

Chapter 1

Introduction

Chapter 1: introduction

Chapter goal:

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



Overview/roadmap:

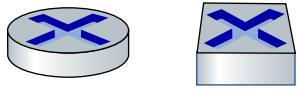
- What *is* the Internet? What *is* a protocol?
- **Network edge:** hosts, access network, physical media
- **Network core:** packet/circuit switching, internet structure
- **Performance:** loss, delay, throughput
- Protocol layers, service models
- Security
- History

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*

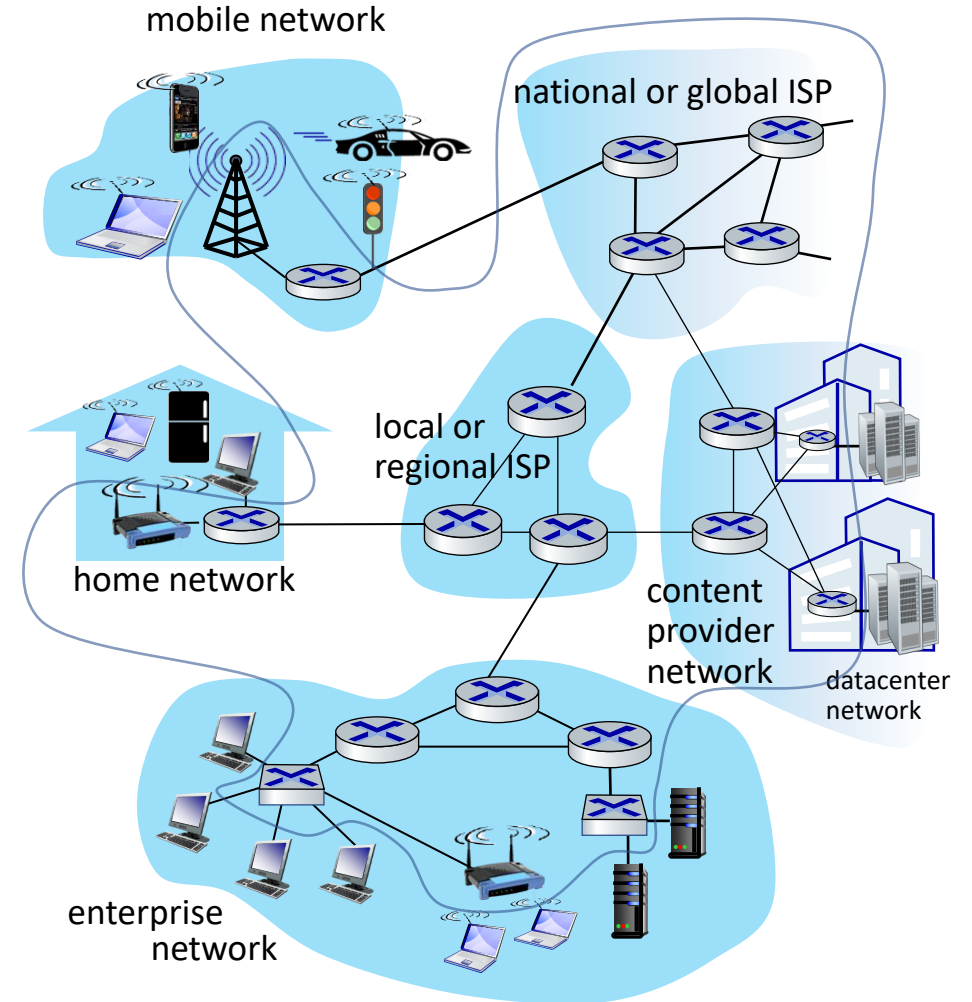
Communication links

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



Networks

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



“Fun” Internet-connected devices



Amazon Echo



IP picture frame



Pacemaker & Monitor



Tweet-a-watt:
monitor energy use



Internet
refrigerator

Security Camera



Slingbox: remote
control cable TV



Web-enabled toaster +
weather forecaster



AR devices



Fitbit



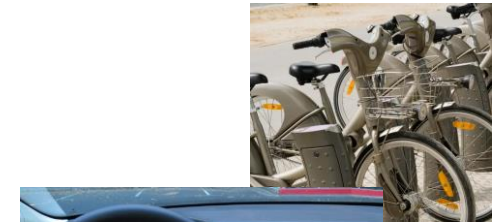
Internet phones



Gaming devices



sensorized,
bed
mattress



bikes



cars

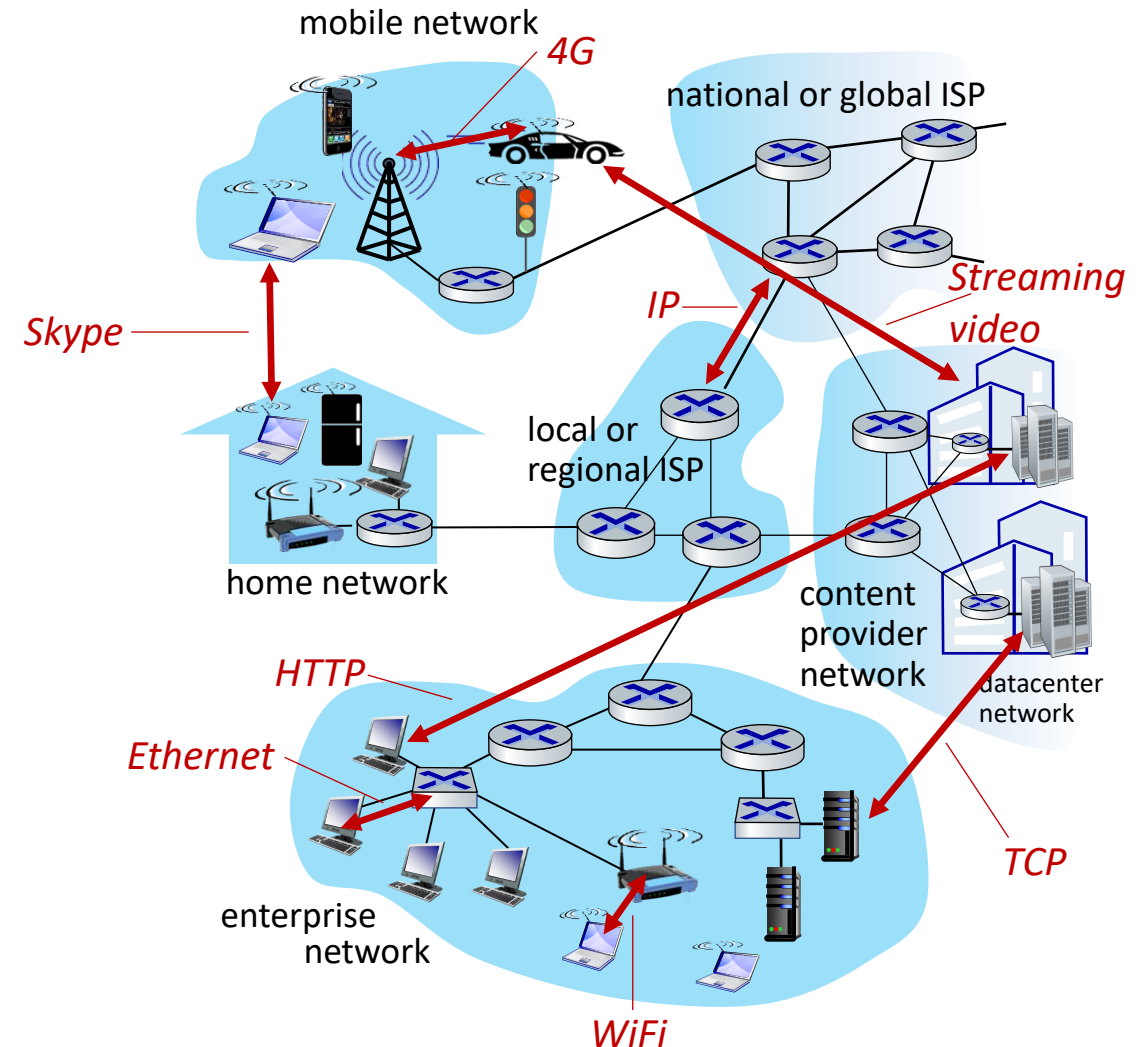


scooters

Others?

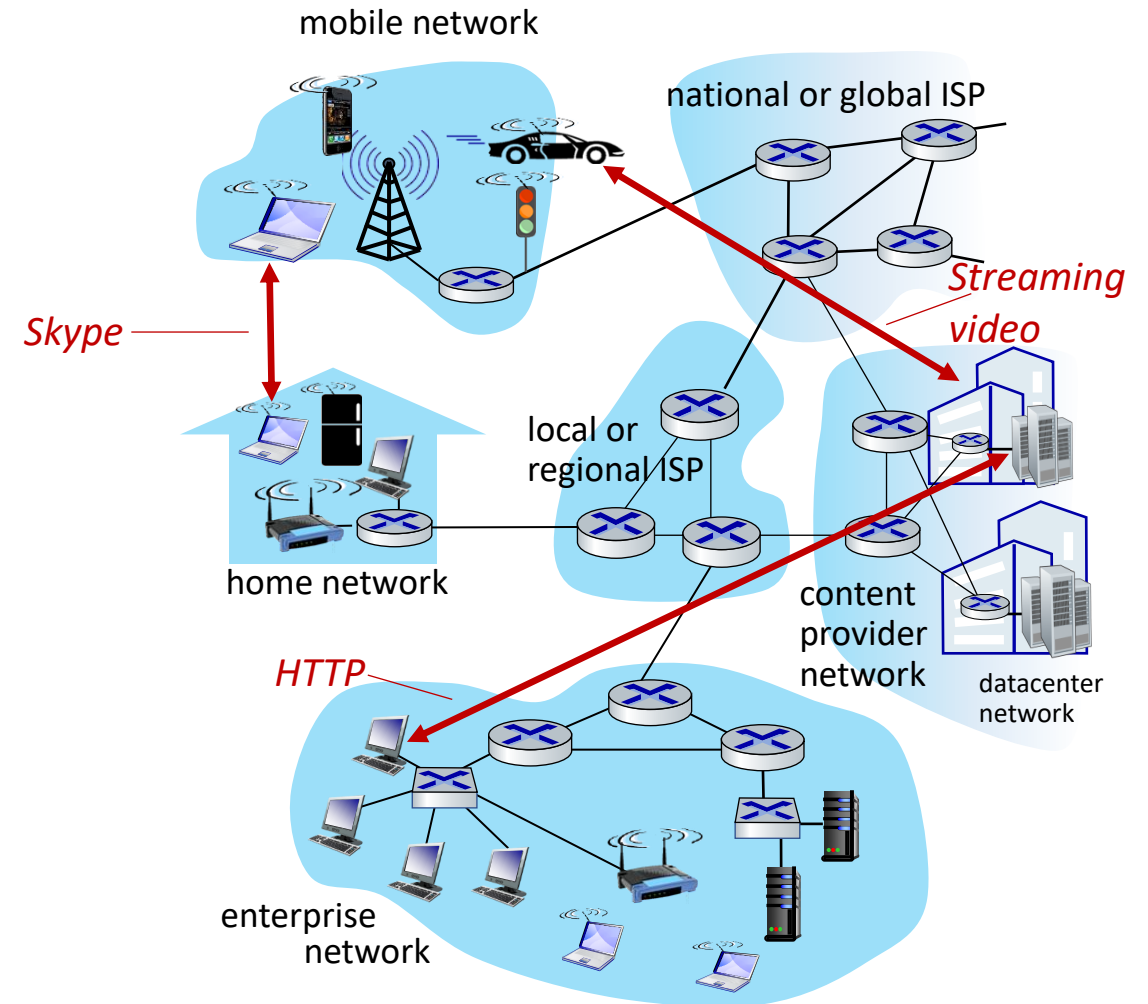
The Internet: a “nuts and bolts” view

- *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

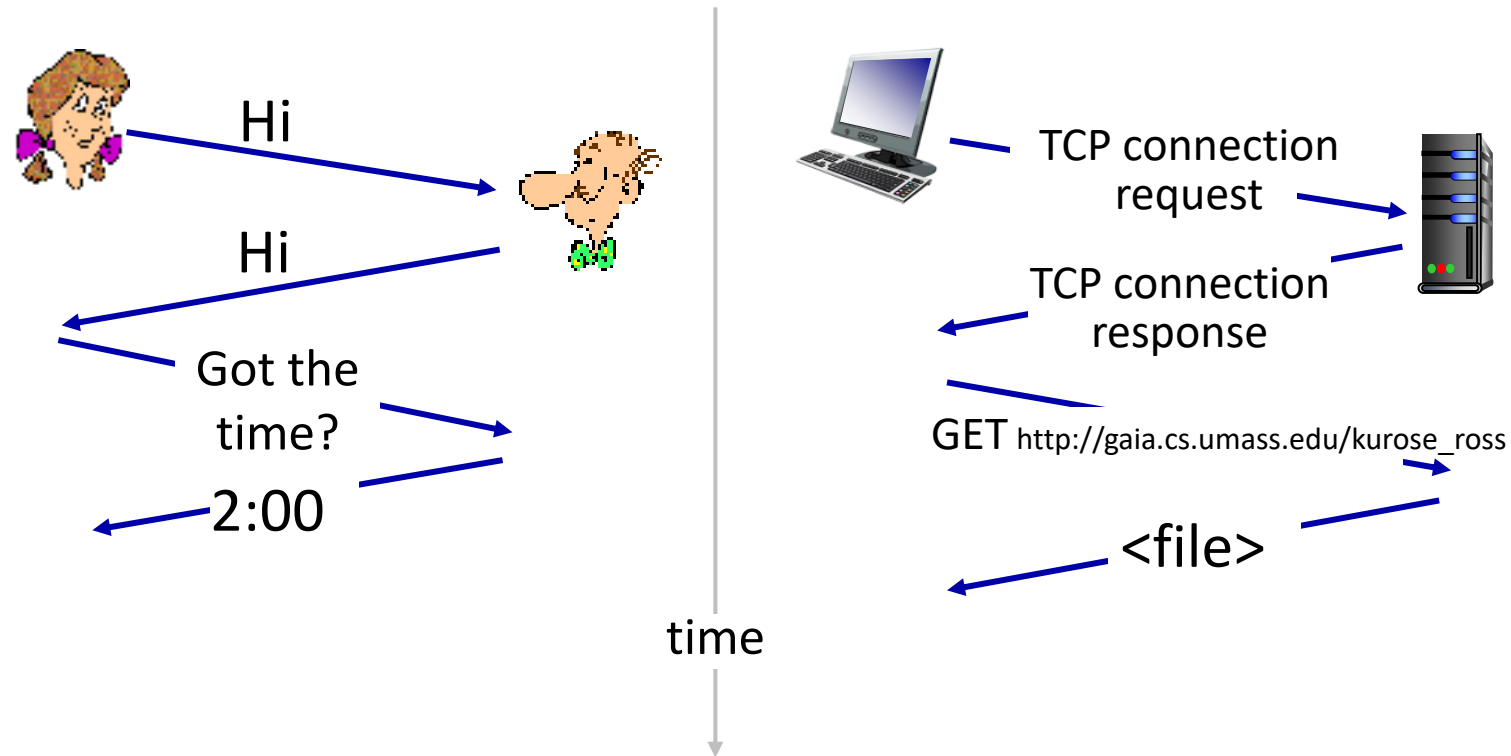
Network protocols:

- 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?

Chapter 1: roadmap

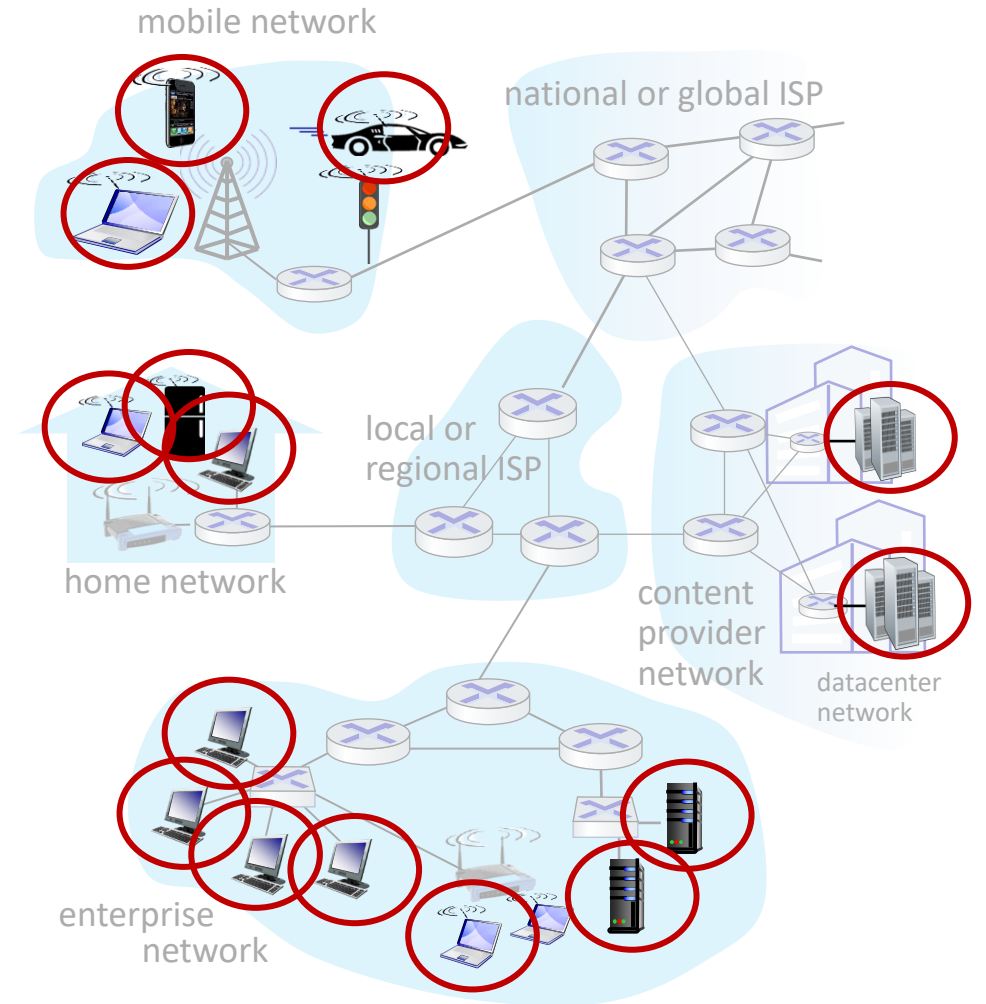
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A closer look at Internet structure

Network edge:

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



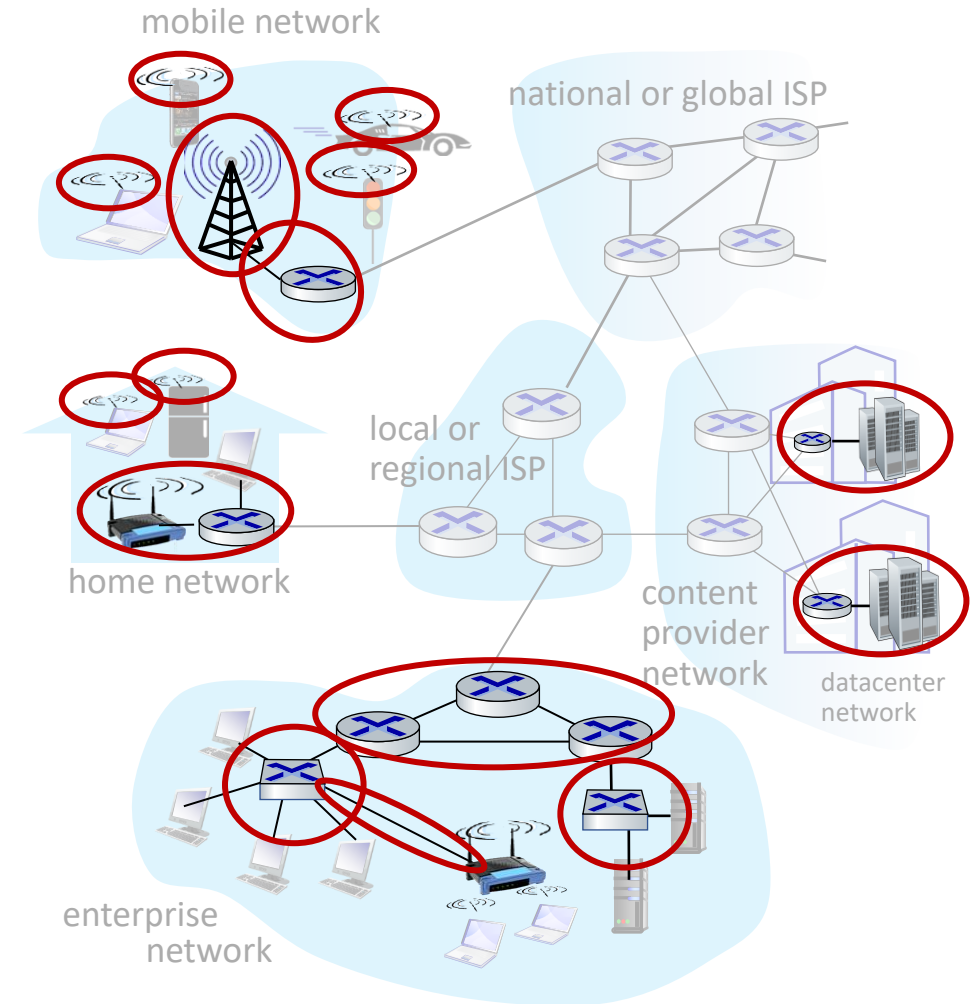
A closer look at Internet structure

Network edge:

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Access networks, physical media:

- wired, wireless communication links



A closer look at Internet structure

Network edge:

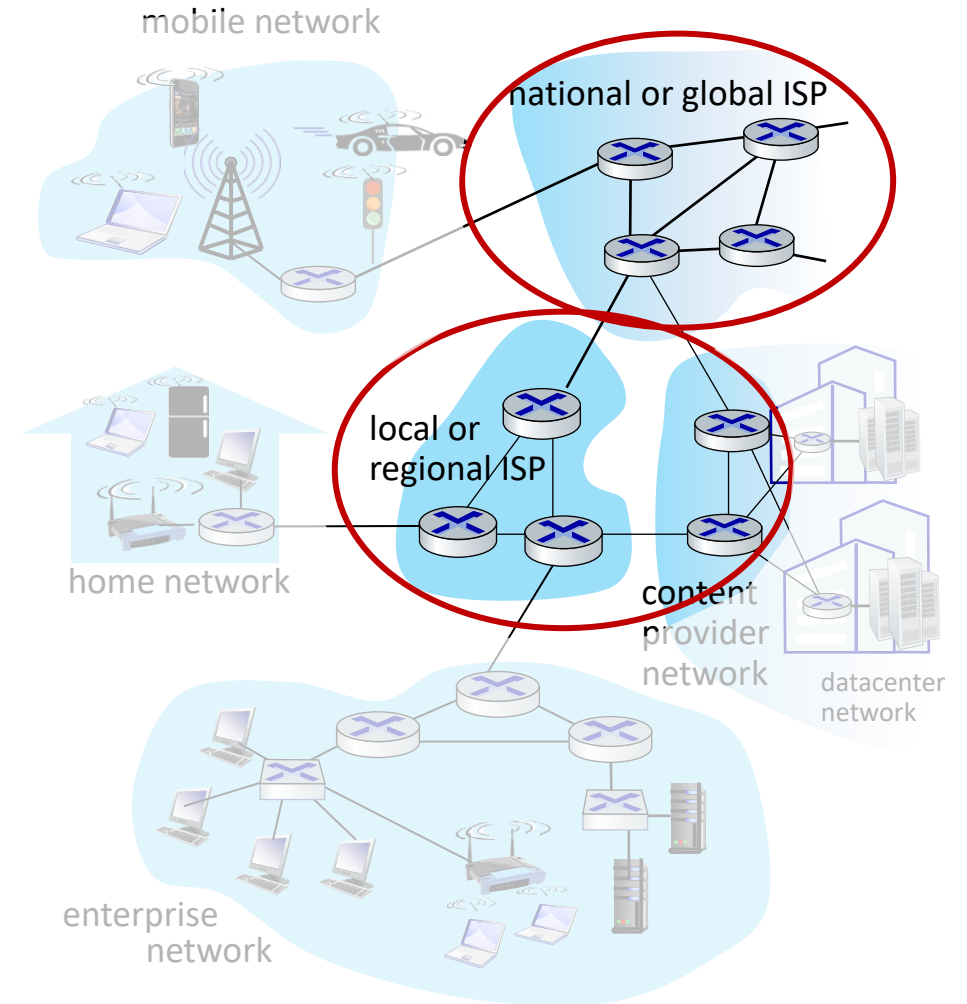
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Access networks, physical media:

- wired, wireless communication links

Network core:

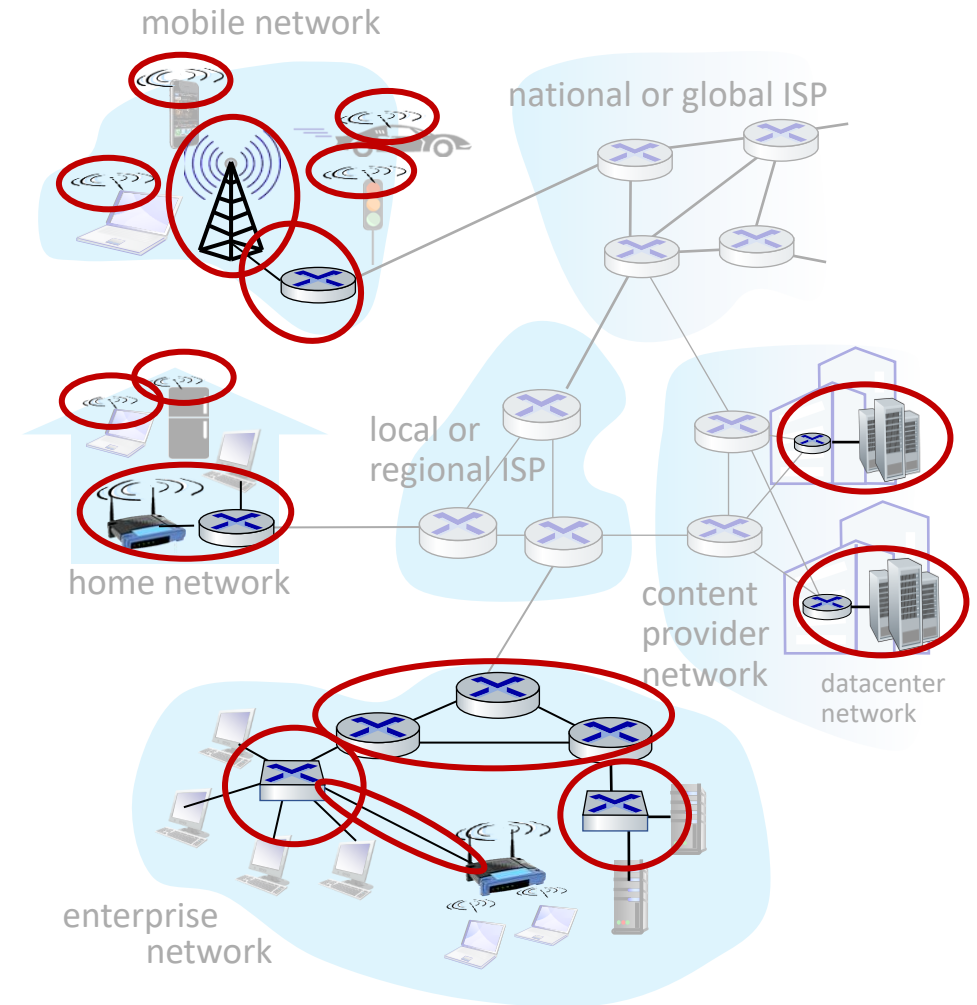
- interconnected routers
- network of networks



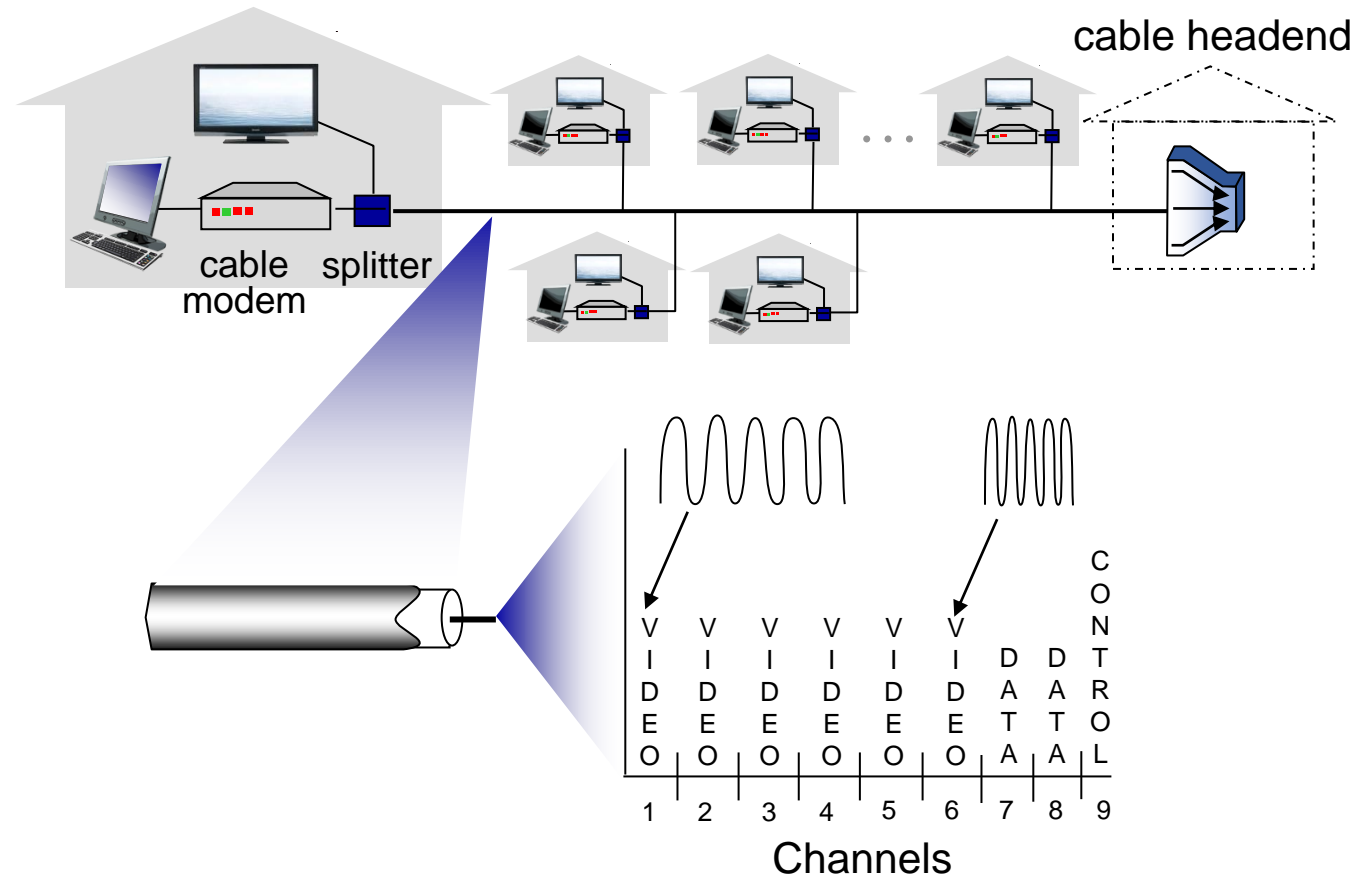
Access networks and physical media

Q: How to connect end systems to edge router?

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

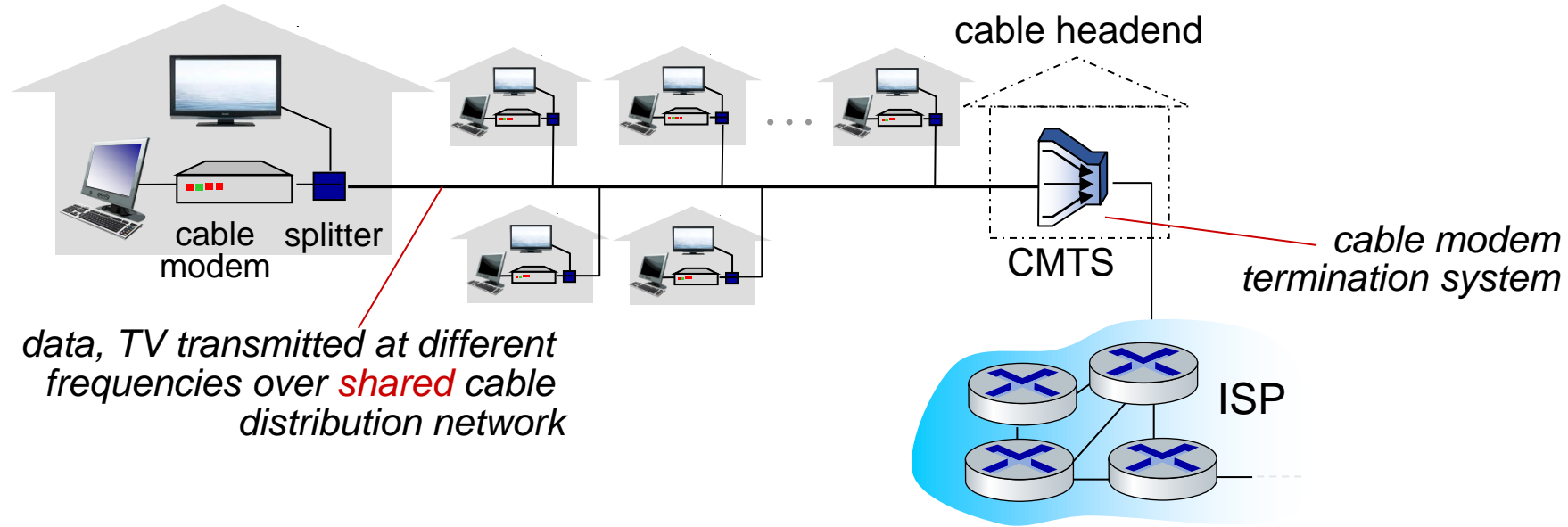


Access networks: cable-based access



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

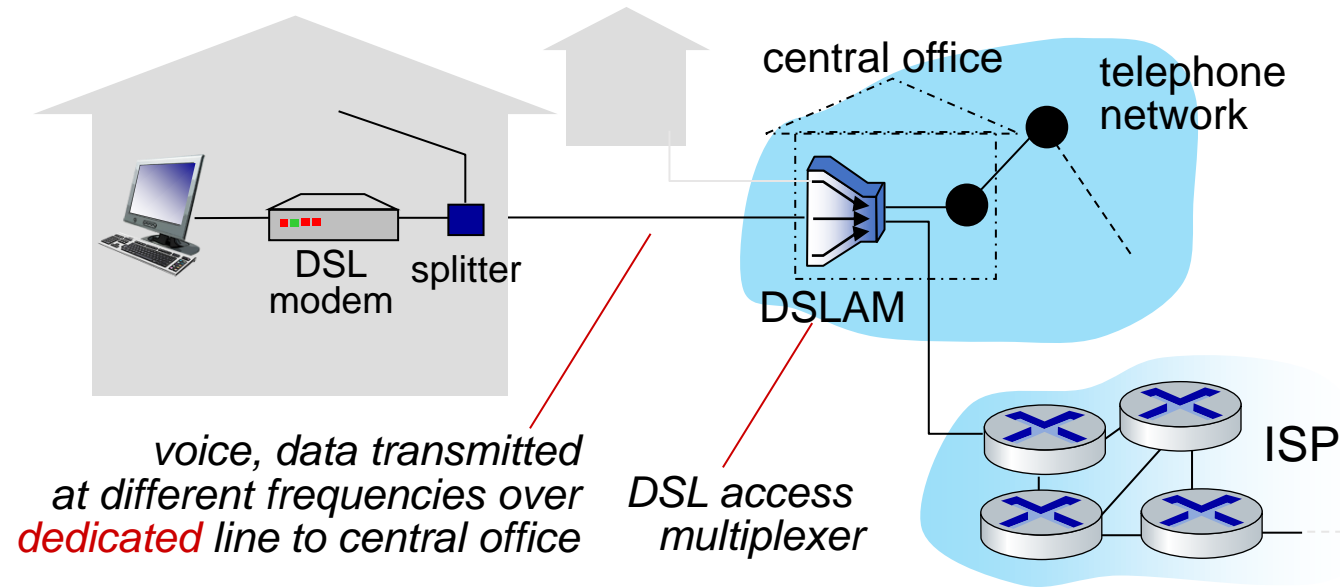
Access networks: cable-based access



■ HFC: hybrid fiber coax

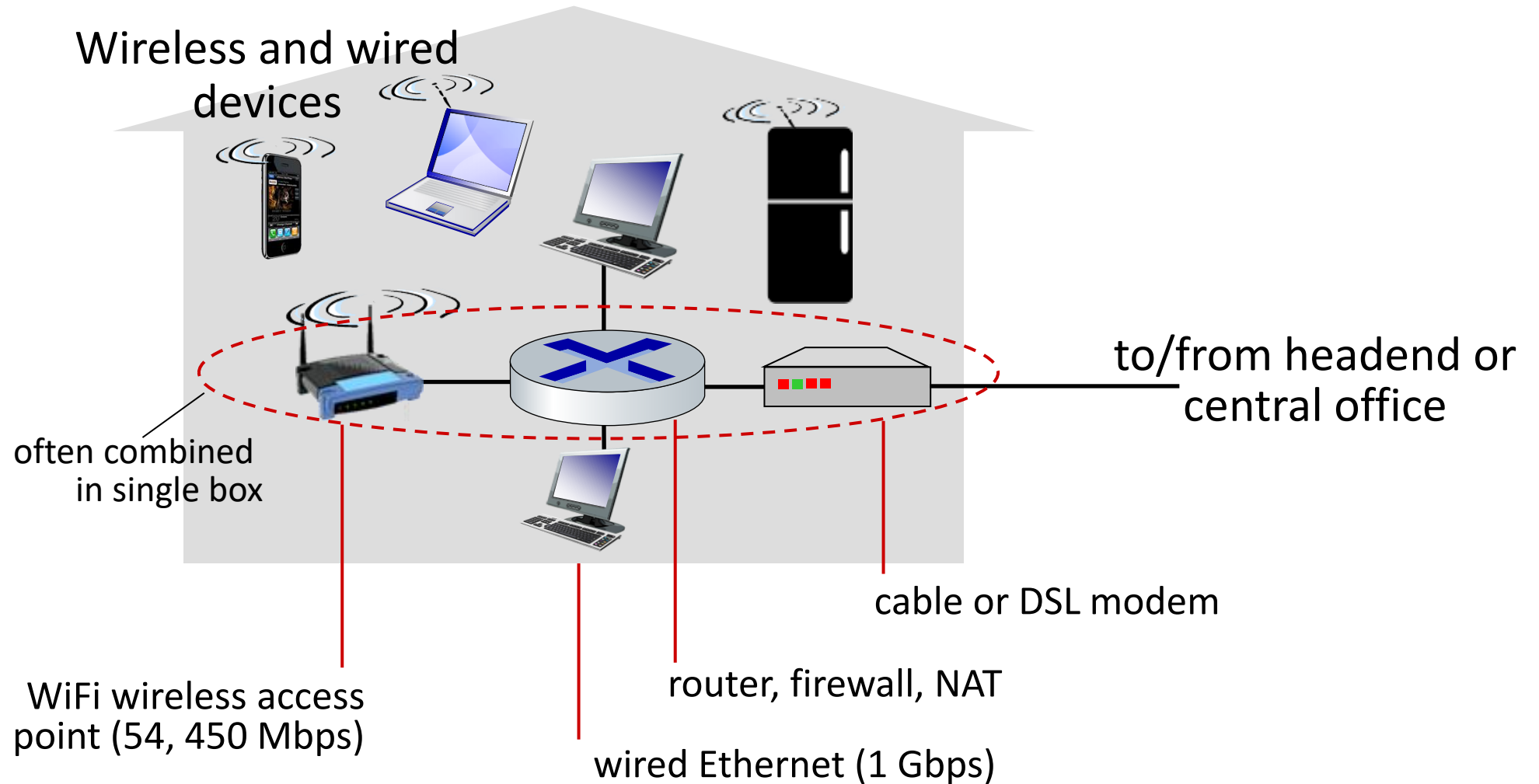
- asymmetric: up to 40 Mbps – 1.2 Gbps downstream transmission rate, 30-100 Mbps upstream transmission rate
- ## ■ network of cable, fiber attaches homes to ISP router
- homes *share access network* to cable headend

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



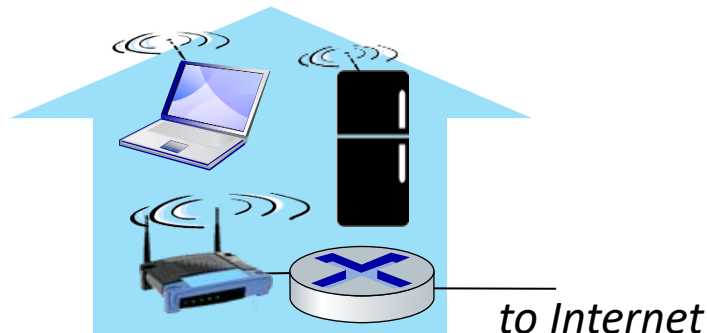
Wireless access networks

Shared *wireless* access network connects end system to router

- via base station aka “access point”

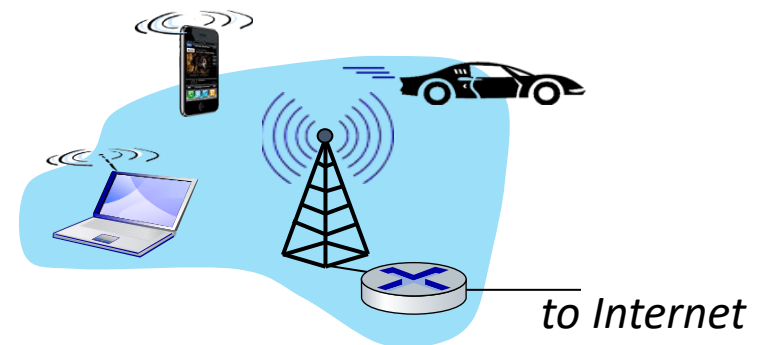
Wireless local area networks (WLANs)

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

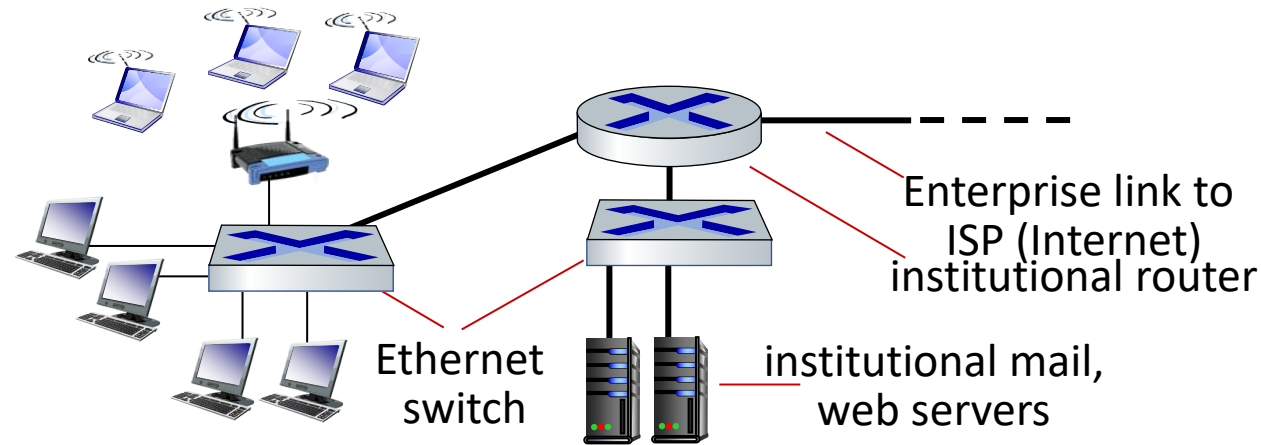


Wide-area cellular access networks

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



Access networks: enterprise networks



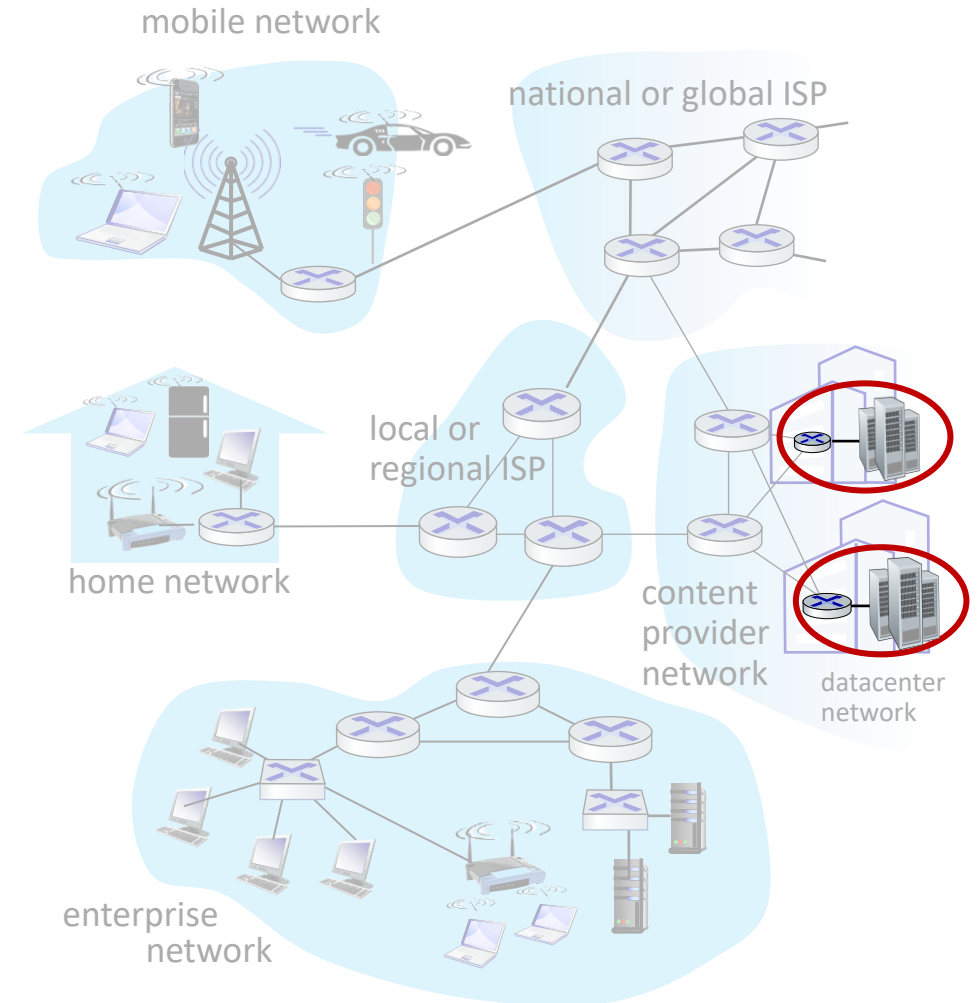
- companies, universities, etc.
- mix of wired, wireless link technologies, connecting a mix of switches and routers (we'll cover differences shortly)
 - Ethernet: wired access at 100Mbps, 1Gbps, 10Gbps
 - WiFi: wireless access points at 11, 54, 450 Mbps

Access networks: data center networks

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



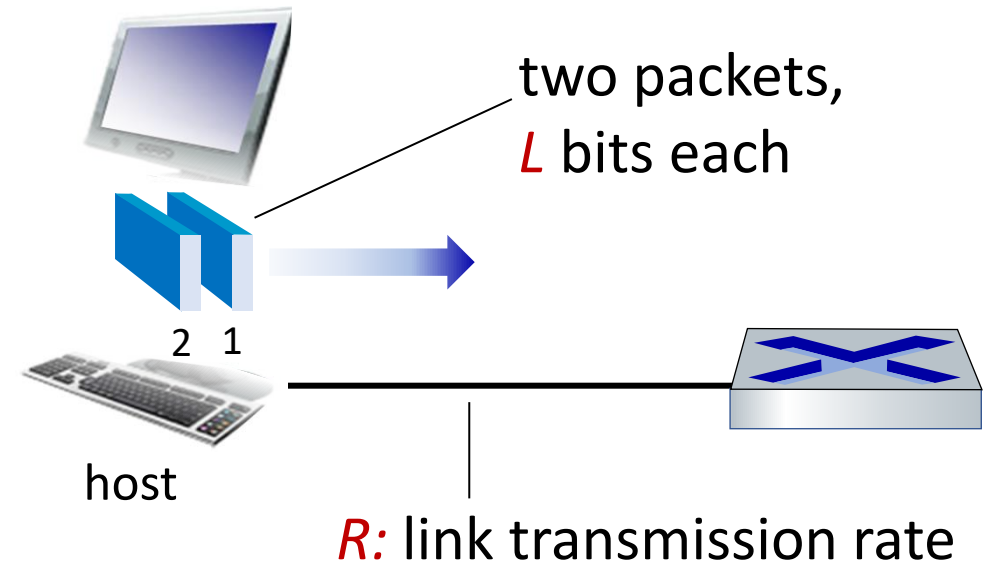
Courtesy: Massachusetts Green High Performance Computing Center (mghpcc.org)



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*



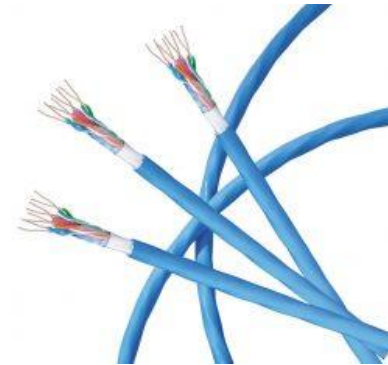
$$\begin{array}{l} \text{packet} \\ \text{transmission} \\ \text{delay} \end{array} = \begin{array}{l} \text{time needed to} \\ \text{transmit } L\text{-bit} \\ \text{packet into link} \end{array} = \frac{L \text{ (bits)}}{R \text{ (bits/sec)}}$$

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

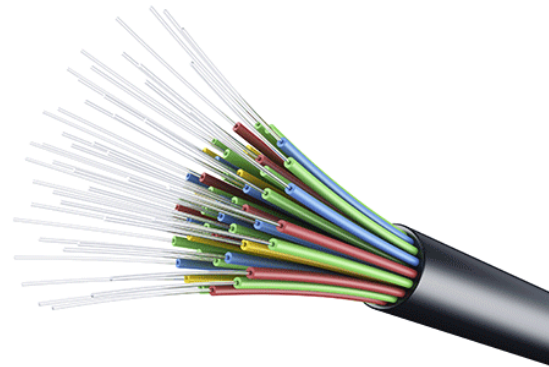
Coaxial cable:

- 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:

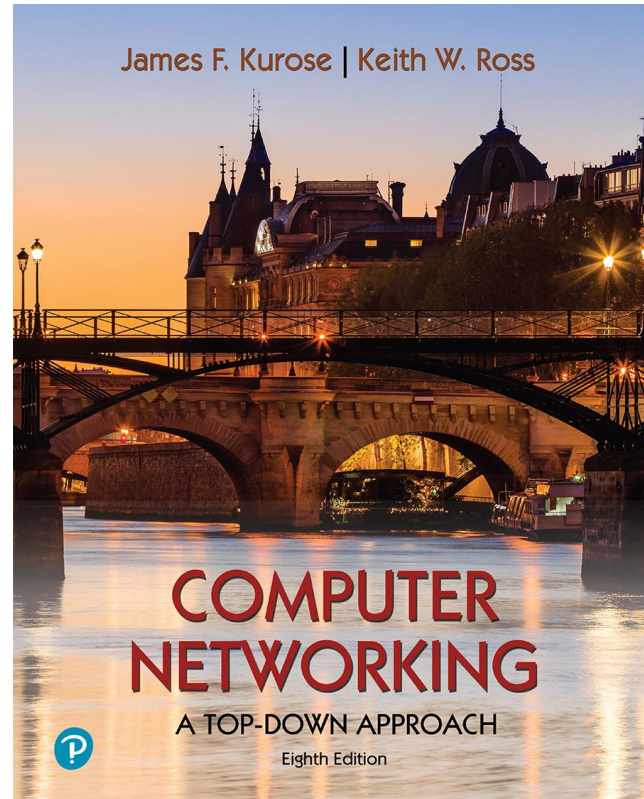
- **Wireless LAN (WiFi)**
 - 10-100’s Mbps; 10’s of meters
- **wide-area** (e.g., 4G/5G cellular)
 - 10’s Mbps (4G) over ~10 Km
- **Bluetooth**: cable replacement
 - short distances, limited rates
- **terrestrial microwave**
 - point-to-point; 45 Mbps channels
- **satellite**
 - up to < 100 Mbps (Starlink)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

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