1. Computer Networks and the Internet

Internet:

Its a computer that network that interconnects hundreds of millions of computing devices through out the world.

Earlier these computing devices were limited to primary desktop PC's, Linux workstations and severs. Increase in the use, non-traditional end systems such as laptops, tablets, smartphones gaming consoles, TV's, webcams etc came into existences.

In Internet jargon all the devices are called as hosts or the end systems

End systems are connected together by a network of communication links and packet switches. Different links can transmit data, ~~at different~~ with the transmission rate of the link (bits/sec).

A packet switch takes a packet arriving on one of its incoming communication links and forwards that packet on one of its communication link.

End systems access Internet through Internet service providers (ISP's), these may include residential ISPs such as local cable or telephone companies, co-operate/university ISP, wifi access etc.

End systems, packet switches and other peice pieces of the Internet runs protocol that controls the sending and receiving information with the Internet. The two Important protocols are Transmissio Control Protocol (TCP) and Internet Protocol (IP)

→ A protocol defines the format and order of messages exchanged between the two or more communicating entities, as well as the actions taken on transmission/reception of a message or an event

The Network Edge

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Access Networks

1. Home Access: DSL, Cable, FTTH, Dial-up and Satellite

DSL: Digital Subscriber line

DSL Internet access is obtained by the local telephone company that provids wired local phone access, when DSL is used the telephone company is its ISP. Here existing telephone lines are used to exchange data with Digital Subscriber line access multiplexer (DSLAM) located at the telephone central office (CO)

The DSL modem Translates the digital data to high frequency tones for transmitting it to telephone CO over telephone wires/lines, These line carry both data and telephone signals simultaneously, which are encoded at diff freq

→ High speed downstream channel 50KHz to 1MHz band
→ Med-Speed upstream channel 4KHz to 50KHz band
→ Ordinary away telephone 0-4KHz band

On the customer side the splitter seperates the data and telephone signal arriving and forwads data signal to DSL Modem.

On the telephone CO the DSLAM seperates data and phone signals and sends data to the Internet Hundreds/thousands of DSL can connect to single DSLAM

DSL Standards defines transmission rates of

12 Mbps - downstream 1.8 Mbps - Upstream	ITU 1999
24 Mbps - downstream 2.5 Mbps - Upstream	ITU 2003

Cable Internet Access:

This makes use of the cable television company's existing cable infrastructure. A residence obtains cable Internet access from the same company that provides its cable television.

These require cable modems that are conneted to the PC through an Ethernet port.

Fibre optic connects the cable head end to the neighborhood junction or fibre node, then from which co-axial cables are used to connect to individual houses

Each junction supports 500-5000 homes bcoz of both fibre optics and co-axial cables are deployed this is reffered as hybrid fiber co-ax (HFC)

At the cable head end, the cable modem termination system (CMTS) is used to translate analog signal recieved to digital data format.

Cable modem divides the HFC to two channels upstream and downstream.

Downstream rates upto 42.8 Mbps

Upstream rates upto 30.7 Mbps

FTTH - fibre to the home:
provide an optical fiber path from the central office (CO) for each home

Physical Media → guided Media → Twisted pair
→ Co-axial
→ Fibre optic
→ Unguided Media

* Twisted Pair Copper wire
→ Consists of 2 insulated copper wires, each about 1mm thick.
→ arranged in spiral pattern.
→ The wires are twisted to reduce the electrical interference from similar pair close by
→ The twisted pairs are wrapped in a protective sheild (shielded twisted pair)
→ Unshielded twisted pair is commonly used for computer networks with in a building ie for LAN's the data range of this may be upto 10Mbps to 10Gbps
→ data rate depends on the thickness of the the twisted pair and the distance between transmitter & reciever.
→ 6a cable achieve data rate up to 10Gbps and distance of hundreds meters.
→ Its a dominant solution for high speed LAN networking.
→ Commonly used for residential Internet access
→ Dial up modem technology enables access at rates of upto 56kps over twisted pair
→ More than 99% of the wired connections of telephone switch use twisted pair copper wire

- Co-axial Cable:
  - → Consists of two copper conductors
  - → The two conductors are concentric rather than parallel.
  - → This const^n and special insulation and sheilding co-axial cable can achieve high data transmission rates.
  - → commonly used in cable television system
  - → provides data rate of 10's of Mbps
  - → Co-axial cable can be used as guided shared medium
  - → end systems can be connected directly to the cable.

- Fibre Optics:
  - → Its a thin flexible medium that conducts pulses of light with each pulse representing a bit
  - → A single optic fibre can support tens or even hundreds of giga bits per second.
  - → Immune to electromagnetic Interference
  - → have very low attenuation upto 100 kilometers
  - → very hard to tap
  - → Used for long distance communication (oversea links)
  - → long distance telephone n/w in United states and else where now we use fibre optics
  - → Its backbone of the Internet.
  - → High cost of optical devices has hindered their deployment for short-haul transport.
  - → The Optical Carrier standard link speeds range from 51.8 Mbps to 39.8 Gbps.

Unguided Media:

Radio

- They carry signals in the electromagnetic spectrum
- They donot require any physical wire to be installed
- They penetrate through wall
- carry signal for long distances.
- The characteristics of the propagation mainly depends on the propogation environment.
- The signals may be subjected to attenuation and disturbance from other transmissions and electromagnetic signals.
- Satellite Radio communication is possible where a communication satellite links two or more Earth based transmitter/reciever
- Two types of satellites used in this are geostationary satellite and low easthing orbiting (Leo) Satellite
- ex: → terrestrial microwave (upto 45 Mbps)
  → LAN (WiFi 54 Mbps)
  → wide area (eg. cellular 4G - 10Mbps)
  → Satellite (few Kbps - 45Mbps
  270 msec end-end delay)

Network Core

Packet Switching

- In n/w application end systems exchange messages these message may be a control function, data, image or an MP3 file
- To send these from source to destination, the source breaks the information to many chunks known as packets which are transmitted over communication links and packet switches with full transmission rate of the link.

L → length of the packet
R → transmission rate bits/sec
L/R → time to transmit the packet

Store and Forward Transmission

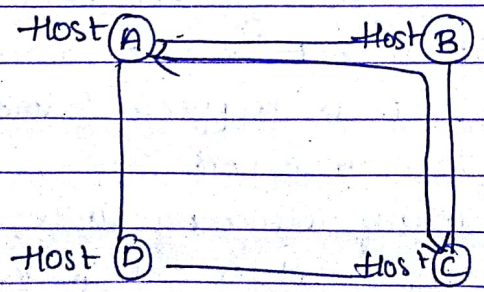
- In this transmission the packet switch must receive the entire packet before it can begin to transmit the first bit of the packet onto the outbound link.
- Typically a router have many incident and outbound links since its job is to switch incoming packets to the outgoing links
- If for example the source has 3 packets to be transmitted & the first packet has reached the router then that packet is not switched to outgoing link rather it is buffered (stored) unless the other two packets are received.
- Since the router has many outgoing links, each link has its own output buffer where the packets are stored before they reach the destination
- This - Buffers play a key role in packet switching ie

when the outgoing link is busy with transmission of other packets then the arriving packets can be stored into the buffer

- In addition to this it has packets suffer from queuing delays and may occur due to congestion in the n/w
- Since the buffer size is finite, The arriving packet may find the buffer is full. In this case packet loss will occur.

Circuit switching:

- In circuit switched network the path to provide communication between the end system is established prior the transmission and is reserved through out.
- Traditional telephone networks are example of circuit switched n/w
- The connection established by the n/w between sender & receiver for the particular connection this is called circuit, the circuit provides a constant transmission rate in the link through out the transmission (guaranteed constant rate)
- Whenever two hosts are communicating the n/w links establishes ~~end~~ dedicated end-to-end connection



Circuit switched n/w consisting of 4 links & 4 switches.

Multiplexing in Circuit Switched N/w

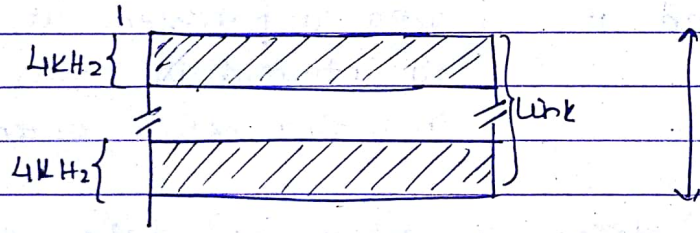
A circuit in a links is implemented by either frequency division multiplexing or Time division multiplexing.

FDM:

- frequency spectrum of link is divided among the established link
- dedicates a frequency band to each of the connection for the duration of the connection

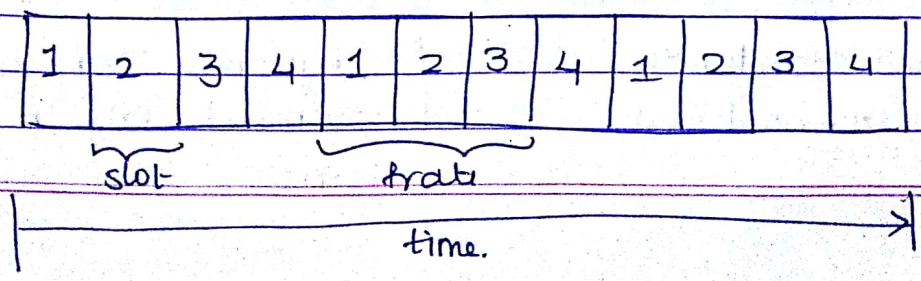
-Ex:

In telephone n/w the freq band is 4KHz
FM radio stations bet^n 88MHz to 108MHz



TDM:

- For a TDM link, time is divided into frames for fixed duration and each frame is divided into a fixed number of time slots
- when a n/w establishes circuit (link), the n/w dedicates one time slot in every frame to that connection
- Transmission rate is equal to the frame rate multiplied by no. of bits in the slot.



Circuit Switching versus packet Switching

Circuit Switching	Packet Switching
1. There are 3 phase → Connection Establishment → Data transfer → Connection Released	direct data transfer takes place.
2. Each data unit know the entire path address and which is provided by the source	Here each data unit just know the final destination address ~~from~~ intermediate path is decided by the routers
3. data is processed at source system	data is processed at all intermediate nodes including source system
4. ~~data~~ delay bet^n data unit is uniform	delay bet^n data unit is not uniform
5. Resource reservation feature is available bcoz of fixed path data transmission	No resource reservation bcoz there is no fixed path for data transmission
6 More Reliable	less Reliable
7 Resource wastage is more	less Resource wastage
8 Fixed Bandwidth	Dynamic Bandwidth
9. No Overhead bit	Overhead bits in each packet

10. Implemented in physical layer	Implemented at Network layer
11. Message or data unit is received in the order sent from the source	Packet are not arrived in sequence and are arranged at the distination
12. ~~The~~ Inflexible bcoz once path is set all data units follow same path	flexible bcoz a diff route is created for each packet to reach the destination
13 Connection oriented	Connection-less

Internet Structure: Network of networks

- end systems use ISP (Internet service providers) to exchange packets or data with in they are directly connected to each other
- The ISP need be DSL, cable, FTTH wifi or cellular always it can be a university or company providing access to its user
- But ~~the~~ connecting user and providing access is a very small part of the Internet access/network. to complete the network the ISP itself must be interconnected this is done by creating network of networks
- One possible way to interconnet ISP is direct connections ie mesh but this turns out to be too costly to implement as there are thousands of ISP's all over and it is also not practically possible connect all the ISP providing individual communication link between the ISP's

n/w of n/w continued

Delay in packet switched networks:

4 types of delay

1) Nodal processing delay
2) Queuing delay
3) Transmission delay
4) Propogation delay

1) **Processing Delay:** d_{proc}

- Time required to examine packets header and determine where to direct the packet is called processing delay
- This may also include other factors like time required to check for bit level errors in packets
- Processing delays in high speed n/w is Typically of order microseconds or less

2) **Queuing Delay:** d_{queue}

- packets wait at the output link for transmission this is called queuing delay
- The length of the queuing delay depends on the packets that are already arrived in the buffer and waiting for transmission, if there are no packets then queuing delay is zero, if the congestion is heavy then the queuing delay increases
- can be of the order microseconds to miliseconds

3) **Transmission Delay:** d_{trans}

transmission is not carried out until all the packets reach the router or buffer. The amount of time required to push all the packets on the link is called transmission delay.

L - Length of the packet (bits)
R - Transmission Rate (bits/sec)

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

Propagation delay: d_{prop}

Its the time required for a packet to propagate from the beginning of the link to its destination

- bits propagates with the speed of the link
- The propagation speed depends on the medium of the link and is in the range of 2×10^8 m/sec to 3×10^8 m/sec equal to speed of light
- shorter distance less delay
  longer distance more delay

d - length of the physical link
s - propagation speed

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

End-End delay

Nodal delay:

$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

End - End delay

$$d_{end-end} = N\left(d_{proc} + d_{trans} + d_{prop}\right)$$

N – no. of routers

Trace route

→ Simple program that can be run on Internet host

- When the destination is mentioned the program in the source send multiple special packets towards the destination.
- These packets on their path pass through many routers, these routers inturn send a small message that contains the information of the router
- If there are N-1 routers the N such packets are sent.
- When the destination recieves the packet it also sends the ~~packet~~ message
- The source records the time elapse of each packet sent and the corresponding message recieved from the router and also stores the router information. In this manner the source can reconstruct the route ~~to~~ take by the packet from source to destination and can determine round trip delays

Throughput:

~~Rate (bits/sec)~~

- Rate (bits / time unit) at which the bits are transferred between sender / reciever

Instantaneous through put is the rate at any point in time at which the host recieves the file

Average through put: rate over long period of time

R_s – rate of the link between server & router
R_c – " " " " " router & client

Minimum of the rate R_s and R_c is the end to end transmission rate.

Protocol layers and their service model
(top-down approach)

Internet protocol stack

Application
transport
Network
link
physical

ISO/OSI Reference Model

Application
Presentation
Session
Transport
Network
link
Physical

Application layer:

→ layer where network applications and their protocols reside
- The protocols include HTTP, SMTP, FTP.
- DNS (Domain name system) – a type of n/w function that translates 32 bit n/w addrss to user friendly names
- ~~It's~~ Application layer protocol is distributed over multiple end systems, with the application in one end system using the protocol to exchange packets of information with the application in another end system
- Packet of information @ this layer is reffered as message

Transport layer:

→ This layer transports the message from the application layer to its application endpoints
→ There are 2 transport protocol TCP & UDP
- TCP: - connection oriented service
  - guranteed delivery of application layer messages
  - Flow control (speed matching @ send and recieves)
  - Breaks large message to smaller segment and provides congestion control mechanism
- UDP:
  - connectionless service for its application
  - No frills service that provides no reliability
  - No flow control
  - No congestion control
- Transport layer packets are reffered as segment

Network layer:

- Network layer packets are reffered as datagram
- This layer responsible for moving datagrams from one host to another
- The transport layer protocol in sources passes transport layer address and destination address to N/w layer
- The n/w layer then service the deliver of the segment to transport layer of destination host
- This layer includes IP → defines feilds of the datagram
- Also contain Routing datagram is the route the datagram takes bet^n the source & destination
- Many other protocols can run in the network layer but IP is highly reffered or used

Link layer:

- datagram routes through series of routers between source & destination
- To carry out routing efficiently between the nodes the n/w layer relies on link layer
- At each node the n/w layer passes the datagram to link layer which delivers datagram to the link layer of the destination note tb which is passed up to link layer.
- This serive provided by link layer depends on specific link layer protocols
- Example of link layer protocols include Ethernet, WiFi, cable access network's DOCSIS protocol
- link layer packets are reffered as frames

Physical layer:

- The job of the physical layer is to move the individual bits within the frame from one node to the next.
- The protocol in this layer are again link dependent and further depend on the actual transmission medium of the link. (ex: Twisted pair, copper wire, single mode fibre optics)