COMP 445
Data Communications & Computer networks
Winter 2022

Introduction

- ✓ What is Internet
- ✓ Architecture of the Internet (edge and core)
- ✓ Switching techniques
- ✓ Delays and throughput in packet switched networks
- ✓ Protocol layering and service models
- ✓ Network security

Introduction – Part 1

✓ What is the Internet
- ✓ Infrastructure and components
- ✓ Platform for distributed applications
- ✓ Protocol definition

✓ Architecture of the Internet – network edge
- ✓ Access networks
- ✓ Physical media

Learning objectives

- To explain the Internet's architecture as an example of a computer network.
- To identify a network components, including its infrastructure and the services it provides to applications
- To explain what is a network protocol
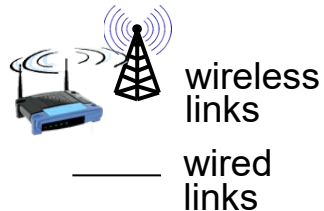- To classify the different access networks and the physical media employed in communication links

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✓ Architecture of the Internet – network edge
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    ✓ Physical media

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

PC

server

wireless
laptop

smartphone

wireless
links

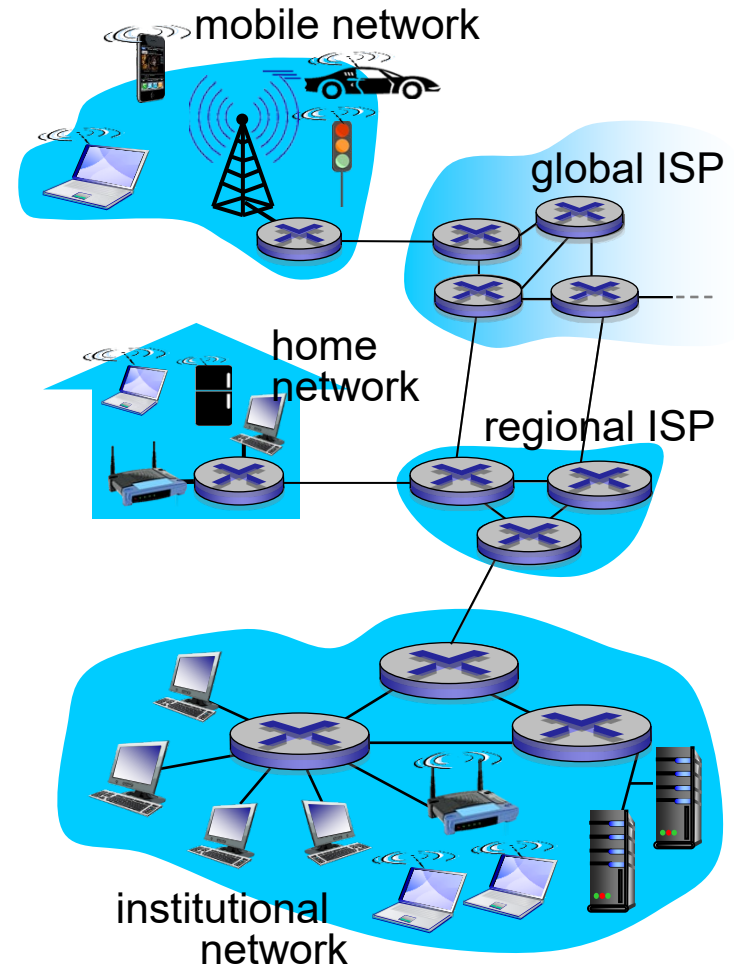——— wired
links

router

- **billions of connected computing devices:**
  - *hosts* = *end systems*
  - running *network apps*

- *communication links*
  - fiber, copper, radio, satellite
  - transmission rate: *bandwidth*

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

mobile network

global ISP

home network

regional ISP

institutional network

"Fun" Internet-connected devices

IP picture frame
http://www.ceiva.com/

Web-enabled toaster +
weather forecaster

Tweet-a-watt:
monitor energy use

Internet
refrigerator

sensorized,
bed
mattress

Internet phones

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

- *Internet:* "network of networks"
  - Interconnected ISPs
- *protocols* control sending, receiving of messages
  - e.g., TCP, IP, HTTP, Skype, 802.11
- *Internet standards*
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force

mobile network

global ISP

home network

regional ISP

institutional network
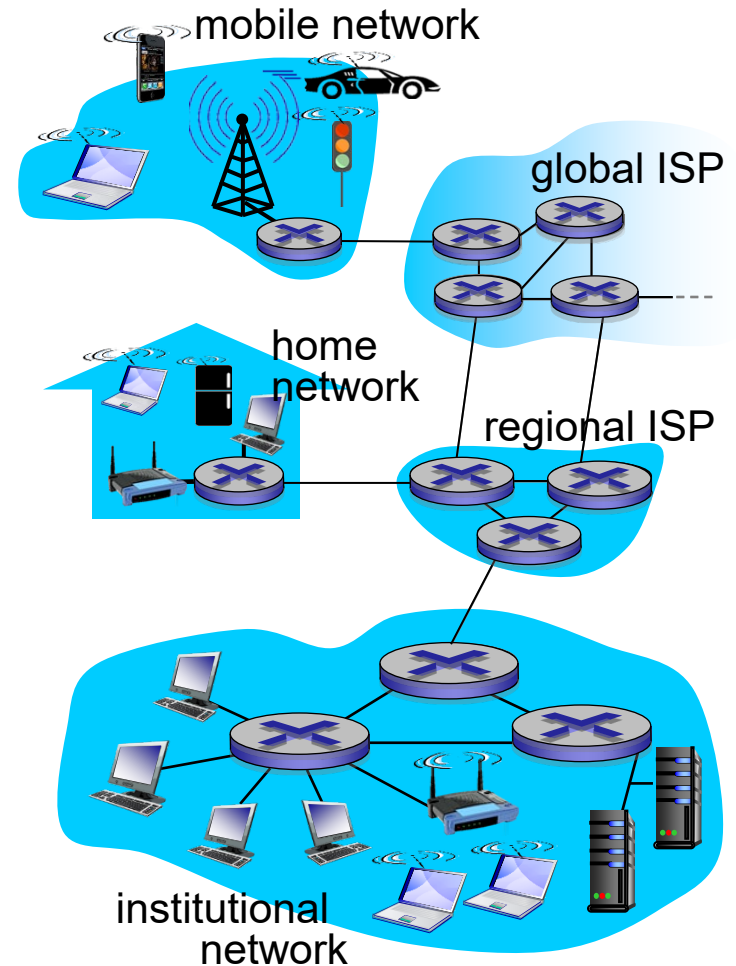
What's the Internet: a modern view

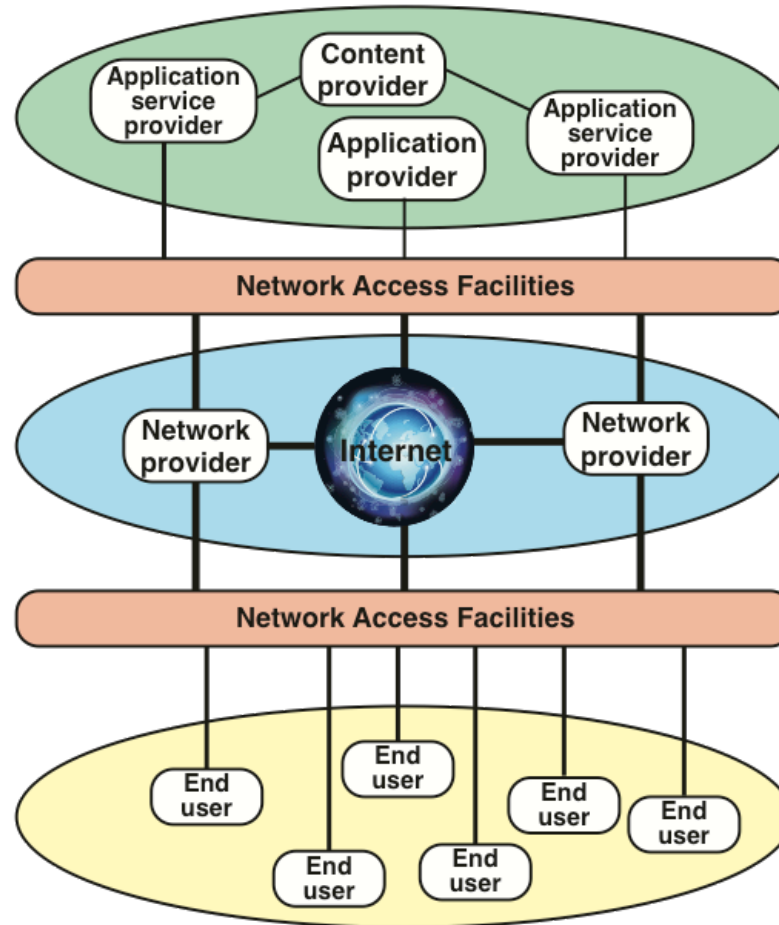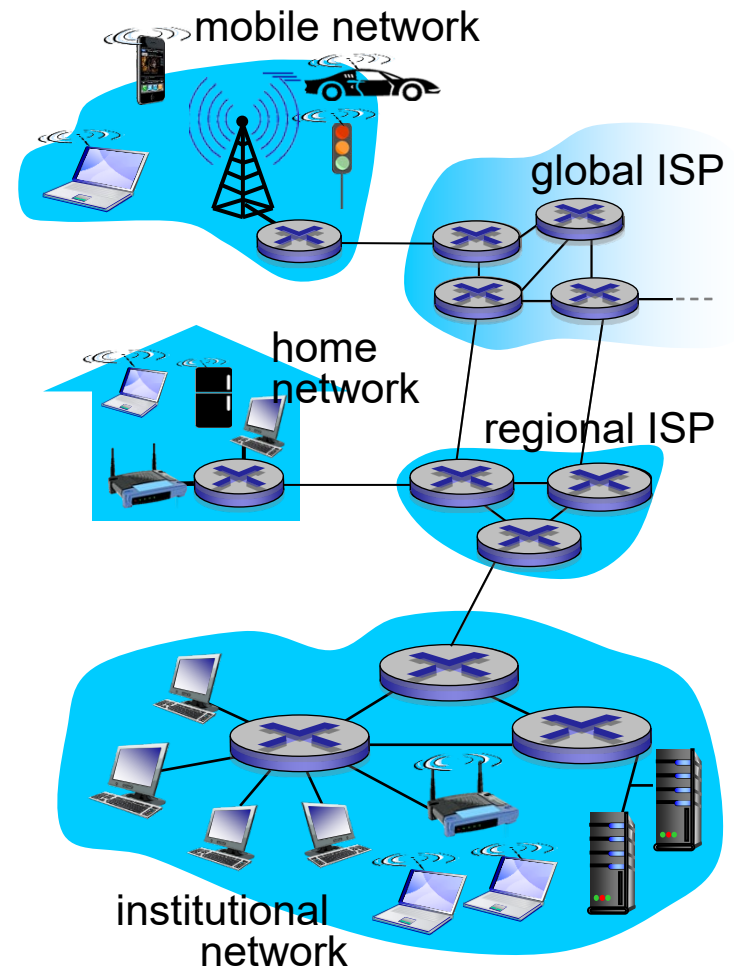

Figure 1.1 The Modern Networking Ecosystem

Introduction – Part 1

✓ What is the Internet
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✓ Architecture of the Internet – network edge
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   ✓ Physical media

What's the Internet: a service view

- *infrastructure that provides services to applications:*
  - Web, VoIP, email, games, e-commerce, social nets, …
- *provides programming interface to apps*
  - hooks that allow sending and receiving app programs to "connect" to Internet
  - provides service options, analogous to postal service

mobile network

global ISP

home network

regional ISP

institutional network

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What's a protocol?

human protocols:
- "what's the time?"
- "I have a question"
- introductions

… specific messages sent

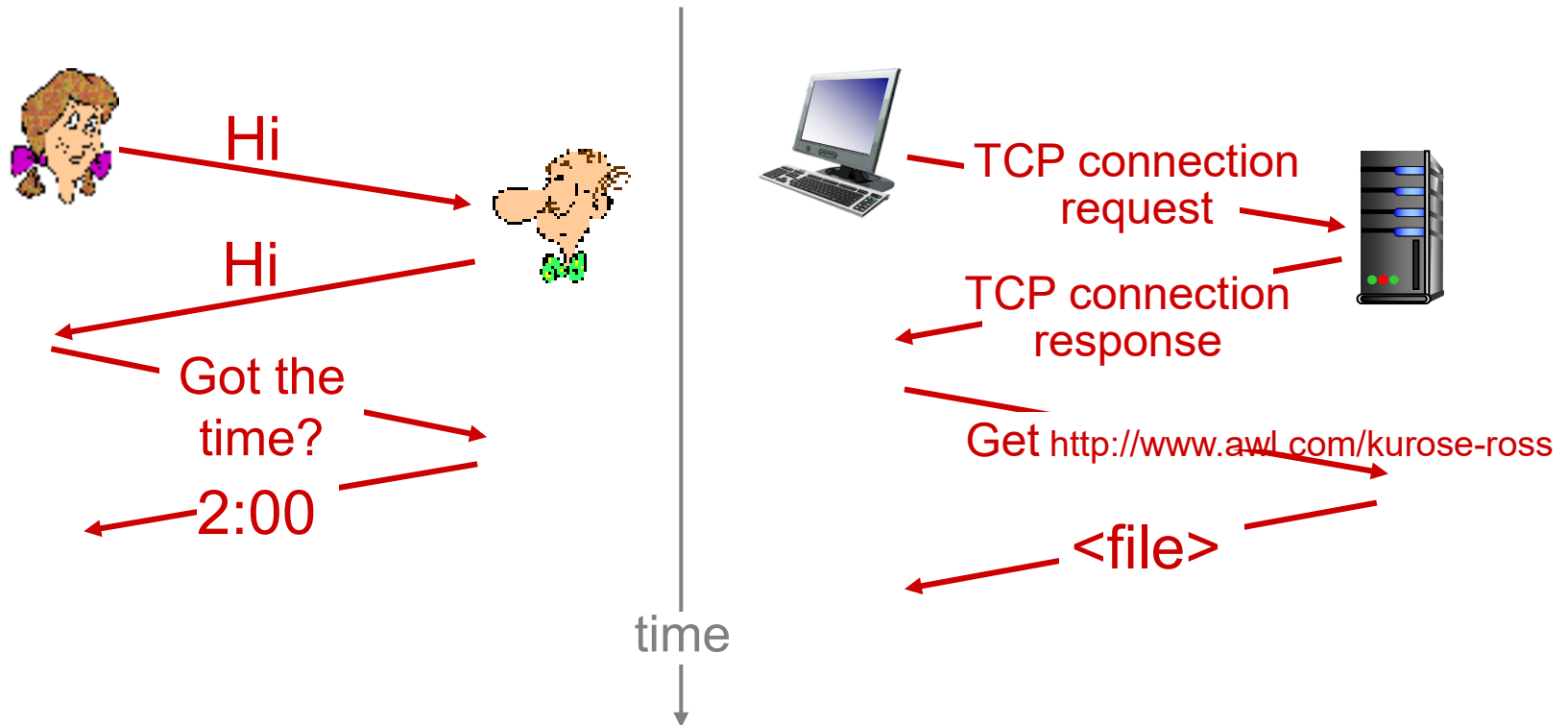… specific actions taken when messages received, or other events

network protocols:
- machines rather than humans
- all communication activity in Internet governed by protocols

protocols define format, order of messages sent and received among network entities, and actions taken on message transmission, receipt

What's a protocol?

a human protocol and a computer network protocol:

Hi

Hi

Got the time?

2:00

TCP connection request

TCP connection response

Get http://www.awl.com/kurose-ross

<file>

time

Q: other human protocols?

# References

Figures and slides are taken/adapted from:

- Jim Kurose, Keith Ross, "Computer Networking: A Top Down Approach", 7th ed. Addison-Wesley, 2012. All material copyright 1996-2016 J.F Kurose and K.W. Ross, All Rights Reserved
- Stallings, W. Data and Computer Communications, Pearson, 10th ed.

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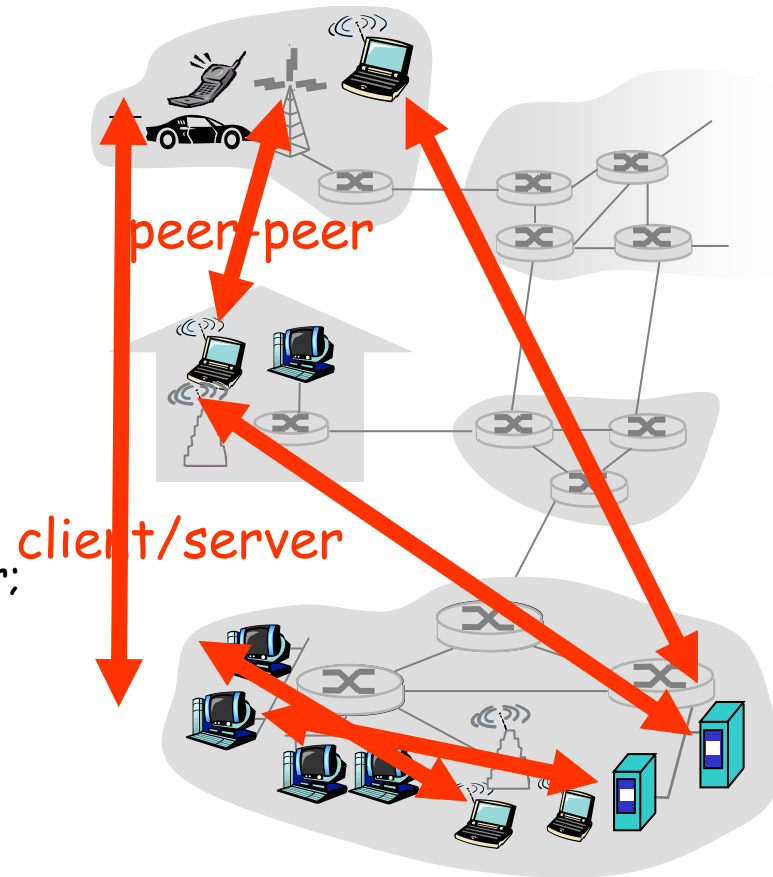   ✓ Physical media

A closer look at 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
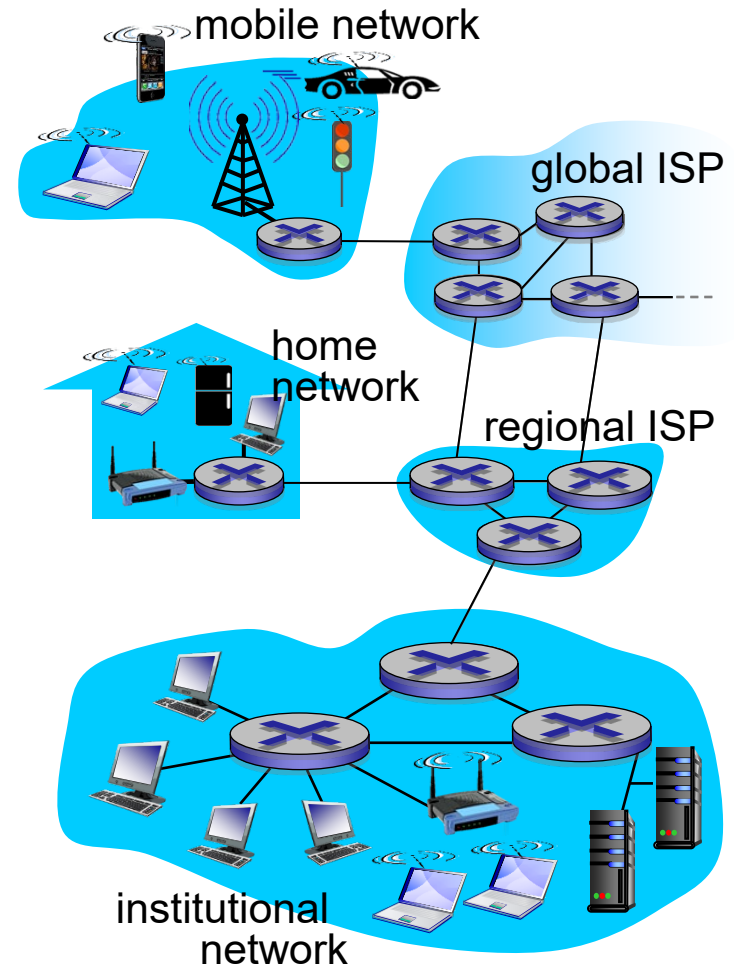
A closer look at network structure:

❑ **end systems (hosts):**
  - ❖ run application programs e.g. Web, email at "edge of network"

❑ **client/server model**
  - ❖ client host requests, receives service from always-on server
  - ❖ e.g. Web browser/server; email client/server

❑ **peer-peer model:**
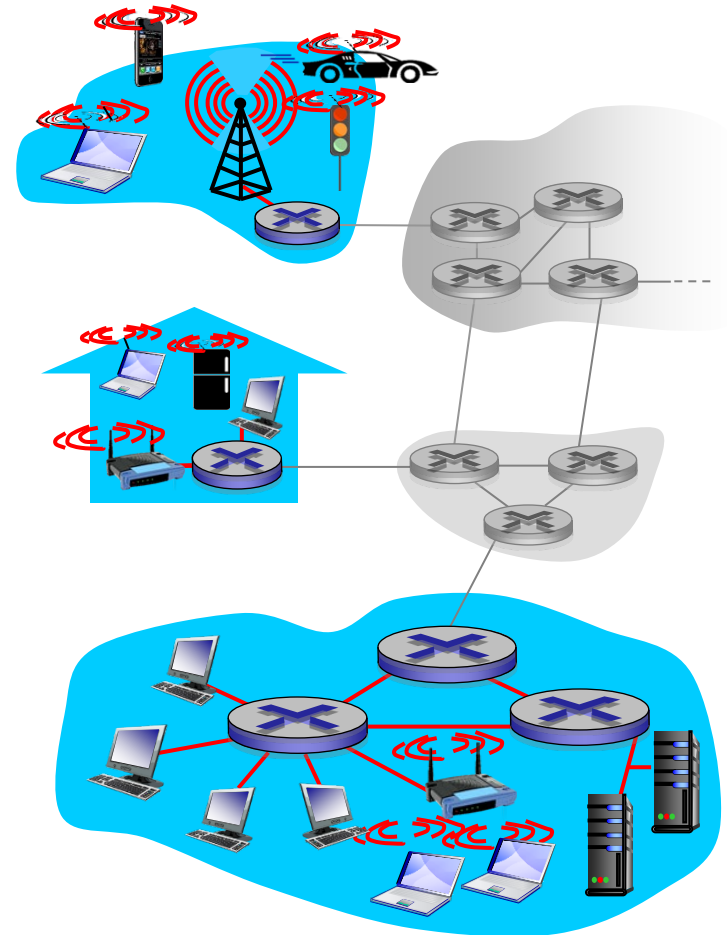 - ❖ minimal (or no) use of dedicated servers
  - ❖ e.g. Skype, BitTorrent

peer-peer

client/server

Access networks and physical media

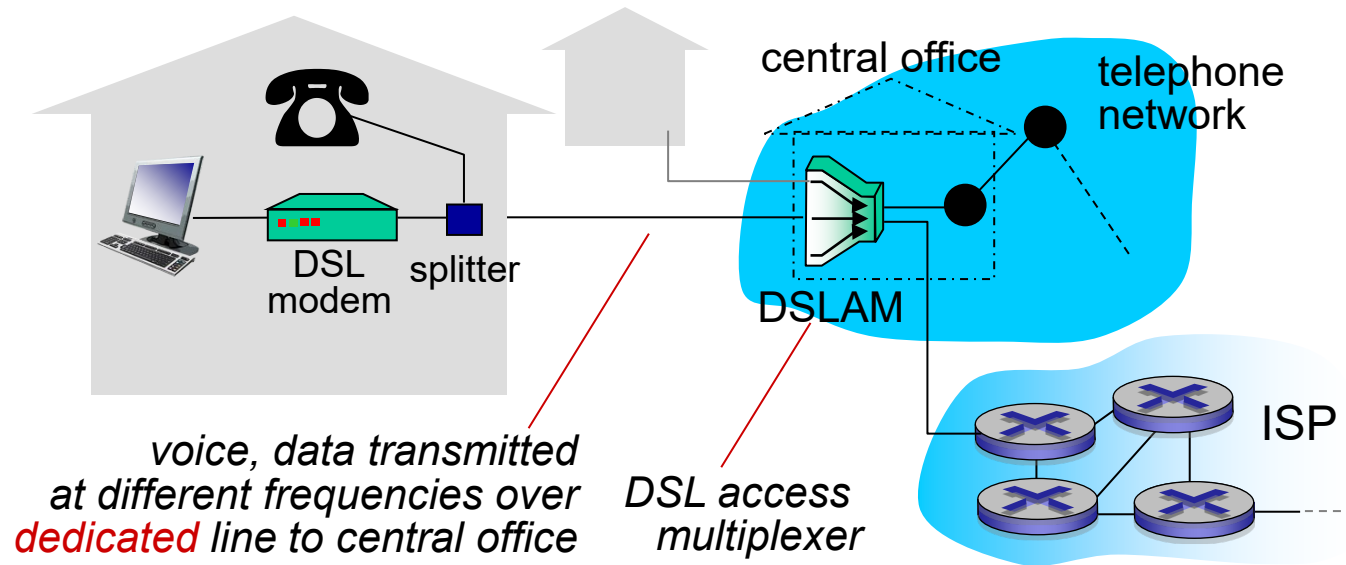*Q: How to connect end systems to edge router?*

- residential access nets
- institutional access networks (school, company)
- mobile access networks

keep in mind:

- bandwidth (related to bits per second) of access network?
- shared or dedicated?

Access network: digital subscriber line (DSL)

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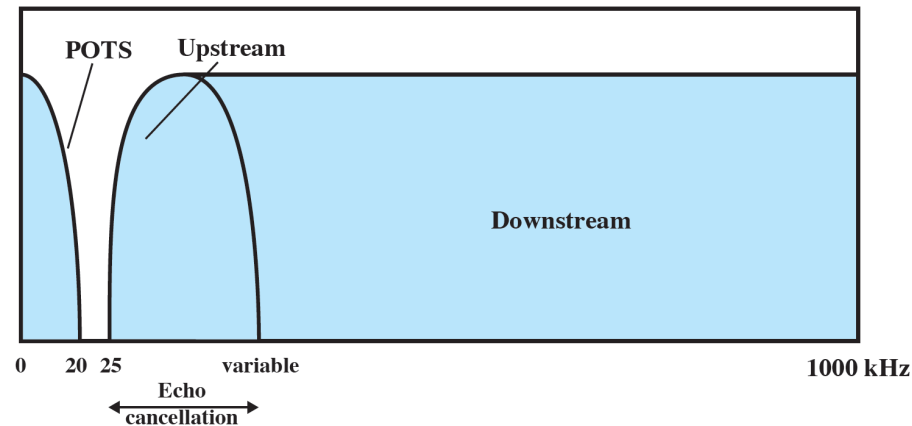*dedicated* line to central office

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)

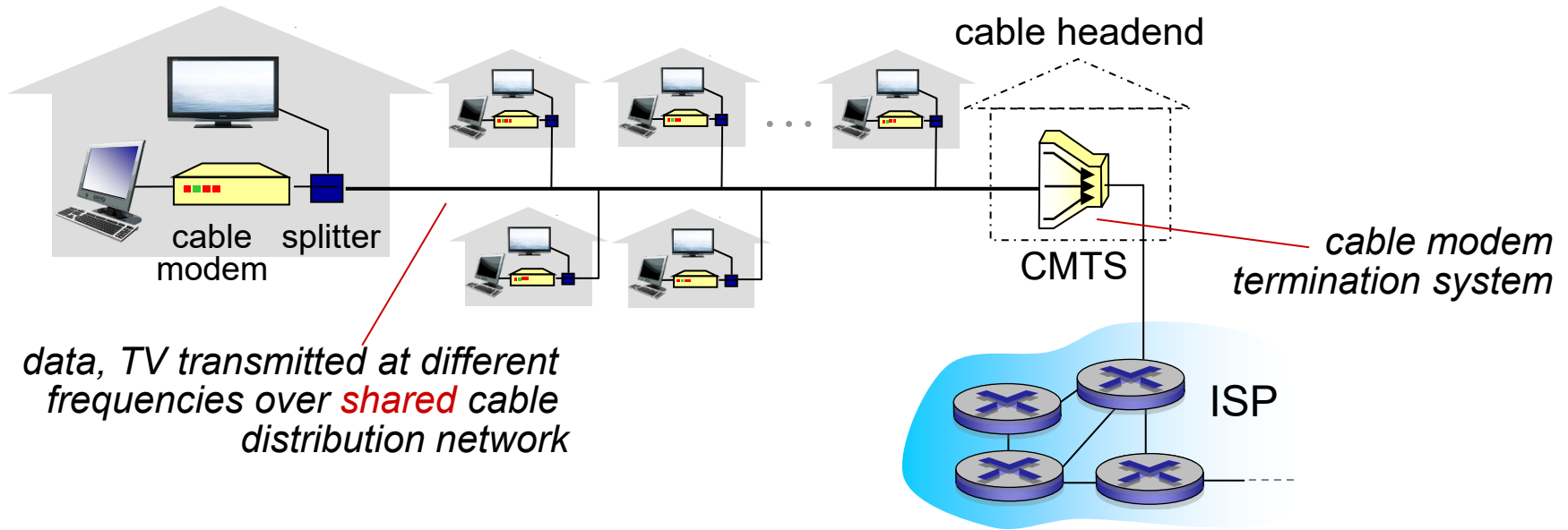# Access network: digital subscriber line (DSL)
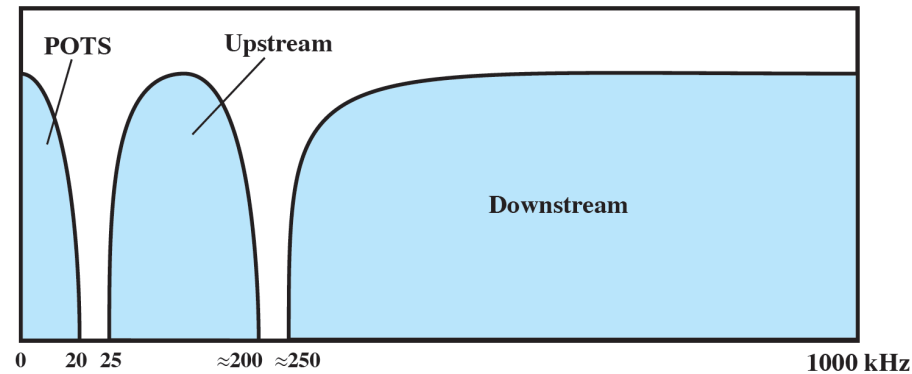
(a) Frequency-division multiplexing

(b) Echo cancellation

Access network: cable network

cable headend

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

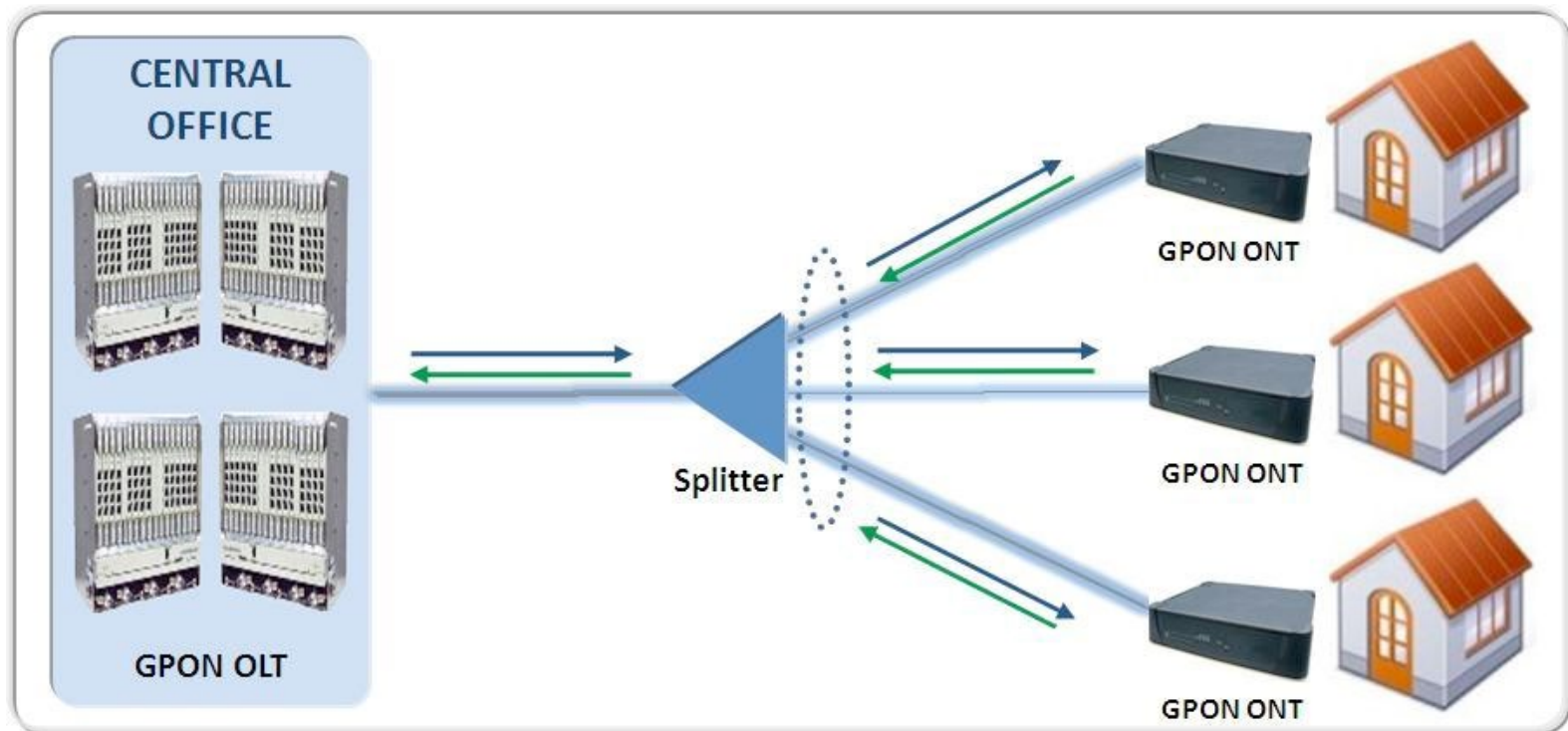cable modem

splitter

CMTS

cable modem termination system

ISP

- HFC: hybrid fiber coax
  - asymmetric: up to 30Mbps downstream transmission rate, 2 Mbps upstream transmission rate
- network of cable, fiber attaches homes to ISP router
  - homes *share access network* to cable headend
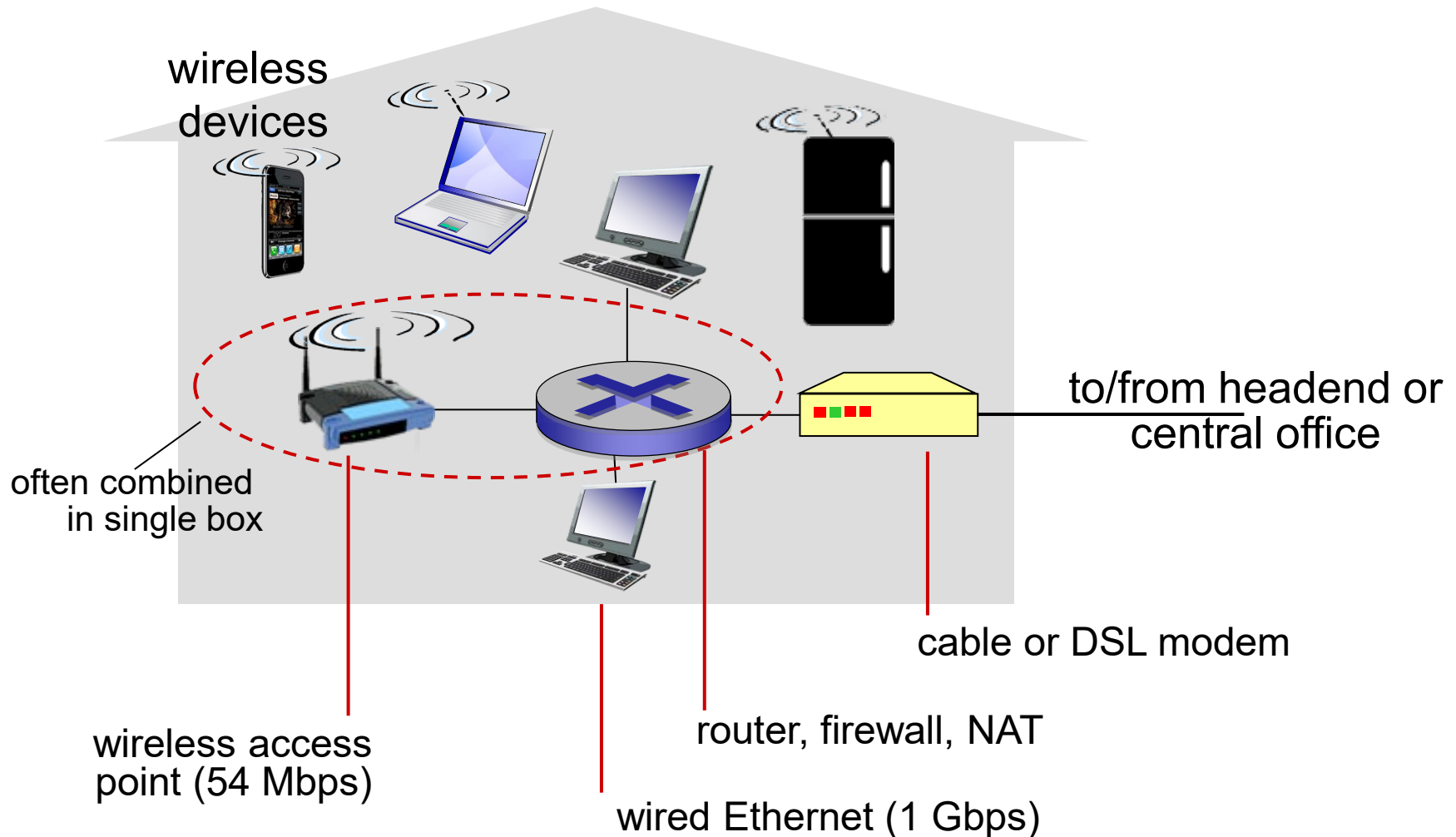 - unlike DSL, which has dedicated access to central office

Access network: cable network

cable headend

cable modem   splitter

Channels

V I D E O	V I D E O	V I D E O	V I D E O	V I D E O	V I D E O	D A T A	D A T A	C O N T R O L
1	2	3	4	5	6	7	8	9

frequency division multiplexing: different channels transmitted in different frequency bands

Access network: fiber to the home (FTTH)

Access network: home network

wireless
devices

often combined
in single box

to/from headend or
central office

cable or DSL modem

router, firewall, NAT

wireless access
point (54 Mbps)

wired Ethernet (1 Gbps)

Enterprise access networks (Ethernet)

institutional link to ISP (Internet)

institutional router

Ethernet switch

institutional mail, web servers
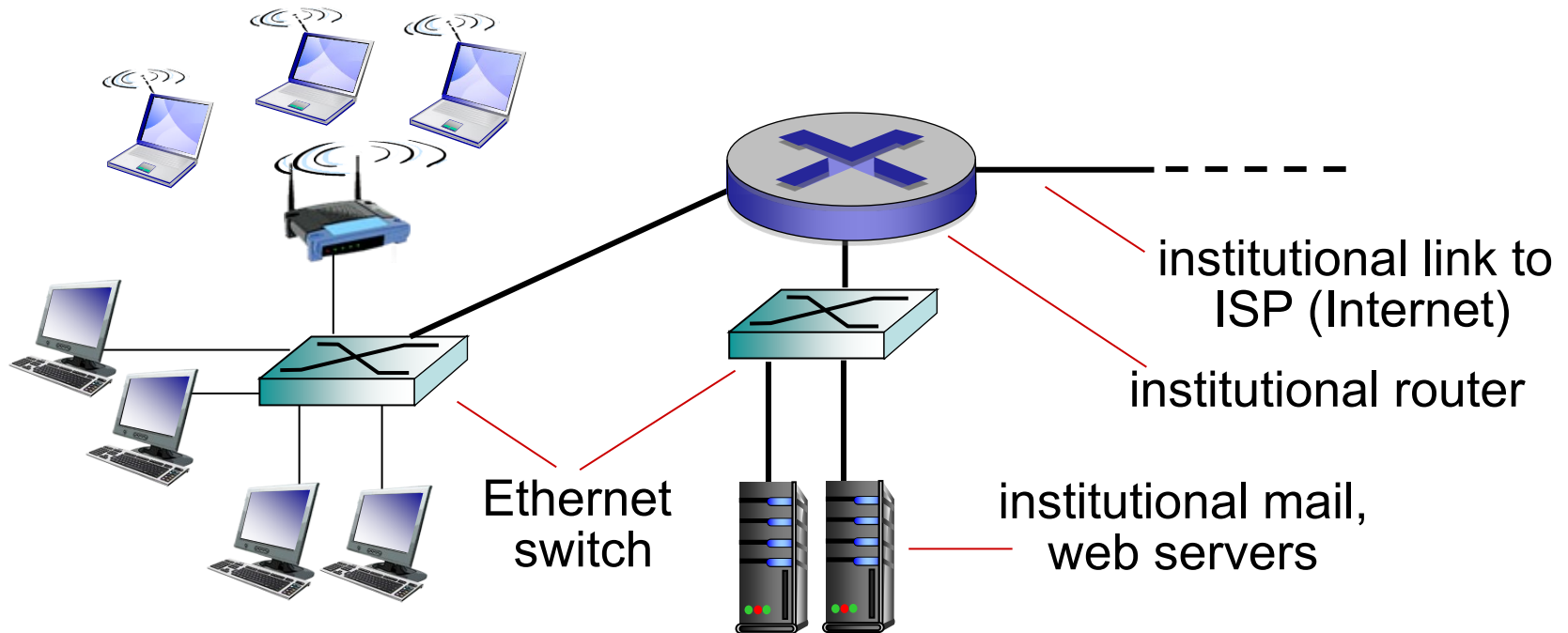
- typically used in companies, universities, etc.
- 10 Mbps, 100Mbps, 1Gbps, 10Gbps, 100 Gbps transmission rates
- today, end systems typically connect into Ethernet switch
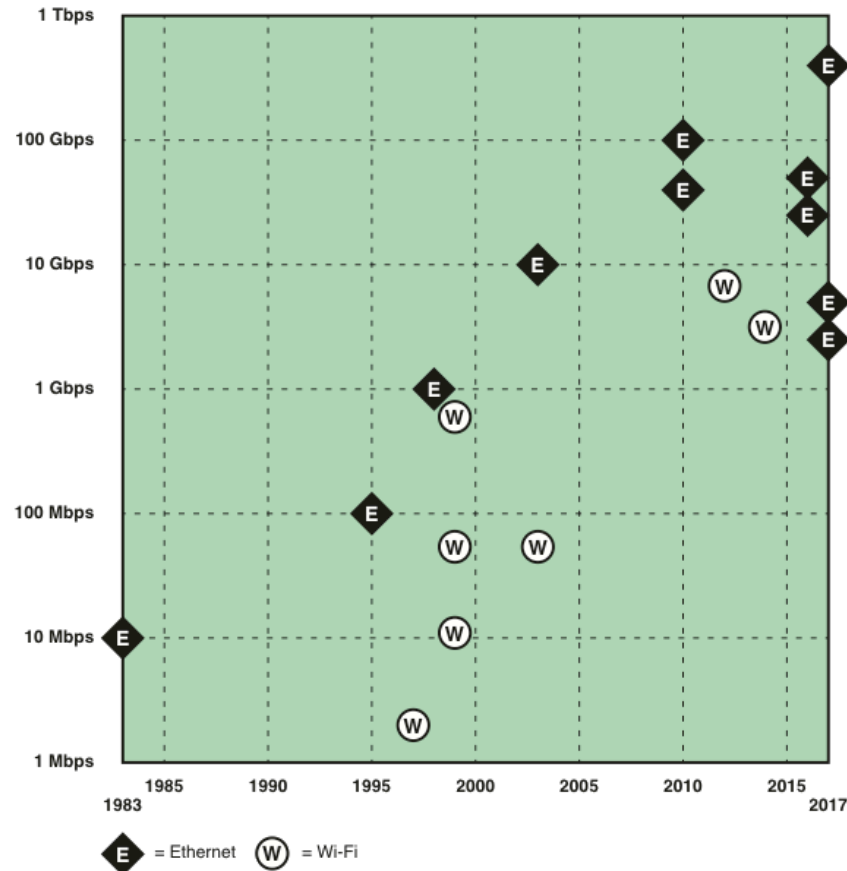
Enterprise access networks (Ethernet)

Figure 1.5 Ethernet and Wi-Fi Timelines

Wireless access networks

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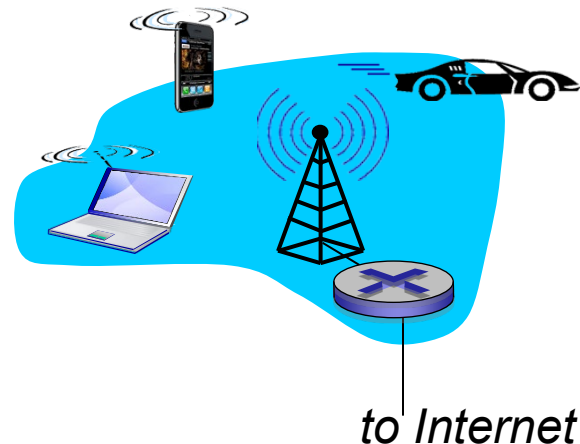 - via base station aka "access point"

wireless LANs:

- within building (100 ft.)
- 802.11 (WiFi): 600 Mbps, 3 Gbps, 6 Gpbs transmission rate

wide-area wireless access

- provided by telco (cellular) operator, typically 10's km
- 4G, 5G (new radio interface)
- Variety of coverage (picocells, femtocells, microcells, macrocells)

to Internet

to Internet

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Host: sends *packets* of data

host sending function:

- takes application message
- breaks into smaller chunks, known as *packets*, of length *L* bits
- transmits packet into access network at *transmission rate R*
  - link transmission rate, aka link *capacity*

two packets, *L* bits each

2 1

host

R: link transmission rate
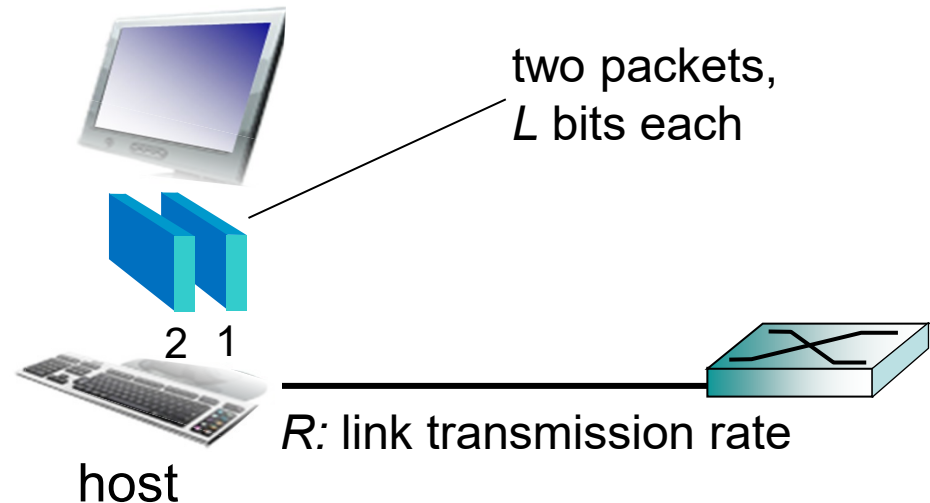
$$\text{packet transmission delay} = \text{time needed to transmit } L\text{-bit packet into link} = \frac{L \text{ (bits)}}{R \text{ (bits/sec)}}$$

Physical media

- **bit:** propagates between transmitter/receiver pairs
- **physical link:** what lies between transmitter & receiver
- **guided media:**
  - signals propagate in solid media: copper, fiber, coax
- **unguided media:**
  - signals propagate freely, e.g., radio
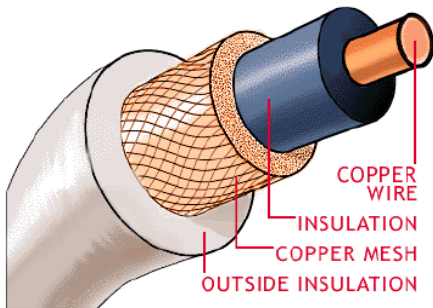
twisted pair (TP)

- two insulated copper wires
  - Category 5: 100 Mbps, 1 Gbps Ethernet
  - Category 6: 10Gbps

Physical media: coax, fiber

coaxial cable:

- two concentric copper conductors
- bidirectional
- broadband:
  - multiple channels on cable
  - HFC

COPPER WIRE
INSULATION
COPPER MESH
OUTSIDE INSULATION

fiber optic cable:

- glass fiber carrying light pulses, each pulse a bit
- high-speed operation:
  - high-speed point-to-point transmission (e.g., 10's-100's Gbps transmission rate)
- low error rate:
  - repeaters spaced far apart
  - immune to electromagnetic noise

Optical fiber
light ray
core
cladding
plastic coating
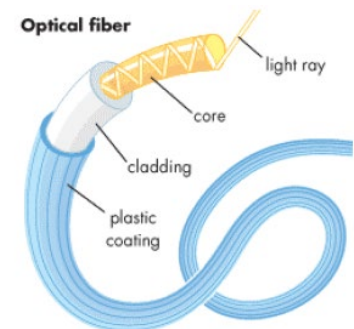
https://virtual.itca.edu.sv/Mediadores/irmfi1/IRMFI_15.htm

Physical media: radio

- signal carried in electromagnetic spectrum
- no physical "wire"
- bidirectional
- propagation environment effects:
  - reflection
  - obstruction by objects
  - interference

radio link types:

- terrestrial microwave
  - e.g. up to 45 Mbps channels
- LAN (e.g., WiFi)
  - 54 Mbps
- wide-area (e.g., cellular)
  - 4G cellular: ~ 10 Mbps
- satellite
  - Kbps to 45Mbps channel (or multiple smaller channels)
  - 270 msec end-end delay
  - geosynchronous versus low altitude

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- Stallings, W. Data and Computer Communications, Pearson, 10th ed.
- Stallings, W. Foundations of Modern Computer Networking, Addison Wesley, 2016.