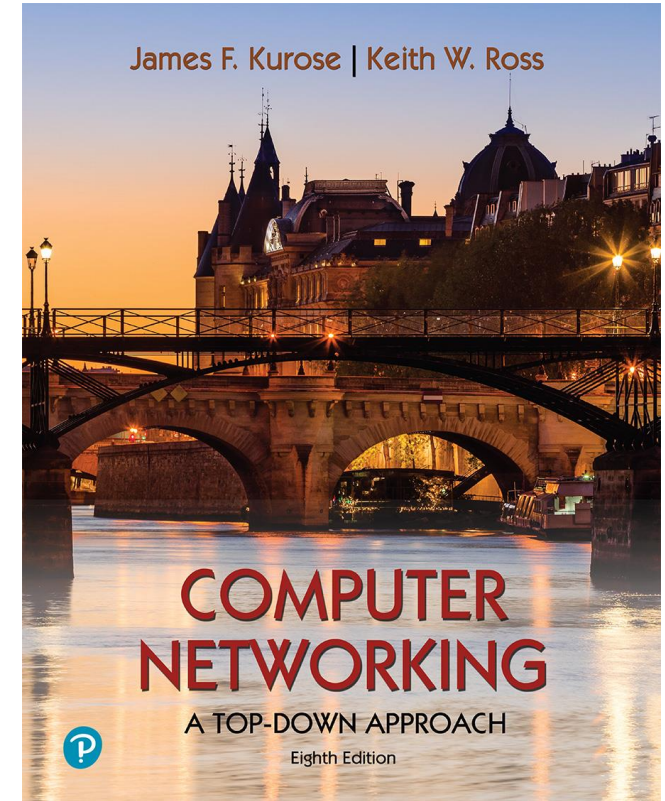


Basics of Computer Networks & Internet

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*Computer Networking: A
Top-Down Approach*

8th edition

Jim Kurose, Keith Ross
Pearson, 2020

Outline

- What is a computer network?
- What *is* the Internet?
- What *is* a protocol?
- **Network edge:** hosts, access network, physical media
- **Network core:** packet/circuit switching, internet structure
- **Network Performance:** loss, delay, throughput, etc
- Protocol layers, architecture, service models

Computer Networks

- What is a computer network?
- Other types of networks?
- How is a computer network different from other types of networks?



Computer Network Types



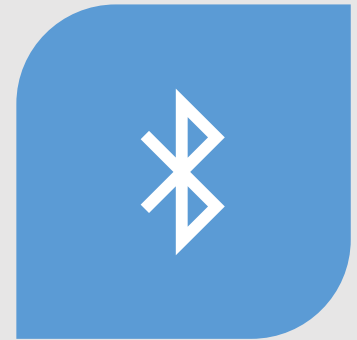
LOCAL AREA NETWORK:
ETHERNET



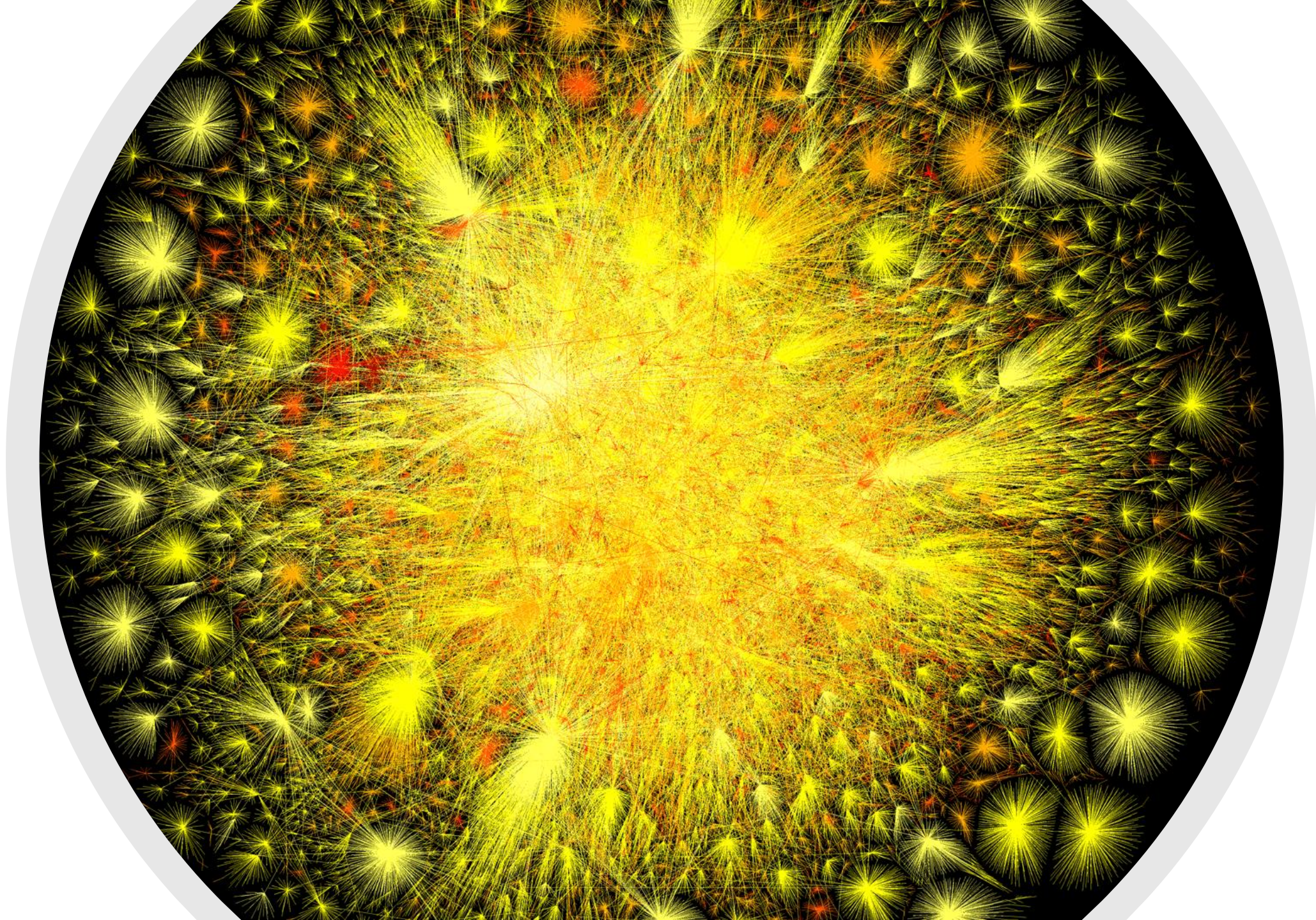
WIRELESS LAN (WLAN): WI-FI



WIDE AREA NETWORK
(WAN): 4G/5G, INTERNET



PERSONAL AREA NETWORK
(PAN): BLUETOOTH





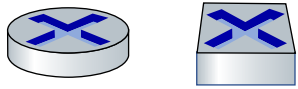
THE
INTERNET😊

The Internet: a “nuts and bolts” view



Billions of connected computing *devices*:

- *hosts* = end systems
- running *network apps* at Internet's “edge”



Packet switches: forward packets (chunks of data)

- *routers, switches*

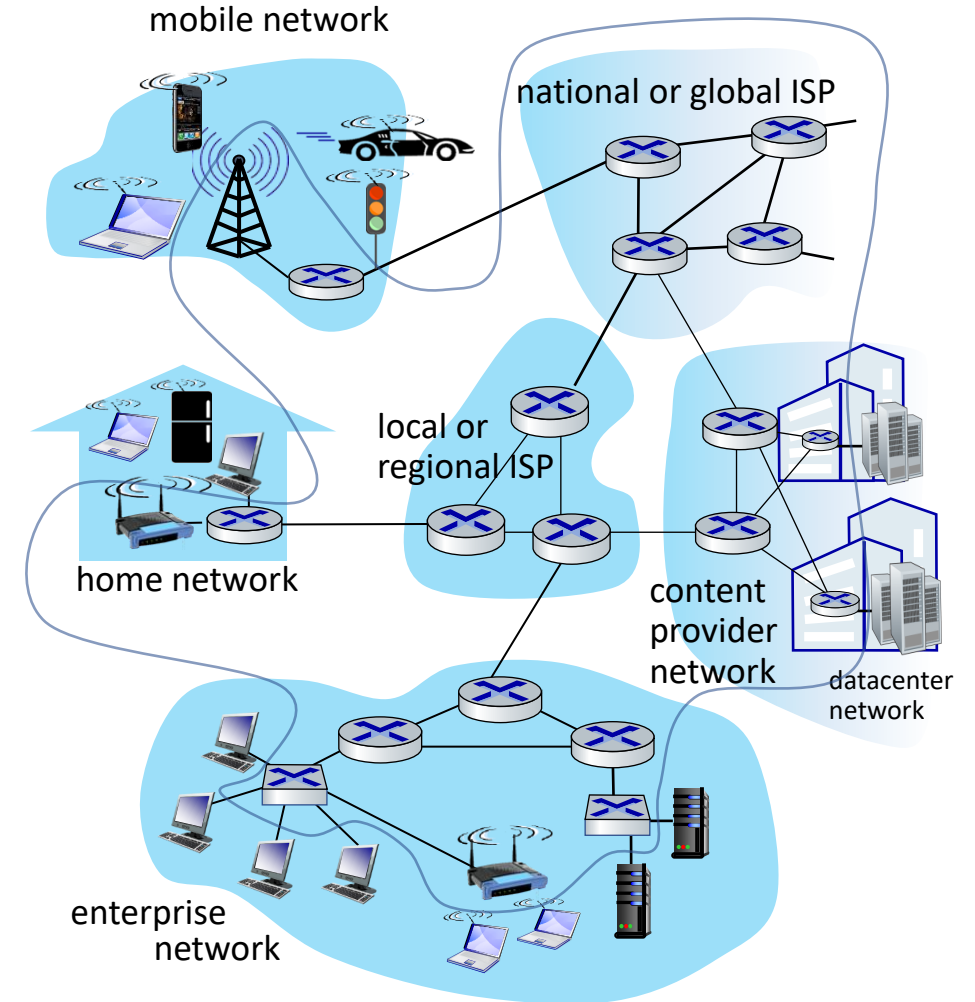
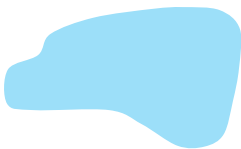
Communication links

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



Networks

- collection of devices, routers, links: managed by an organization



“Fun” Internet-connected devices



Amazon Echo



Internet refrigerator



Security Camera



Internet phones



IP picture frame



Slingbox: remote control cable TV



Gaming devices



Pacemaker & Monitor



Web-enabled toaster + weather forecaster



sensorized, bed mattress



Fitbit



AR devices



diapers



Tweet-a-watt:
monitor energy use



bikes



cars

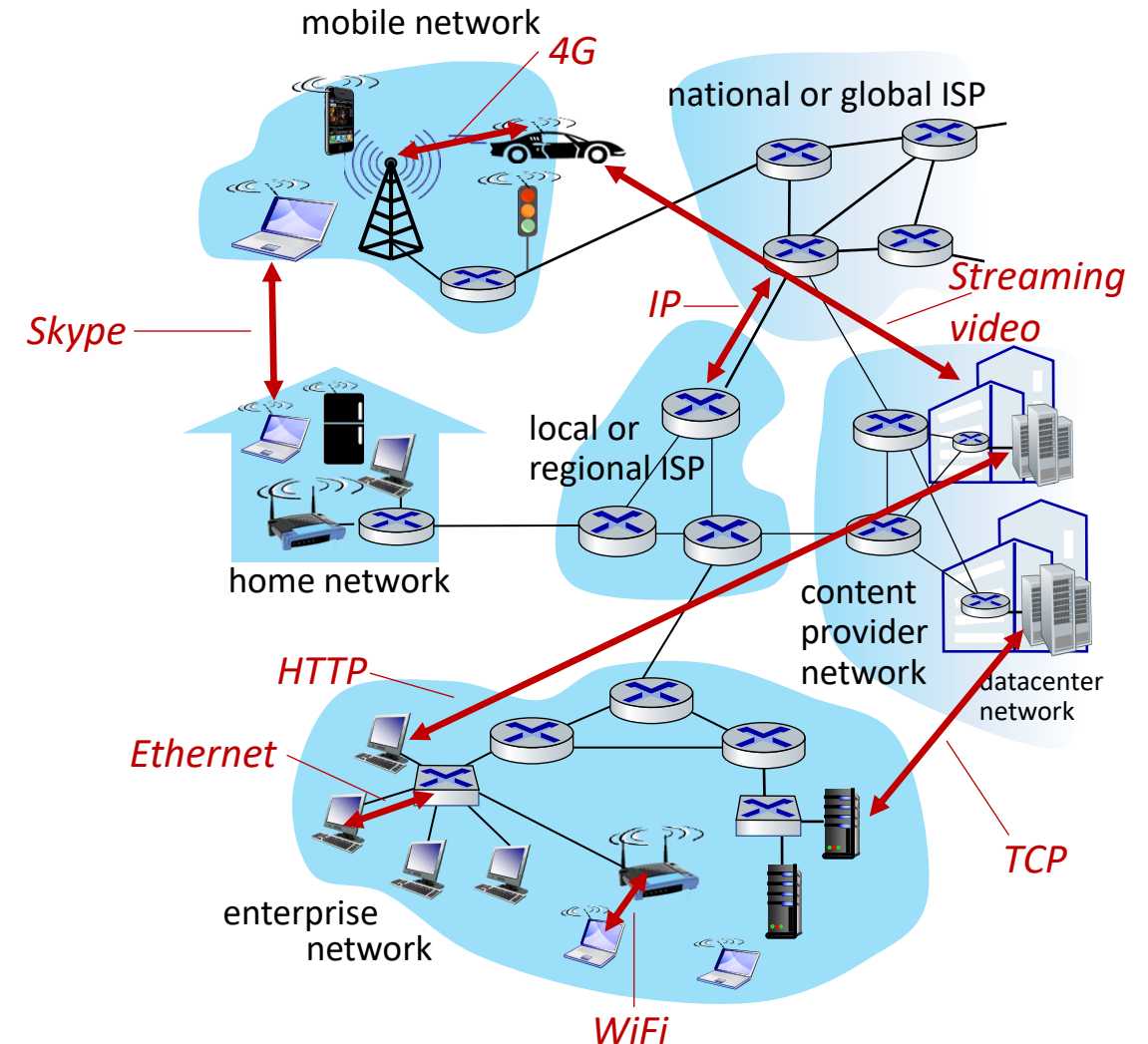


scooters

Others?

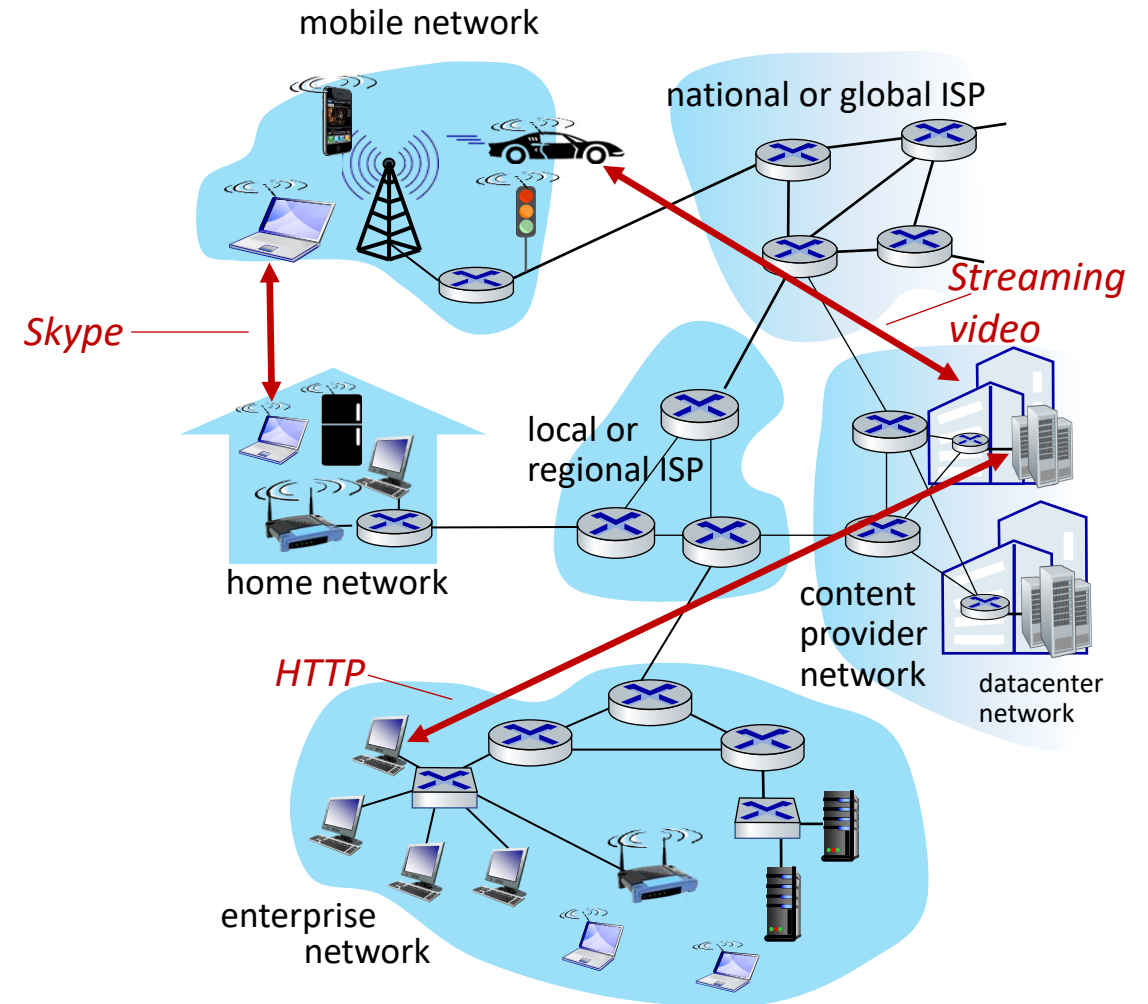
The Internet: a “nuts and bolts” view

- *Internet: “network of networks”*
 - Interconnected ISPs
- *protocols are everywhere*
 - control sending, receiving of messages
 - e.g., HTTP (Web), Streaming video, Skype, TCP, IP, WiFi, 4/5G, Ethernet
- *Internet standards*
 - RFC: Request for Comments
 - IETF: Internet Engineering Task Force



The Internet: a “services” view

- *Infrastructure* that provides services to applications:
 - Web, streaming video, multimedia teleconferencing, email, games, e-commerce, social media, inter-connected appliances, ...
- provides *programming interface* to distributed applications:
 - “hooks” allowing sending/receiving apps to “connect” to, use Internet transport service
 - provides service options, analogous to postal service



What's a protocol?

Human protocols:

- “what’s the time?”
- “I have a question”
- introductions

Rules for:

- ... specific messages sent
- ... specific actions taken
when message received,
or other events

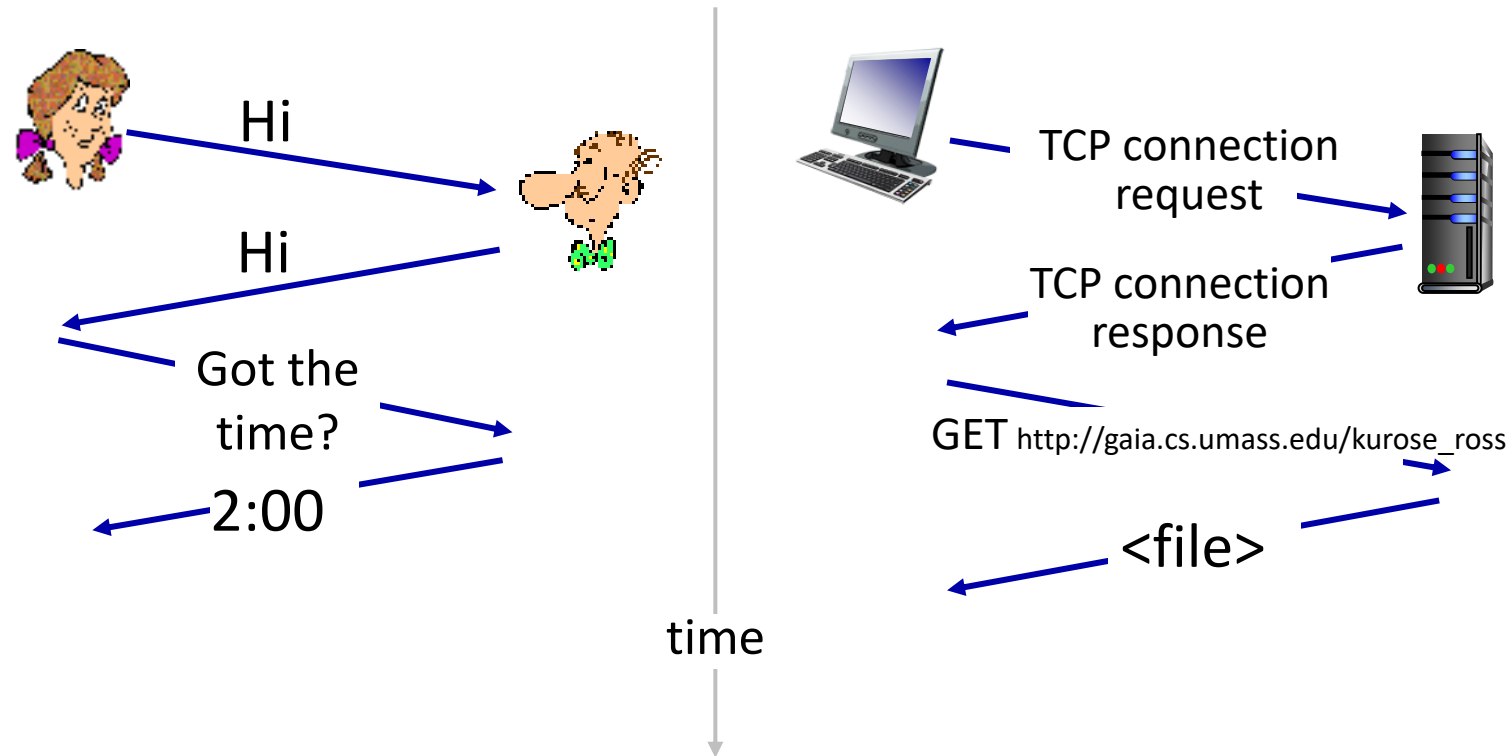
Network protocols:

- computers (devices) rather than humans
- all communication activity in Internet
governed by protocols

*Protocols define the **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:



Q: other human protocols?

Network Communication Protocols

- TCP (transmission control protocol)
- UDP (user data protocol)
- IP (internet protocol)
- HTTP (hypertext transfer protocol)
- SMTP (simple mail transfer protocol)
- FTP (file transfer protocol)
- 802.3 (Ethernet) Protocol
- 802.11 (Wi-Fi) Protocol

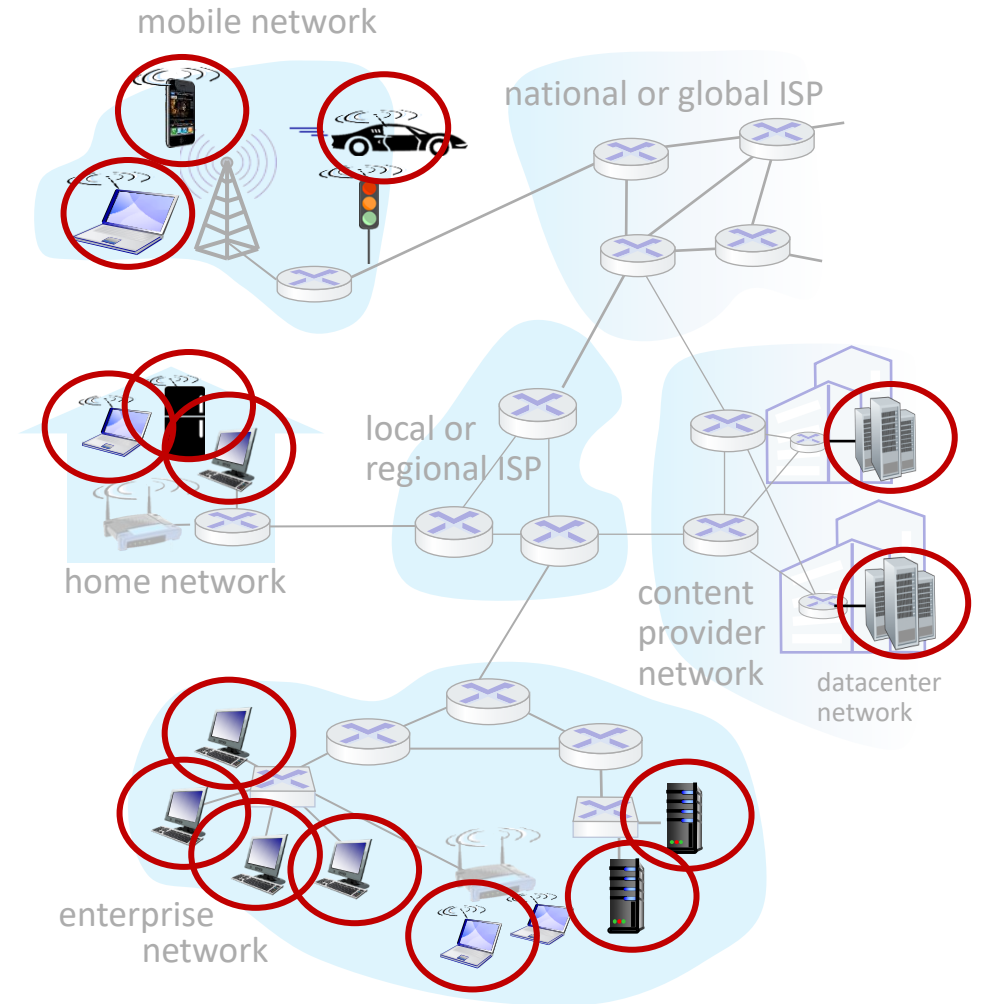
Outline

- What is a computer network?
- What *is* the Internet?
- What *is* a protocol?
- **Network edge:** hosts, access network, physical media
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A closer look at Internet structure

Network edge:

- hosts: clients and servers
- servers often in data centers



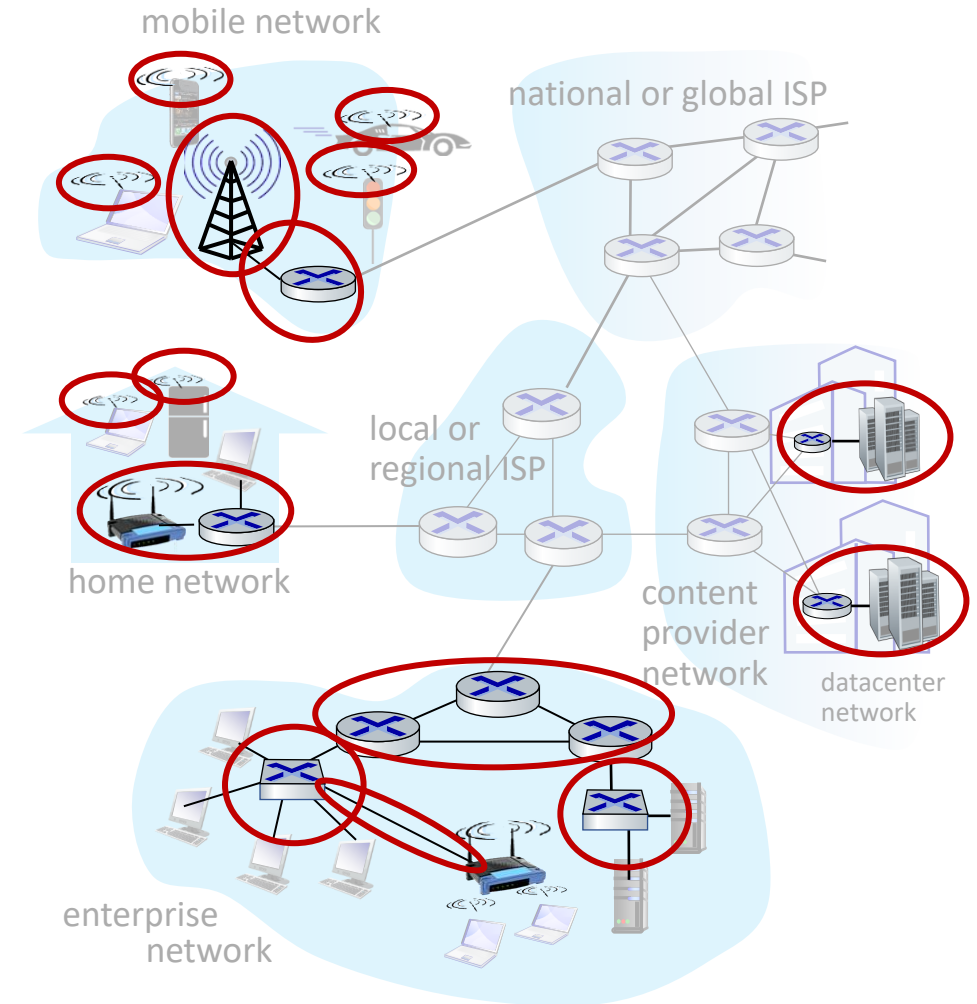
A closer look at Internet structure

Network edge:

- hosts: clients and servers
- servers often in data centers

Access networks, physical media:

- wired, wireless communication links



A closer look at Internet structure

Network edge:

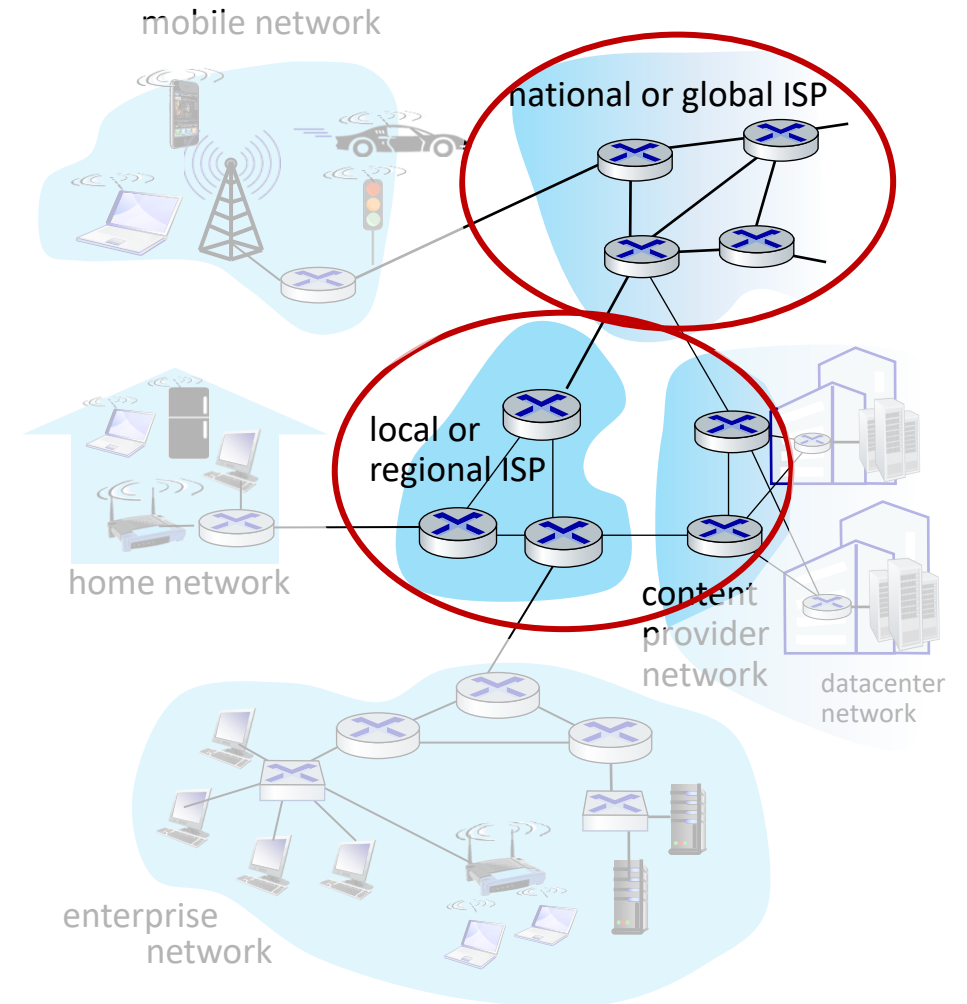
- hosts: clients and servers
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Access networks, physical media:

- wired, wireless communication links

Network core:

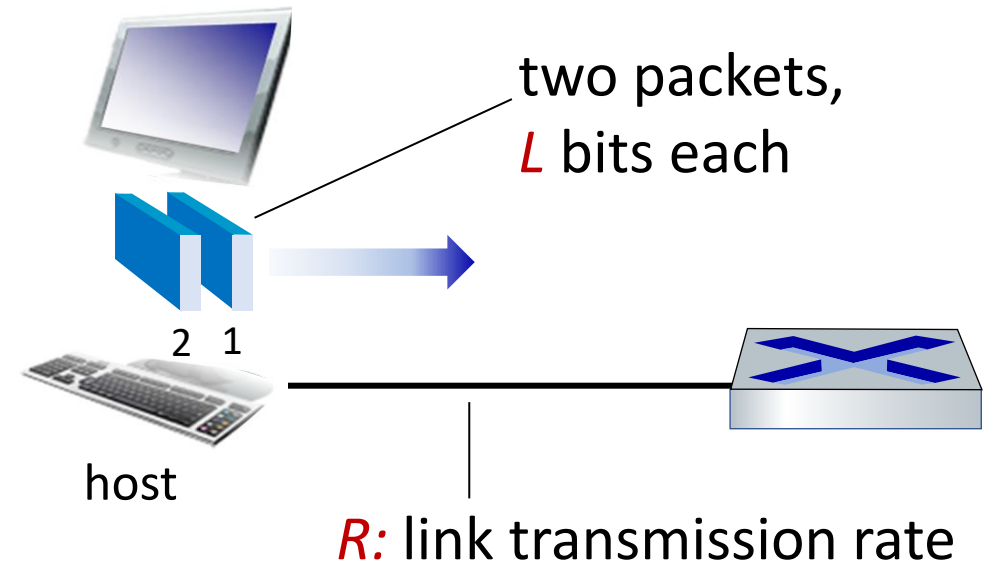
- interconnected routers
- network of networks



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, aka link bandwidth*



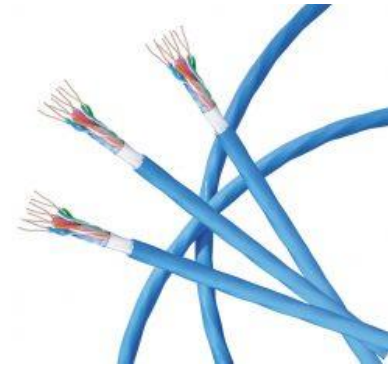
$$\begin{array}{l} \text{packet} \\ \text{transmission} \\ \text{delay} \end{array} = \begin{array}{l} \text{time needed to} \\ \text{transmit } L\text{-bit} \\ \text{packet into link} \end{array} = \frac{L \text{ (bits)}}{R \text{ (bits/sec)}}$$

Links: physical media

- **bits:** propagate between transmitter/receiver pairs using electromagnetic waves or light pulses
- **physical link/media:** what lies between transmitter & receiver
- **guided media:**
 - signals propagate in solid media: copper, fiber, coax
- **unguided media:**
 - signals propagate freely, e.g., radio channels

Twisted pair (TP)

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



Links: physical media

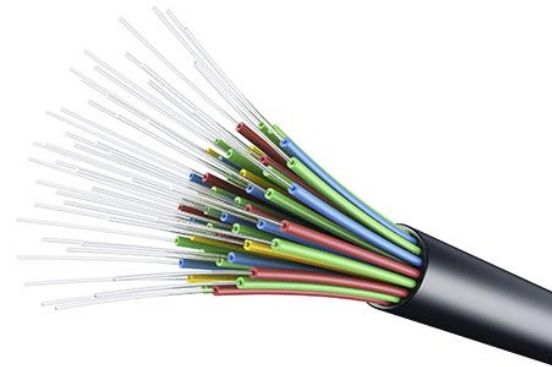
Coaxial cable:

- two concentric copper conductors
- bidirectional
- broadband:
 - multiple frequency channels on cable
 - 100's Mbps per channel



Fiber optic cable:

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



Links: physical media

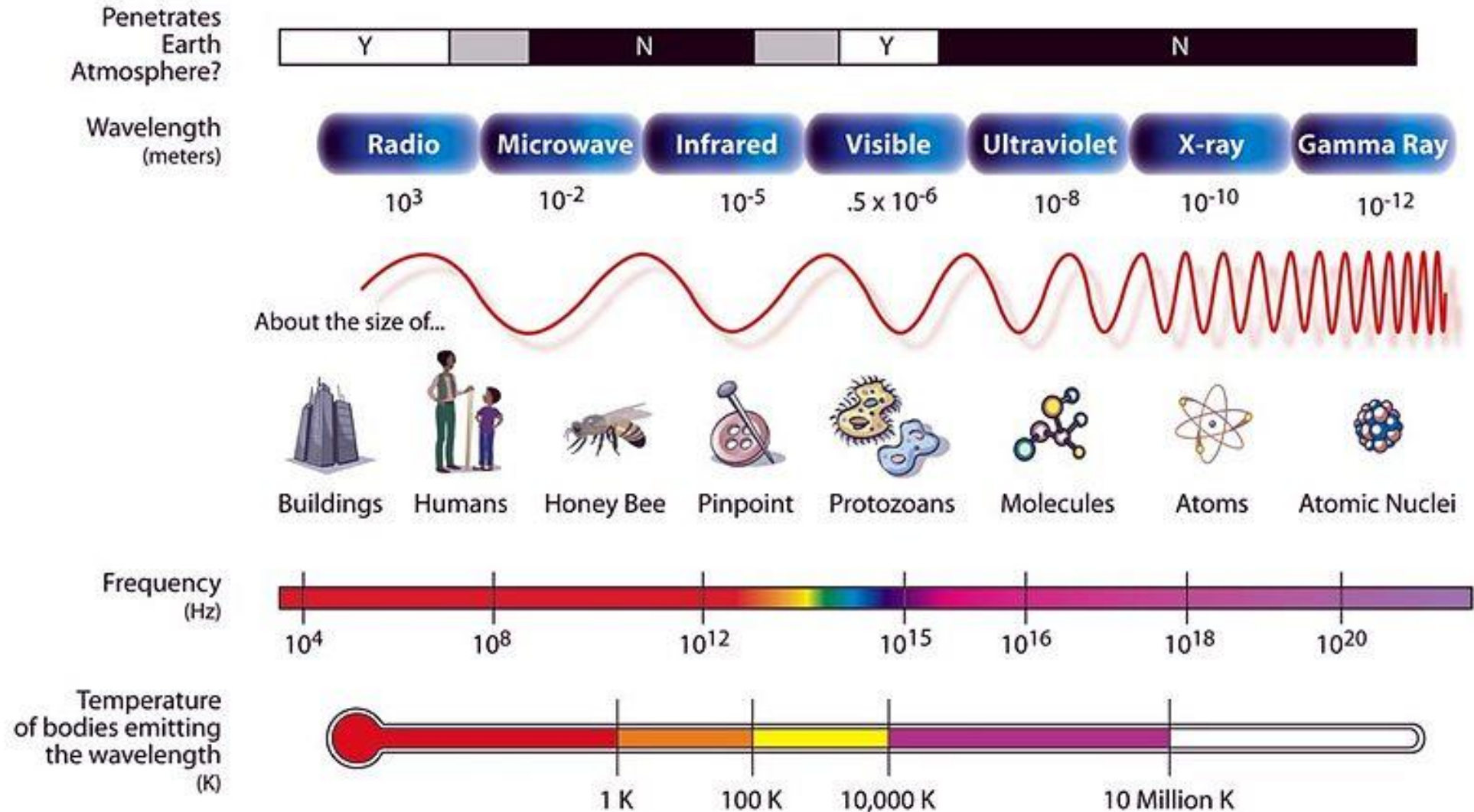
Wireless radio

- signal carried in various “bands” in electromagnetic spectrum
- no physical “wire”
- broadcast, “half-duplex” (sender to receiver)
- propagation environment effects:
 - reflection
 - obstruction by objects
 - Interference/noise

Radio link types:

- **Wireless LAN (WiFi)**
 - 10-100’s Mbps; 10’s of meters
- **wide-area** (e.g., 4G/5G cellular)
 - 10’s Mbps (4G) over ~10 Km
- **Bluetooth**: cable replacement
 - short distances, limited rates
- **terrestrial microwave**
 - point-to-point; 45 Mbps channels
- **satellite**
 - up to < 100 Mbps (Starlink) downlink
 - 270 msec end-end delay (geostationary)

THE ELECTROMAGNETIC SPECTRUM



Radio waves

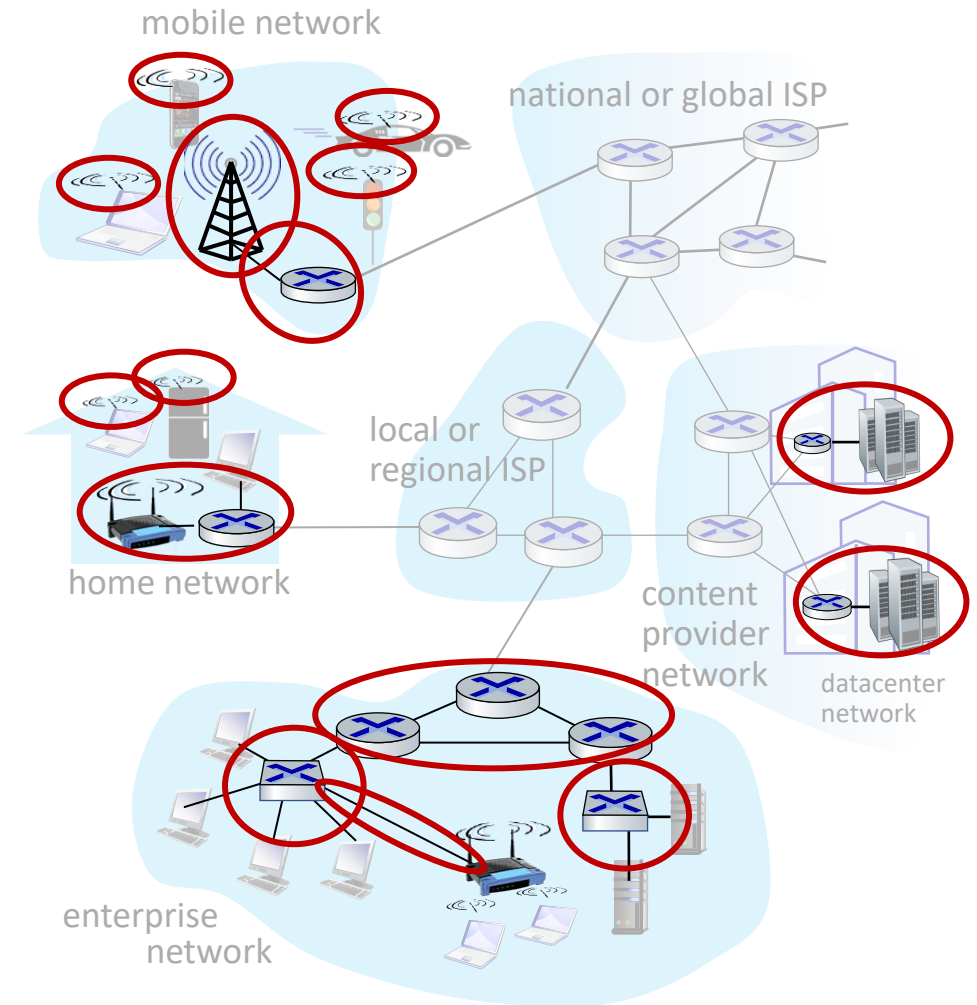
- One type of EM waves
- 30 Hz to 300 GHz
- 1-30 GHz also called as Microwaves
- 30-300 GHz also called as Millimeter waves
 - Unused, abundant, main candidate spectrum for 5G operations

Band	Frequency range	Wavelength range
Extremely Low Frequency (ELF)	<3 kHz	>100 km
Very Low Frequency (VLF)	3 to 30 kHz	10 to 100 km
Low Frequency (LF)	30 to 300 kHz	1 m to 10 km
Medium Frequency (MF)	300 kHz to 3 MHz	100 m to 1 km
High Frequency (HF)	3 to 30 MHz	10 to 100 m
Very High Frequency (VHF)	30 to 300 MHz	1 to 10 m
Ultra High Frequency (UHF)	300 MHz to 3 GHz	10 cm to 1 m
Super High Frequency (SHF)	3 to 30 GHz	1 to 10 cm
Extremely High Frequency (EHF)	30 to 300 GHz	1 mm to 1 cm

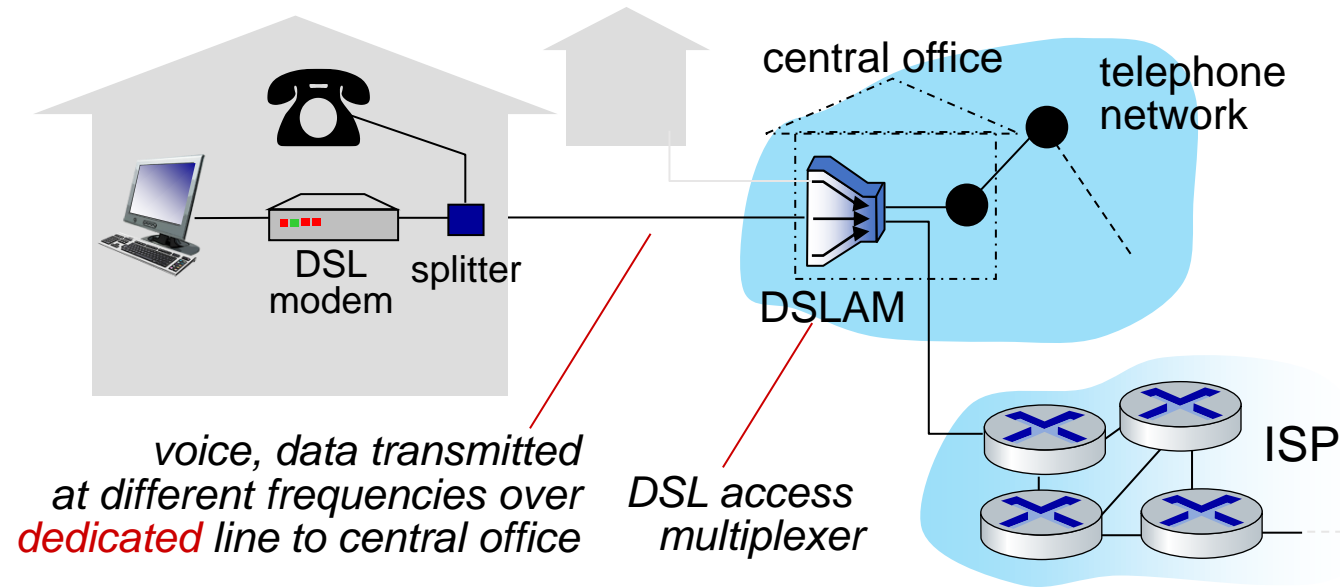
Access networks and physical media

Q: How to connect end systems to edge router?

- residential access networks
- enterprise access networks (school, company)
- wireless access networks (WiFi, 4G/5G)

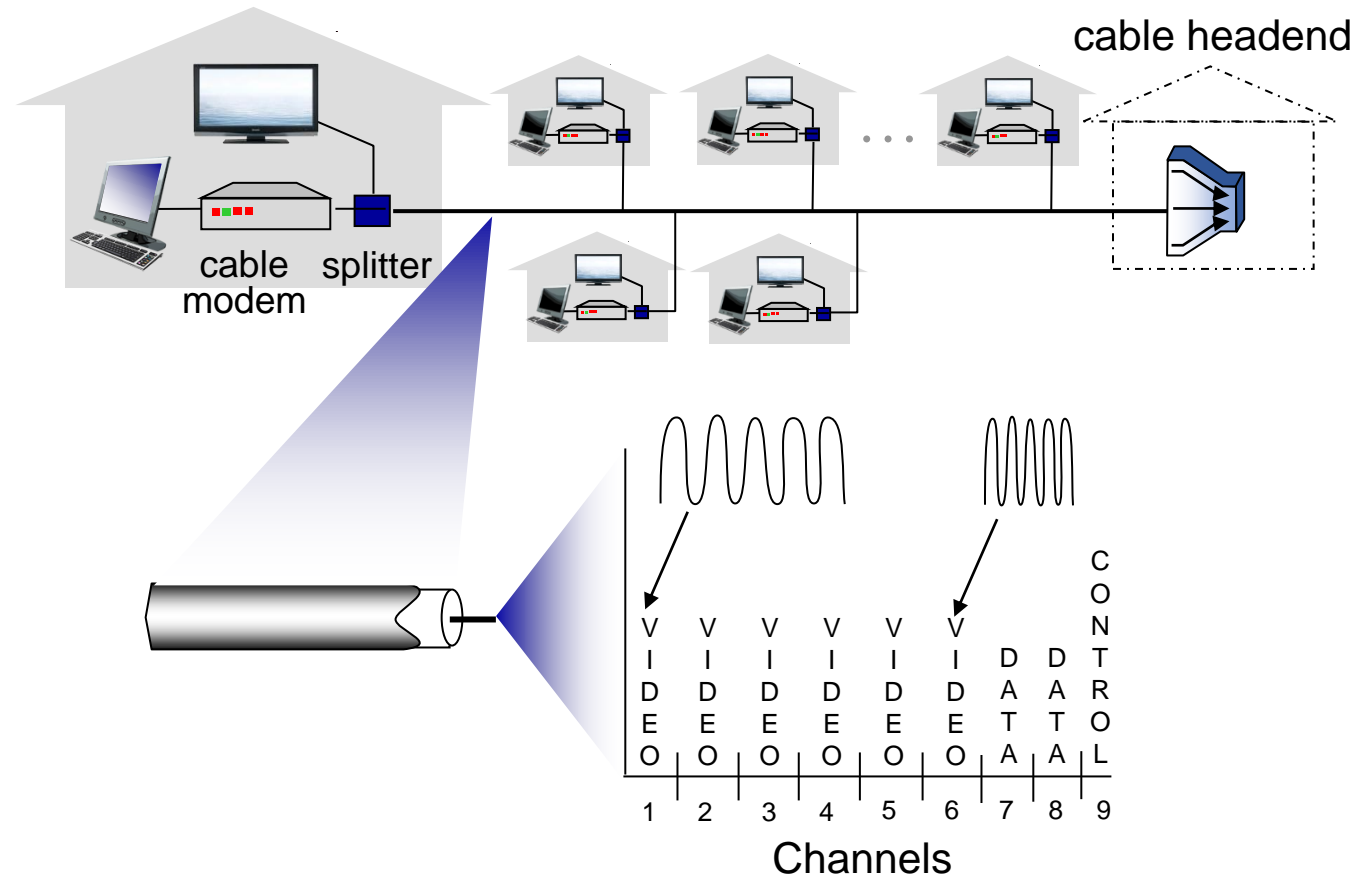


Access networks: digital subscriber line (DSL)



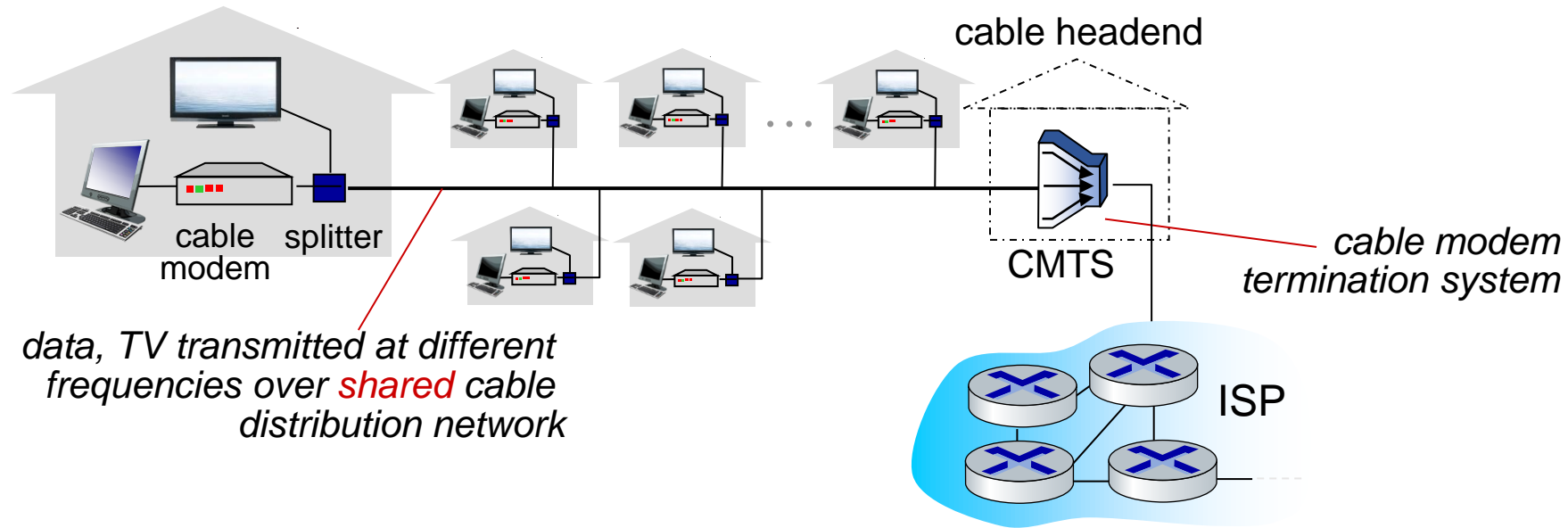
- use *existing* telephone line to central office DSLAM
 - data over DSL phone line goes to Internet
 - voice over DSL phone line goes to telephone net
- 24-52 Mbps dedicated downstream transmission rate
- 3.5-16 Mbps dedicated upstream transmission rate

Access networks: cable-based access



frequency division multiplexing (FDM): different TV channels & data transmitted in different frequency bands on the shared coaxial cable

Access networks: cable-based access



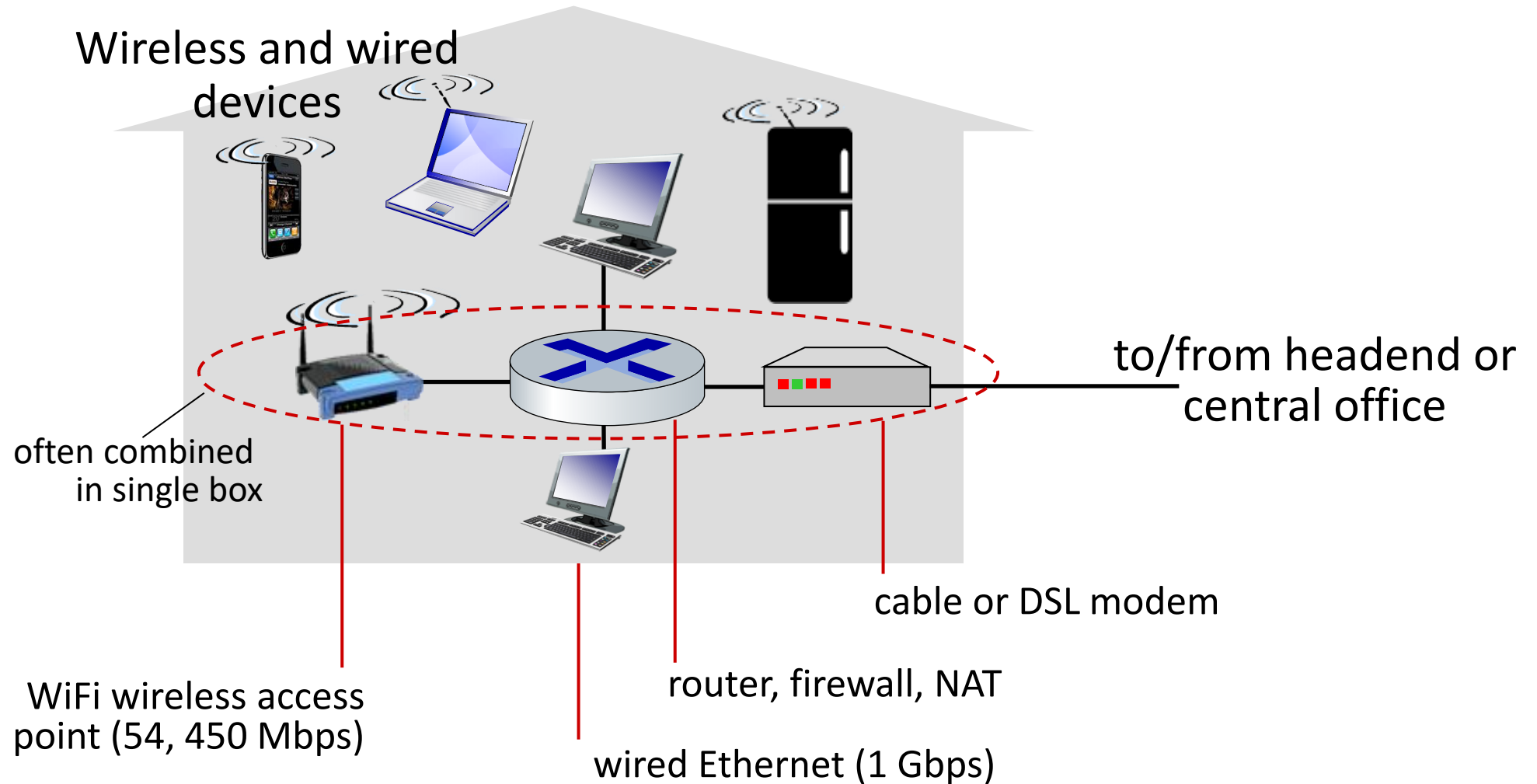
■ HFC: hybrid fiber coax

- asymmetric: up to 40 Mbps – 1.2 Gbps downstream transmission rate, 30-100 Mbps upstream transmission rate

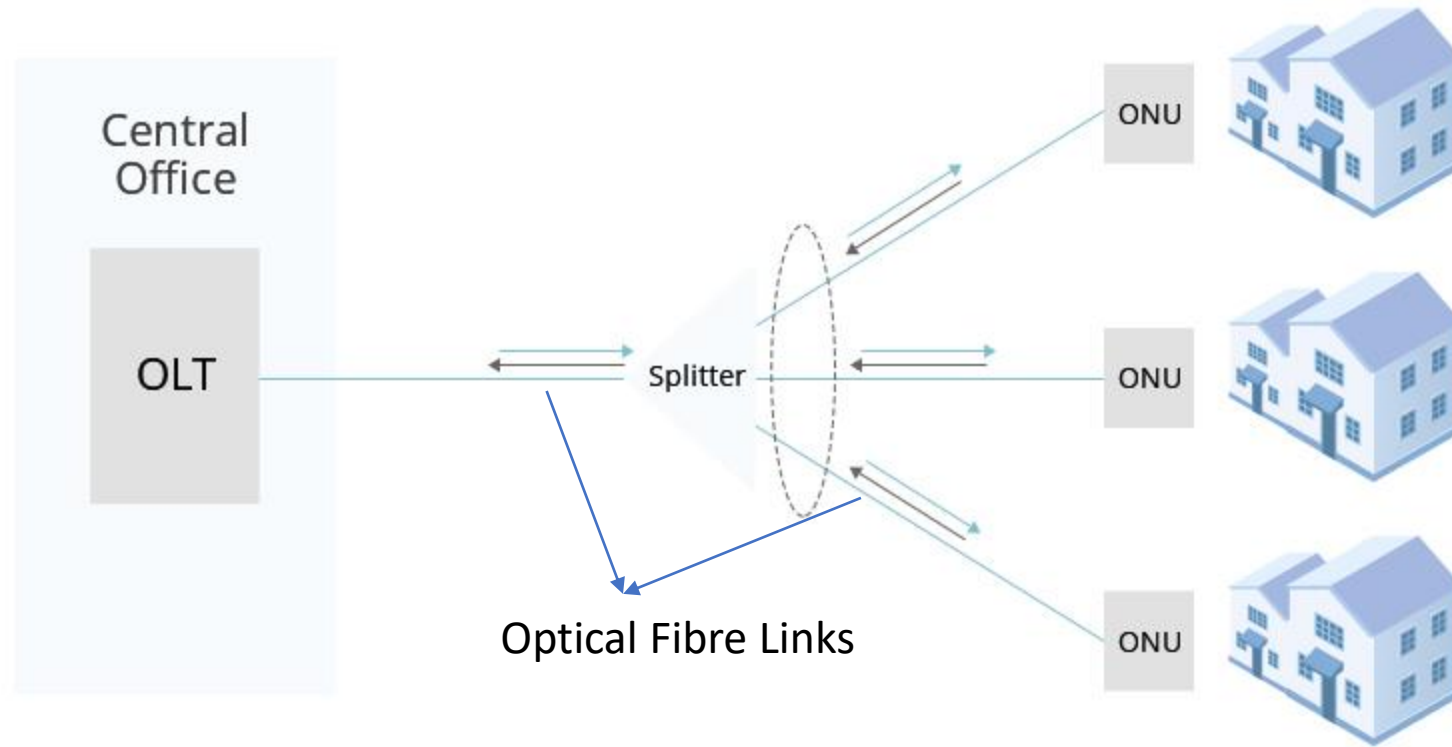
■ network of cable, fiber attaches homes to ISP router

- homes *share access network* to cable headend

Access networks in homes: Wi-Fi/Ethernet



Access networks in homes: FTTH



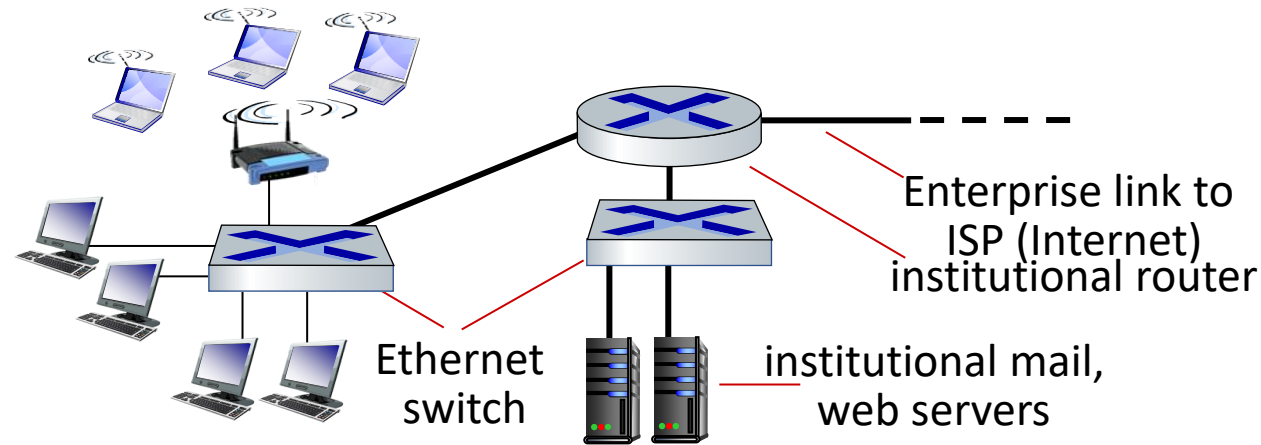
FTTH: Fibre To The Home

OLT: Optical Line Terminal

ONU (ONT): Optical Network Unit/Terminal



Access networks in enterprises



- companies, universities, etc.
- mix of wired, wireless link technologies, connecting a mix of switches and routers (we'll cover differences shortly)
 - Ethernet: wired access at 100Mbps, 1Gbps, 10Gbps
 - WiFi: wireless access points at 11, 54, 450 Mbps

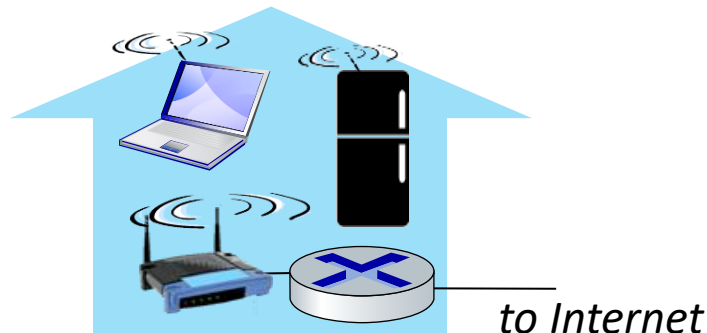
Wireless access networks

Shared *wireless* access network connects end system to router

- via base station aka “access point”

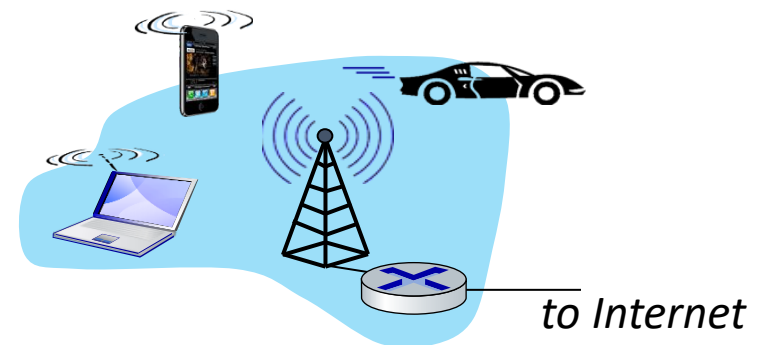
Wireless local area networks (WLANs)

- typically within or around building (~100 ft)
- 802.11b/g/n (WiFi): 11, 54, 450 Mbps transmission rate



Wide-area cellular access networks

- provided by mobile, cellular network operator (10's km)
- 10's Mbps
- 4G/5G cellular networks

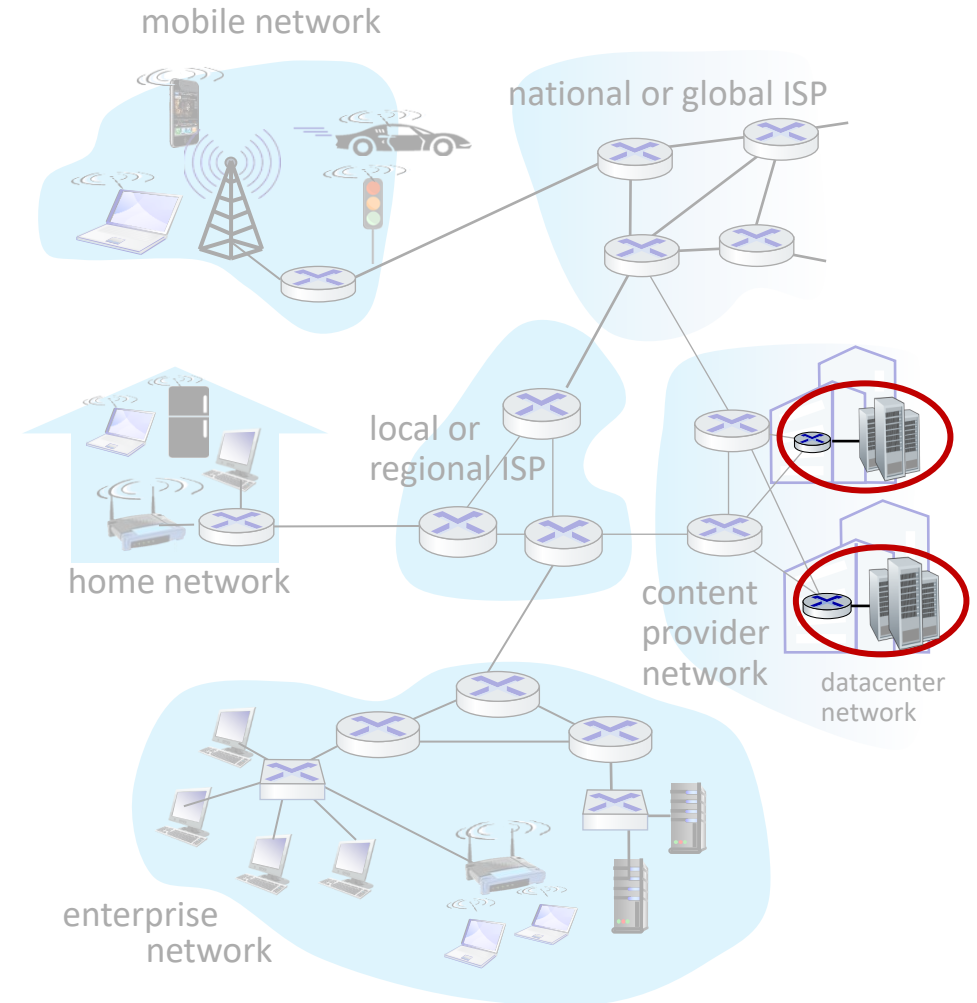


Access networks in data centers

- high-bandwidth links (10s to 100s Gbps) connect hundreds to thousands of servers together, and to Internet



Courtesy: Massachusetts Green High Performance Computing Center (mghpcc.org)



Next Lecture: Outline

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Readings

- Chapter 1.1 & 1.2 of Computer Networking: A Top-Down Approach **by James F. Kurose and Keith W. Ross**, 8th Edition, 2020, Addison Wesley (Pearson Education)
 - https://gaia.cs.umass.edu/kurose_ross/videos/1/
- <https://cse.iith.ac.in/academics/plagiarism-policy.html>