IP Packets that limits how long a packet can travel in a network before being discarded.

- helps prevent infinite loops.
- helps traceroute track network paths.
- controls packet lifespan in a network.

Throughput: Rate (bits/time unit) at which bits are being sent from sender to receiver.

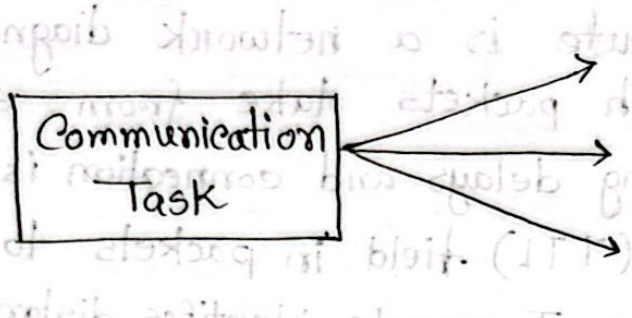
- Instantaneous: rate at given point in time
- average: rate over longer period of time

* $R_s < R_c$, the average end-end throughput is determined by sender's rate (R_s)
* $R_s > R_c$, the average end-end throughput is determined by bottleneck link in the path (R_c)

Bottleneck link:
link on end-end path that constrains end-end throughput (bandwidth)
- It limits overall transmission speed

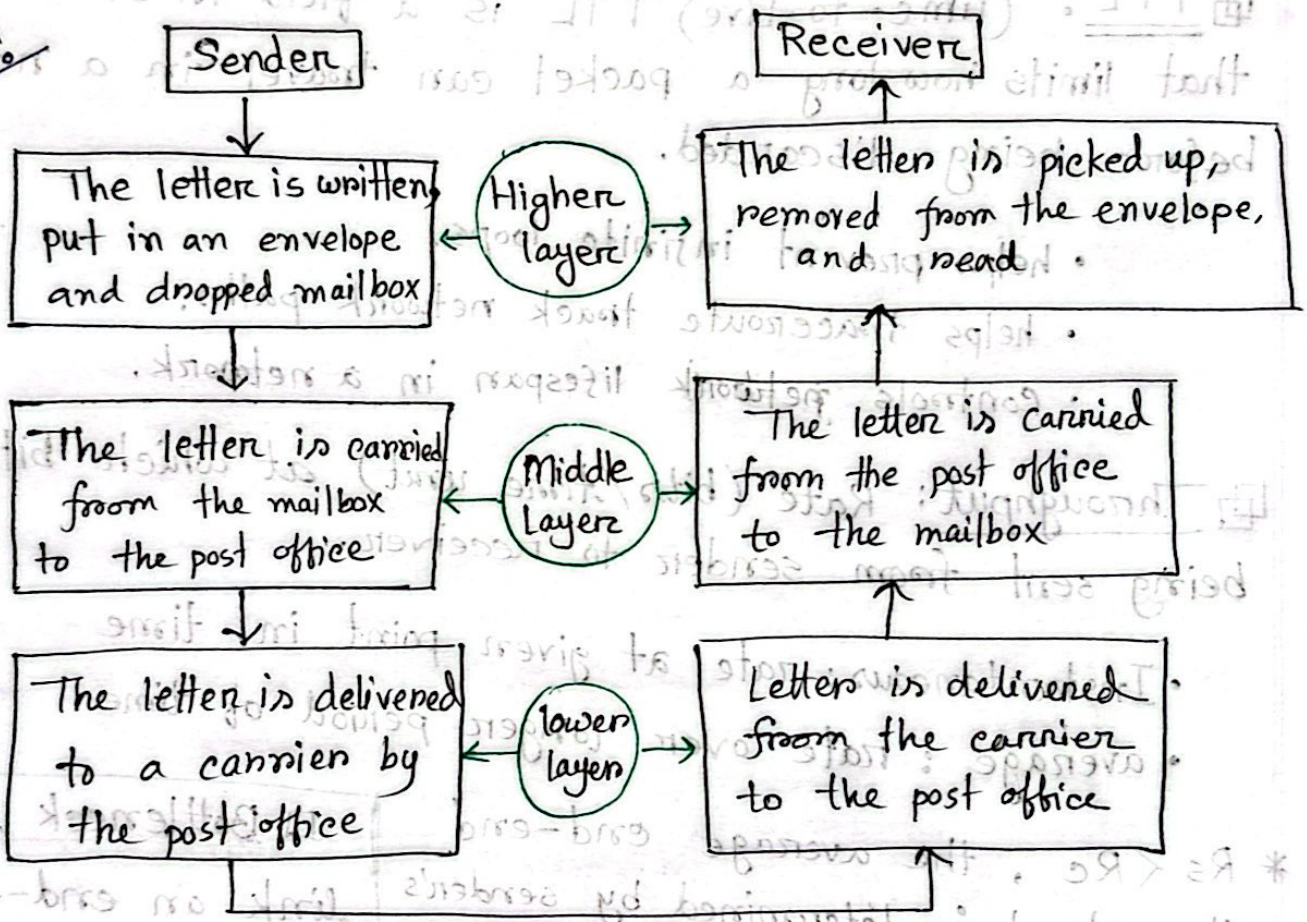
Soln: Optimize Routing, increase bandwidth, manage network traffic

Layering:



Layers involved in sending a letter:-

Just an example!!!



Benefits of using a layered model:

- To find out fault easily
- Changes in one layer doesn't affect other layers
- Have defined information that they act upon.

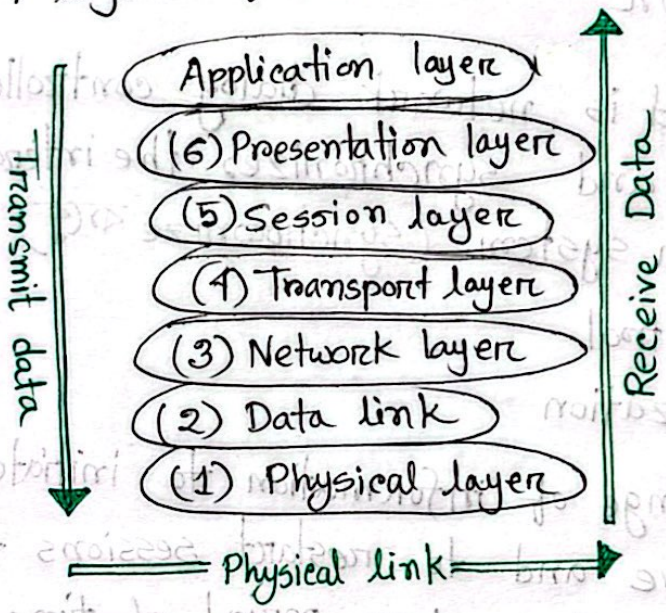
Networks are complex as it has: hosts, routers, links of various media, applications, protocols, hardware and software.

□ There are 2 types of ~~mode~~ layered model:

① TCP/IP Model ② OSI model

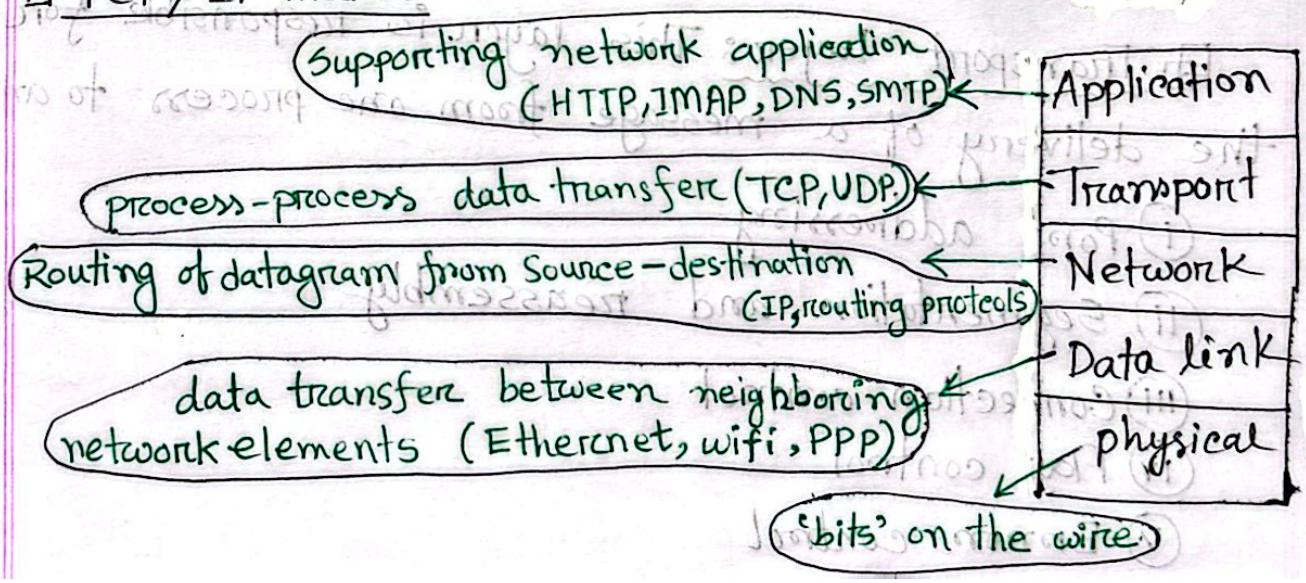
□ OSI model: Open System Interconnection, Developed by the International Organization for Standardization (ISO).

• 7 layers of OSI:



• OSI model is a conceptual framework that divides network communications functions into 7 layers.

□ TCP/IP model:



* Slide (41-45): Encapsulation, (figure)*

⊞ Application Layer: Provides User Inteface

⊞ Presentation Layer: It is concerned with syntax and semantics of the information exchanged between two systems.

(i) Translation
(ii) Encryption
(iii) Compression

⊞ Session Layer: It is network dialog controller. It establishes, maintains and synchronizes the interaction between communication system. (synchronize করে)

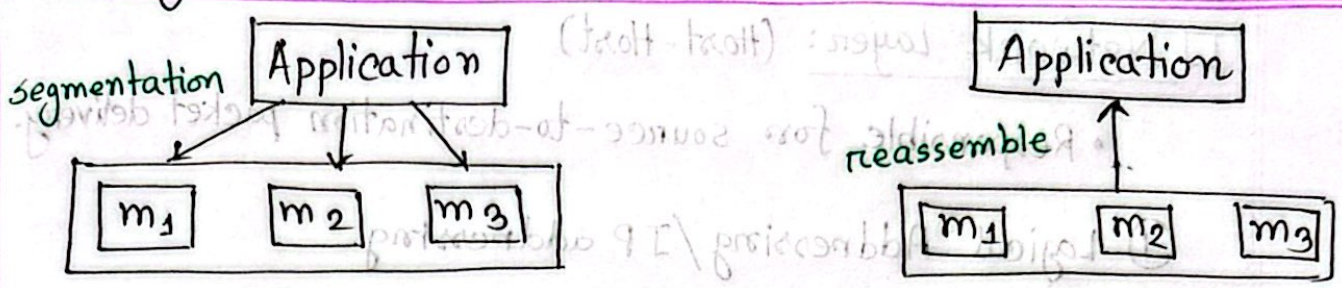
(i) Dialog control
(ii) Synchronization

It handles the exchange of information to initiate dialogs, keep them active and to restart sessions that are disrupted or idle for a long period of time

⊞ Transport Layer: This layer is responsible for the delivery of a message from one process to another.

(i) Port addressing
(ii) Segmentation and reassembly
(iii) Connection control
(iv) Flow control
(v) Error control

Sending portion: Receiving portion:



- Transport layer PDU is called Segments.
- Common Protocol used in Transport Layer is TCP and UDP.

Port address – 16 bit

It is represented as decimal value.

- MAC Address – 48 bit - represented by 12 hexadecimal digit
- IP Address – 32 bit

MAC (media Access control) address. Every port has a unique MAC addr

Connection Control: Manages the establishment, maintenance and termination of a connection between two devices in a network.

Flow Control: Ensures efficient data transfer and prevents overflow at the receiver. Prevents a fast Sender from overwhelming a slow receiver by controlling the data transmission rate.

Error Control: Detects and corrects errors that occur during data transmission. It ensures that the data is received same as the one sent by the sender.

PDU = Protocol Data unit.

☐ Network Layer: (Host-Host)

- Responsible for source-to-destination packet delivery.

(I) Logical Addressing/IP addressing
(II) Routing
(III) Sender-Reciever/source-destination packet transfer.

- Network layer PDU is called packets
- Common network layer Protocol is called Internet Protocol. (IP)
- Universal address, IP address - 32 bit (192.168.10.1) each decimal represented by 8 bit.

☐ Data link Layer: Responsible for moving frames from one hop(node) to the next. It makes the physical layer appear error free to the upper layer. (link-link)

(I) Framing
(II) Physical addressing
(III) Flow control
(IV) error control
(V) Access control. → কোন device এর Access লাগবে তা control করে।

∴ Data link PDU is frames.

Question: As flow control and error control service is provided by application layer, why does data link layer provides it too?

Slide (61, 62, 63)

Physical layer: It co-ordinates the functions required to transmit a bit stream over physical medium.

(I) Physical characteristics of interfaces and media
(II) Representation of bits
(III) Data rate
(IV) Physical topology
(V) Line configuration
(VI) Transmission mode

- data → bit → signal
- wireless হবে, না কি wire ?
- simplex, নাকি half simplex, নাকি full simplex এইসব নির্ধারণ করে Physical layer.

Summary of OSI model:

- Application — To allow access to network resources
- Presentation — Translate, encrypt, and compress data
- Session — To establish, manage and terminate sessions
- Transport — To provide reliable process to process message delivery and error recover
- Network — To move packets from source to destination; to provide internetworking
- Data Link — To organize bits into frames; to provide hop-to-hop delivery
- Physical — To transmit bits over a medium; to provide mechanical and electrical specifications