

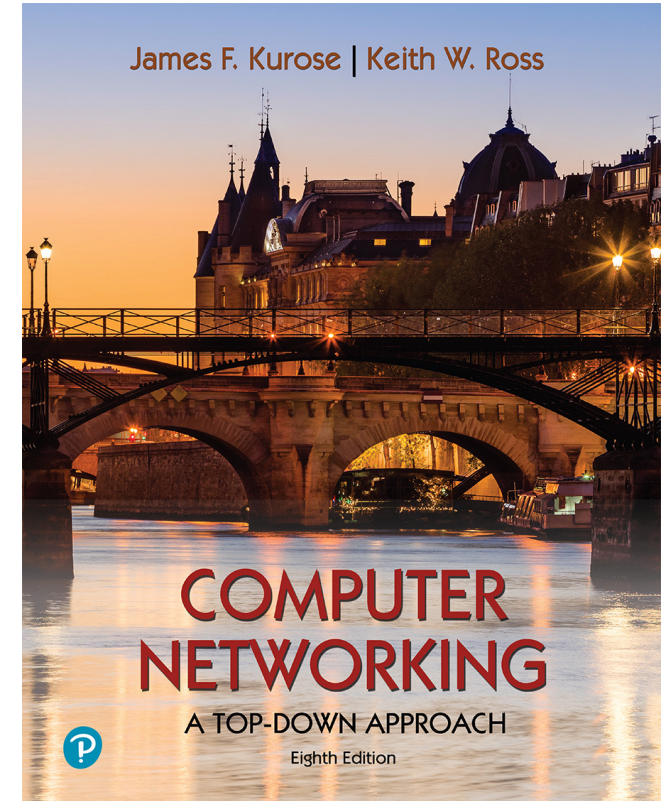
# Chapter 1

# Introduction

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Adapted from the slides of the book's authors



*Computer Networking: A  
Top-Down Approach*

8<sup>th</sup> edition

Jim Kurose, Keith Ross  
Pearson, 2020

# Announcements

- Just for reference:
  - **A**: top 15-20%
  - **A-**: next 10-15%
  - **B+, B, B-**: next 25-40%
  - **C+, C, C-**: next 10-20%
- Grading standard is the same for both undergraduates and graduates
  - Final grades will be assigned separately
- Wireshark Lab-1 has been uploaded
  - Wireshark Introduction
  - Basics of HTTP
- Reminder:
  - Complete the AI Quiz

# Chapter 1: introduction

## *Chapter goal:*

- Get “feel,” “big picture,” introduction to terminology
  - more depth, detail *later* in course



## *Overview/roadmap:*

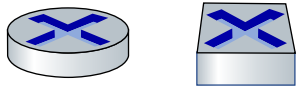
- What *is* the Internet? What *is* a protocol?
- **Network edge:** hosts, access network, physical media
- **Network core:** packet/circuit switching, internet structure
- **Performance:** loss, delay, throughput
- Protocol layers, service models
- Security

# 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*

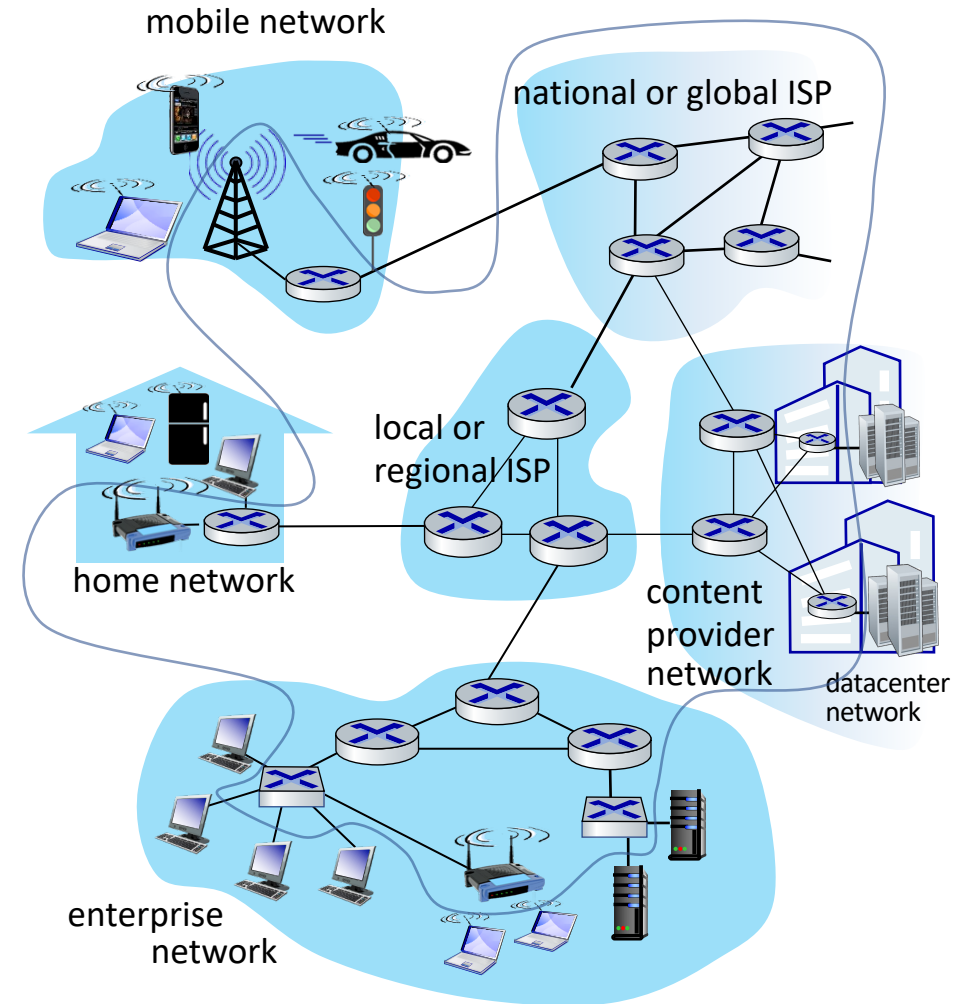
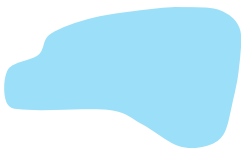
*Communication links*

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



*Networks*

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



# “Fun” Internet-connected (host/end) devices



Amazon Echo



Internet refrigerator



IP picture frame



Pacemaker & Monitor



Tweet-a-watt:  
monitor energy use



bikes



Security Camera



Slingbox: remote control cable TV



Web-enabled toaster +  
weather forecaster



AR devices



cars



scooters



Internet phones



Gaming devices



sensorized,  
bed  
mattress



Fitbit

*Others?*

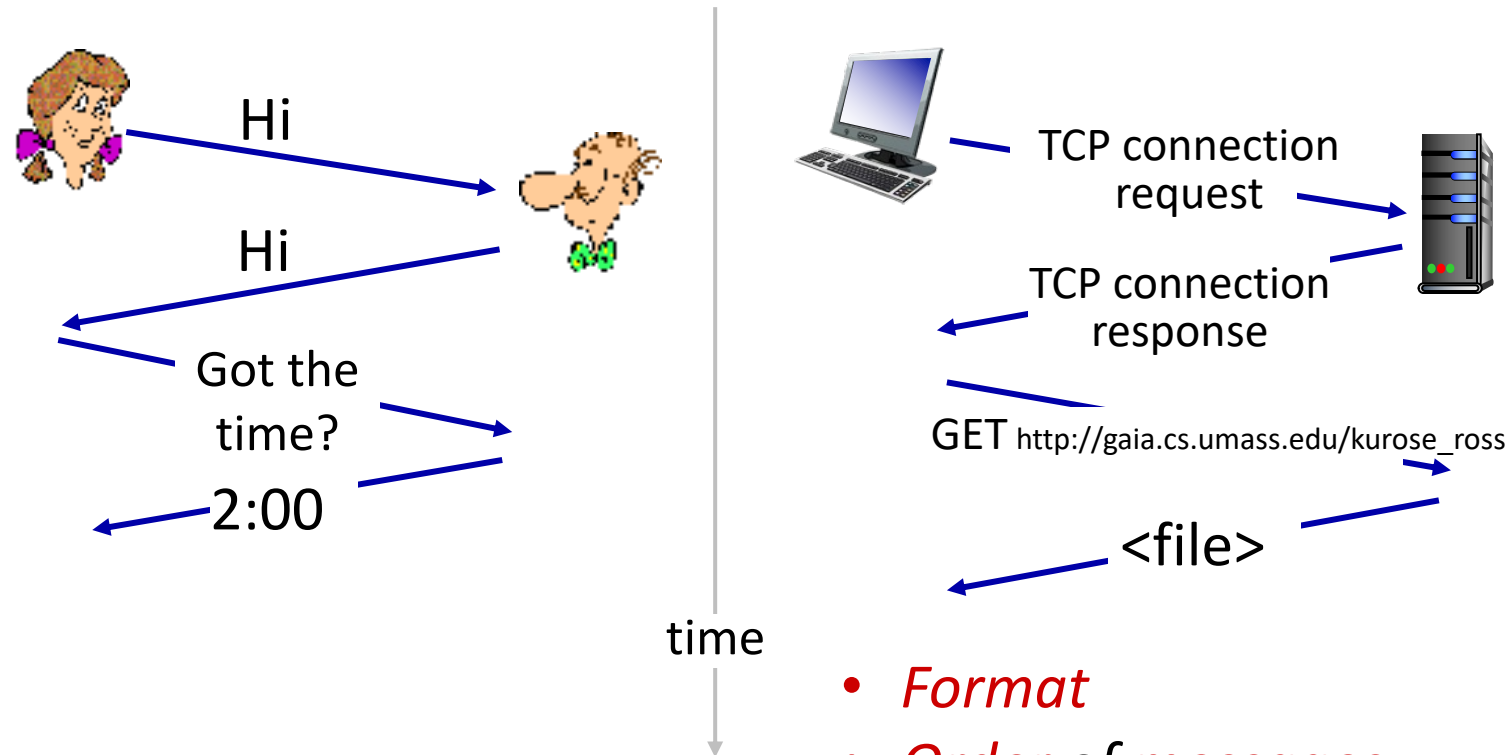
# What's the Internet: “nuts and bolts” view -continued

- *Software: protocols* control sending, receiving of msgs
  - e.g., HTTP (web), SMTP (for email server),
  - Wifi /BT (802.x) for wireless devices,
  - Ethernet (for local area networks),
  - TCP/UDP (for hosts on the internet)
  - IP (for the routers in the core networks)
- Internet standards define these protocols
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force



# What's a protocol?

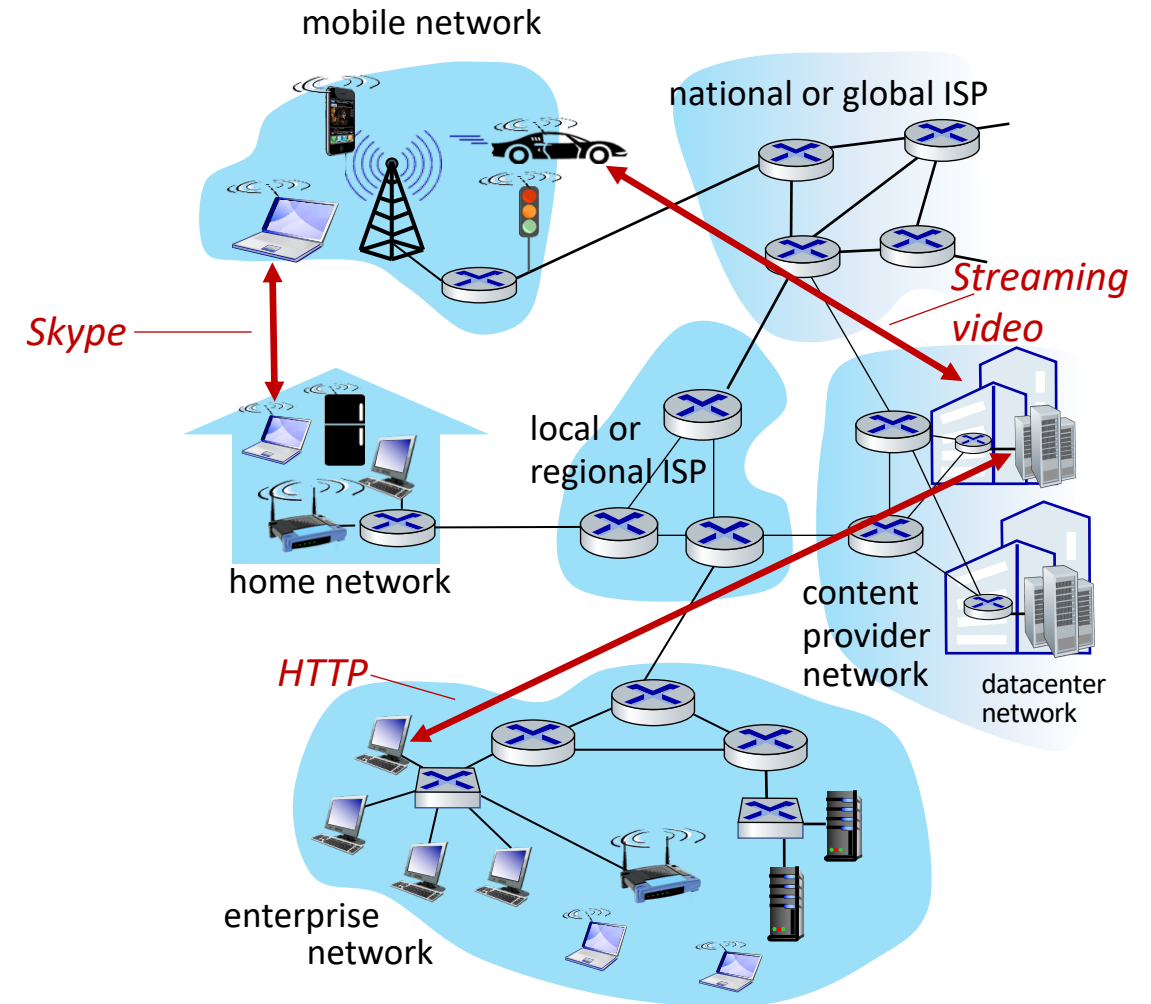
A human protocol and a computer network protocol:



- *Format*
- *Order of messages*
- *Actions taken on message Tx and RX*

# The Internet: a “services” view

- As an *Infrastructure* that provides services to applications:
  - Web, streaming video, multimedia teleconferencing, social media,...
  - provided by hardware and software (*protocols*)
- 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 the Internet: a service view

- services provided by protocols
  - running on hosts and routers.
- two types of services provided to apps:
  - Connectionless (UDP)
    - faster/quicker delivery (no need to set up any connection)
    - less reliable, no orderly packets delivered
    - Suitable for real-time streaming
  - Connection-oriented (TCP)
    - Suitable for file/email transfers

# Chapter 1: roadmap

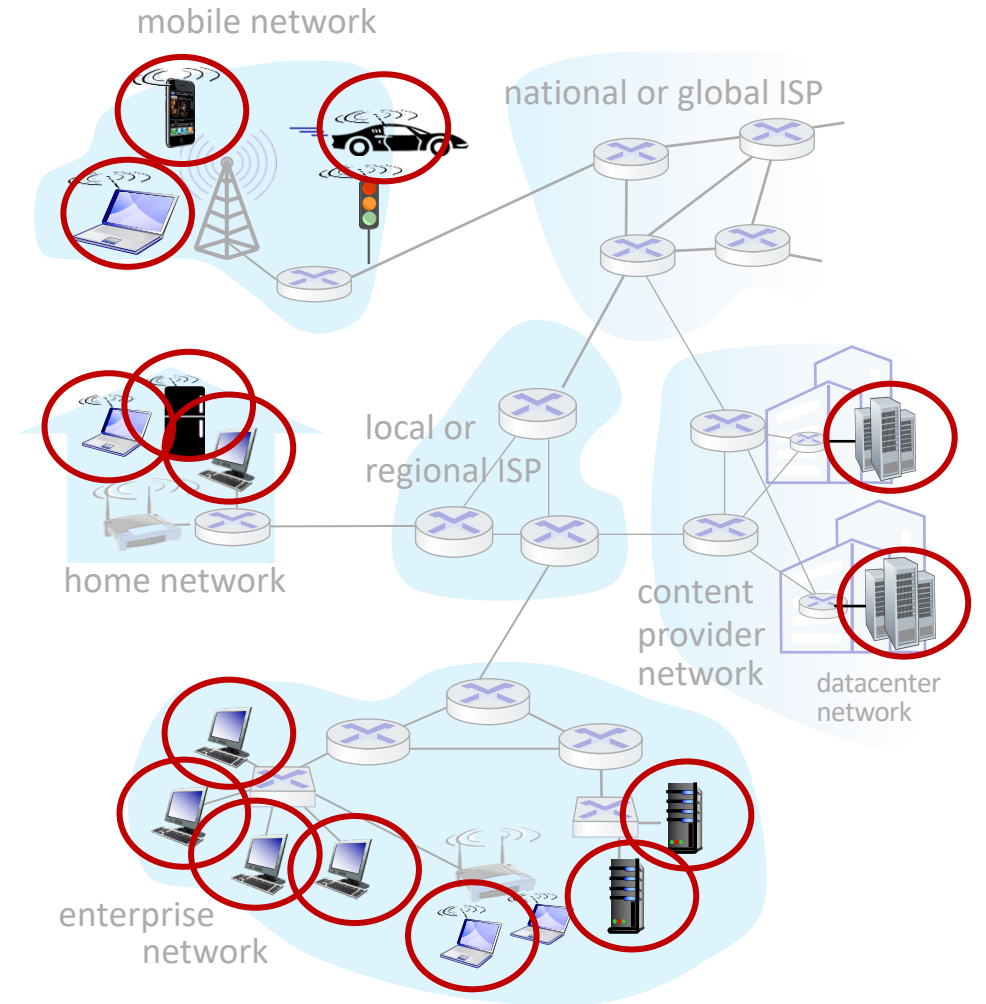
- What *is* the Internet?
- What *is* a protocol?
- **Network edge:** hosts, access network, physical media
- Network core: packet/circuit switching, internet structure
- Performance: loss, delay, throughput
- Security
- Protocol layers, service models
- History



# A closer look at Internet structure

## Network edge:

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



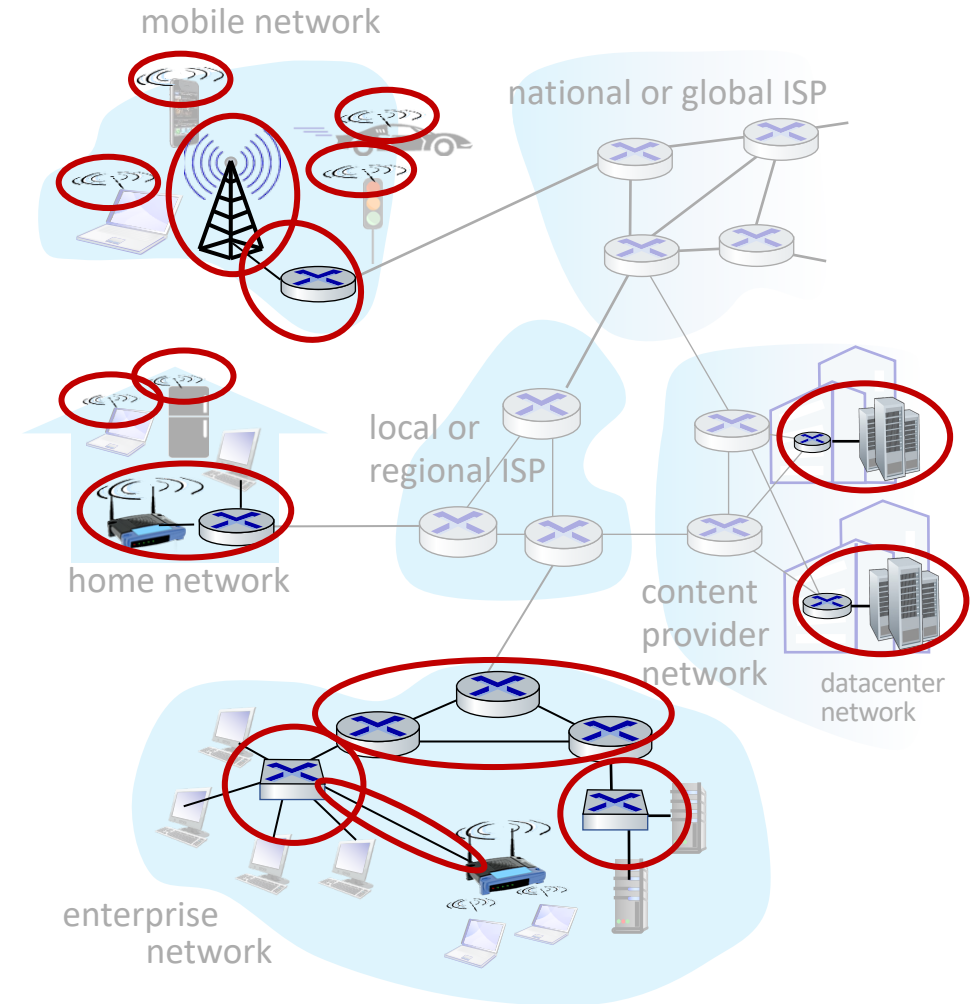
# A closer look at Internet structure

## Network edge:

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## Access networks, physical media:

- wired, wireless communication links



# A closer look at Internet structure

## Network edge:

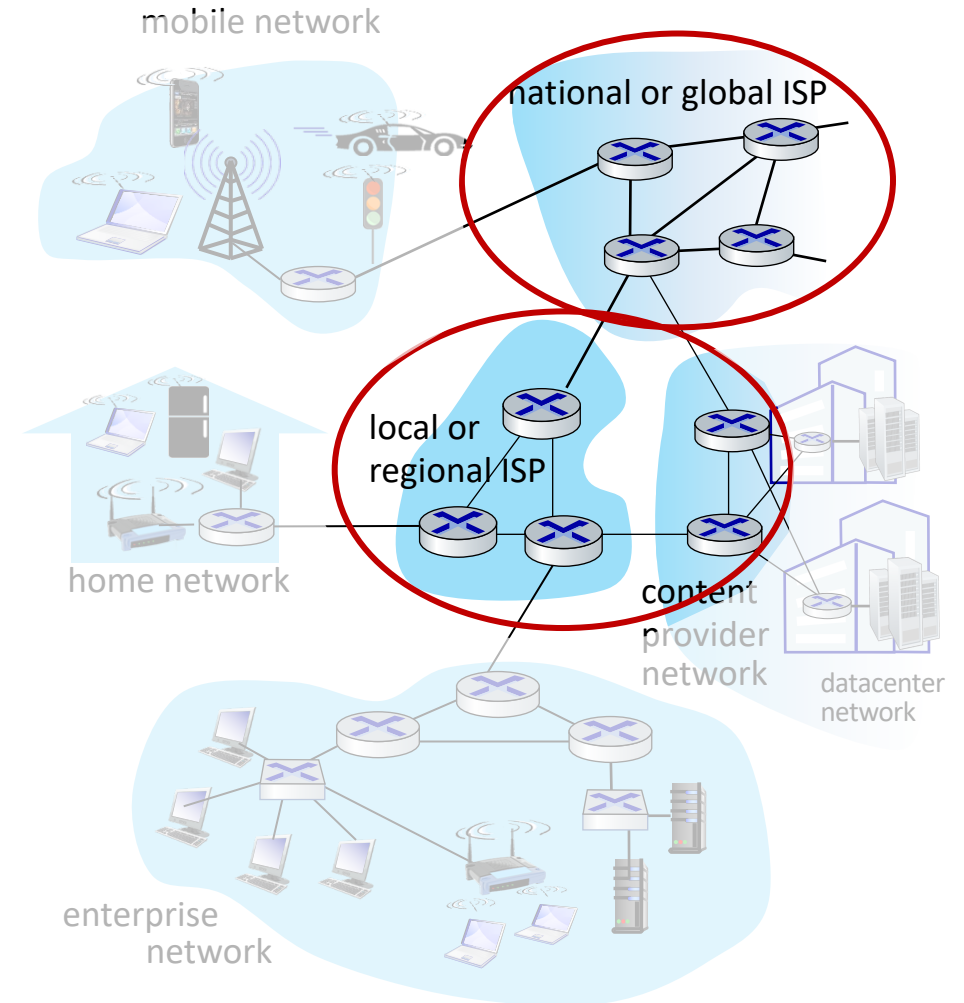
- hosts: clients and servers
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## Access networks, physical media:

- wired, wireless communication links

## Network core:

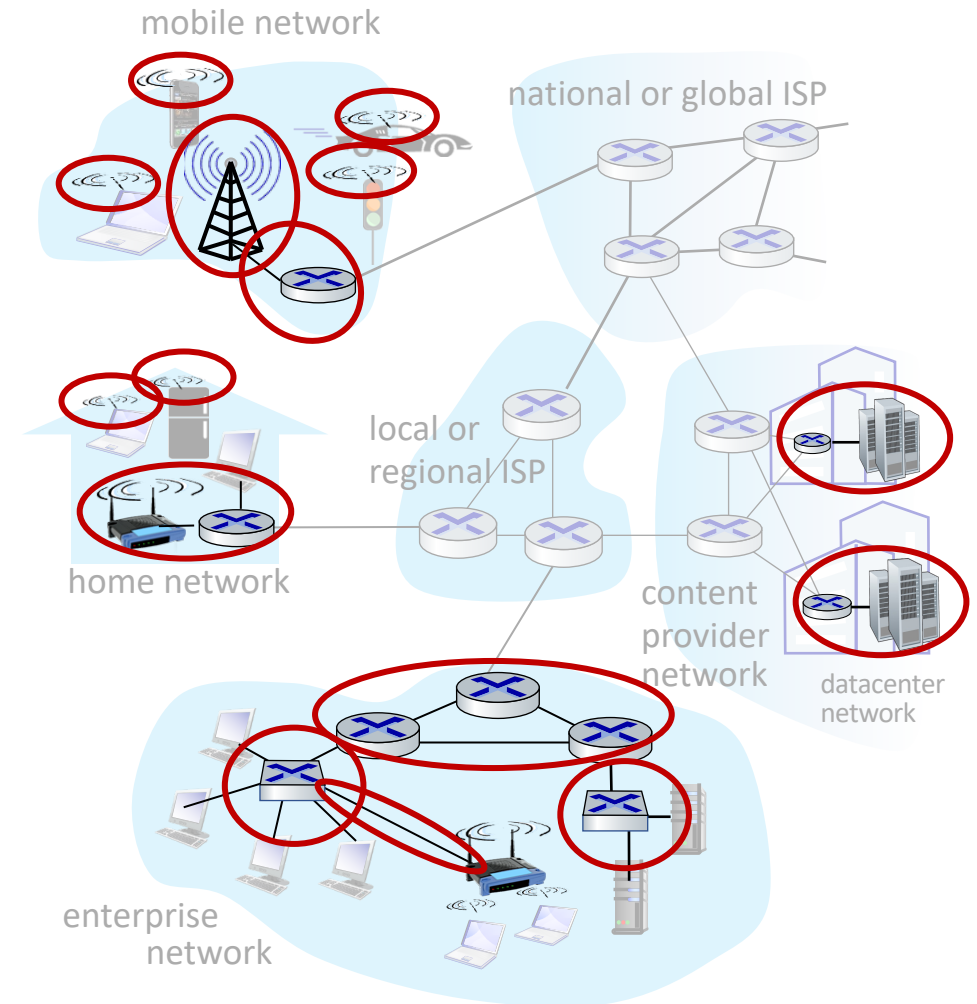
- interconnected routers
- network of networks



# Access networks and physical media

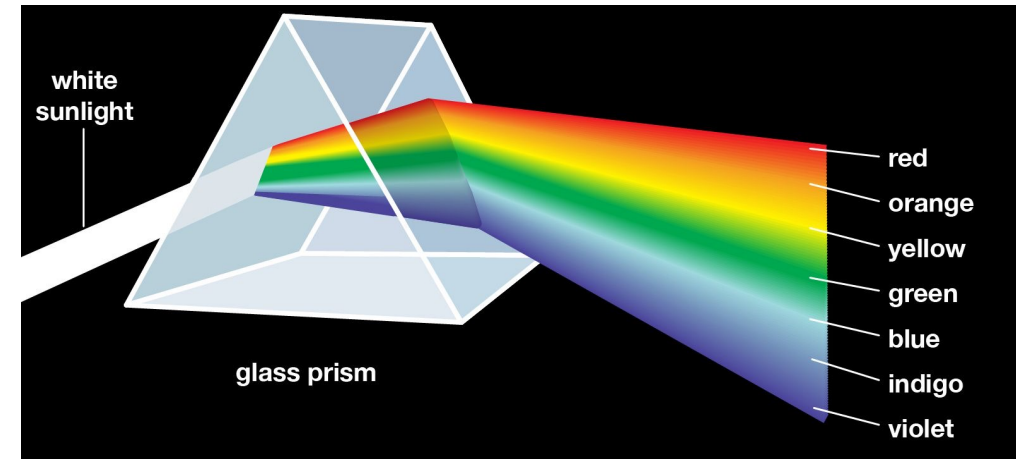
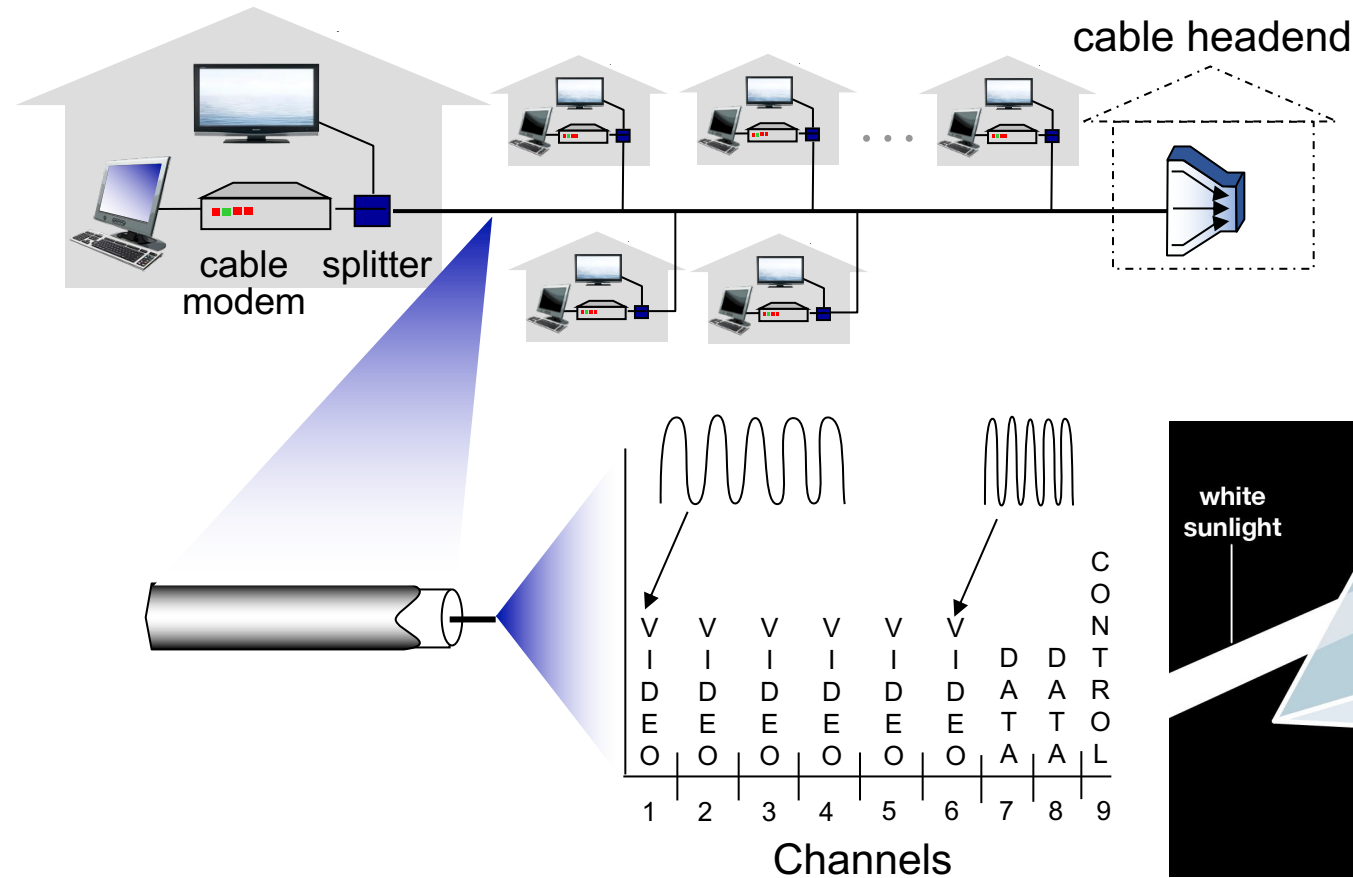
*Q: How to connect end systems to edge router?*

- residential access nets
- institutional access networks (school, company)
- mobile access networks (WiFi, 4G/5G)



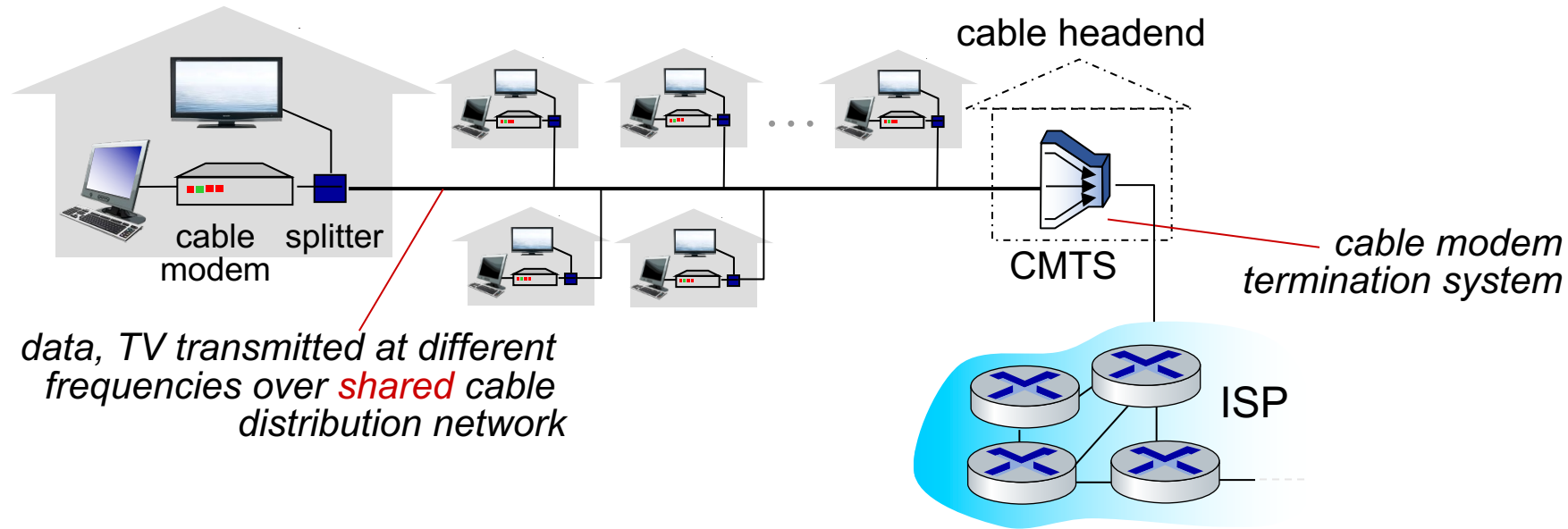


# Access networks: cable-based access



*frequency division multiplexing (FDM)*: different channels transmitted in different frequency bands

# Access networks: cable-based access



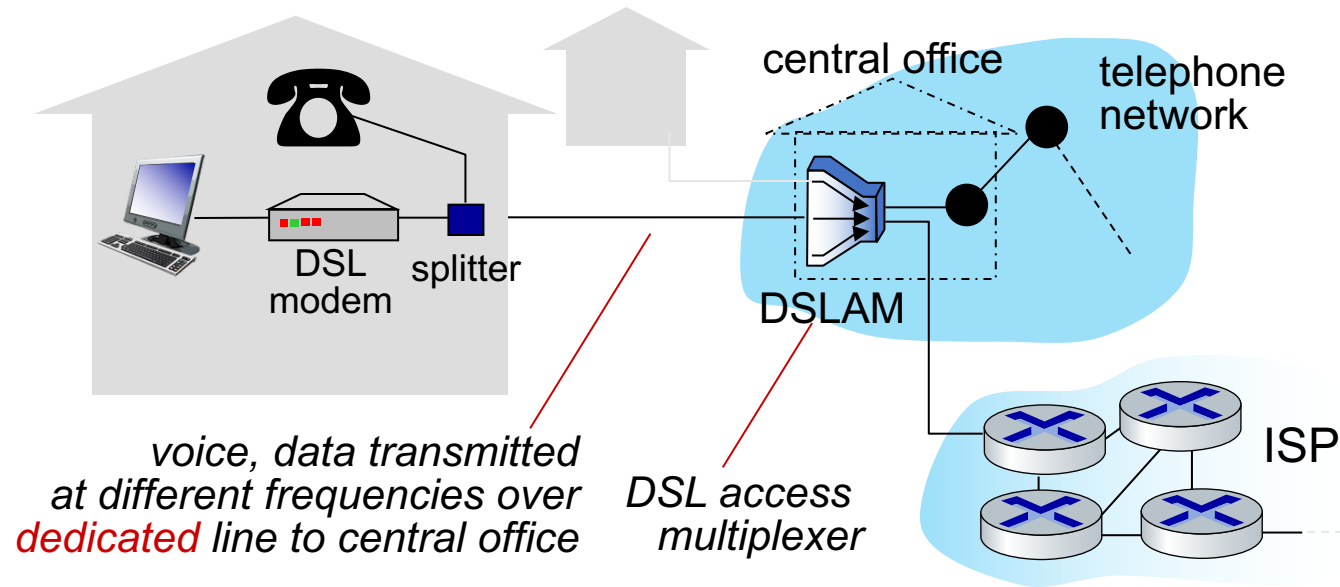
- HFC: hybrid fiber coax

- 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

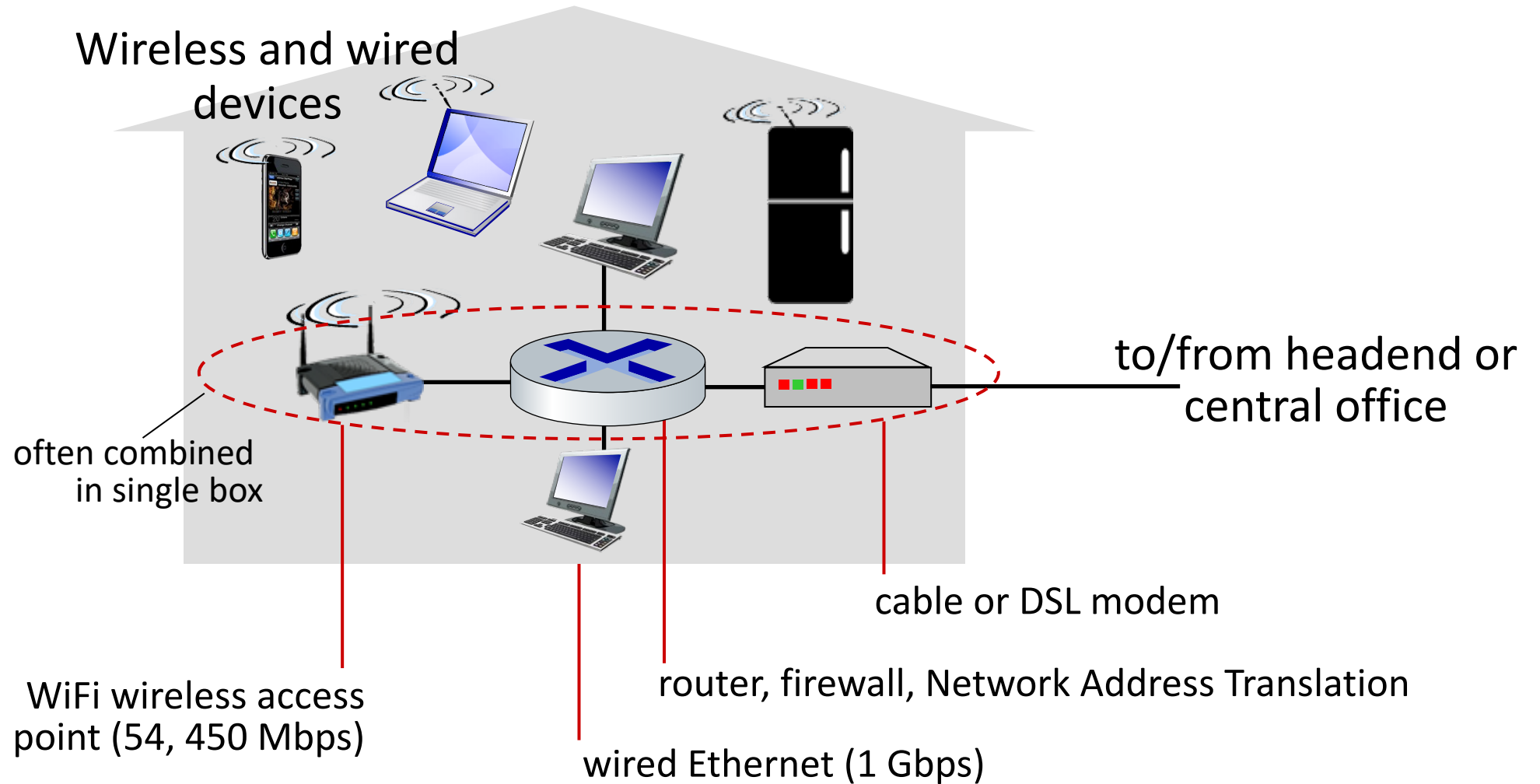
- homes *share access network* to cable headend

# Access networks: 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: home networks



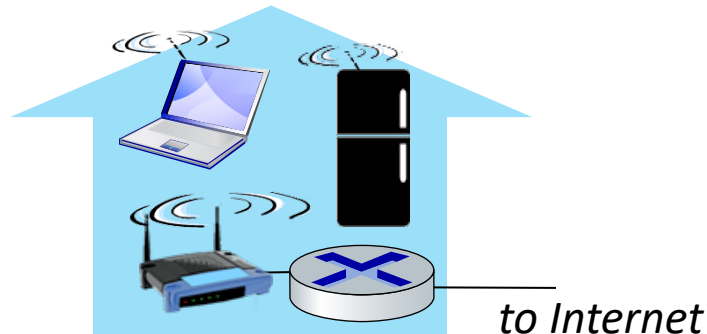
# Wireless access networks

Shared *wireless* access network connects end system to router

- via base station aka “access point”

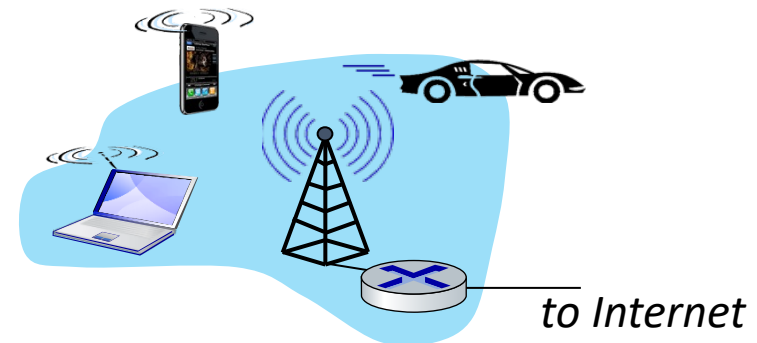
## Wireless local area networks (WLANs)

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

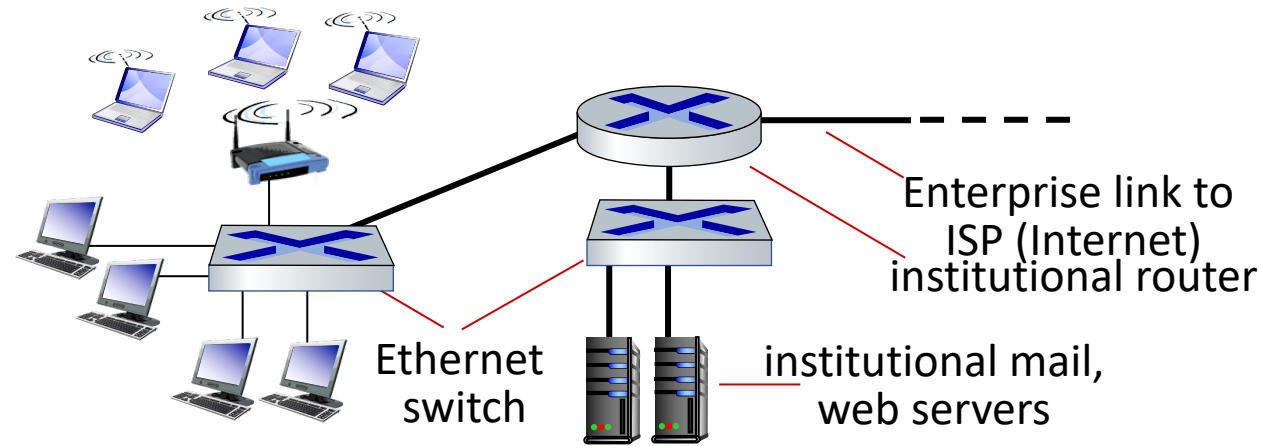


## Wide-area cellular access networks

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



# Access networks: enterprise networks



- 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

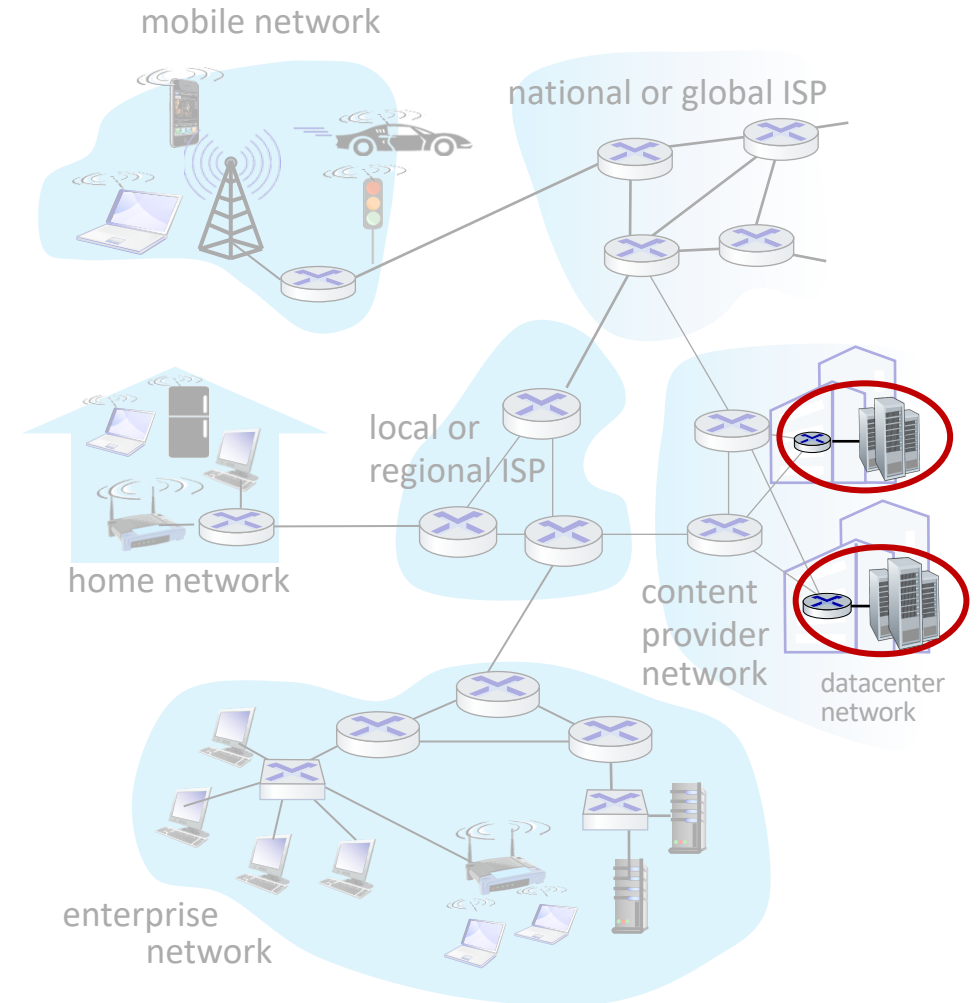


# Access networks: data center networks

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



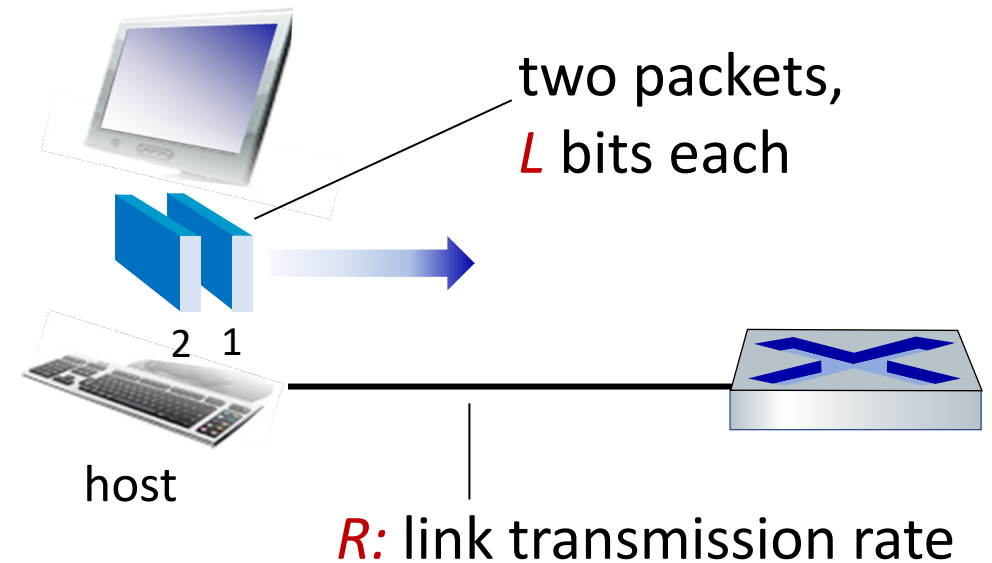
Courtesy: Massachusetts Green High Performance Computing Center ([mghpcc.org](http://mghpcc.org))



# 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*



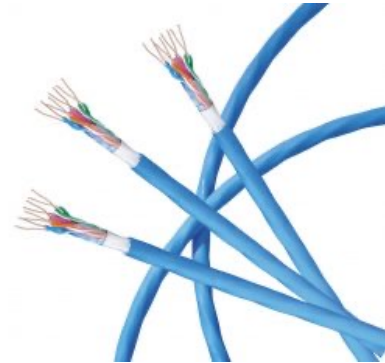
$$\begin{array}{l} \text{packet} \\ \text{transmission} \\ \text{delay} \end{array} = \begin{array}{l} \text{time needed to} \\ \text{transmit } L\text{-bit} \\ \text{packet into link} \end{array} = \frac{L \text{ (bits)}}{R \text{ (bits/sec)}}$$

# Links: physical media

- **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 Ethernet



# Links: physical media

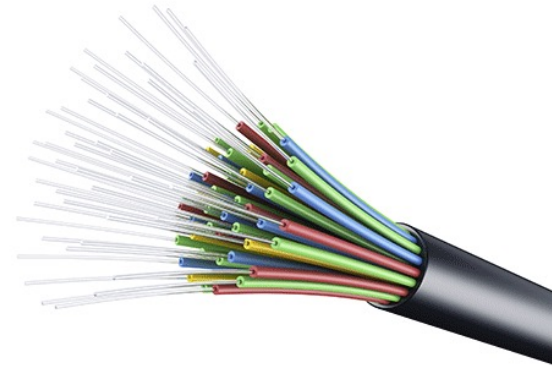
## Coaxial cable:

- 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

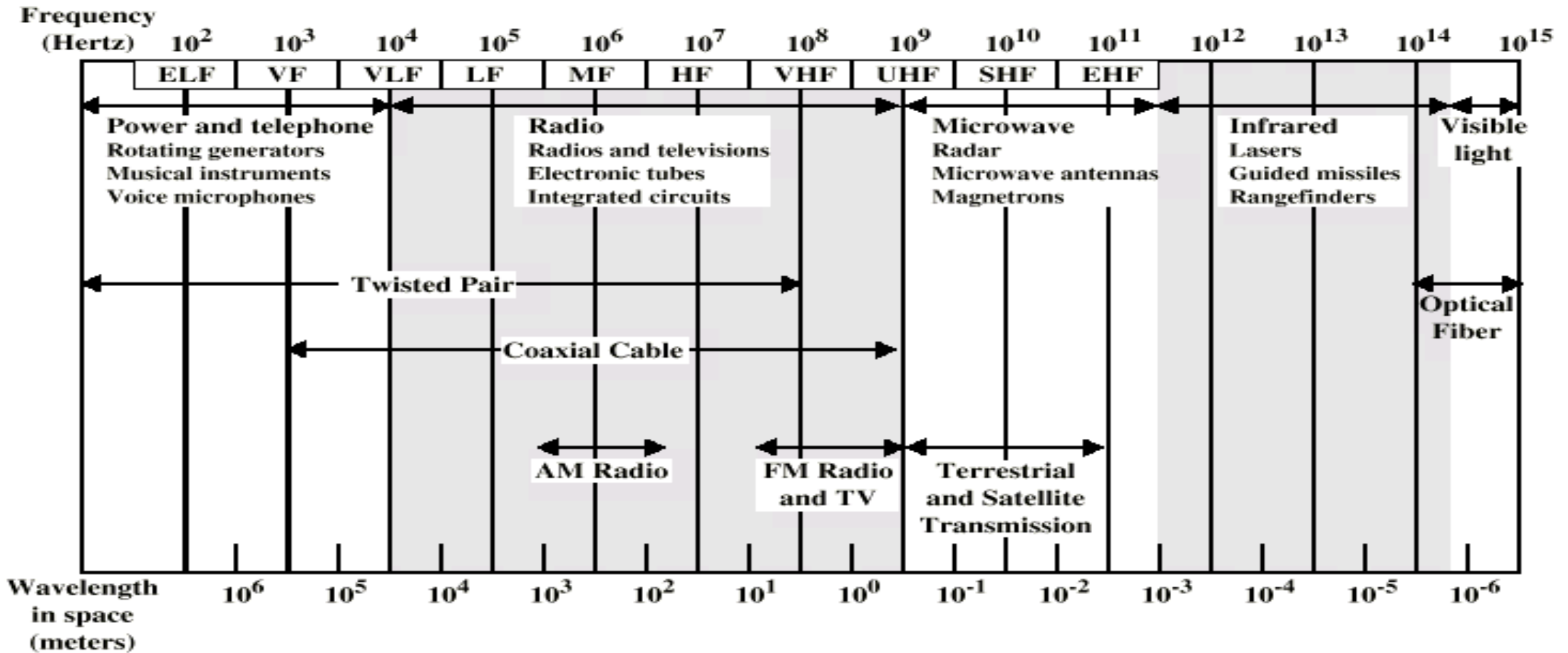
## Wireless radio

- 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 cellular)
  - 10’s Mbps over ~10 Km
- **Bluetooth**: cable replacement
  - short distances, limited rates
- **terrestrial microwave**
  - point-to-point; 45 Mbps channels
- **satellite**
  - up to 45 Mbps per channel
  - 270 msec end-end delay

# Electromagnetic Spectrum



ELF = Extremely low frequency

VF = Voice frequency

VLF = Very low frequency

LF = Low frequency

MF = Medium frequency

HF = High frequency

VHF = Very high frequency

UHF = Ultrahigh frequency

SHF = Superhigh frequency

EHF = Extremely high frequency