Lecture 1,2: Internet, Network Structure, Network Core @August 24, 2021

What is Internet?

Network of networks; loosely hierarchical.

Components -

1. Computing devices - **Hosts or end systems** - laptops, smartphones, tablets, TVs, gaming consoles, thermostats, home security systems, home appliances, watches, eye glasses, cars, traffic control systems.
2. **Communication links** - coaxial cable, optical fiber, copper wire, radio spectrum - have different **transmission rates.**
3. **Packet Switches** - **Routers** (used in network core) **or link-layer switches** (used in access networks) **-** takes the packet arriving on its incoming link and forwards it to an outgoing link.
4. **ISPs** (Internet Service Providers) - End systems access internet through ISPs - local cable or telephone companies, corporate ISPs, university ISPs, and cellular data ISPs.
5. Protocols - TCP, IP, HTTP, Ethernet
6. Internet Standards - IETF (Internet engineering task force) → RFC (Request for comments) documents

Service View

Internet as a platform for distributed applications.

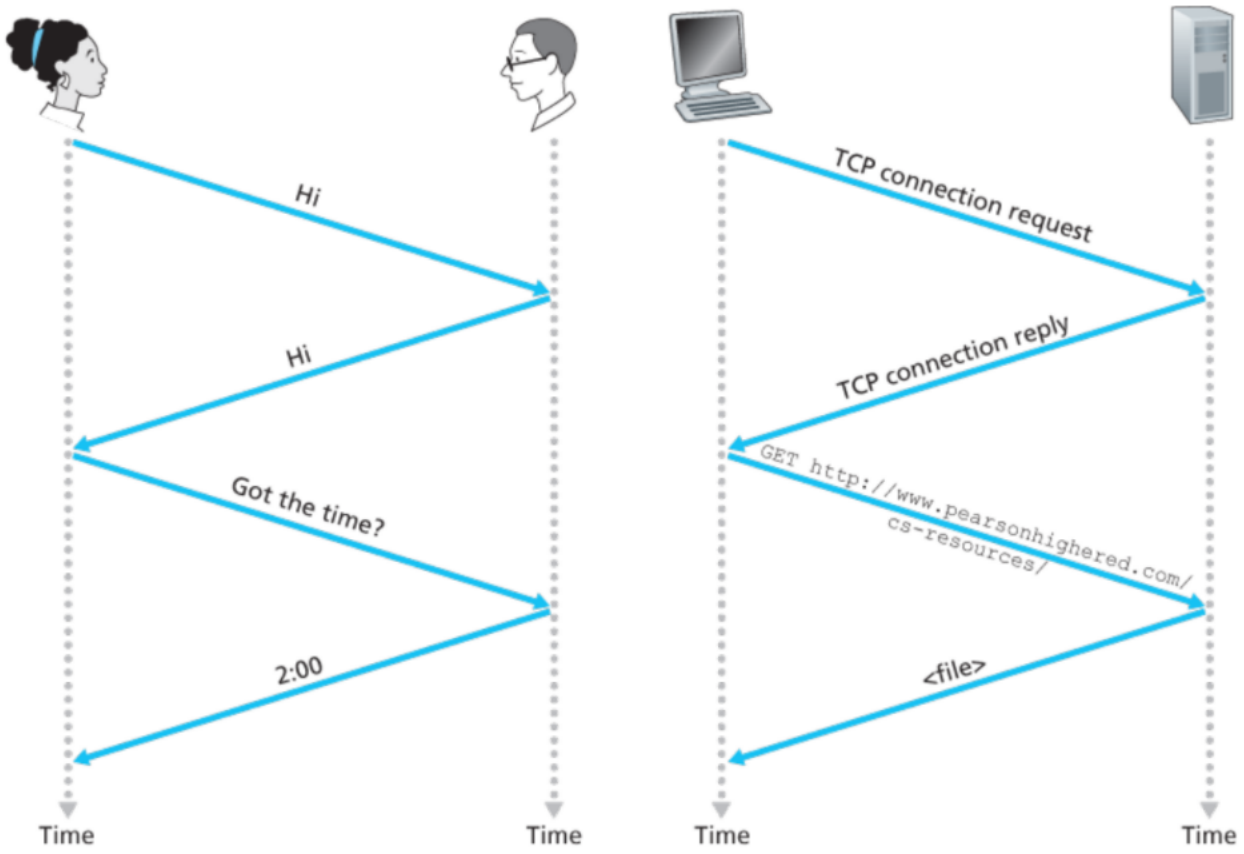
Distributed applications - web, VoIP, email, games, e-commerce, file sharing

Socket Interface - It specifies how a program running on one end system can ask Internet to deliver data to a specific destination running on a different end system. It is a set of rules to be followed by sending end system.

Communication Services - reliable data delivery, best effort

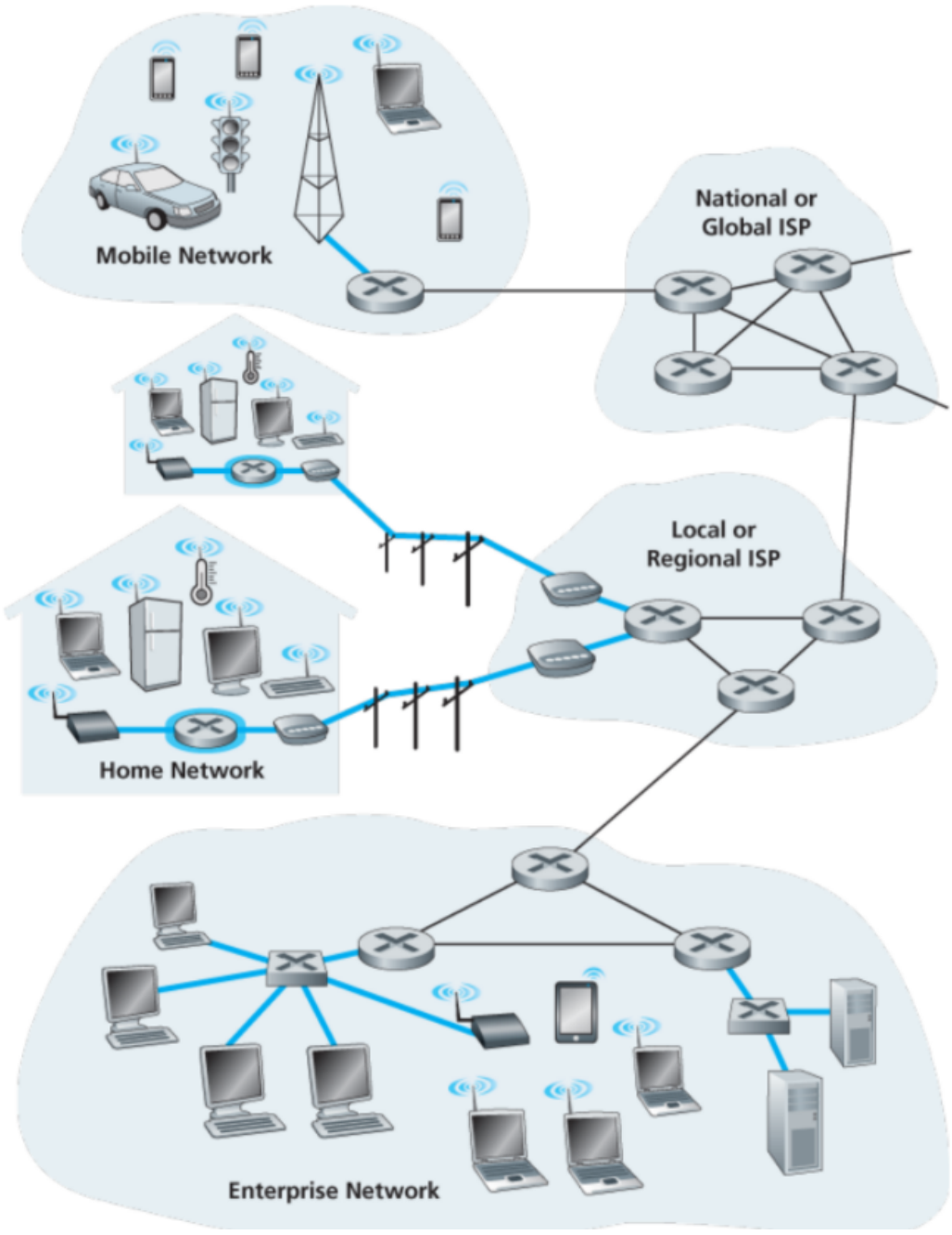
Network Protocols

Define format, order of msgs sent and received, actions taken on msg transmission, receipt.



Network Structure

1. Network Edge - hosts - clients & servers
2. Access Network - The network devices physically connected to edge devices, such as, edge routers.
3. Physical Media - wired, wireless, communication links



Network Edge

Hosts can be clients or servers.

Access Network

Connect end systems to edge routers -

1. **Residential access nets** - via DSL (digital subscriber lines) - uses telephone lines or cable, these are now combined with wireless LAN (WiFi).

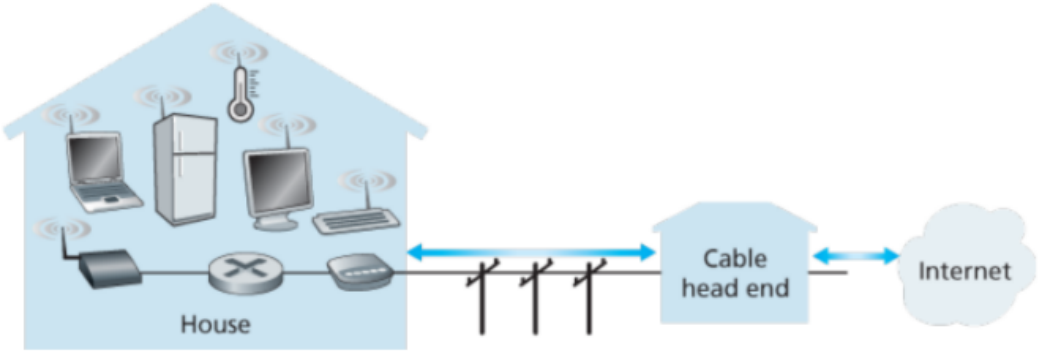


Figure 1.9 A typical home network

▼ The telephone line carries both data and traditional telephone signals encoded at different frequencies (frequency division multiplexing) -

A high speed downstream channel (50 kHz to 1 Mhz)

A medium speed upstream channel (4 kHz to 50 kHz)

An ordinary 2 way telephone channel (0 to 4 kHz)

On the customer side, a splitter separates the data and telephone signals arriving to the home and forwards the data signal to the DSL modem. On the telco side, in the CO, the DSLAM separates the data and phone signals and sends the data into the Internet. Hundreds or even thousands of households connect to a single DSLAM, this calls for protocols to avoid collision during upload.

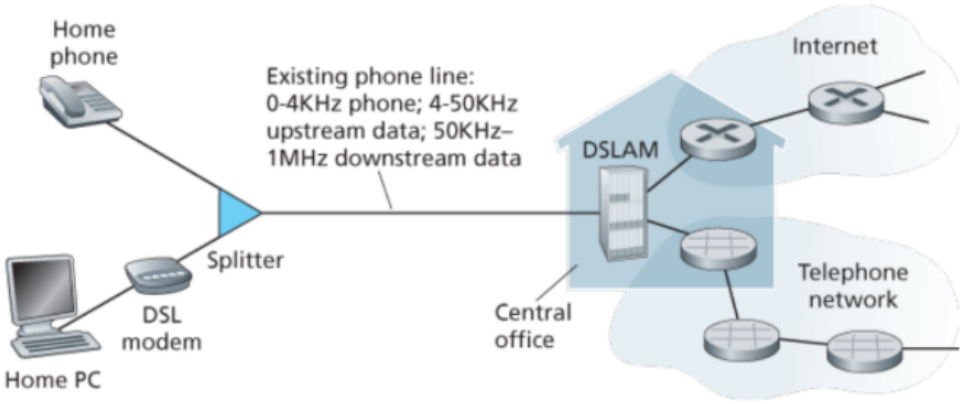


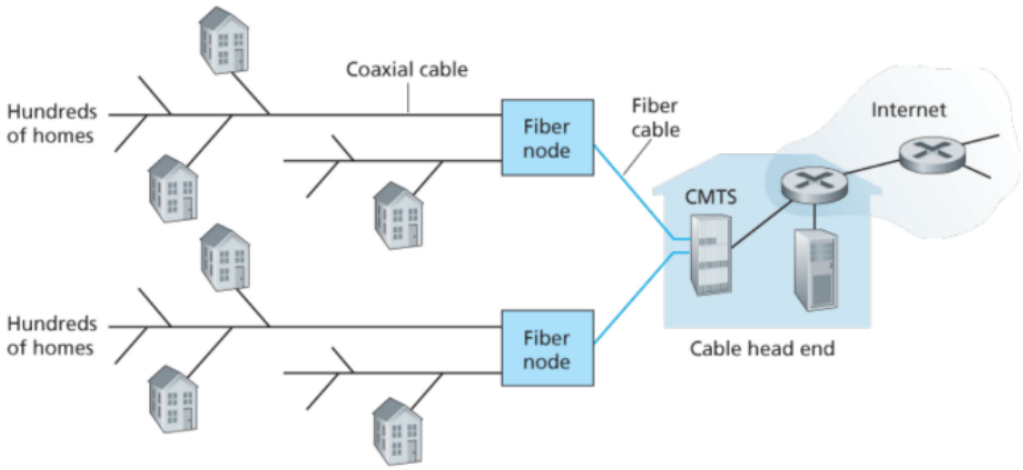
Figure 1.5 DSL Internet access

▼ Cable internet access uses the cable television company's existing infrastructure to provide internet access.

It uses both optic fibers and coaxial cable, and hence is referred to as Hybrid Fiber Coax (HFC). It is shared broadcast medium i.e. every packet sent by head goes to every home.

They require special modems, cable modems, which connects to home PC through ethernet port. It divides the HFC into 2 channels, a downstream and an upstream.

At the cable head end, the cable modem termination system (CMTS) serves a similar function as the DSL network's DSLAM—turning the analog signal sent from the cable modems in many downstream homes back into digital format.

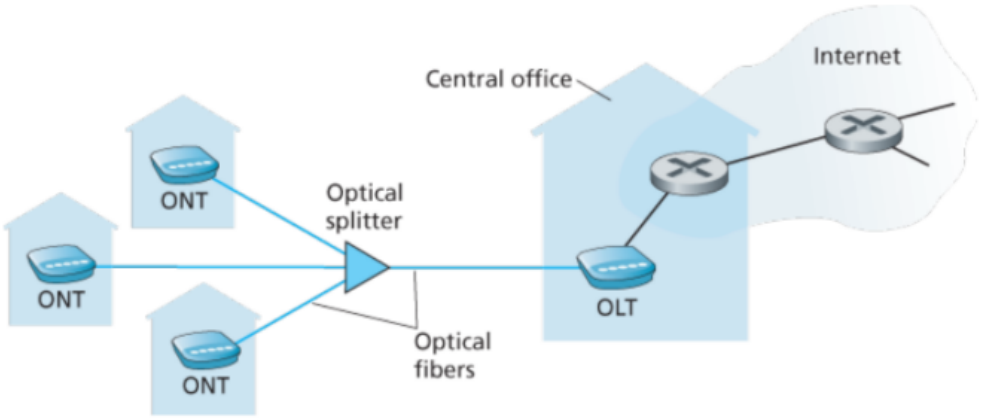


▼ Fiber to the home (FTTH)

An optical fiber runs from CO to home, provides high speed. A common optical fiber from CO to near homes, and then optical fibers split for each home. The splitting can be performed by AON (active optical networks) i.e. switched ethernet or by PON (passive active networks).

PON -

Optical Network Terminator (ONT) from each home meets at the splitter for the neighborhood, and goes to Optical Line Terminator (OLT) through a dedicated optical fiber, which converts the optical signals into electrical ones.

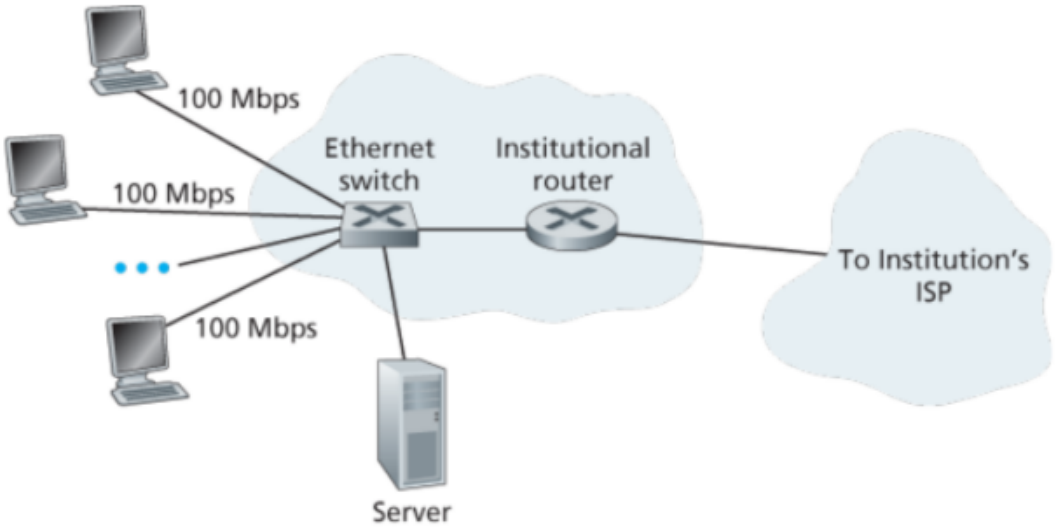


▼ Other options are -

Satellite link - StarBand and HughesNet

Dial Up Access

2. **Enterprise nets** - LAN → ethernet used to connect an end system to the edge router.



Wireless LAN (WiFi) → users send/receive packets to/from an access point connected to enterprise network, which is in turn connected to a wired Internet.

3. **Mobile Access Net -**

   Uses radio spectrum.

3. **Wide-area Wireless Access -**

   3rd Gen wireless provides packet switched wide area network - need to be within a few 10s of Kms of base station.

   LTE (Long term evolution) is based on 3G.

Physical Media

1. **Guided Media** - transmission over solid media like copper, fiber (glass fiber containing light pulses), coaxial cable(bidirectional)

   ▼ Twisted Pair Copper Wire -

   Least expensive, most commonly used, 10 Mbps to 10 Gbps.

2 insulated copper wires about 1mm thick, arranged in a spiral pattern, wires are twisted to reduce electrical interference. Pairs are bundles together and wrapped in a protective shield.

- ▼ Coaxial Cable -

  2 concentric copper conductors, 10s of Mbps

- ▼ Fiber Optics -

  Thin, flexible medium to conduct light, 10s or 100s of Gbps, immune to electromagnetic interference, low signal attenuation upto 100s of Km, hard to tap - costly.

2. **Unguided media** - transmission over atmosphere, such as, radio (half duplex - wireless LAN(WiFi), wide area(4G cellular)); Bluetooth; digital satellite channel

   - ▼ Terrestrial Radio Channels -

     Carry signal in the electromagnetic spectrum, no physical wires, can penetrate walls.

     Short distance 1-2 m

     Local areas 10 to few 100s m

     Wide area 10s of kms

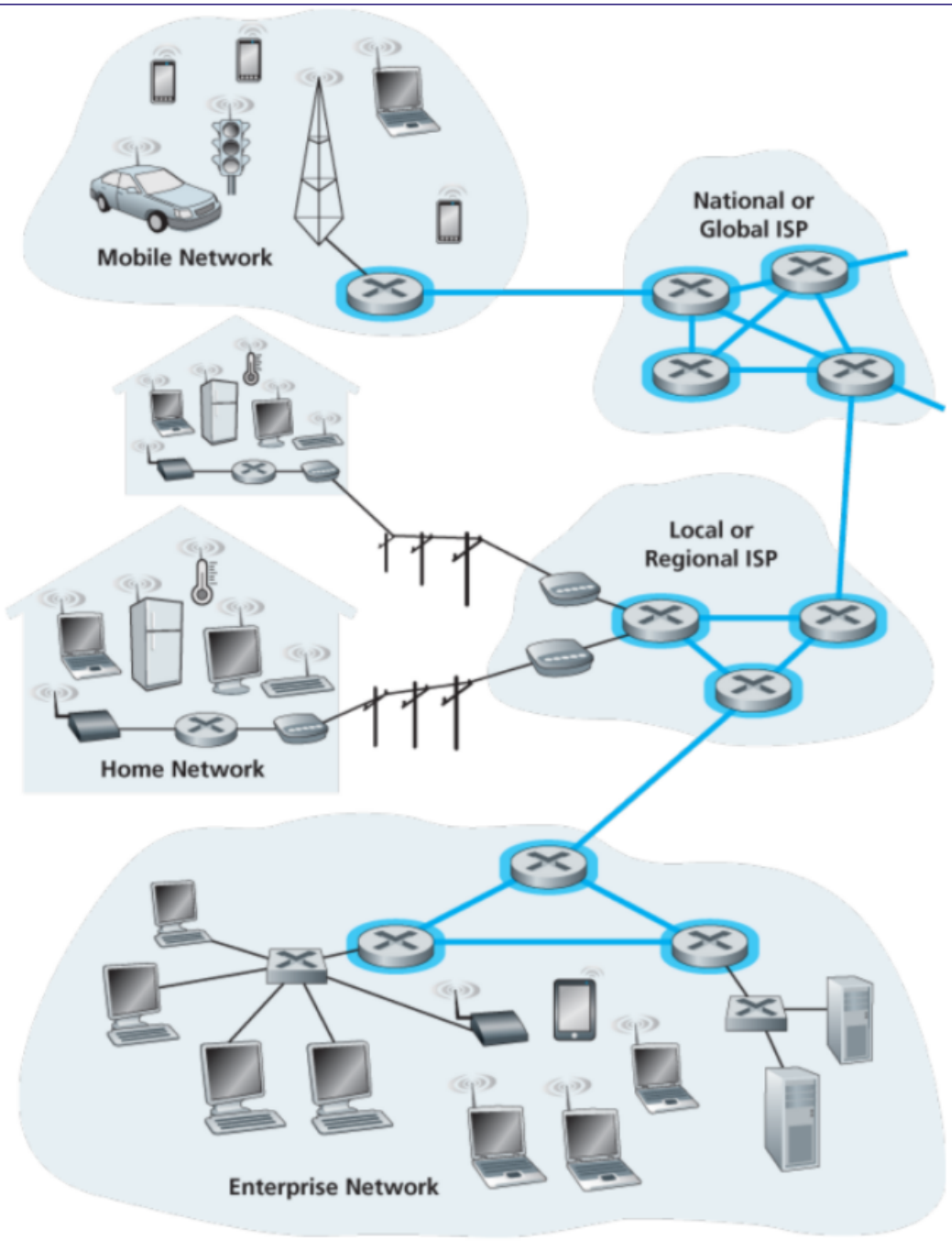
   - ▼ Satellite Radio Channels -

     Link two or more earth based transmitters / receivers, ground stations, receive signal on one frequency, regenerates it using repeater and transmits on another frequency.

     Geostationary satellites or low-earth orbiting satellites (LEO - under development)

Network Core

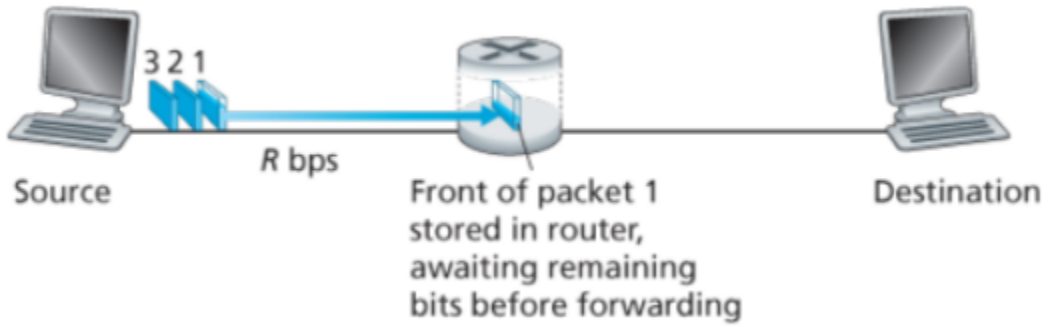
Mesh of packet switches.



▼ **Packet Switching -**

The source breaks the long message into smaller chunks of data known as packets. Each packets travels through packet switches and are transmitted over each communication link at a rate equal to full transmission rate of the link. Uses **store-**

and-forward transmission, i.e. it must receive the entire packet before it can begin to transmit the data.



Delay - Transmission delay (when last bit leaves, and first bit arrives.) ; Propagation delay (signal propagates at speed of light, can be ignored) ; Queuing delay

L-bit packet

R-bandwidth of link

Time to reach from source to 1st packet switch = L/R = 10Kbits / 100 Mbps

Overall time to send 3 bits = 4L/R

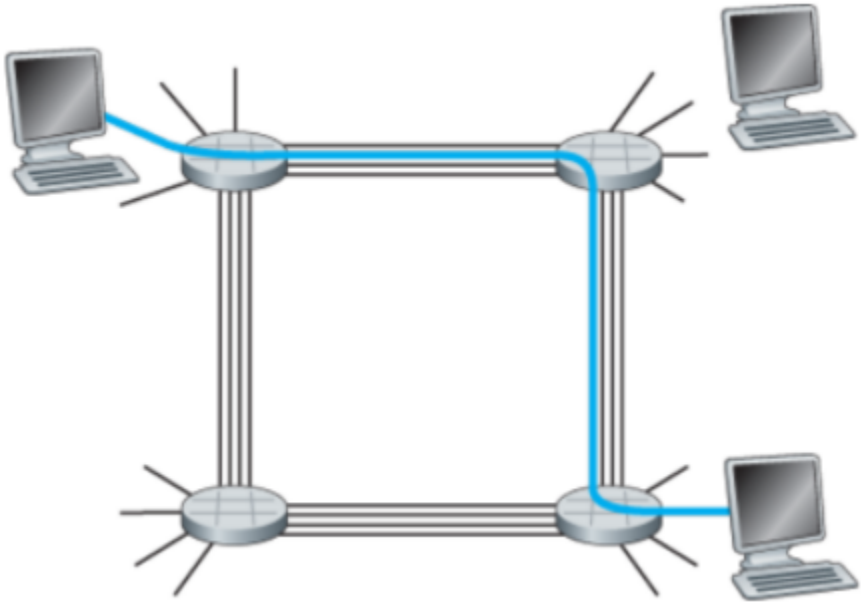
Time to send 1 packet from one end to other (n-links, n-1 routers) = NL/R

Packet Loss - if buffer queue is full.

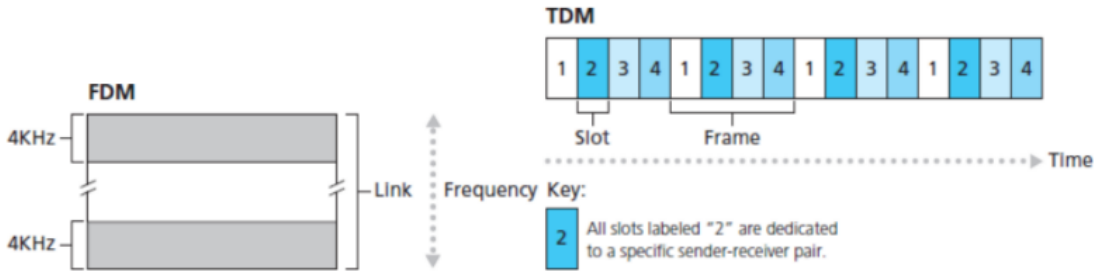
Router is responsible for packet forwarding, using IP address. It uses a forwarding table to to decide the route.

▼ **Circuit Switching -**

End to end resources allocated between source and destination for the communication session such as a traditional telephone network.



1. Frequency Division Multiplexing - frequency spectrum of a link is divided among connection i.e. one frequency band is dedicated to one connection over 2 links and other frequency band is dedicated to other connection over the same links.
2. Time Division Multiplexing - time is divided into frames, and the network dedicates one time slot in every frame to each connection.



Packet switching vs Circuit switching :

PS DisAdv - is not suitable for real time services because of unpredictable delays.

PS Adv - better sharing of transmission capacity than circuit switching, simpler, efficient, less costly, more efficient if we consider user's idle time.

CS DisAdv - is wasteful and establishing dedicated paths is complicated for packet switches.

CS Adv - is reliable and fast (irrespective of number of packet switches that come in the way).

Lab 1

Packet Sniffer

Passive tool, captures packets being exchanged over the network, can also store and display the content of protocol fields in the captured packets. It never sends or receives the packets from the applications but it does receive a copy of packets.

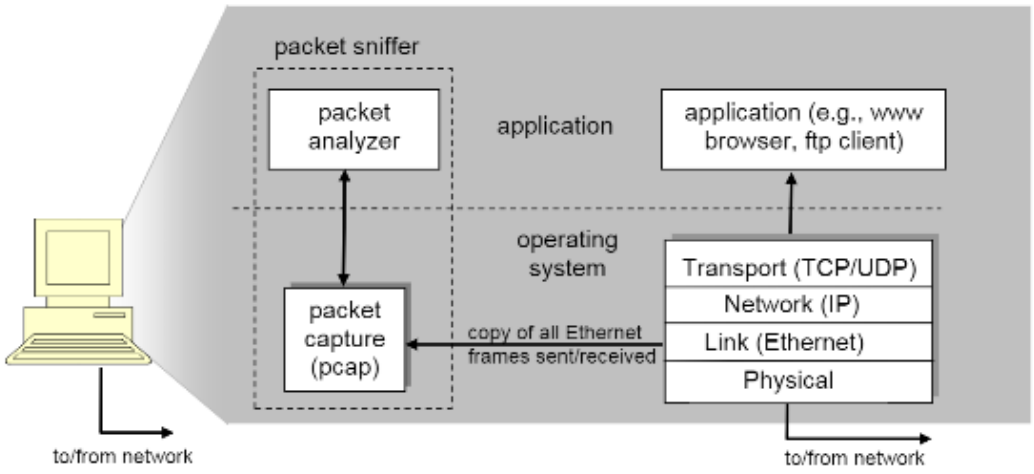


Figure 1: Packet sniffer structure

Packet sniffer has a packet capture library that receives a copy of every link-layer frame (messages exchanged by higher layer protocols are eventually encapsulated as link layer frames) sent and received by your computer.

PDF Answers

1. TCP, HTTP, QUIC, TLSv1.3, TLSv1.2, ICMPv6, ARP
2. Time of GET: 19:30:15.218968; Time of OK: 19:30:15.495072

3. Internet address of gaia.cs.umass.edu: 128.119.245.12; Internet address of my laptop: 10.0.0.144

Readme Answers

1. Internet address of gaia.cs.umass.edu: 128.119.245.12; Internet address of my laptop: 10.0.0.144
2. Status Code: 200; Phrase: OK
3. Languages accepted: US English(en-US) or English(en); Header: Accept Language
4. Content Size: 81 bytes; Header: Content-length
5. Time of GET: 19:30:15.218968; Time of OK: 19:30:15.495072; Time elasped: 0.000276104 seconds