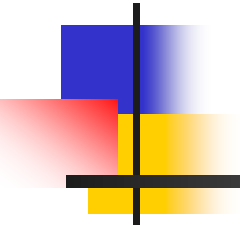# EE4204/ EE4204E/ TEE4204 Computer Networks (part 1)

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Electrical and Computer Engineering

Networks Overview (Set 1)

- ## References

  - J.F. Kurose and K. W. Ross, "Computer Networking: A Top-Down Approach", *Pearson Publishers* (Source of most of the figures)

  - Peterson and Davie, "Computer Networks: A Systems Approach", *Morgan Kaufmann Publishers*

Networks: What? Why?

- A Network is a set of systems interconnected by communication links that is primarily used for information transfer

- System – end system, switch, router, hub

- End system, desktop computer, server, laptop, tablet, smart phone, smart Internet devices like camera, TV etc

- Links – wired, wireless

- Different forms of information:
    - Text, voice, audio, video, picture, graphics

Network Applications

1. Web browsing
2. E-mail, E-learning, File transfers
3. Online Social Networks
4. Video and audio streams
5. Voice over Packets
6. Gaming
7. Distributed databases (banking, airline Transactions)

What's the Internet: "nuts and bolts" view

❖ millions of connected computing devices:
- *hosts* = *end systems*
- Hosting/running *network apps*

❖ *communication links*
- fiber, copper, radio, satellite
- transmission rate: data rate in bits per second (bps) related to *bandwidth*

❖ *Packet switches:* forward packets (chunks of data)
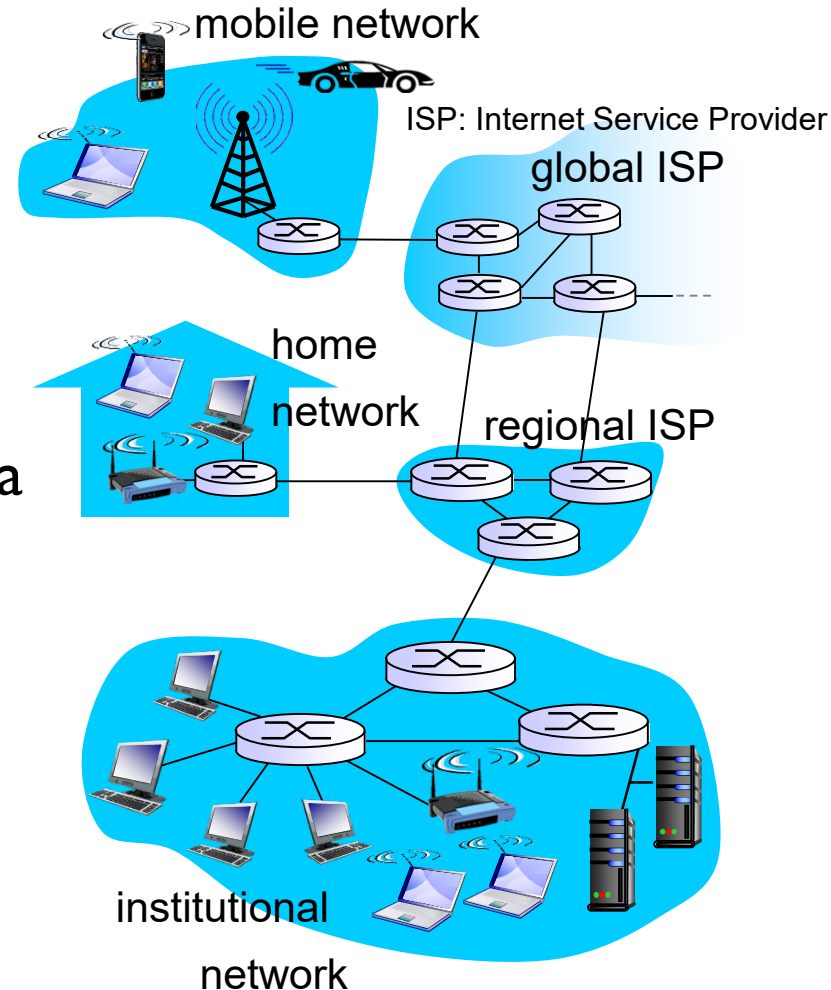- *routers* and *switches*

PC

server

wireless laptop

smartphone

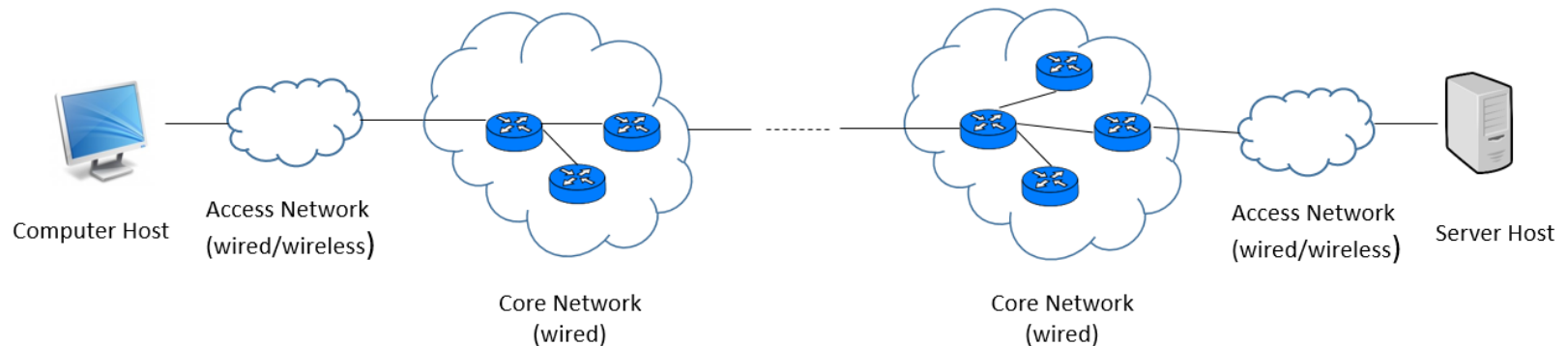access point, base station, tower

Switch/router

mobile network

ISP: Internet Service Provider

global ISP

home network

regional ISP

institutional network

Data Transfer between Hosts

- ❖ Refer Figure in next slide
- ❖ Sender host needs to transfer data to the receiver host
- ❖ An end-to-end logical connection (or channel) is created between sender and receiver hosts
- ❖ Data is segmented into pieces of chunks called packets
- ❖ Each packet is a piece of data chunk along with header (eg. Receiver host address)
- ❖ Packets are transported through the logical connection traversing through access networks and core networks (through links and switches)
- ❖ Two kinds of packet switches
  - ▪ Link layer switch (Eg: Ethernet switch)
  - ▪ Network layer switch, Eg. IP (Internet Protocol) router
  - ▪ Meaning of layers, differences between the switches and routers & more details will be discussed later.
- ❖ Receiver host assembles packets into original data

EE4204(Part 1) Notes1

Hosts connected by networks – An Example

Computer Host — Access Network (wired/wireless) — Core Network (wired) — Core Network (wired) — Access Network (wired/wireless) — Server Host

Problems and Requirements

❖ Deliver data with an acceptable delay
❖ Use the network resources effectively for improved performance (low delay, high throughput)
❖ Reliability
  ▪ Network should hide the errors
  ▪ Handle Bit errors (1 to a 0, and vice versa)
  ▪ Handle Burst errors – several consecutive errors
  ▪ Handle Packets loss (Congestion)
  ▪ Handle Link and Node failures
  ▪ Ensure messages are not delivered out-of-order
❖ Security
  ▪ Encryption, authentication, authorization
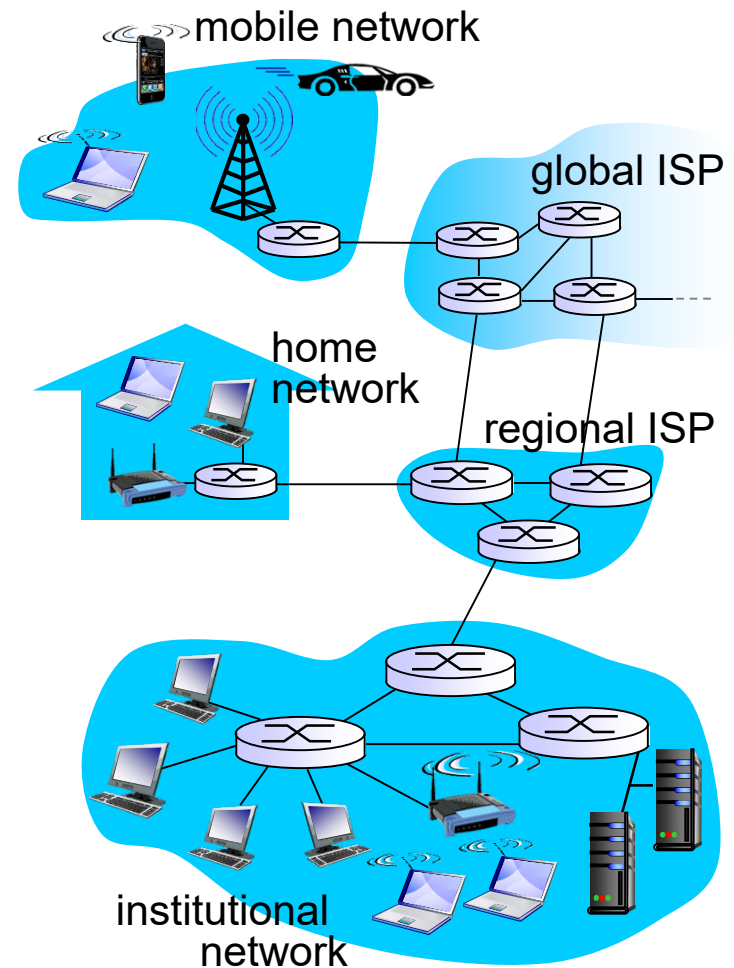 ▪ Attack detection and mitigation

Network Structure

❖ *network edge:*
- hosts: clients and servers
- servers often in data centers

❖ *access networks, physical media:* wired, wireless communication links

❖ *network core:*
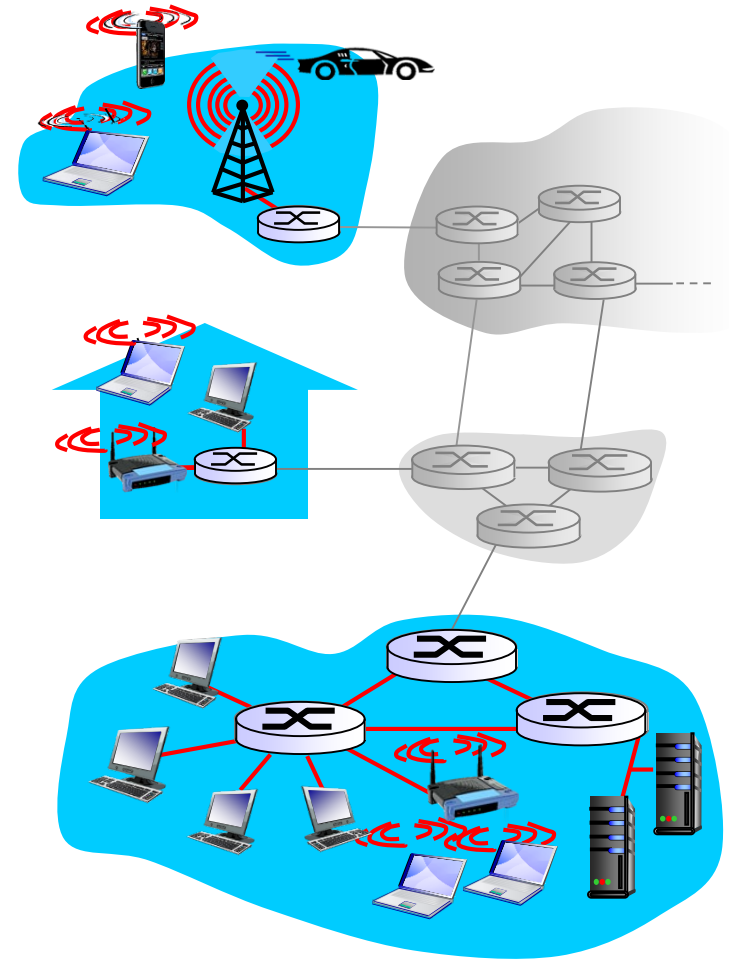- interconnected routers
- network of networks

mobile network

global ISP

home network

regional ISP

institutional network

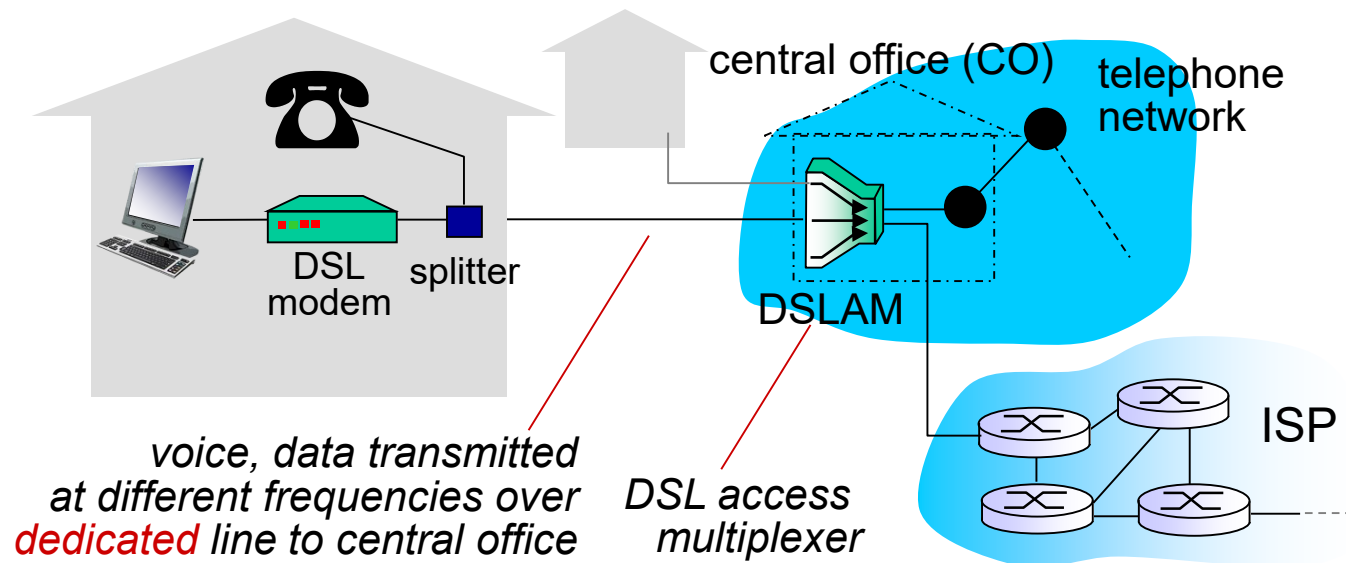# Access Networks

How to connect end systems to edge router?

❖ residential access nets

❖ institutional access networks (school, company)

❖ mobile access networks

Basic Types of Access Networks

- ❖ Telephone network based Access
    - ▪ Digital Subscriber Line (DSL) modem
- ❖ Cable TV network based Access
    - ▪ Cable modem
- ❖ Fiber network based access
- ❖ Local area wired access
    - ▪ Wired local area network (LAN)
    - ▪ Ethernet LAN
- ❖ Local area wireless access
    - ▪ 802.11 wireless LAN, wifi
- ❖ Wide area wireless access
    - ▪ Cellular mobile network, 3G, 4G

Access net: Digital Subscriber Line (DSL)

voice, data transmitted
at different frequencies over
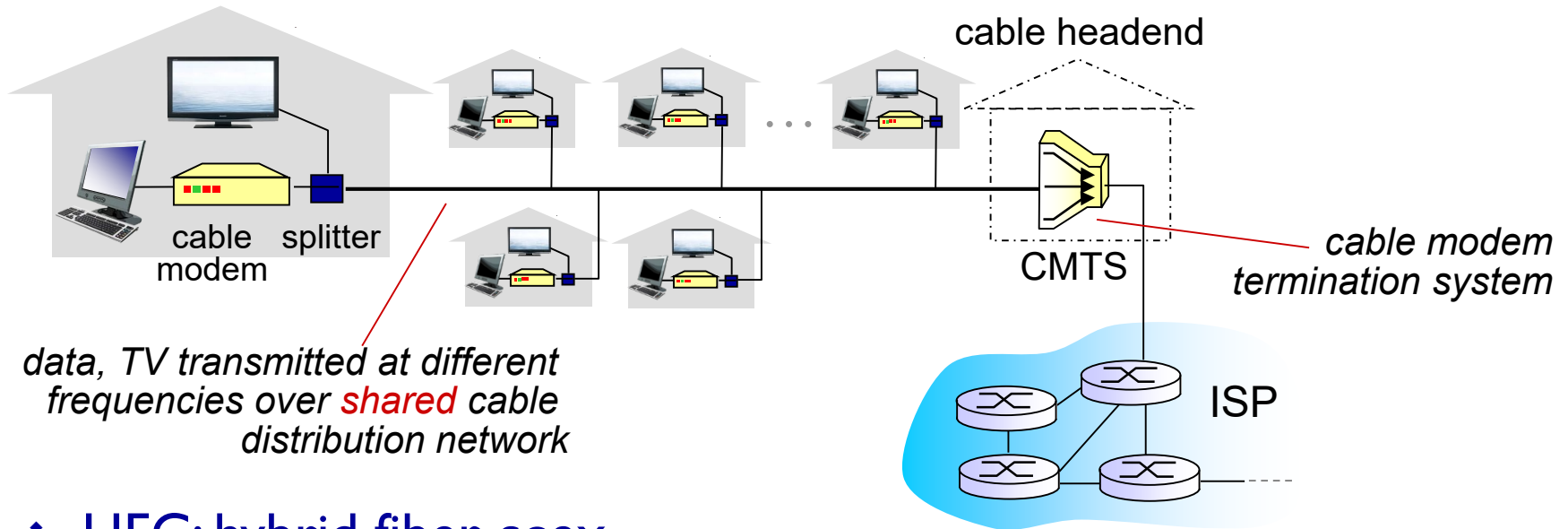*dedicated* line to central office

DSL access
multiplexer

❖ use *existing* telephone line to central office DSLAM
  ▪ data over DSL phone line goes to Internet
  ▪ voice over DSL phone line goes to telephone net
❖ < 2.5 Mbps upstream transmission rate (typically < 1 Mbps)
❖ < 24 Mbps downstream transmission rate (typically < 10 Mbps)
❖ Technology advances, higher rates are possible

Access net: Cable Network

cable headend

cable modem   splitter
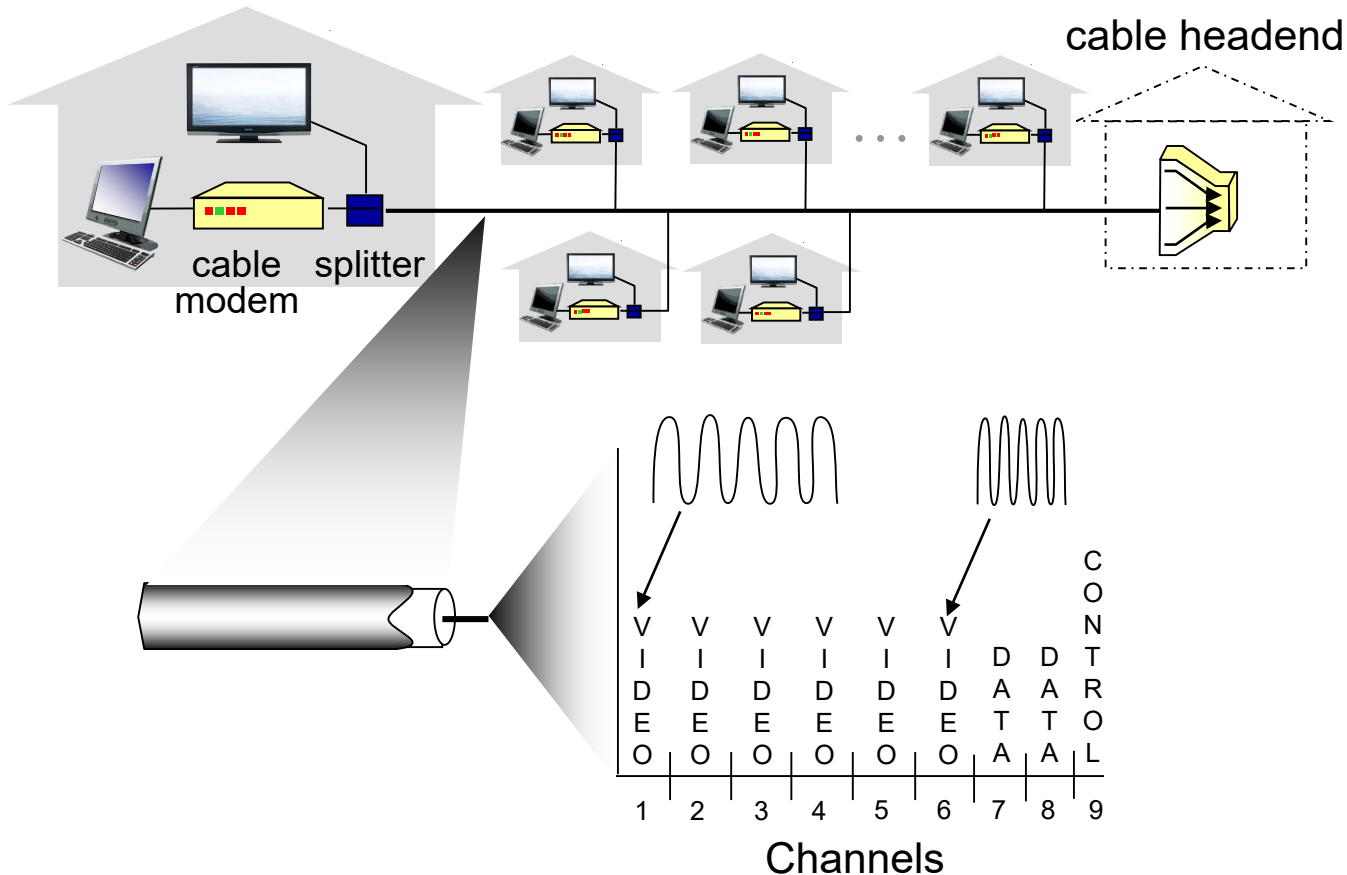
Channels

frequency division multiplexing: different channels transmitted in different frequency bands; Cable headend broadcasts TV channels through a distribution network of coaxial cable and amplifiers to homes

EE4204(Part 1) Notes1

Access net: Cable Network (contd.)

cable headend

cable modem
termination system

CMTS

ISP

cable modem   splitter

data, TV transmitted at different frequencies over *shared* cable distribution network

❖ **HFC: hybrid fiber coax**
- Fibers connecting cable headend and neighborhood junctions each of which reaches 500-5000 homes through coaxial cable
- asymmetric: up to 30Mbps downstream transmission rate, 2 Mbps upstream transmission rate, higher rates are now possible

❖ **network** of cable, fiber attaches homes to ISP router
- homes *share access network* to cable headend
- unlike DSL, which has dedicated access to central office

EE4204(Part 1) Notes1

Fiber Network based Access Networks

❖ Optical Fiber based Fiber to the home (FTTH) solution (See figure in next slide)

❖ Huge bandwidth (each home can get a few Gbps) and low bit error rate (BER < 10^{-12})

❖ The distance from service provider's central office (CO) can be up to 20 km whereas it is 5 km for DSL or Cable Modem

❖ N: subscribers, L km distance between CO and user (subscriber)

❖ Passive Optical Networks (PON) (See Figure) is an attractive solution

- Optical Line Terminal OLT at CO; Optical network units ONU at home
- N+1 transceivers, one at OLT and one at each of N ONUs
- Only one fiber from CO to subscriber premise, total fiber length: L km
- Uses inexpensive passive optical splitter/coupler, closer to subscriber
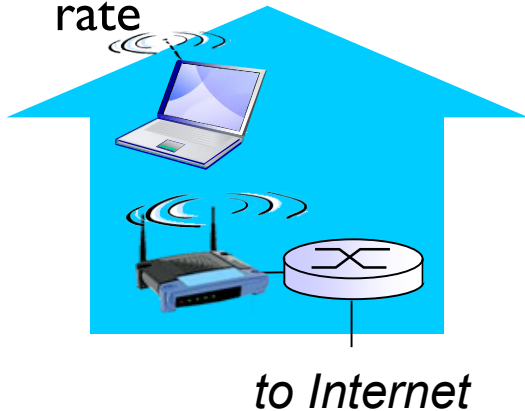- Eg: Ethernet PON

Passive Optical Network (PON)

Passive Splitter/Coupler

OLT At CO

Subscribers

ONU At Home
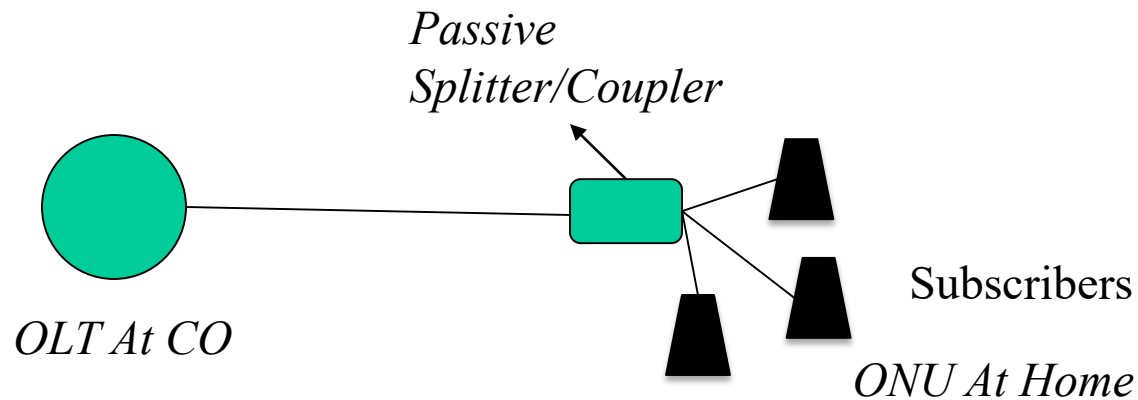
Wireless access networks

❖ shared *wireless* access network connects end system to router
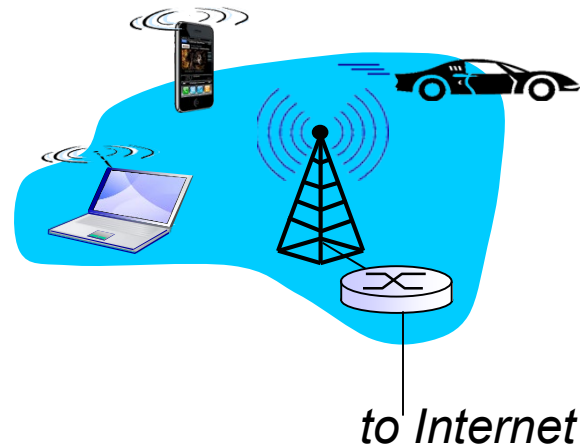 - via base station aka "access point"

wireless LANs:

  - LAN: local area network
  - within building (100 ft)
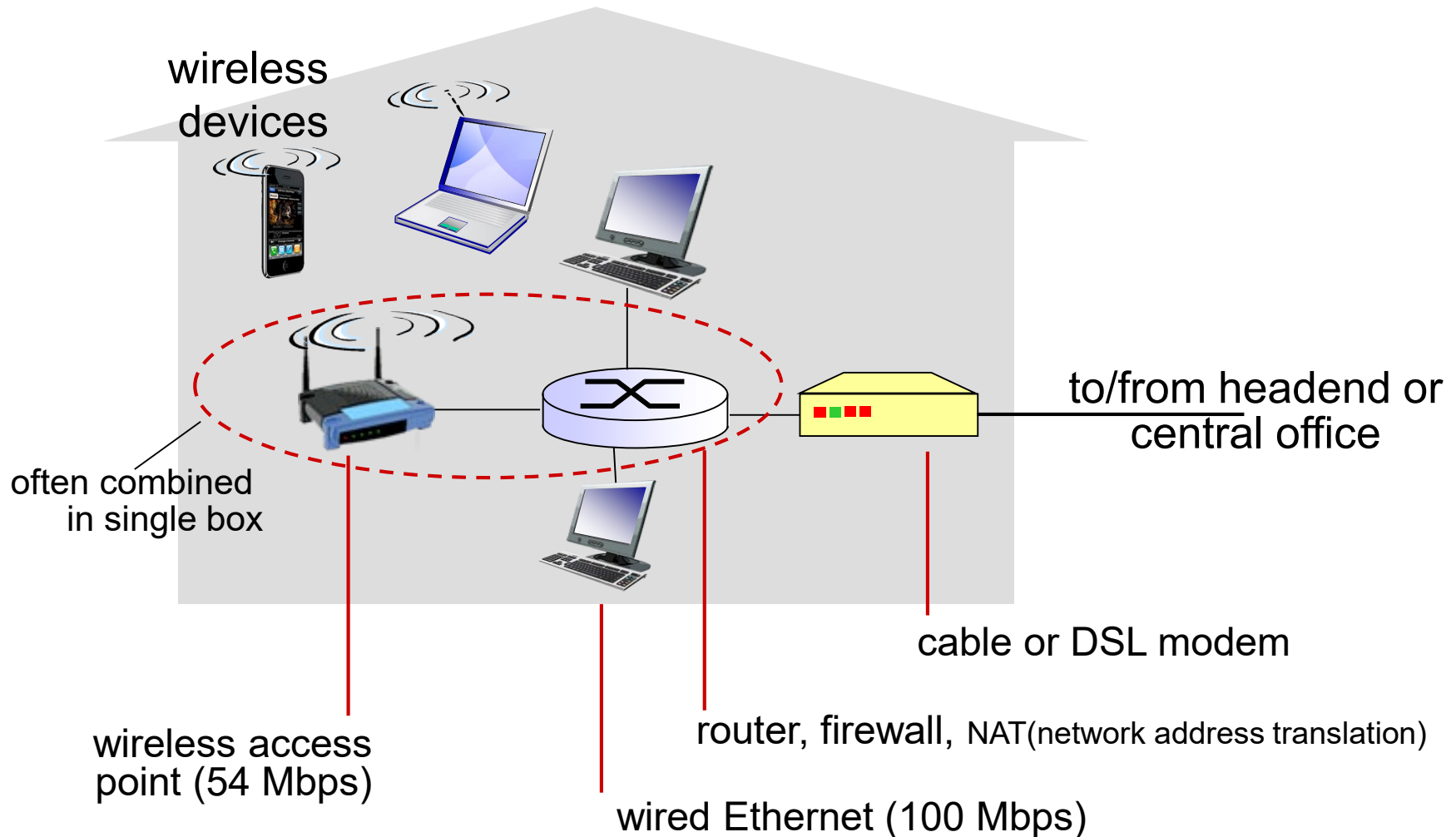 - 802.11b/g/n /ac (WiFi): 11, 54 Mbps (&more) transmission rate
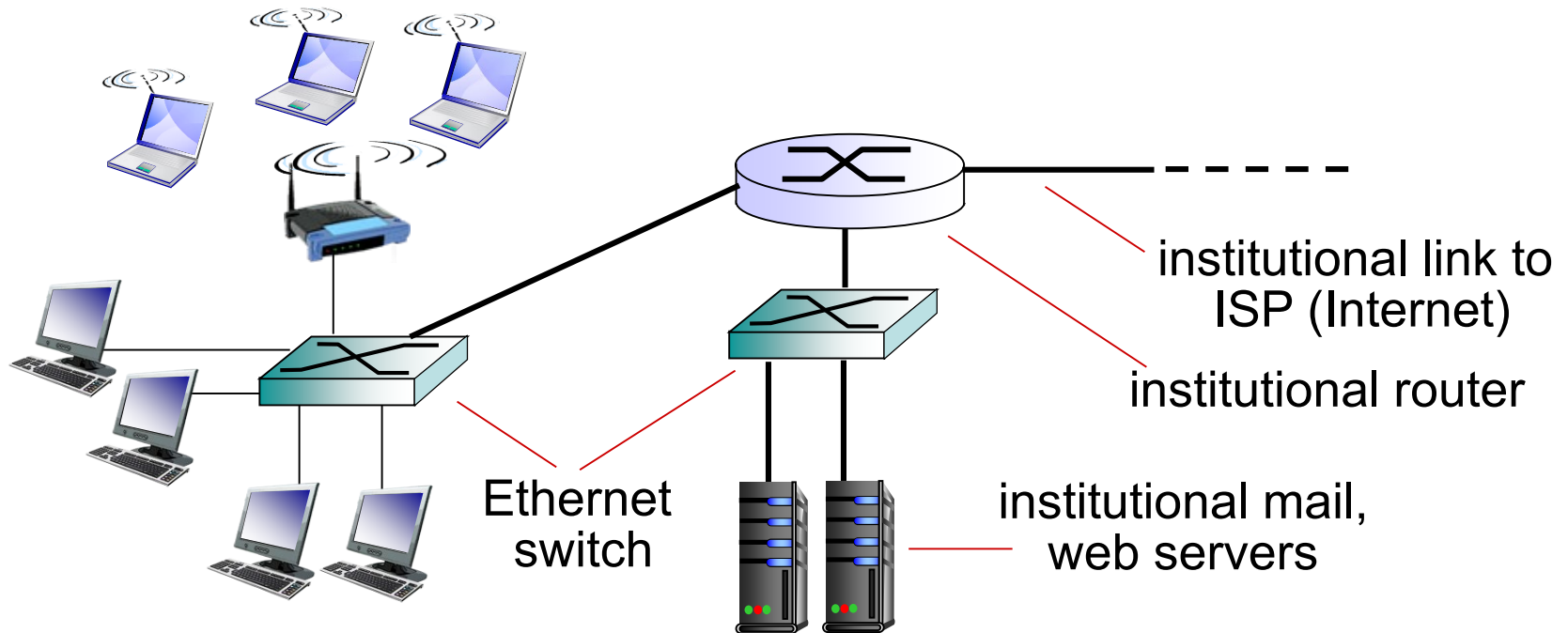

to Internet

wide-area wireless access

  - provided by telco (cellular) operator, 10's km
  - between 1 and 10 Mbps (&more)
  - 3G, 4G: LTE

to Internet

Access net: home network

wireless
devices

often combined
in single box

to/from headend or
central office

cable or DSL modem

wireless access
point (54 Mbps)

router, firewall, NAT(network address translation)

wired Ethernet (100 Mbps)

Enterprise access networks

institutional link to ISP (Internet)
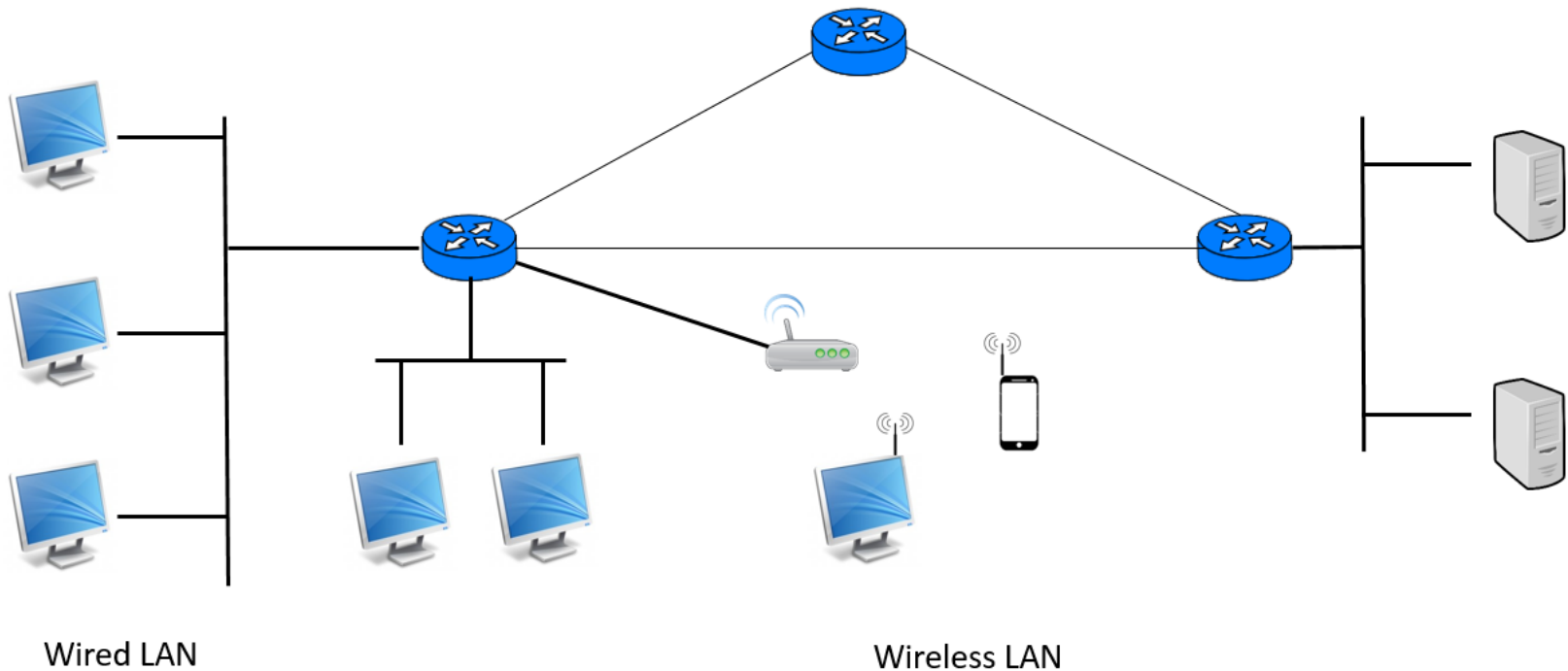
institutional router

Ethernet switch

institutional mail, web servers

- ❖ typically used in companies, universities, etc
- ❖ 10 Mbps, 100Mbps, 1Gbps, 10Gbps transmission rates
- ❖ today, end systems typically connect into Ethernet switch

Company/Institution/Enterprise Network – with wired LAN, wireless LAN, switched network

Wired LAN

Wireless LAN

Network Links

Broadcast Links vs. Point-to-Point Links

Links: How fast can we transmit data?

❖ Data is transmitted through a link bit-by-bit from one end to another end using transmitter/receiver (transceiver).

❖ A link (or communication channel) is characterized by the following.

❖ Bandwidth
  ▪ Bandwidth of the transmitted signal as constrained by the transmitter and transmission medium, expressed in Hertz

❖ Data Rate (Transmission Rate)
  ▪ The rate in bits per second (bps) at which data is transmitted

❖ Channel Capacity
  ▪ The maximum rate (bps) at which data can be transmitted over a communication path or channel under certain conditions such as SNR (signal-to-noise ratio)

❖ In the context of "computer networks" the terms bandwidth, data rate, and capacity are sometimes used interchangeably. Students should be able to distinguish them based on "unit" and "context".

Broadcast Links

❖ Wired or Wireless broadcast links

- see Figure in next slide (wired broadcast link)
- Multiple hosts (nodes) connected by a broadcast link (also called multiple access or shared access link)
- One node transmits; all nodes receive
- Link bandwidth (or data rate) shared by the hosts
- 100 Mbps link; the number of bits that can be transmitted by all hosts in one second is at most 100 million bits.
- Typically used in home, companies (within an office, lab, building)
- Local area network (LAN)

Wired Broadcast Link – An Example

Host

Broadcast link
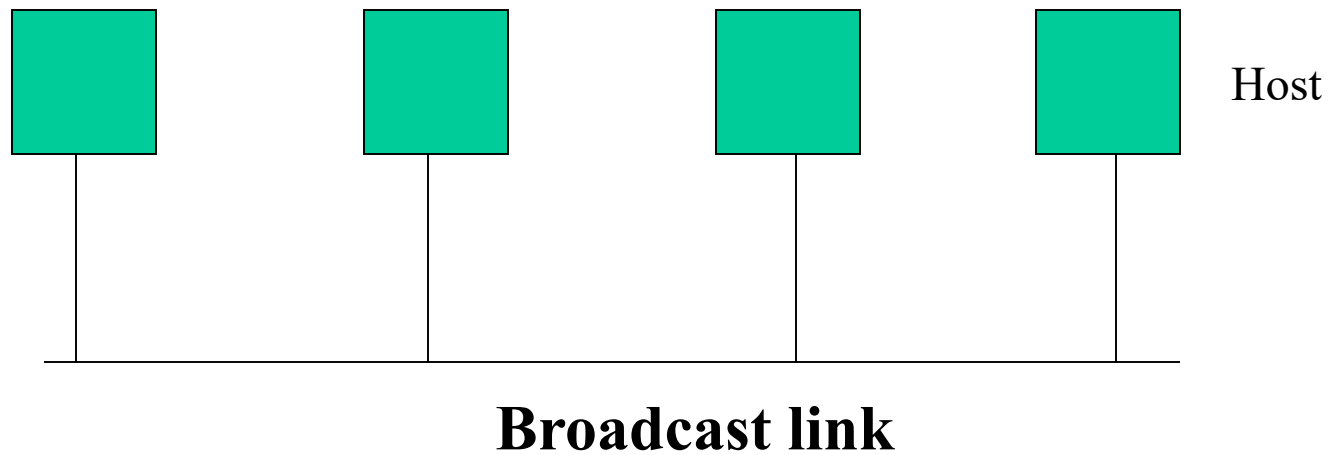
Point-to-Point Links

❖ Typically used in switched networks (campus network, enterprise network, ISP network)

 ▪ Link connecting two switches (say, s1 and s2)

 ▪ Dedicated to s1 and s2; i.e., can be used only by s1 and s2 for sending and receiving data

 ▪ 100 Mbps link; a switch can send/receive at most 100 million bits in one second

❖ Switched network (see figure in next slide)

 ▪ Data traverses through one or more switches and links

 ▪ A switch has a number of input and output ports (or links)

 ▪ Data is forwarded from an input link to an output link within a switch (called switching)

 ▪ Eg: data sent from switch 1 to switch 3 traverse through switch 2; data is said to be switched at switch 2 from the port (connecting switch 1) to the port (connecting switch 3)

 ▪ Eg: core network

# Switched Network with Point-to-Point links – An Example
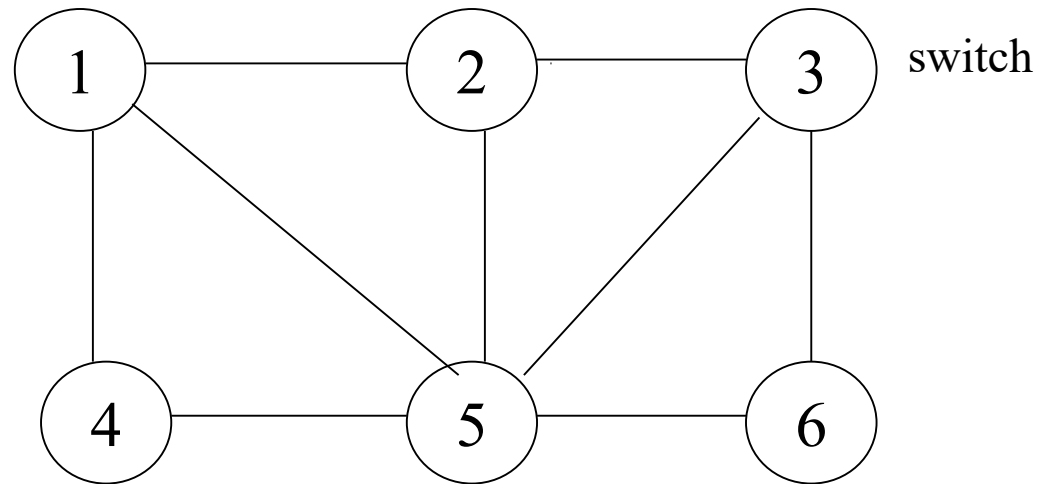
switch

Computer Networks – A Classification

❖ A computer network comprises nodes and links

❖ Nodes (computers, switches, routers, gateways)

❖ Links
- Wired: twisted pair, coax cable, optical fiber
- Wireless: microwave, spread spectrum radio, infrared

❖ One classification: access networks, core networks

❖ Another Classification
- Local area networks (LANs) (a class of access networks)
- Metropolitan area networks (MANs)
- Wide area networks (WANs)

Local Area Networks

❖ Small geographical area, e.g., office, lab, home, campus

❖ Typically broadcast link, multiple access link, shared medium

❖ Medium access control (MAC)

- Wired LAN: Ethernet (IEEE 802.3)
  - Broadcast medium
  - 10 Mbps, 100 Mbps
- Wired LAN: Token Ring (IEEE 802.5)
  - Token passing ring
  - 4 Mbps, 16 Mbps
 - Not popular now
- Wireless LAN (IEEE 802.11)

Local Area Networks - Ethernet
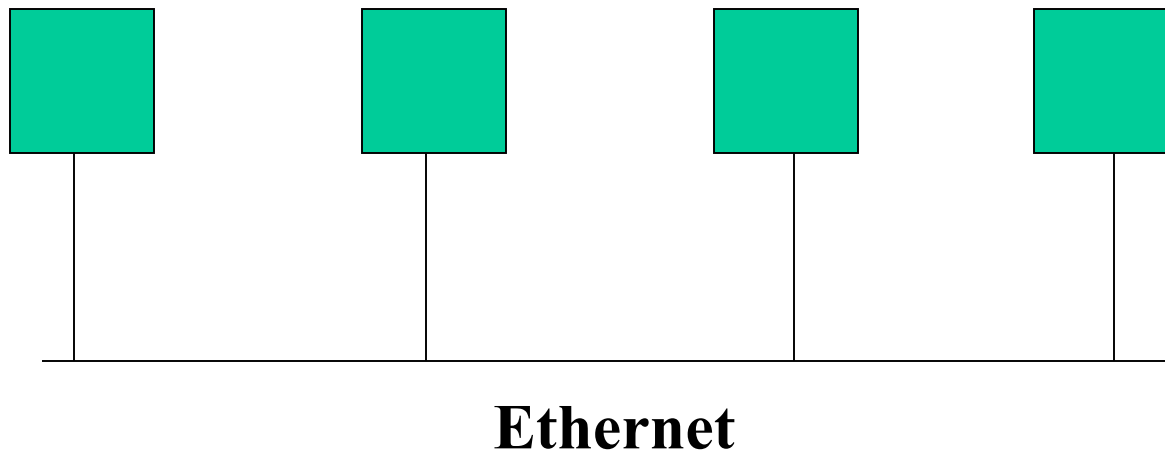
Ethernet

Ethernet –MAC -Principle

❖ Broadcast medium
  ▪ Traffic transmitted by a host can be seen by every host
❖ There is no coordination among the hosts and a host attempts to transmit data independent of others
❖ Possibility of more than one host transmitting data frames at the same time leading to collisions
❖ Mechanisms for detecting a collision and retransmitting data in the event of a collision are used [Details are available in Lecture Notes on Ethernet]

Local Area Networks – Token Ring
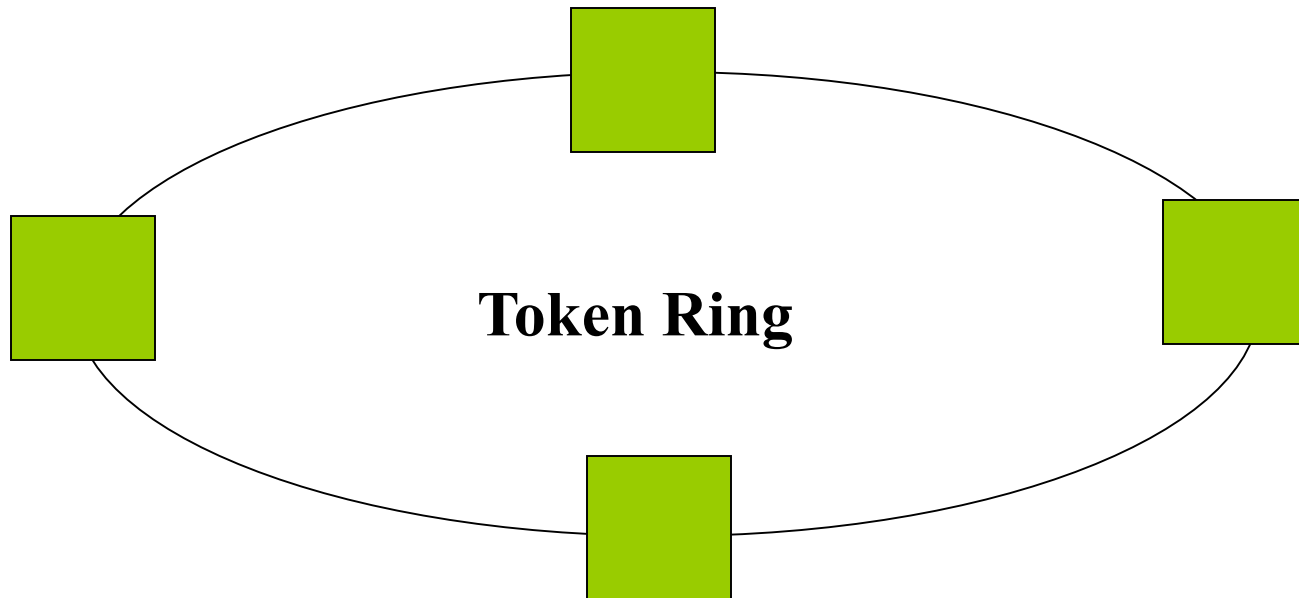
Token Ring

Token Ring – MAC - Principle

❖ Broadcast Medium

❖ No collision

❖ A special packet called Token is circulating around the ring

❖ A host waits for its turn; captures token; transmits traffic; passes token to the next host

❖ Packet makes one full round and is drained at the source (eventually it is a broadcast)

Metropolitan Area Networks

❖ Medium geographical area: city

❖ Interconnects a number of LANs

❖ Fiber Distributed Data Interface (FDDI)

- Token ring, 100 Mbps

❖ Synchronous Optical Network (SONET)

- Fixed bandwidth allocation, in multiples of 51.84 Mbps

- Fixed TDM (time division multiplexing)
  - Discussed later

❖ Asynchronous Transfer Mode (ATM)

- Flexible bandwidth allocation, statistical TDM (discussed later)

❖ Generally switched-networks (eg: SONET, ATM)

Wide Area Networks

- ❖ Large geographical area (country, continent, world)
- ❖ Irregular topologies, point-to-point links
- ❖ Links could be of thousands of km long
- ❖ Interconnecting several LANs and MANs
- ❖ IP, SONET, ATM, WDM technologies
- ❖ IP is carried on SONET, ATM, WDM networks
    - ▪ IP – Internet Protocol
    - ▪ SONET – Synchronous Optical Networks
    - ▪ ATM – Asynchronous Transfer Mode
    - ▪ WDM - Wavelength Division Multiplexing
        - • simultaneous transmission of messages on different wavelengths on a fiber each operating at the rate of a few Gbps)
        - • aggregate capacity in Terabits-per-second