Computer Networks

Module-I

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Objectives

1. Internet
2. Network Edge
   - Access Networks
   - Physical Media
3. Network Core
   - Packet Switching
   - Circuit Switching
   - Hierarchy Internet Service Providers
4. Parameters of Networks
   - Delay
   - Throughput
   - Loss
5. Protocol Layers
6. Security

Internet: Network of Networks

:

- **A nuts-and-Bolt Description** : Network of End Devices/Hosts, communication links and packet switches
  1. End Devices: Computing devices, Household appliances, Security Devices, Automobiles, Sensing devices
  2. Communication Links: Optical Fiber, Coaxial Cable, Copper wire, Radio Spectrum
  3. Packet Switches: Link layer switches and Routers
  4. Protocol: A set of rules that control sending and receiving information.
- **A Service Description** : Internet provides services to applications.
  1. Services: Reliability, Timeliness
  2. Applications: Web surfing, e-mail, Online Games, Video Streaming, etc.

Internet

Figure: Components of Internet

Protocol

Protocol defines the **format** and the **order** of messages exchanged between two or more communicating devices and the **actions** taken on the transmission and reception of messages.

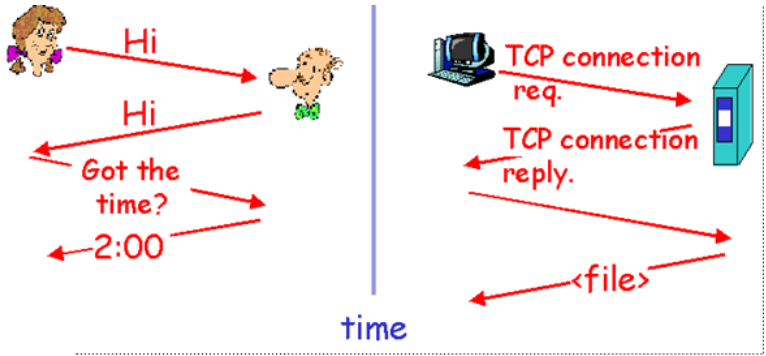


Figure: Human Protocol and a Computer Network Protocol

Network Edge

- End Devices/Hosts sit on the Network edge.
- Hosts are further categorised as Client and Server.
- These devices are connected to the the first router of the path via access Networks and physical media.

Access Network:

- Home Access
  - Digital Subscriber Line (DSL)
  - Cable
  - Fiber To The Home (FTTH)
- Access in Enterprise (Home)
  - Ethernet
  - Wifi
- Wide area access
  - 4G and LTE

Network Edge

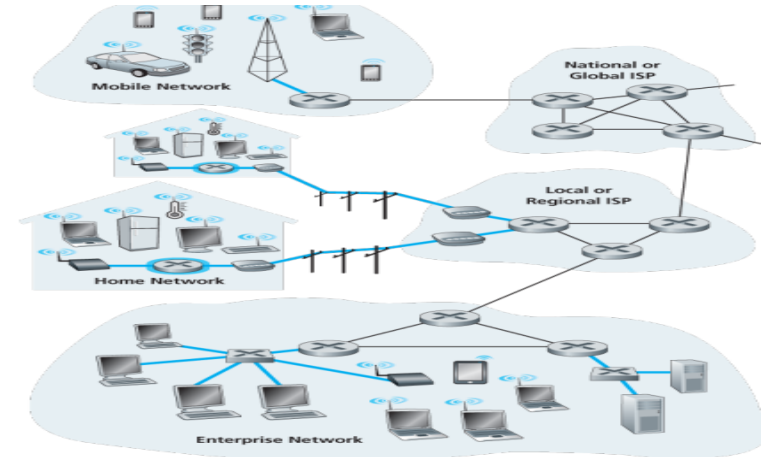
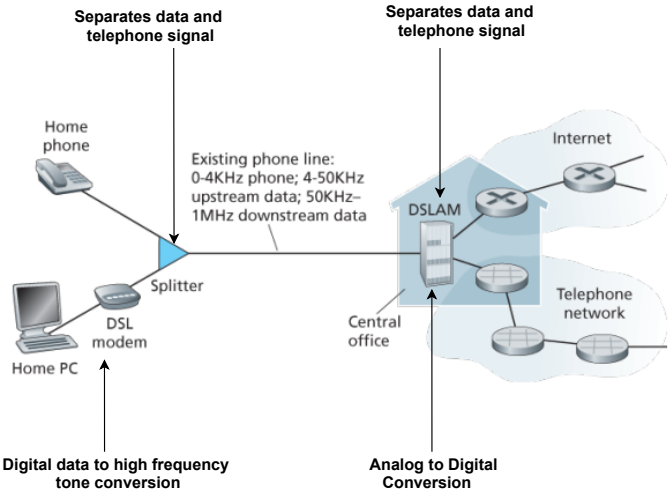


Figure: Access Networks

DSL


Separates data and telephone signal
Separates data and telephone signal
Home phone
Existing phone line: 0-4KHz phone; 4-50KHz upstream data; 50KHz–1MHz downstream data
Internet
DSLAM
Splitter
DSL modem
Home PC
Central office
Telephone network
Digital data to high frequency tone conversion
Analog to Digital Conversion

DSL

- DSL uses telephone line to connect to the Edge Router. Hence, Internet Service Provider (ISP) for DSL is Telco(Telephone Company).
- At Home: DSL Modem and Splitter
- At Central Office (CO): DSL Access Multiplexer (DSLAM)
- The telephone line (**twisted pair copper wire**) carries both data and telephone signals simultaneously, encoded at different frequencies:
  1. Downstream channel: 50 kHz 1 MHz
  2. Upstream channel: 4 kHz to 50 kHz
  3. Two way telephone channel: 0 to 4 kHz

Cable Internet Access or Hybrid Fiber Coax

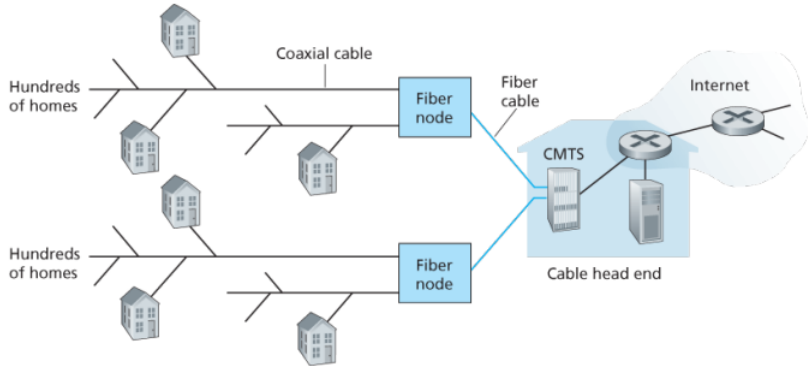


Figure: Hybrid Fiber Coax

HFC

- Cable Internet Access uses cable television infrastructure to connect to Edge Router. Hence, ISP for cable Internet access is the cable television company.
- At Home: cable modem is connected to PC through ethernet port.
- At Cable Head end: Cable Modem Termination System (CMTS) converts analog to digital signal
- Cable internet access is a broadcast medium: Every packet sent from head end travels through each link to each home and every packet sent from a home travels on the upstream channel.

Fiber To The Home (FTTH)

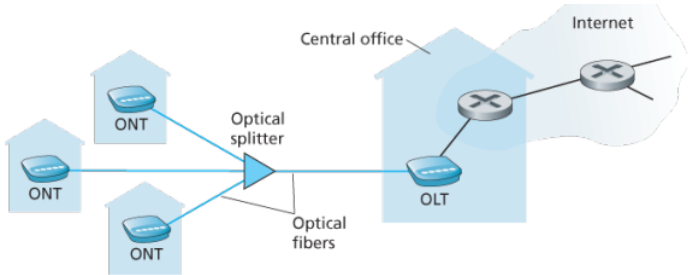


Figure: Passive Optical Network (PON) implementing Fiber To The Home

FTTH

- Provide an optical fiber path from CO to home.
- Direct Fiber implements this idea where one fiber leaves CO for each home.
- Generally, each fiber cable is shared by many homes.
- Home: Optical Network Terminator (ONT) and splitter
- CO: Optical Line Terminator (OLT)

LAN and WAN

LAN: Local Area Network (short range)

- Wireless LAN: wifi based on IEEE802.11
- Wired LAN: Ethernet

WAN: Wide Area Network: 4G, LTE : Long range

Physical Media

- A bit is sent by Electro-Magnetic waves or optical pulses across various physical media from sender to receiver
- Physical media is of two types:
  1. Guided: wave guided along solid medium
  2. unguided: wave propagated in free space
- Usually, the deployment cost is more than material cost.

Twisted pair copper wire

- Most commonly used and least expensive. Used in telephone communication
- It consists of two insulated copper wires (each about 1 mm thick) arranged in a regular spiral pattern. The wires are twisted together to reduce the electrical interference from similar pairs close by.
- Unshielded Twisted Pair (UTP) is used for LANs and supports speed from 10 Mbps to 10 Gbps. Speed depends on the distance between sender and receiver, and thickness of the wire.

Figure: Twisted pair copper wire

Coaxial Cable

- Used in television signal transmission
- Two copper conductors arranged in parallel with each other.
- It is used as a guided shared medium as cable television and cable internet digital signal is shifted to another frequency band and the resulting analog signal is transmitted over coaxial cable.

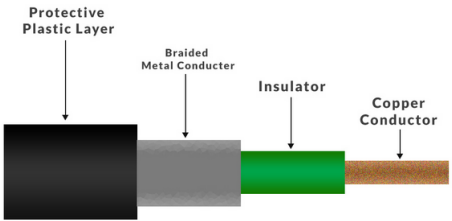


Figure: Coaxial cable

Fiber Optics

- Unlike twisted pair and coaxial cable, optical fiber conducts pulses of light where each pulse is a bit.
- It supports rate upto 100 Gbps.
- It is immune to EM interference and can transmit signals upto 100 kms.
- cost is high.

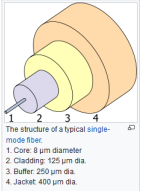


Figure: optical fiber

Terrestrial Radio Channel

- Radio channels carry signal in EM spectrum.
- Do not need any wired infrastructure
- Path loss, fading, interference occurs.
- Very short distance communication: wireless headsets and keyboards
- Local area: wireless LAN
- Wide area: cellular communication

Satellite Radio Channel

Signal is transmitted to satellite at one frequency band, where signal is regenerated by repeater and transmitted back to the receiver at a different frequency band.

- Geostationary Satellites
- Low Earth Orbiting (LEO) Satellites

Network Core: Packet Switching and Circuit Switching

Network core is a mesh of packet switches (routers and link layer switches) and links.

1. **Packet Switching**

- End system exchange information with each other in the form of messages.
- A message can be the control messages like request for a connection or Acknowledgement, and the actual information.
- Information may be text documents, video, image, etc.
- A long message is broken into chunks of bits known as packets to be transmitted over the link from source to destination.
- Every link has a fixed *transmission rate*. If transmission rate is R Mbps it depicts that from that link in a second only R Mb can travel.
- A packet of L bits will take L/R *microseconds* to get transmitted over a link of R Mbps.

Packet Switching: Store and Forward

A packet switch must receive entire packet before transmitting it.

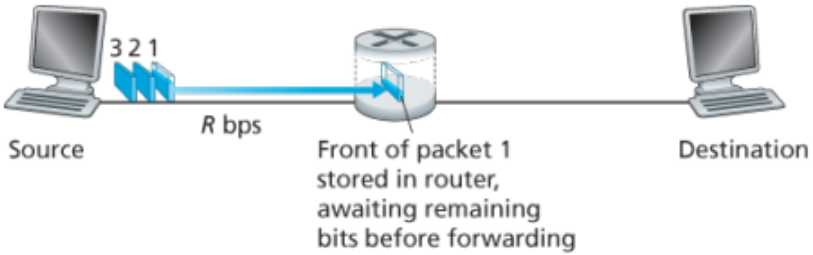


Figure: Store and forward transmission

Packet Switching: Transmission Delay

Transmission delay of **P** packets of **L** bits over **N** links of **R** bps.

Packet Switching: Queuing Delay and Packet Loss

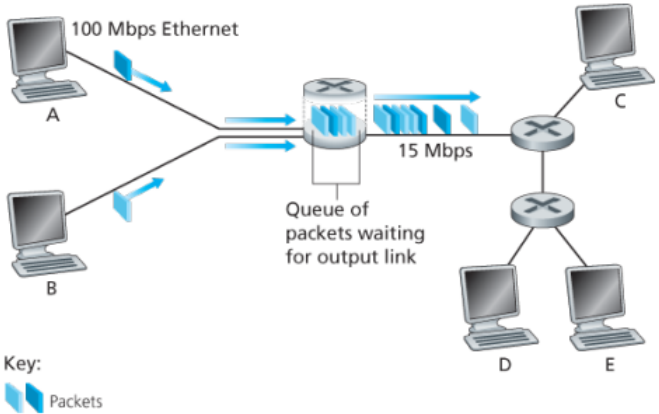


Figure: Output Buffer, queuing delay, congestion, and packet drop

Packet Switching: Forwarding tables and Routing protocols

- At each router depending on the forwarding table, packet is forwarded to the correct link of the path.
- Forwarding table consists of destination network address, subnet mask, and link of the router.
- AND operation between the destination address stored in the packet and subnet mask gives the destination network address.
- The forwarding table is maintained by Routing protocols on routers.

Circuit Switching

- Reservation based
- The resources (**buffer, link transmission rate**) along the path are reserved.
- Telephone network utilizes circuit switching for signal transmission.
- Sender, receiver and resources establishes a connection and maintains it throughout the transmission.
- This connection is called **Circuit**.
- Each link (shown in the figure in the next slide) consists of four circuits.
- If transmission rate of link is 4 Mbps, then transmission rate of each circuit will be 1 Mbps.

Circuit Switching

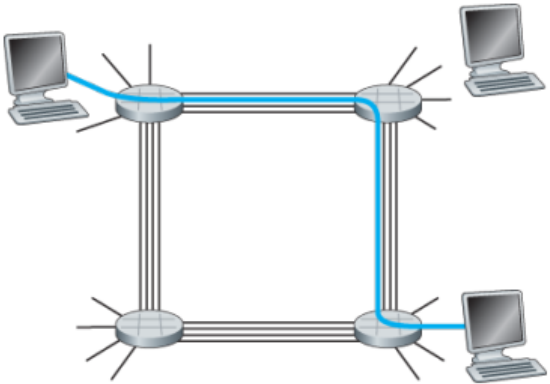


Figure: Circuit Switching: Each link consists of four circuits, so each circuit will have $1/4^{th}$ of the transmission rate of the link

Circuit Switching:Multiplexing

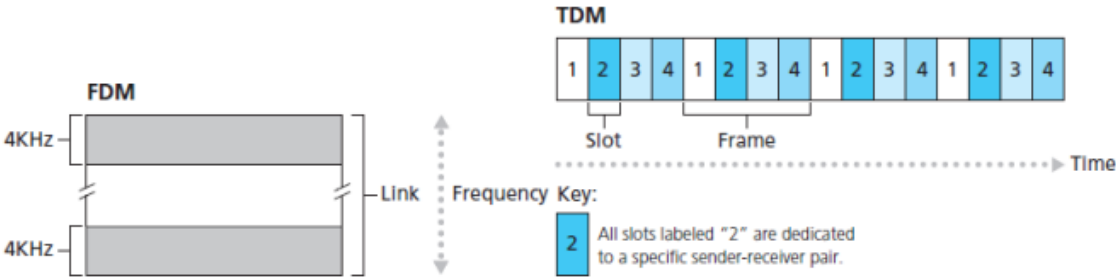


Figure: Frequency Division Multiplexing and Time Division Multiplexing

FDM and TDM

FDM:

- Each link is divided into band of frequency. That frequency band is dedicated to particular circuit all the time.
- Channel: Carrier frequency
- Bandwidth: A band (range) of frequency allocated to a particular channel
- Frequency Spectrum: Range of frequency allocated for an application

TDM:

- The time domain is segmented into frames, with four time slots in each frame; each circuit is assigned the same dedicated slot in the revolving TDM frames.
- transmission rate= frame rate * bits per slot
- Entire frequency band is utilized by the circuit for that slot of time.

Circuit switching vs packet switching

Internet Service Provider (ISP)

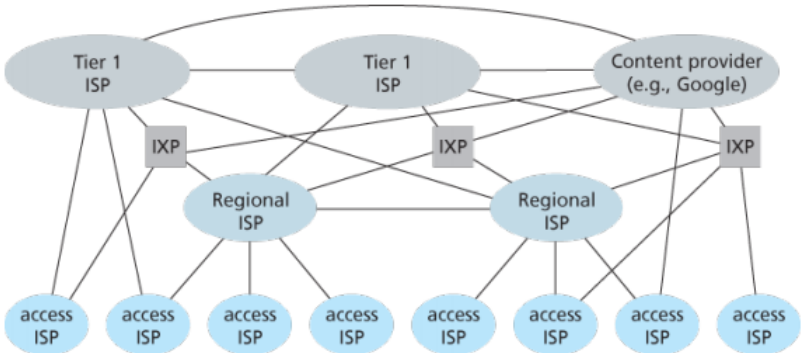


Figure: Interconnection of ISPs

ISP

- Point of Presence (POP): a group of one or more routers (at the same location) in the provider's network where customer ISPs can connect into the provider ISP.
- Peer: Two ISPs connect to each other settlement free.
- Internet Exchange Point (IXP): A meeting point where multiple ISPs can peer together.
- Content Providers: maintains private TCP/IP network and bypasses tier-1 ISPs by connecting to lower tier ISPs directly or through IXP.

Delay

Types of delay:

- **Processing delay:** The time required to examine the packet's header and determine where to direct the packet. It also includes the error checking. (up to *microseconds*)
- **Queuing delay:** The time a packet waits to be transmitted onto the link. It depends on the number of packets in the queue that in turn depends on arrival rate of packets and service rate of the router. (*microseconds* to *milliseconds*)
- **Transmission delay:** The amount of time required to **push/transmit** all of the packet's bits into the link. It depends on the length of packet and transmission rate of the link. (*microseconds* to *milliseconds*)
- **Propagation delay:** Time required to reach the router/destination from the start of the link. It depends on the distance between source and destination. (*milliseconds* in WAN)

Delay

$$Total_Delay = D_{proc} + D_q + D_t + D_{prop} \quad (1)$$

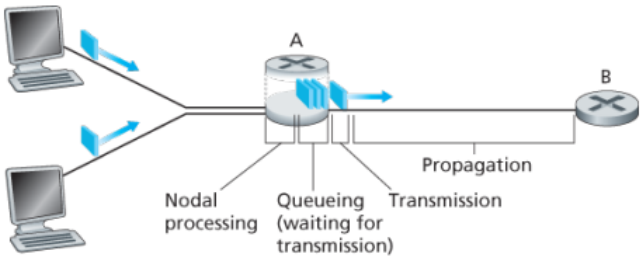


Figure: Various types of delay

Queuing Delay and Packet Loss

Queuing delay depends on the traffic intensity.
Packet Loss condition:

$$L * a/R > 1 \tag{2}$$

L is number of bits in the packet
a is the average rate of packet arrival in queue
R is the transmission rate

Throughput

- The **instantaneous throughput** at any instant of time is the rate (in bits/sec) at which a Host receives the file
- If a file of **F** bits takes **T** *seconds* to be transferred to the host, the **average throughput** of the host is **F/T** *bps*

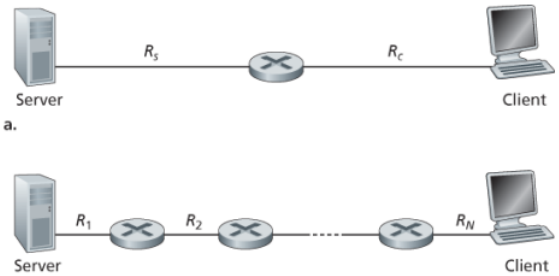
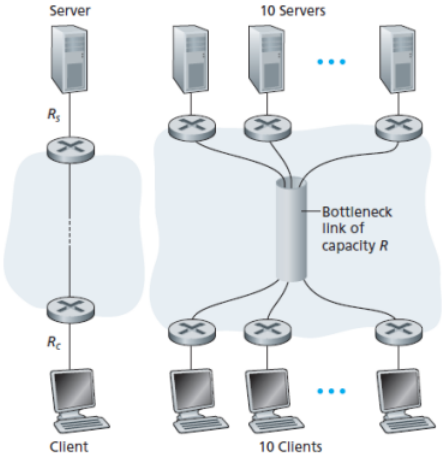


Figure: Throughput

Throughput


Server
10 Servers
R_s
Bottleneck
link of
capacity R
R_c
Client
10 Clients

OSI Layer

Open System Interconnection consists of seven layers:

- Application Layer:
- Presentation Layer:
- Session Layer:
- Transport Layer:
- Network Layer:
- Data Link Layer:
- Physical Layer:

Internet Layer

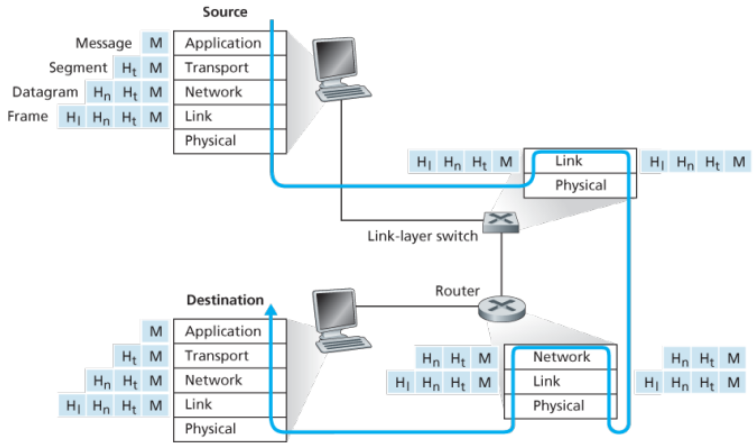


Figure: OSI Layer

Security

- **Malware** is enters the end device with other downloaded material (text, audio, video), and delete the files and send private information to attackers.
- **Botnet** is a network of infected devices controlled by the attackers.
- Most of the Malware are of
- Self Replicating nature.
- **Viruses** are malware that require some form of user interaction to infect the user's device.
- **Worms** are malware that can enter a device without any explicit user interaction.

Attack on Servers and Network Infrastructure: denial-of-service (DoS)

- **Vulnerability attack**: This involves sending a few well-crafted messages to a vulnerable application or operating system running on a targeted host. If the right sequence of packets is sent to a vulnerable application or operating system, the service can stop or, worse, the host can crash.
- **Bandwidth flooding**: The attacker sends a deluge of packets to the targeted host—so many packets that the target's access link becomes clogged, preventing legitimate packets from reaching the server.
- **Connection flooding**: The attacker establishes a large number of half-open or fully open TCP connections (TCP connections are discussed in Chapter 3) at the target host. The host can become so bogged down with these bogus connections that it stops accepting legitimate connections.

Distributed Denial of Service (DDoS)

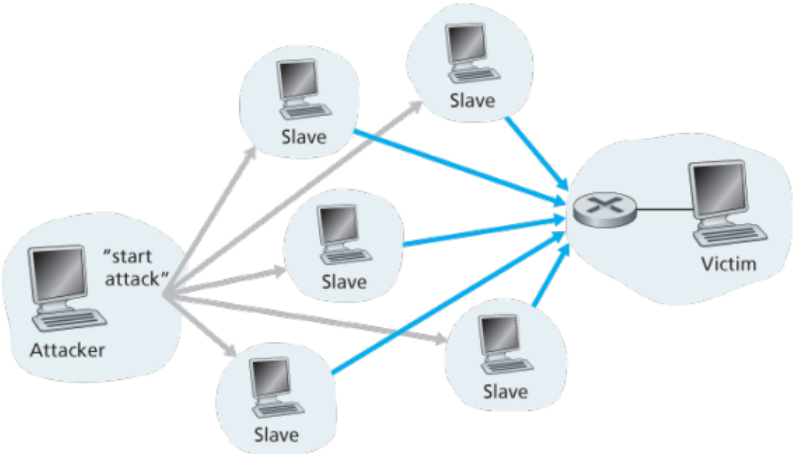


Figure: DDos

Other Attacks

- Packet Sniffer and Cryptography
- IP Spoofing and End point authentication