COMPUTER NETWORKS AND INTERNET

What is the Internet?

* Describe the nuts and bolts of internet i.e basic hardware and software components that make up the internet

* second we can describe the networks interms of networking infrastructures that provides services to distributed applications.

Nuts and bolts Description

→ hosts or end systems (TVs, phones, laptops, gaming consoles cell phones etc)

→ end systems are connected together by a network of Communication links and packet switches.

→ communication links are made up of different types of physical ~~devices~~ media like coaxial cable copper wire, fiber optics and radio system.

→ Different links transfer data at different rates

→ transmission rate of a link is measured in bits/secon

→ one end system sends data to the other end system

→ sending end systems segments ~~and~~ the data and adds header bytes to each segment

→ the resulting packages of information is known as packets in in the jargon of computer networks and send to the other end systems ...... they are reassembled to the original data

→ packet switches takes a packet arriving on one of its incoming communication links and forwards that packet on one of its outgoing communication links.

→ two important types of packet switches are routeres and link-layer switches

→ link-layers are used in access networks

→ routers are used in the network-core.

→ The sequence of communication links and packet switches traversed by a packet from the sending end system to the receiving end system is known as the route or path.

→ packet switched networks are similar to the transportation networks of highways, roads and intersections.

→ End system access the internet through Internet service providers (ISP).

→ End systems, packet switches and other pieces of the Internet run protocols that control the sending and receiving of information within the Internet.

→ The transmission control protocol (TCP) and the Internet protocol (IP) are the two most important protocol in the Internet.

→ Internet standards are developed by the Internet Engineering Task Force (IETF)

→ Internet is also defined as an infrastructure that provides services to applications

→ applications includes electronic mail, web surfing, instant messaging, Voice over IP etc and these apps are said to be distributed applications and they run on end systems.

→ how does one application piece running on one end system instruct the Internet to deliver data to another software piece running on another end system.

→ End systems attached to the Internet provide an application programming Interface (API)

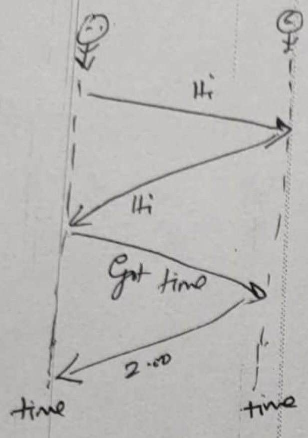
→ API specifies how a software piece running on one end systems asks the Internet Infrastructure to deliver data to a specific destination software piece running on another end system.

→ the internet API is a set of rules that the sending software piece must follow so that the Internet can deliver the data to the destination software piece.

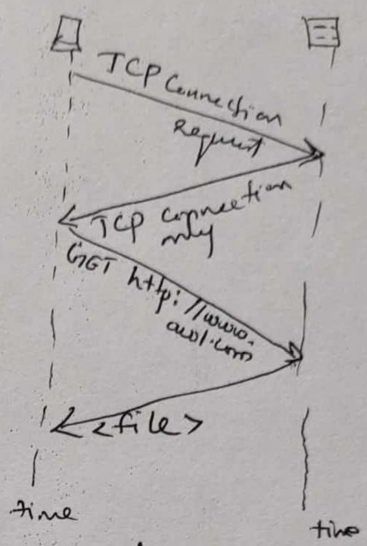
→ e.g Alice wants to send letter to Bob

→ The Internet is an infrastructure for providing services to distributed applications.

Protocol:



Human protocol



Computer network protocol

A protocol defines the format and the order of messages exchanged between two or more communicating entities as well as the actions taken on the transmission and/or receipt of a message or other event.

The Network Edge

→ End systems are also referred to as hosts because they hosts (ie run) application programs such as web browser, web server, an e-mail reader pgm or an e-mail server pgm

→ hosts are further divided two categories < clients, servers

client and server program

→ client pgm is a pgm running on one end system that requests and receives a service from a server pgm running on another end system.

→ The web, e-mail, file transfer, remote login etc adopt the client server model.

→ client application run on one computer and the server program runs on another computer client - server internet applications are defined as distributed applications.

Access Networks

→ The physical link that connect an end systems to the first router on a path from the end system to any other distant end systems.

* Dial up, DSL, cable, Fiber to the home (FTTH), Ethernet, WiFi, Wide - Area wireless Access, Wimax

→ fig

Dial up

→ the term dial up is used because the user's software actually dials an ISP's phone no and makes a traditional connection with the ISP.

→ fig Dial-up internet access

→ Two drawbacks of dial up connection

→ ① It is very slow providing a maximum rate of 56 kbps. It takes approximately 8 mts to download a single 3mts MP3 song and several days to download a 1 Gbyte movie

→ ② It ties up a ordinary phone line, so while one family member uses a dial-up modem to surf the web other family members cannot receive or make phone calls over the phone line.

DSC (Digital Subscriber Line)

→ two most prevalent types of broad band residential access are digital subscriber line (DSL) and cable

→ A residence obtains DSL Internet access from the same Company that provides it wired local phone access.

→ when DSL is used a customer telco is also its ISP.

→ Fig 1.6

→ telephone line carries simultaneously both data and telephone signals which are encoded at different frequencies
- high speed downstream channel 50 kHz to 1 MHz band
- Medium speed upstream channel in the 4 kHz to 50 kHz band
- Ordinary telephone channel in the 0 to 4 kHz band

→ this approach makes the single DSL link appear as if there were 3 separate link, so that a telephone call and the internet connection can share the DSL link at the same time

→ Two Advantages

① * It can transmit and receive data at much higher rates

* A DSL customer will have a transmission rate in the 1 to 2 Mbps range for downstream and upstream rates ~~for downstream~~ 128 kbps to 1 Mbps

* Because the upstream and down stream rates are different the access is said to be asymmetric

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② * Users can simultaneously talk on the phone and access the Internet.

* Here the user need not dial an ISP phone no to get Internet access, instead they have an "always-on" permanent connection to the ISP's DSLAM (Digital subscriber line access multiplexer).

Cable.

In a traditional cable television system, a cable head end broadcasts television channels through a distribution network of coaxial cable and amplifiers to residents.

→ DSL and dial up make use of telephone infrastructure where cable Internet access uses the cable television Company's existing cable infrastructure.

→ A residents obtains cable Internet access from the same company that it provides cable television

→ Since both fiber and coaxial cable are employed in this system it is referred to as hybrid fiber Coax (HFC).

→ Cable internet access needs special modems called cable modems.

→ Cable Internet access shares the broadcast medium.

→ Every packet sent by the head end travels downstream on every link to every home and every packet sent by a home travels on the upstream channel to the head end

→ So if several users are simultaneously downloading a video file on the downstream channel, the actual rate at which each user receives its video file will be significantly lower than the aggregate cable down stream rate

→ On the otherhand if there are only few active users and they are all websurfing, then each of users may actually receive webpages at full Cable downstream rate, because the users will rarely request a web page exactly at the same time

→ Since both downstream and upstream are shared a distributed multiple access protocol is needed to coordinate transmissions and avoid collisions.

The network core.

Circuit switching and Packet switching

→ two fundamental approaches to move data through a network of links and switches are
* Circuit Switching
* packet switching

→ in circuit switching the resources needed to transfer the data along the path are reserved for the duration of the communication session between the end systems

→ in packet switched network the sources are not reserved and the session messages use the resources on demand and as a consequence they may have to wait for access to a communication link.

(e.g going to a hotel by not reserving before and waiting there if not reserved

→ telephone networks are e.g of circuit switched networks.

→ when one person want to send information to another over a telephone network, the sender has to establish a connection between the sender and the receiver.

→ this is a bonafide connection for the switches on the path between the sender and the receiver

→ in the jargon of telephon this is called as a circuit.

→ When the network establishes a circuit, it also reserves a constant transmission rate in the network links for the duration of the connection.

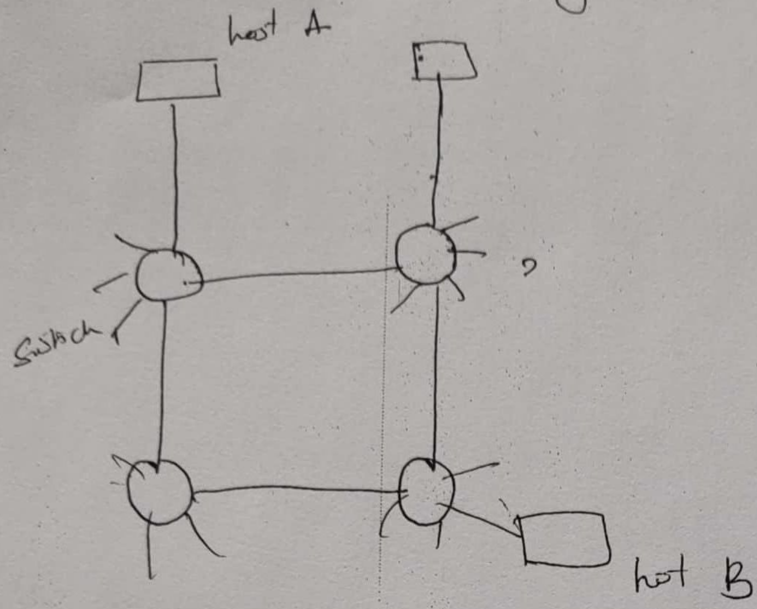
→ Since the bandwidth has been reserved for this sender to receiver connection the sender can transfer the data to the receiver at the guaranted constant rate.

→ Todays internet is a packet-switched network.

→ The packets are trannsmitted over a series of communication links, but here the packets are send without reserving any bandwidth.

→ if one of the link is congested, because the other packets need to be transmitted over the link at the same time than our packet has to wait in a buffer at the sending side of the transmission link and suffer a delay.

Circuit switching.



→ Four circuit switches are connected by 4 links

→ Each link has n circuits

→ so each link can support 'n' simultaneous connections

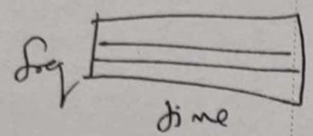
→ The end systems are connected to the switch.

→ when two hosts want to communicate, the network establish a dedicated end-to-end connection between the two hosts.

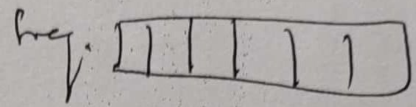
→ Since each link has n circuits, each link used by the end-to-end connection gets a fraction of 1/n of the links bandwidth for the duration of the connections

→ Circuit link is implemented by either TDM or FDM.

FDM (Frequency Division Multiplexing)



TDM



(e.g) A link transmits 8,000 frames per/sec and each slot consists of 8 bits

What is the transmission rate of the circuit?

i.e $8000 \times 8 = 64$ kbps

→ in circuit switching idle period or silent periods are more.

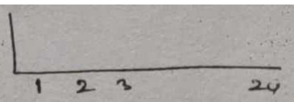
problem:

How long does it take to ~~find~~ send a file of 640,000 bits from host A to host B over a circuit switched network?

Assume: It uses TDM with 24 slots/sec

The link speed is 1.536Mbps

And 500 msec to establish a connection



transmission rate = 1.53 Mbps

S = 640,000 bits

The transmission rate of each user's data = 1.536 Mbps / 24 = .064 Mbps

= 64 kbps

time taken is = 640,000 / 64 000

= 10 secs.

Add the establishment time

∴ 10.5 sec

packet switching

→ In modern Computer the source breaks long messages into smaller chunks of data through Communication links and packet switches.

→ packets are transmitted over each communication link at a rate equal to the full transmission rate of the link.

→ Most packet switches uses store-and-forward transmission at the inputs to the link.

→ Store and forward transmission means that switch must receive the entire packet before it can begin to transmit the first bit of packet onto the outbound link.

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→ Consider how long it takes to send a packet of 'L' bits from one host to another host across a packet switched network.

→ Suppose there are Q links between the two hosts each of rate 'R' bps

→ Assume this is the only packet in the network

→ The packet must be transmitted onto the first link by host A

this takes L/R seconds.

→ It will be transmitted on each of the Q-1 remaining links, that is it must be stored and ~~forwarded~~ Q-1 ~~links~~ times each time with a ~~forward~~ store and forward delay of L/R. So the total delay is QL/R.

→ Each pckt has a multiple links attached to it.

→ for each attached link the packet switch has an output buffer (output queue), which stores pckt that the router is about to send into that link.

→ output buffers play a key role in pckt switching.

→ If the output link is busy with transmission of other pckts the arriving pct must wait in the output buffer.

→ thus in addition to store and forward delays packets buffer output buffer queuing delays.

→ the buffer is finite size so either the arriving pckt or pkt in the que may get lost so pckt loss also happens.

pckt switching V circuit switching.

→ pckt switching is not suitable for real time services
e.g telephone calls and video conference calls

→ pckt switching offers better sharing of bandwidth than circuit switching

→ pckt switching is simpler more efficient and less costly to implement than circuit switch

Why pkt sty is more efficient

① Suppose A user share a 1 Mbps link.

→ The user generats data at a rate of 100 kbps

→ The users are active only 10% of the time.

→ But in circuit switching 100 kbps must be reserved for each user at all time.

∴ the circuit switching can support only

$\frac{L}{R}$ at a time ie $\frac{1Mbps}{100kbps} = 10$ users

$\left[1Mbps = 1000 kps = \frac{1000kps}{100kps} = 10 \right]$

With pkt switching

→ the probability that a specific user is active is .1%.

→ If there are 35 user

probability of active usr = .1

nonactive usr = .9

ie $35C_{10} (.1)^{10} (.9)^{25}$

if more user.

$35C_{10}(.1)^{10}(.9)^{25} + 35C_{11}(.1)^{11}(.9)^{24}$

$+ \ldots 35C_{11}(.1)^{35}$

$\simeq .0004$

[another method

$\frac{35}{10^6} \times 11 = .000385$

$\simeq .0004$]

Circuit switch

(2) 10 user, 1000 bits pkts by one user and if TDM is 10 slots per frame it will take 10 seconds to send the data

But in pkt switching all the data can be send by 1 send.

Circuit Switching.

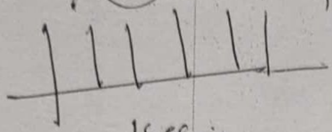
1 person 24

file size = 64×10^4 bytes

= .64 Mb

Speed Rate = 1.536 Mbps

24



1sec

24 users sharing time slot

R for one person = $\frac{1.536}{24}$

$\frac{\text{Data}}{\text{Rate}}$ is time taken.

ie $T = \frac{.64\text{Mb}}{1.536\text{Mb}} \times 24$ = 10 sec + .5 sec

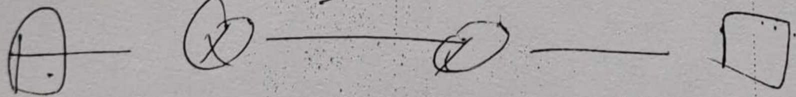
= 10.5 second.

packet switching.

L — size of data

R — Bandwidth

→ L/R   L/R → L/R.



L = 7.5

R = 1.5

$= \frac{3L}{R} =$

3L

$\frac{L}{R} + \frac{L}{R} + \frac{L}{R} = 15$ sec

$\frac{7.5}{1.5} = 5 + 5 + 5 = 15$

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35 users.

prob active = .1   .9

ie $^{35}C_{10} (.1)^{10} (.9)^{25}$

class A 1 – 126

B 128 – 191

C 192 – 223

$T_t = \frac{L}{B}$ — size / rate — transmission delay

Data as K means $K = 1024$

$M - 1024 \times 1024$

$G = 1024 \times 1024 \times 1024$

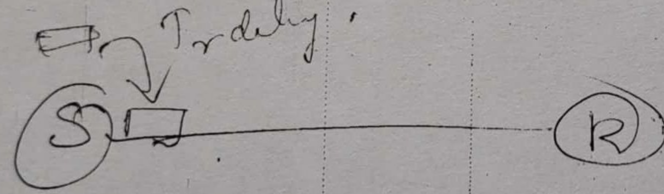
BW

$K = 1000$

$M = 10^6$

$G = 10^9$

data in powers of 2 and Bandwidth as 1000



propagation delay $T_p = \frac{d}{V}$ d is the distance

V is velocity.

$V = 3 \times 10^8 \times .7$

$= 2.1 \times 10^8$ m/s in optical fibre.

$d = 2.1$ km

$V = 2.1 \times 10^8$ m/s

$T_p = \frac{2.1 \times 10^3}{2.1 \times 10^8} = 10^{-5}$ sec

5. Consider the car - caravan analogy discussed in class for transmission and transmission delays and assume the following scenario

a) Suppose there are 3 toll booths each separated by a distance of 150km (d)

b) The caravan is composed of 10 cars (L)

c) The toll process takes 12 s for each car and the cars travel at 100 km/hour (s)

Find out the end to end delay.

$d_{trans} = 12\ s/car \times 10\ car = 120s = 2$ mts

$d_{prop} = d/s = 150\ km / 100\ km/h = 3/2 \times 60$ mts $p/h = 90$ mts

$\therefore$ total time = for one toll = 92 mts for the

second part $92 \times 2 = 184$ mts

4) Consider the Scenario where an ISP Connects a 100 Mbps institutional LAN to the internet and its transmission speed is 12Mbps. On an average, the ISP link receives 2000 pkts per second and the averge pkt size is 4 kbits.

a) Obtain the traffic Intensity ratio

$$TI = La/R$$

L = 2000 pkts per second

a = 4 k bits per second

R = 12 Mbps

$$\therefore TI = \frac{\cancel{2000} \times \cancel{4}^{1} \times \cancel{10^3}}{\cancel{12}_{3} \times \cancel{10^6}_{10^3}} = 2/3$$

b) What number of pkts can make averge queues extremely large?

$TI = 1$ is extremly large.

$$\therefore 1 = \frac{x \times \cancel{4}^{1} \times \cancel{10^3}}{\cancel{12}_{3} \times \cancel{10^6}_{10^3}}$$

$$x = 3000$$

(2) How long does it take a packet of length 1000 bytes to propagate over a link of distance 2500 km. propagation speed is 2.5×10^8 m/s and transmission rate 2 Mbps ?

$$d_{prop} = d/s$$

$$= \frac{2.5 \times 10^6 \, m}{2.5 \times 10^8 \, m} = \frac{1}{10^2} = 10 \, ms = \left[.01 \, sec \right]$$

(3) Suppose there is a 10 Mbps Microwave link between a geostationary satellite and its base on Earth.
Every minute the satellite takes a digital photo and sends it to the base station. Assume propagation speed of 2.4×10^8 meters / sec.

$$d_{prop} = d/s$$

Geostationary satellites are placed 36000 km above earth's surface

i.e. 36×10^6 meter.

$$\therefore d_{prop} = \frac{36 \times 10^6}{2.4 \times 10^8} = \cancel{0.15 \text{ seconds}} \; 150 \, msec = .15 \, sec$$

1 Suppose Host A wants to send large file to Host B. The path from Host A to Host B has 3 links of rate $R_1 = 500$ kbps

$R_2 = 2$ mbps

$R_3 = 1$ mbps

- assuming no other traffic in the N/w

① obtain throughput for the file transfer

sdn Throughput is min of all the given things

ie 500 kbps.

② Suppose the file is 4 million bytes. Roughly how long it take to transfer the file to Host B.

sdn Size $L = 4 \times 10^6 \times 8$

$R = 500$ kbs

$$\therefore t = \frac{4 \times 10^6 \times 8}{.5 \times 10^6}$$

$= 64$ second

Note:
Band width
$k = 1000$
$M = 10^6$
$G = 10^9$

3) Repeat ① & ② with R2 Reduced to 100 kbps

throughput = 100 kbps

$$t = \frac{4 \times 10^6 \times 8}{.1 \times 10^6} = 320 \text{ second}$$

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Comparing Transmission and Propagation Delay

1 car 12 seconds

so 10 cars 120 seconds = 2 mts.

car travelling time (propagation) on the highway at a rate of 100 km/hour.

suppose 10 cars are travelling together as a caravan

The time required for the tollbooth to push the entire caravan on to the highway (transmission)

10 car is 2 mts

propagation delay is 100 km / 100 km/hour = 1 hour

∴ the time taken is 60 mts + 2 mts = 62 mts.

Queing delay and packet Loss

→ Most complicated and interesting component of nodal delay is the queing delay d_{queue}

→ Unlike the other delays queing delay can vary from packets to packets.

→ e.g. if 10 pkts arrive at an empty queue at the same time, the first pkt ~~transmit~~ will suffer no queing delay, while the ~~last~~ last packet will suffer a relatively large queing delay.

So in characterizing queuing delay we use statistical measures such as average queuing delay, variance of queuing delay and the probability that the queuing delay exceeds some specified value.

→ when is queuing delay large and when is it insignificant?

This depends on the rate at which traffic arrives at the queue, the transmission rate of the link, and the nature of the arriving traffic (i.e. periodically or in bursts)

→ Let a denote the average rate at which pkts arrive at the queue [a is in units of pkts/sec]

→ R is the transmission rate

→ Assume all pkts consists of L bits.

→ the average rate at which bits arrive at the queue is La bits/sec.

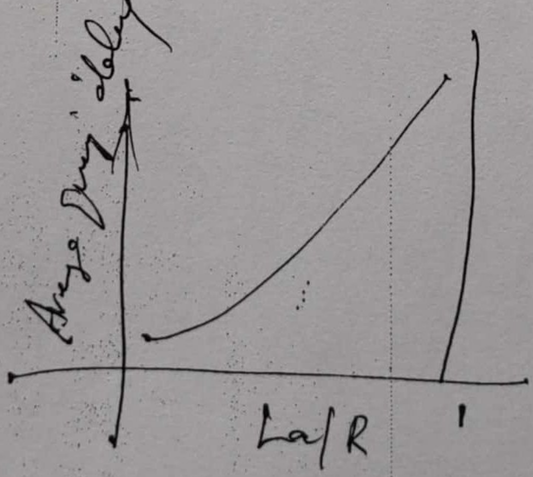
→ The ratio La/R is called traffic intensity

→ traffic intensity plays an important role in queing delay.

→ If La/R > 1, the average rate at which bits arrive at the queue exceeds the rate at which the bits can be transmitted from the queue. So the queue will tend to increase.

→ So the golden rule in traffic engineering is Design your system so that the traffic intensity is no greater than 1.

→ If La/R < 1 No queing delay



→ Long distance telephone network are done by fiber optics. However the high cost of optical devices such as transmitters, receivers and switches has hindered their deployment for short haul transport. e.g LAN is into the home in a residential access network.

Terrestrial Radio channels.

→ Radio channels carry signals in the electromagnetic spectrum.

→ They are an attractive medium because they require no physical wire to be installed.

→ It can penetrate walls, provide connectivity to a mobile user and potentially carry a signal for long distance.

→ Terrestrial radio channels can be classified into two groups

→ that operate in local areas, typically sapanning from ten to a few hundred meters

→ that operate in the wide area, spanning tens of kilometers.

satellite Radio channels

→ A communication satellite links two or more earth based microwave transmitter/receiver known as ground stations.

→ The satellite receive transmission on one frequency band, regenerates using the signal using a repeater and transmitts the signal on another frequency.

→ Two types of satellites used in communication are
- geostationary satellites
- low earth orbiting satelities.

→ geostationary satellities permanently remain above the same spot on earth.

→ It is achieved by placing the satellite in orbit at 36,000 kilometers above the earths space.

→ A delay of 280 milliseconds from ground station through satellite back to ground station.

LEO satellites are placed much closer to earth and do not remain permanently above one spot on earth.

→ They rotate around earth and may communicate with each other as well as with ground stations.

Physical Media

→ E.g of physical media includes twisted-copper wire coaxial cable, twisted pair-copper wire or coaxial cab

→ physical media falls into two categories

→ guided media (e.g fiber optic cable, twisted copper wire, or coaxial cable)

→ unguided media (e.g wireless lan or digital satellite

Twisted copper wire

→ The least expensive and most commonly used guided transmission medium is twisted-pair copper wire.

→ It is used by the telephone network

→ It consists of two insulated copper wires each about 1mm thick, arrayed in a regular spiral pattern.

→ The wires are twisted together to reduce the electrical interference.

→ Unshield twisted pair (UTP) is commonly used for Computer networks within a building

→ Data rates for LANs using twisted pair ranges from ~~10 Mb~~ 10 Mbps to 1 Gbps.

→ Category 5 UTP can achieve data rates of 1Gbps

→ Twisted pair is commonly used for residential Internet access.

Coaxial Cable.

→ Coaxial cable Consists of two Copper Conductors, but the two conductors are Concentric rather than parallel.

→ They have high bit rates. it is quite Common in Cable televisions systems.

→ Cable television systems are coupled with cable modems to provide residential users with internet access at rates of 1 Mbps or higher.

→ Coaxial cable can be used as a guided shared medium.

→ A no of end systems can be connected directly to the cable with each of the end systems receiving whatever is sent by the other end systems

Fiber optics

→ It is a thin, flexible medium that conducts pulses of light, with each pulse representing a bit.

→ A single optical fiber can support tremendous bit rates, up to tens or even hundreds of gigabits per second.

→ They are immune to electromagnetic interference, have very low signal attenuation up to 100 kilometers and are very hard to tap.

→ These characteristics made it for long haul guided transmission media, particularly for overseas links.

Protocol Layers and Their Service model.

Internet

- numerous applications & protocols
- various types of end systems
- packet switches
- various types of link-level media

Layered Architecture:-

Human analogy :- air line systems
not only analog but some structure
layers, implements functionality, service
Layered architecture allows us to discuss a well defined specific part of a large and complex system.

① Each Layer performs certain actions within that layer
② It uses the services of the layer directly below it.
→ provides modularity.

Advantage of layering

→ a structured way to discuss system Components
→ Modularity makes it easier to update system components.

Disadvantage

→ one layer may duplicate lower-layer-function (e.g error recovery)
→ functionality at one layer may need information only in another layer (time stamp).

Two Architecture

Internet protocol stack

1. Application
2. Transport
3. Network
4. Link
5. Physical

OSI reference model.

1. Application
2. Presentation
3. Session
4. Transport
5. Network
6. Link
7. Physical

1. Application Layer:

Pkt of information is called message.

(e.g.) HTTP, FTP, SMTP

Application layer protocol is distributed over multiple end systems

2. Transport:

TCP, UDP → Connectionless

→ Connection oriented

→ Congestion-control mechanisms

→ no reliability, no flow control, no congestion control

pkt is called as segment

3. Network layer:

pkt as datagram.

IP portal; includes routing protocols.

4. Link layer:

pkts as frames; link layer moves entire frame one network element to an adjacent network element.

(e.g.) Ethernet, wifi, PPP

5. physical layer:

The job of physical layer is to move the individual bits within the frame from one node to the next.

protocols depends on the physical media used.

Session layer:

provides delimiting and synchronizing of data exchange including the means to build a checkpointing and recovery scheme

Presentation layer:

provide services that allow communicating applications to interpret the meaning of the data exchanged.

It includes data compression and data encryption.