# Chapter 1 Introduction

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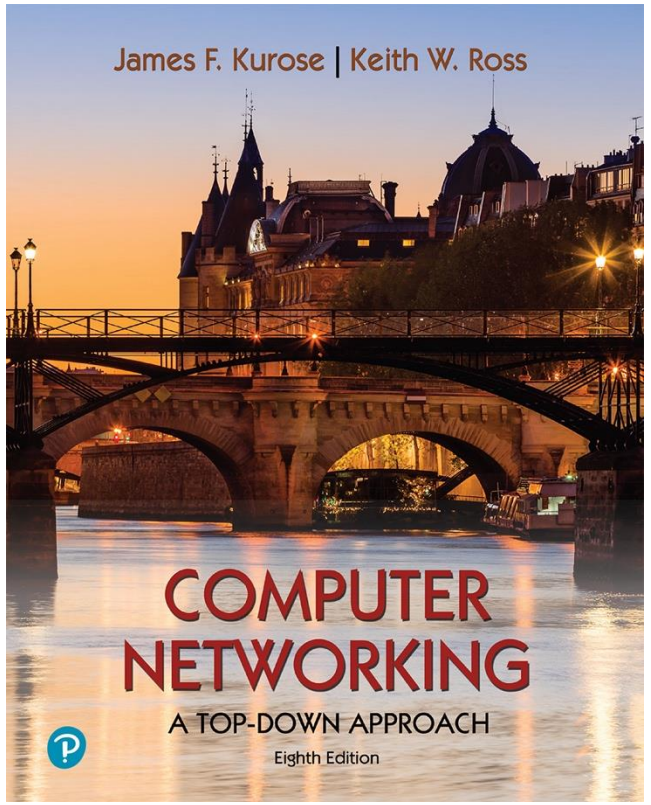



*Computer Networking: A Top-Down Approach*
8th edition
Jim Kurose, Keith Ross
Pearson, 2020

Adapted from the slides of the book's authors

# Chapter 1: introduction

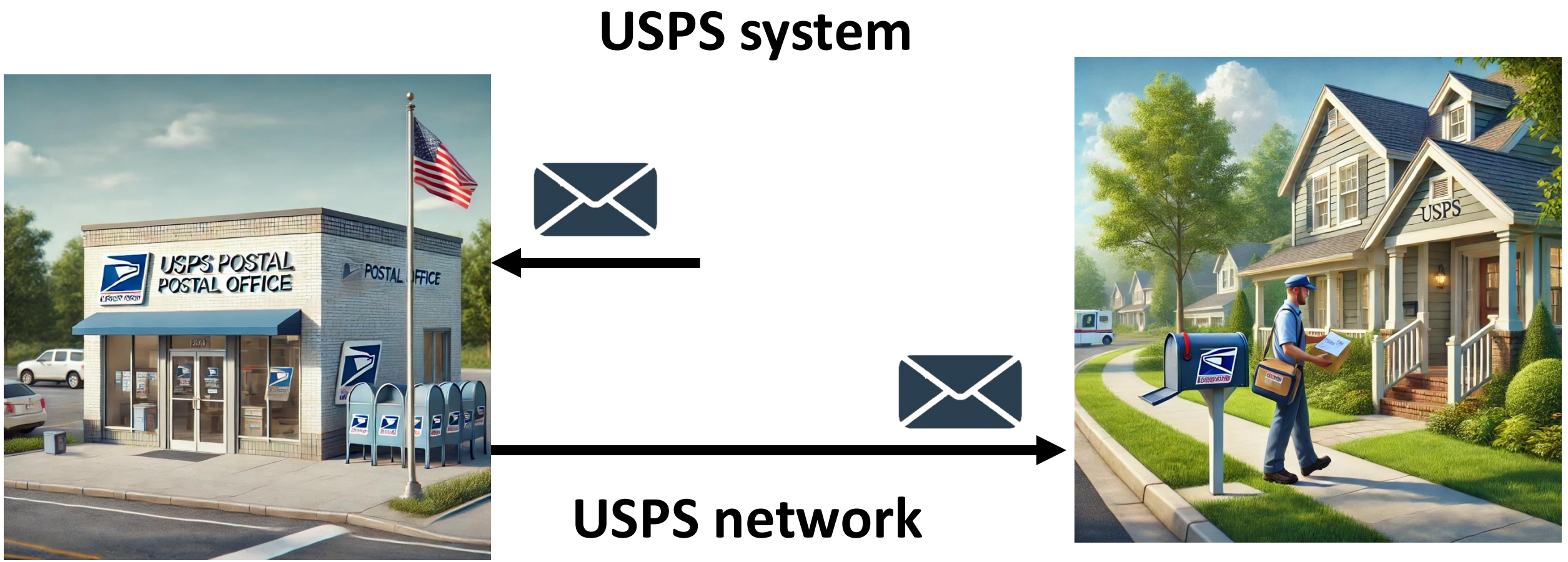
## *Chapter goal:*

- 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

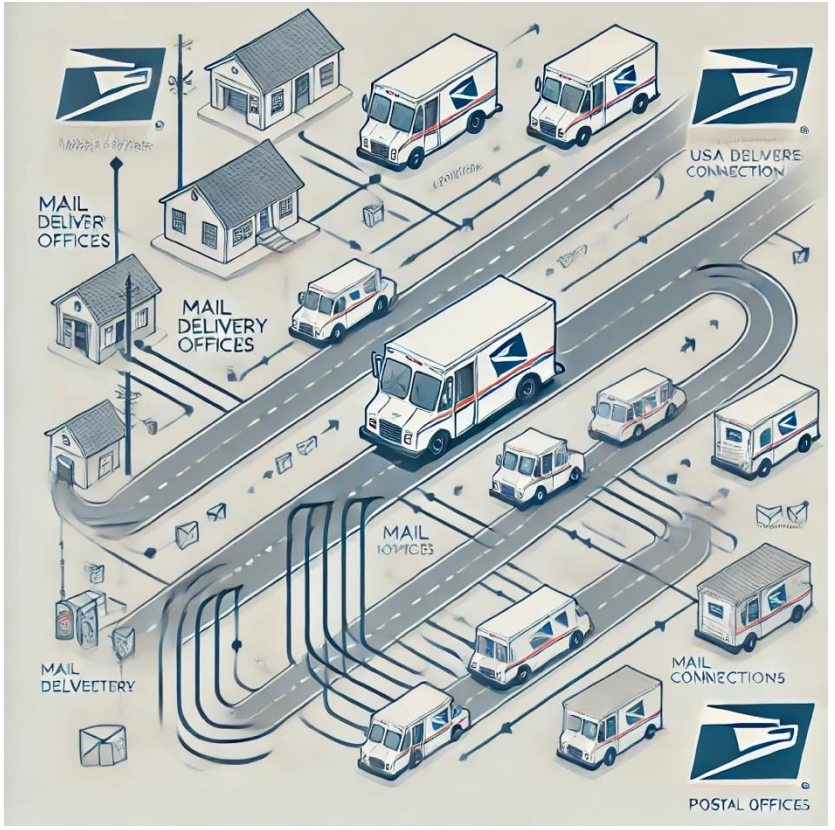
# What's Internet? An analogy: USPS



# What's Internet? An analogy: USPS



**USPS system**



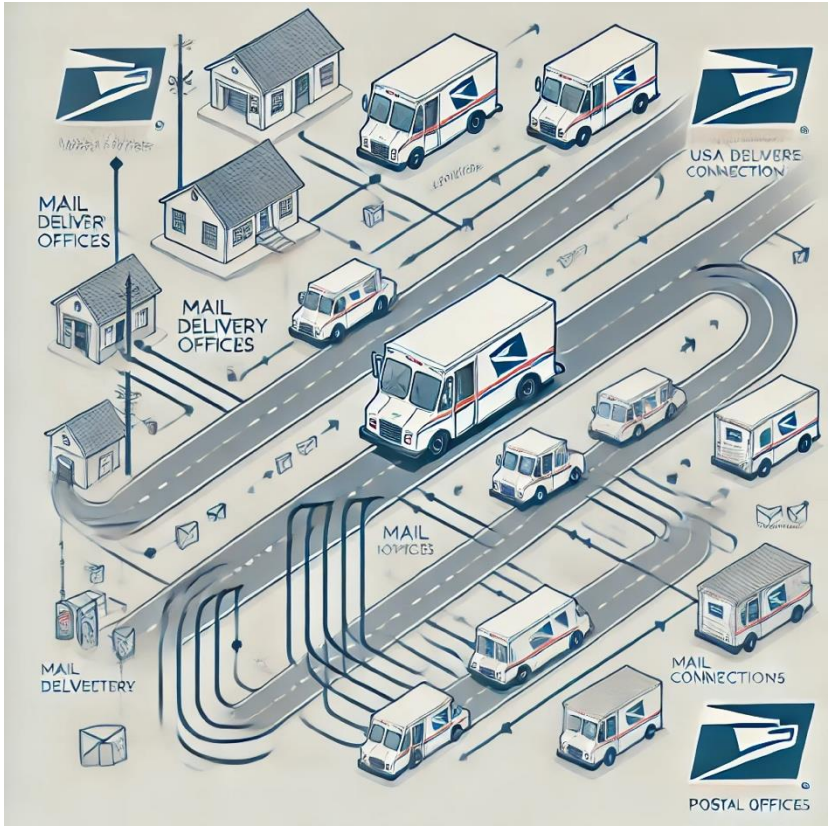

**USPS network**

# What's Internet? An analogy: USPS



**USPS system**

**USPS edge**




**USPS core network**

# What's Internet?


## Internet System

Packets

Packets

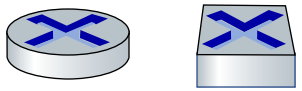
**Internet edge**

**Internet core network**

# 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*

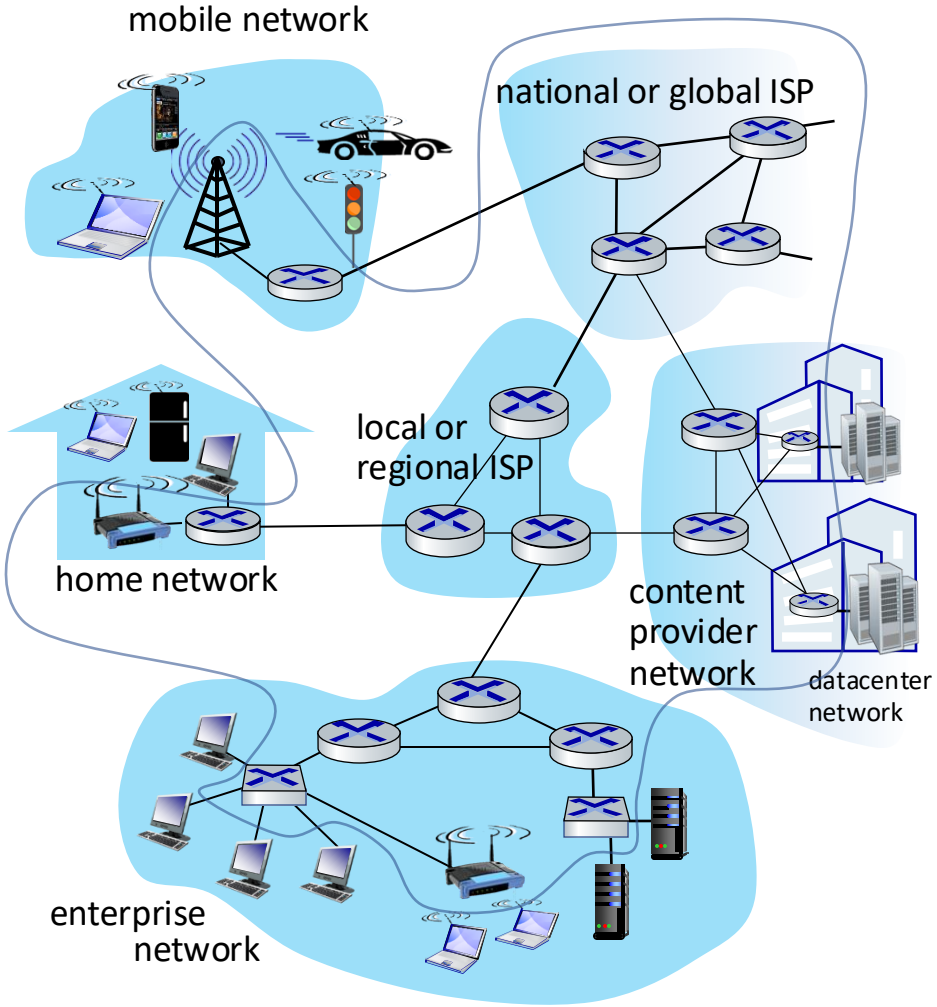
*Communication links*

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



*Networks*

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



# 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?

## *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

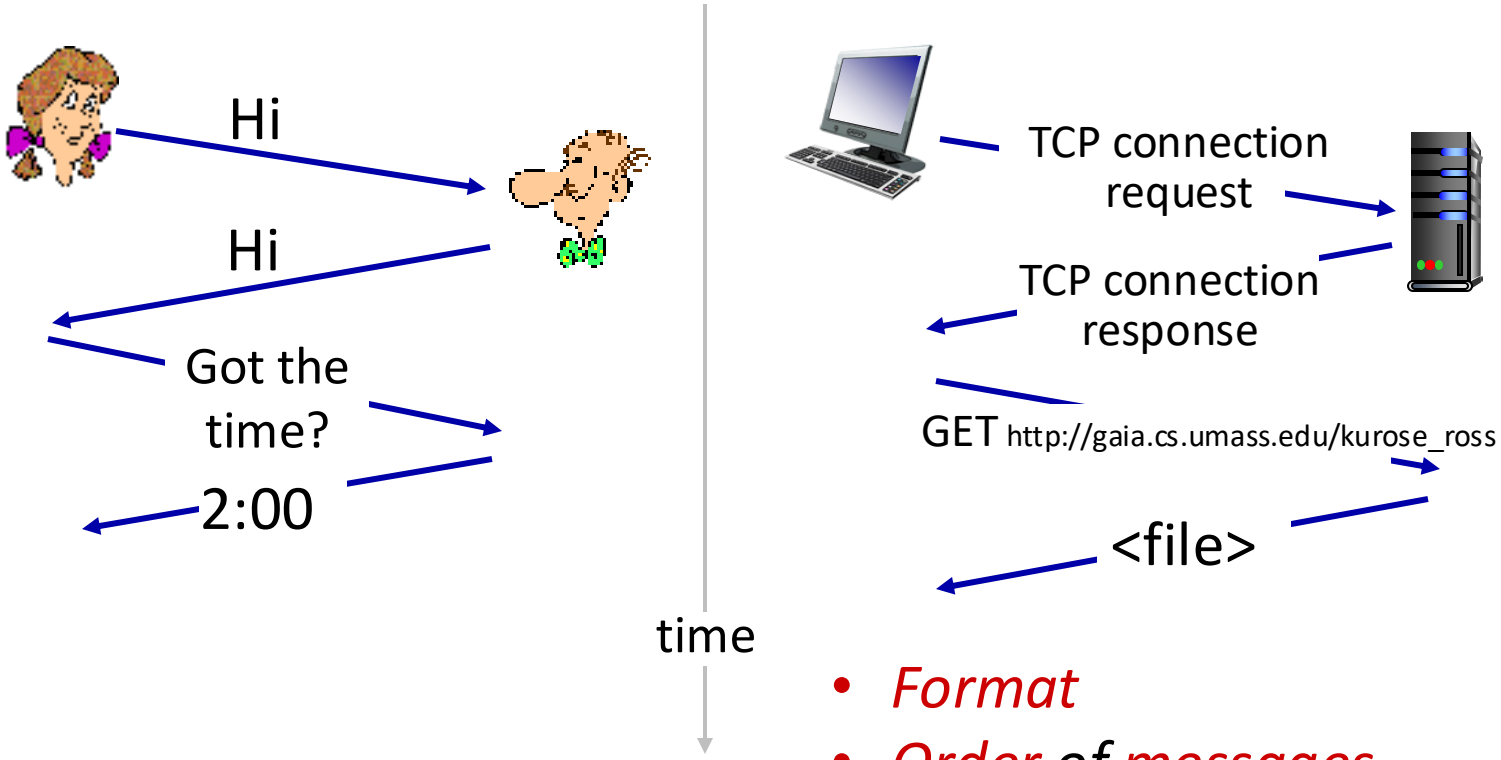
## *Network protocols:*

- 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?

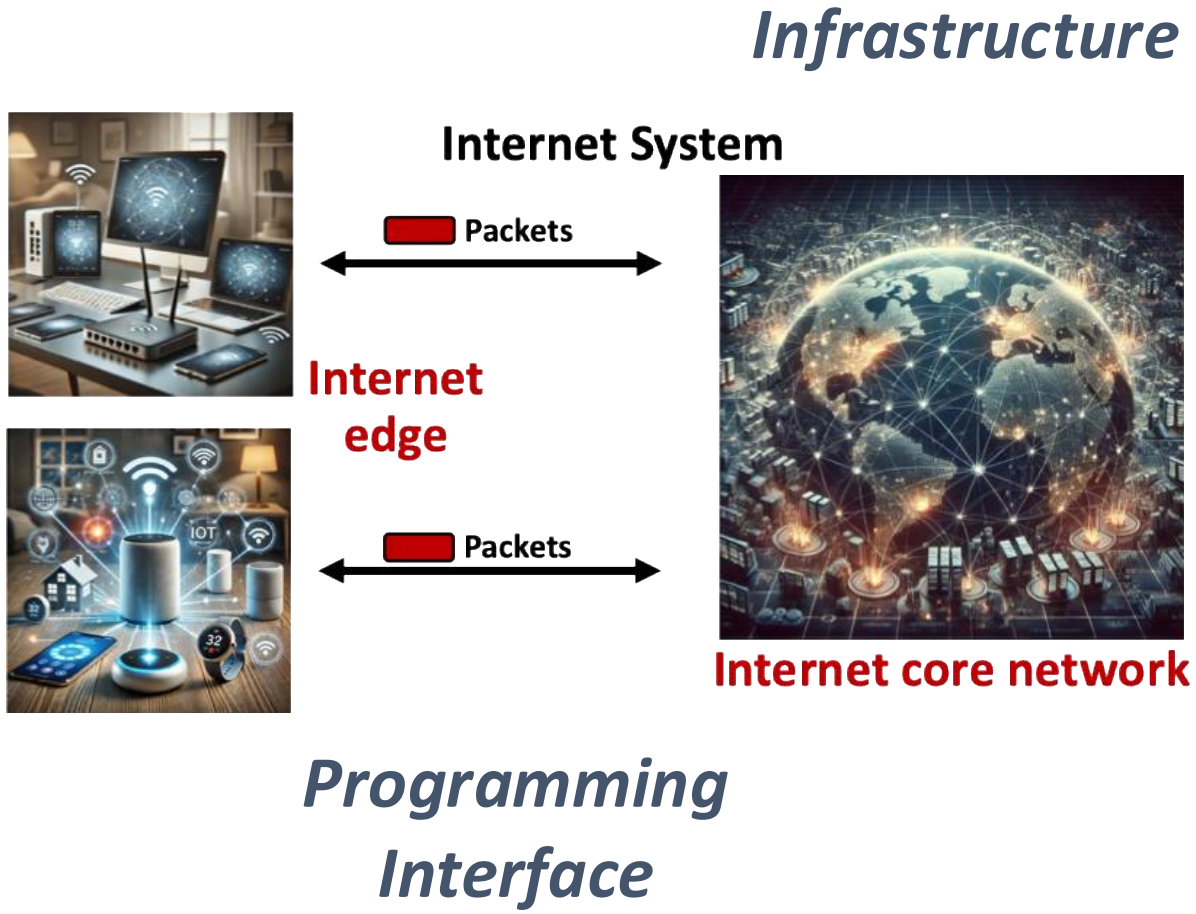
A human protocol and a computer network protocol:




- *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

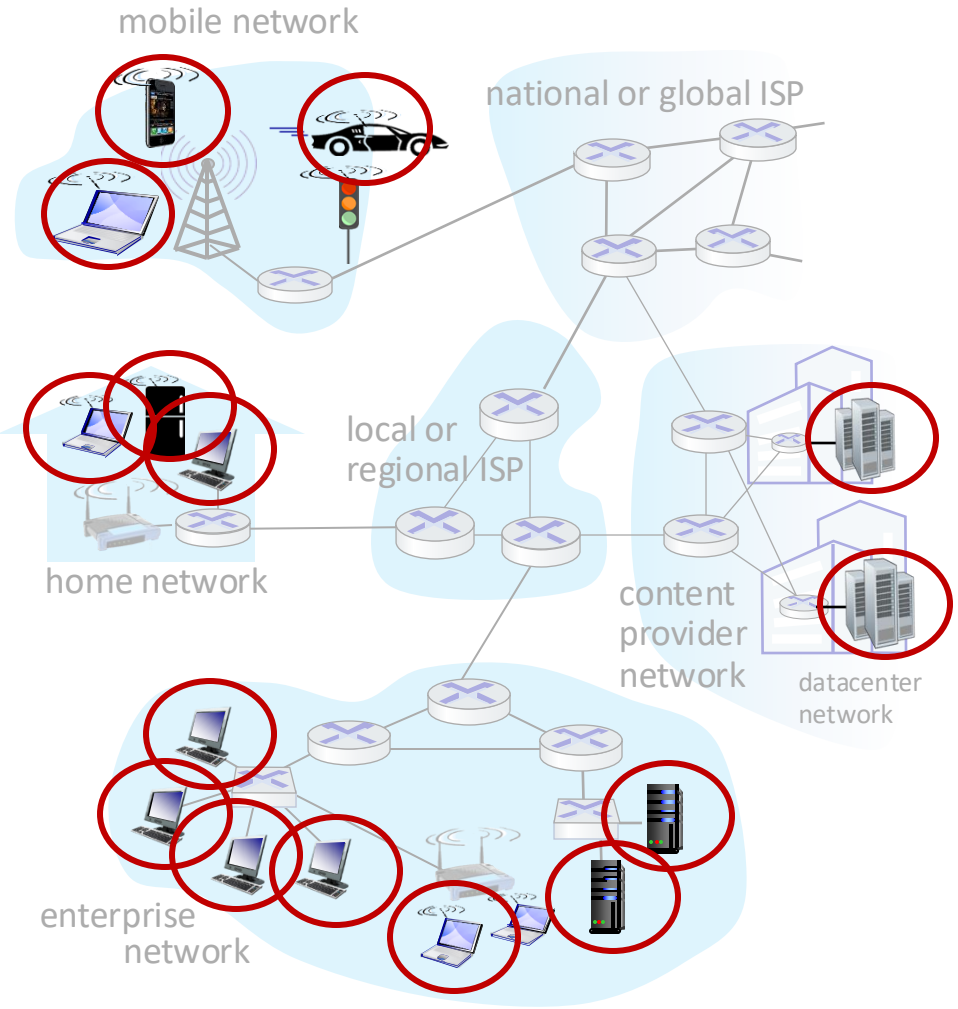
# Chapter 1: roadmap

- 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



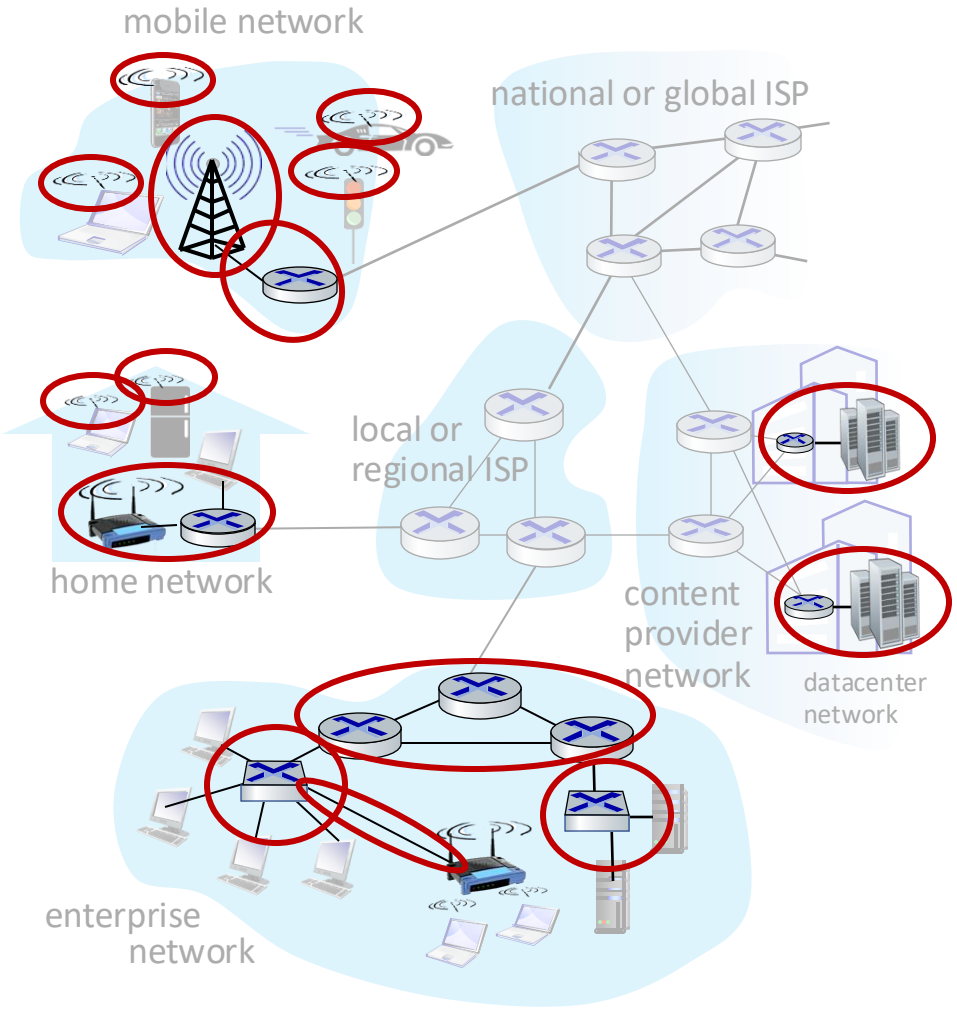
# A closer look at Internet structure

## Network edge:

- 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:

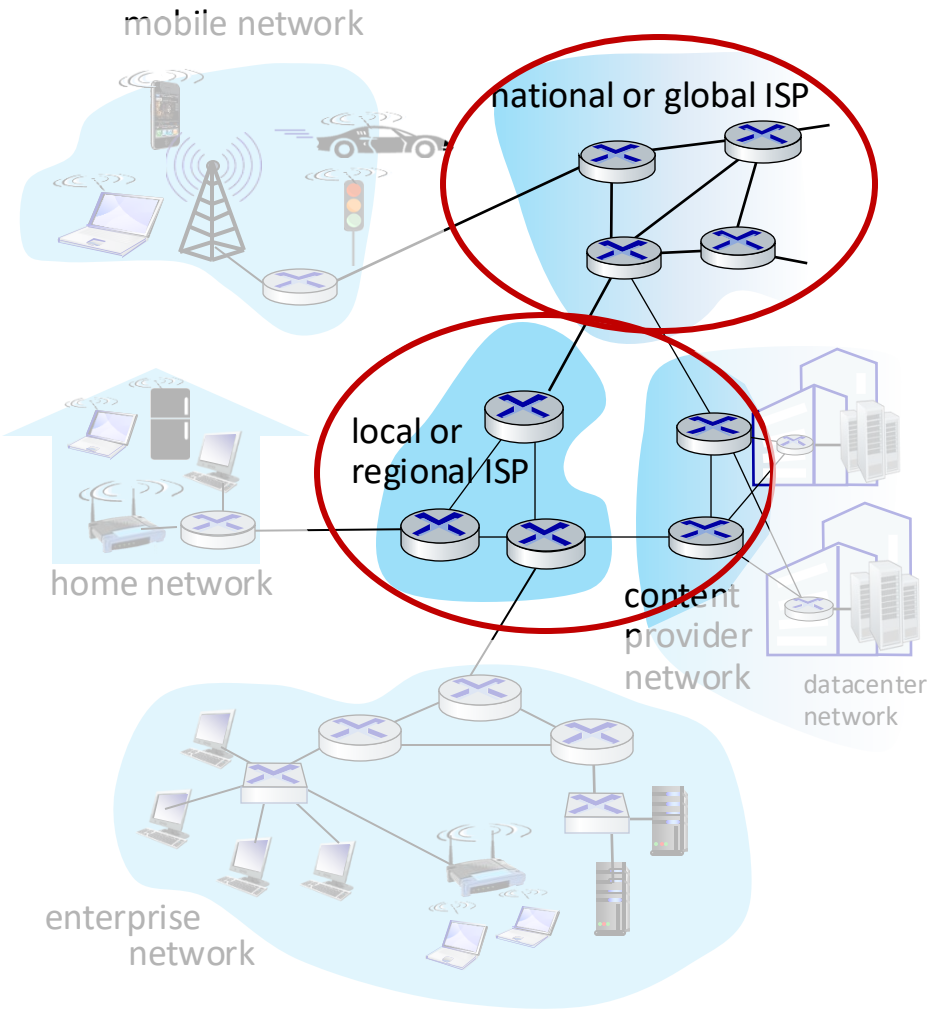
- hosts: clients and servers
- servers often in data centers

## Access networks, physical media:

- wired, wireless communication links

## Network core:

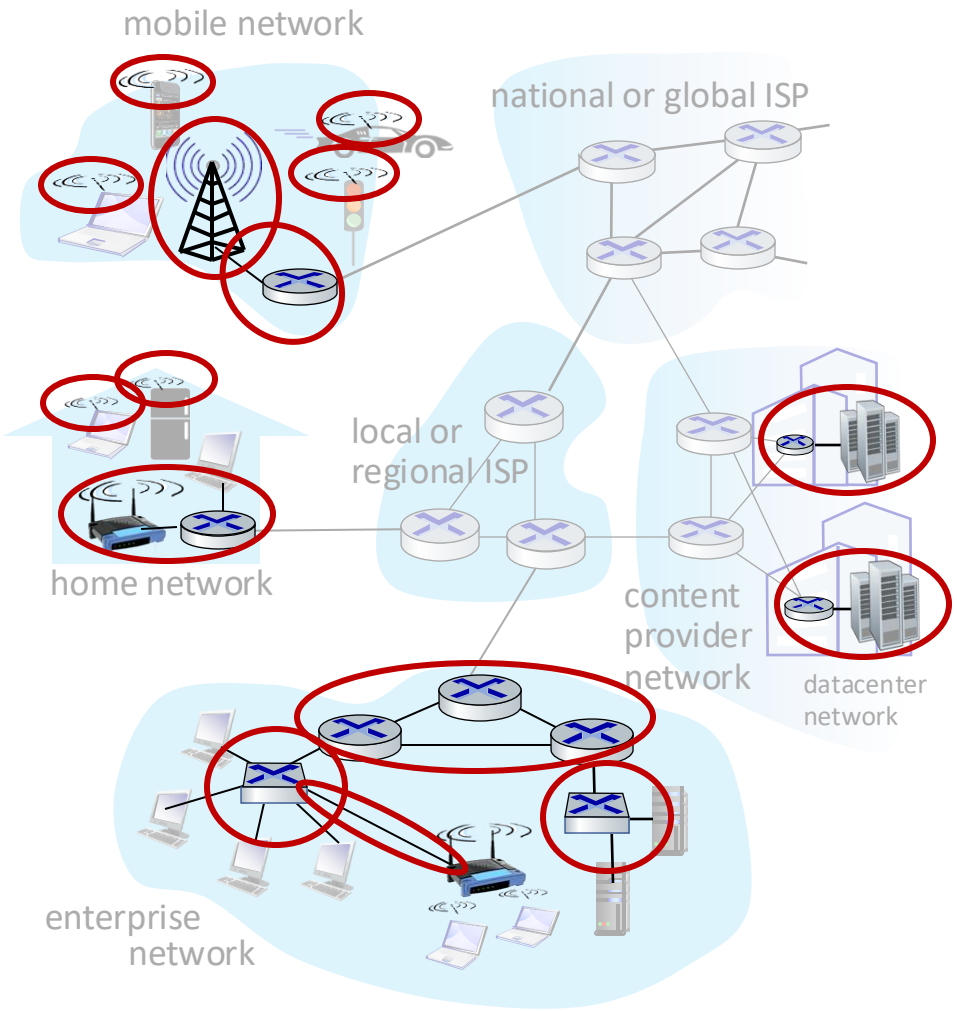
- interconnected routers
- network of networks



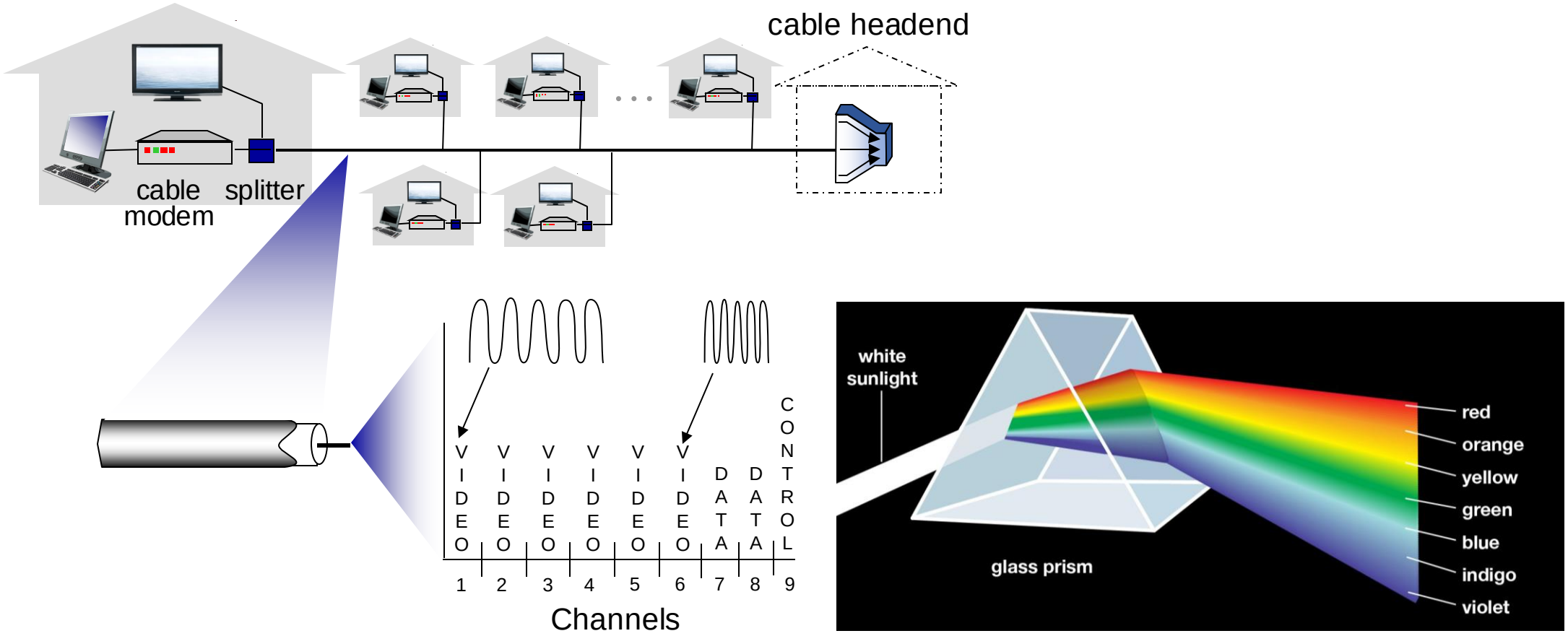
# Access networks and physical media

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

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

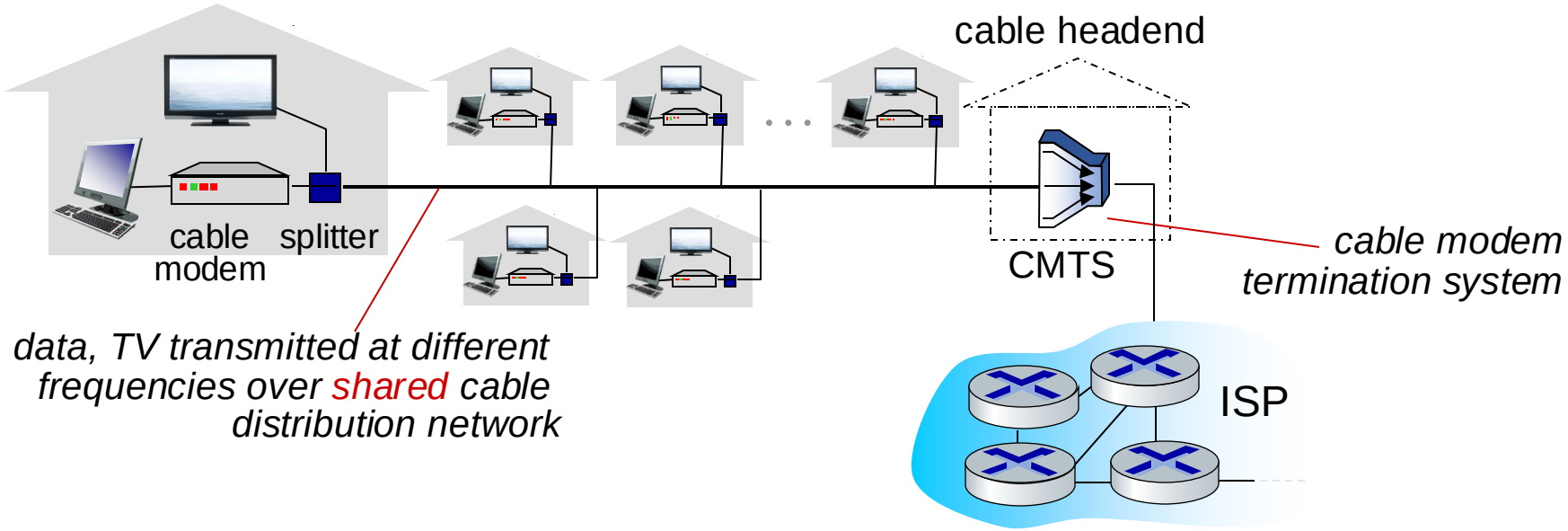


# Access networks: cable-based access



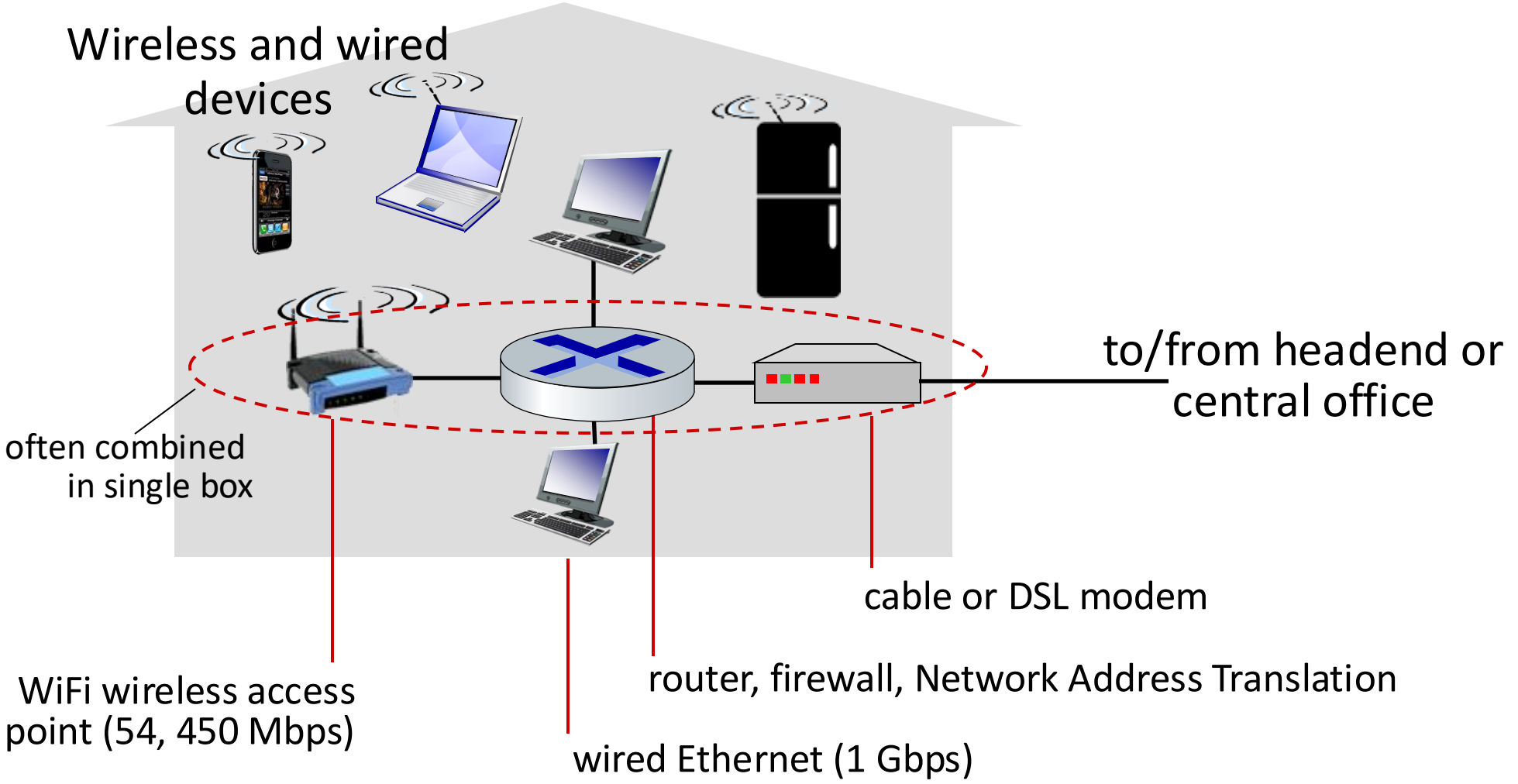

*frequency division multiplexing (FDM):* different channels transmitted in different frequency bands

# 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: home networks



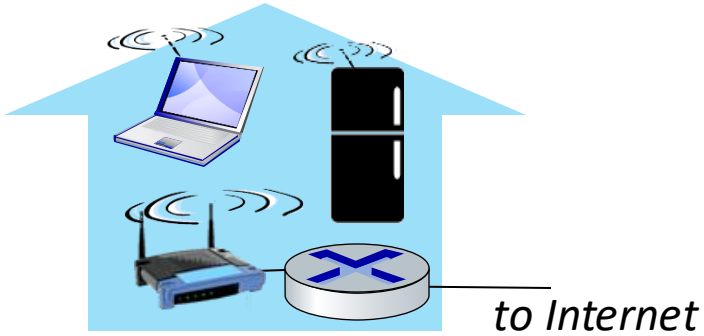
# Wireless access networks

Shared *wireless* access network connects end system to router

- via base station aka “access point”

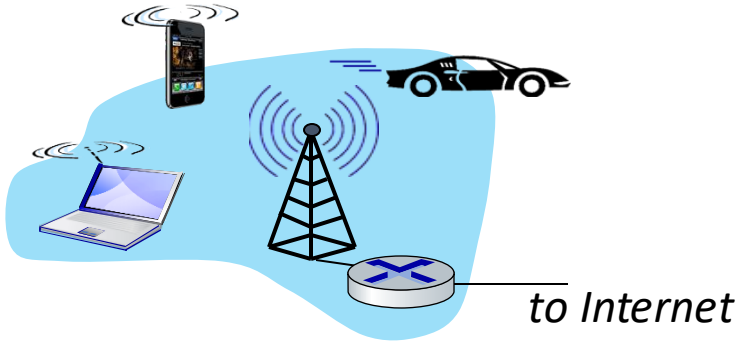
## Wireless local area networks (WLANs)

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

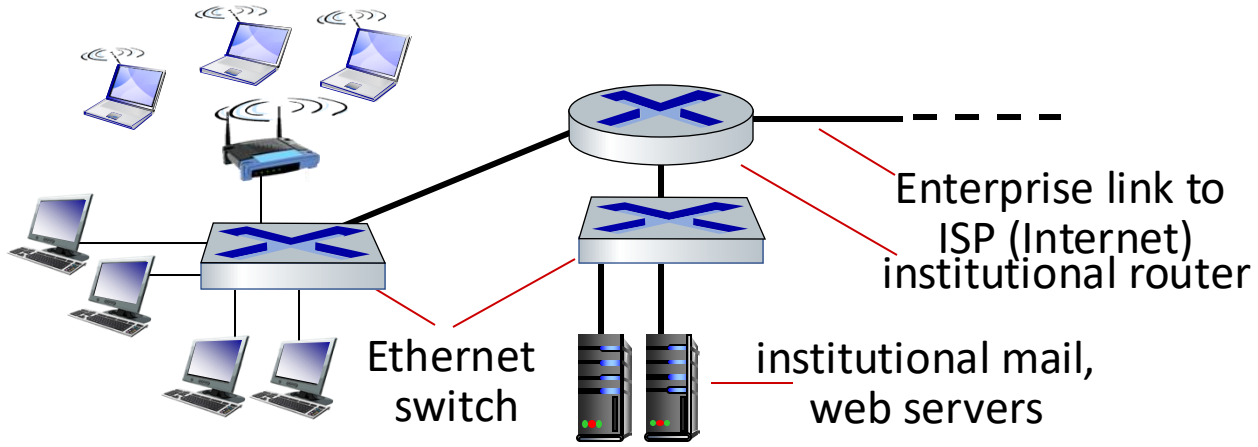



## Wide-area cellular access networks

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



# Access networks: enterprise networks

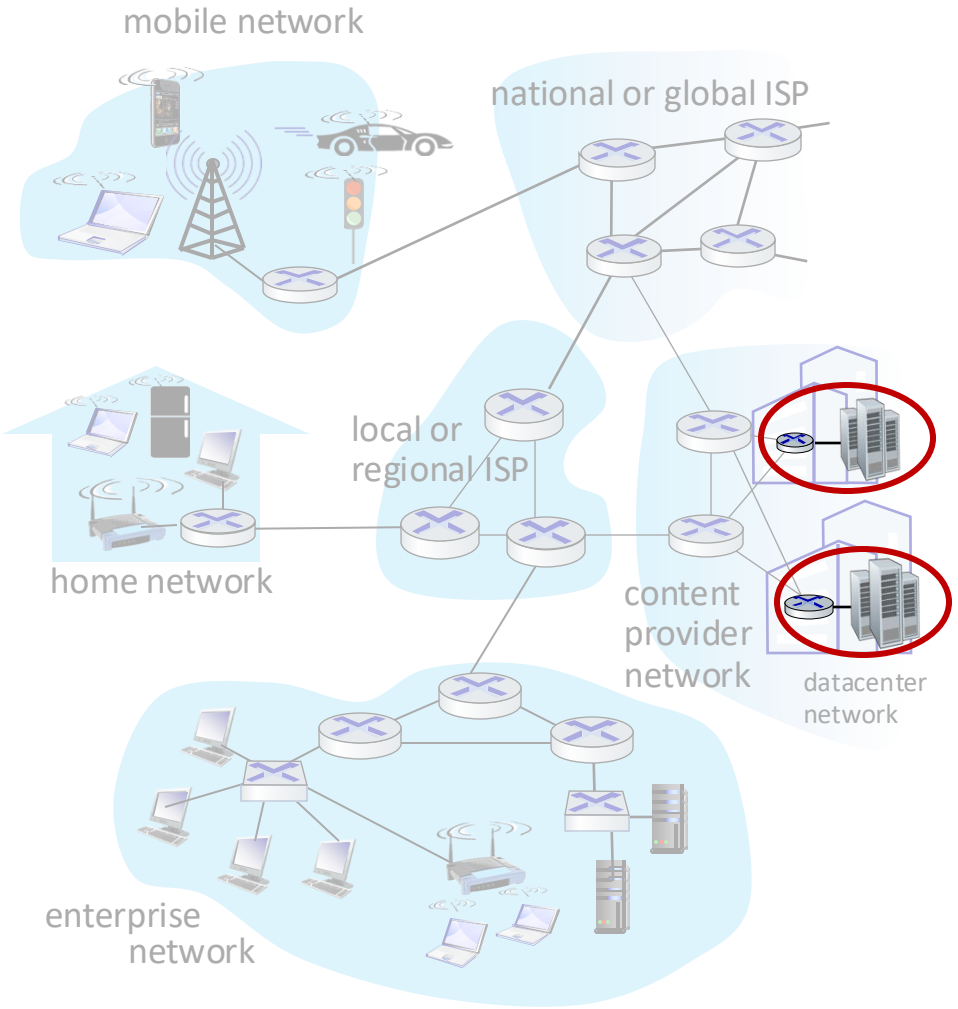



- companies, universities, etc.
- mix of wired, wireless link technologies, connecting a mix of switches and routers (we'll cover differences shortly)
  - Ethernet: wired access at 100Mbps, 1Gbps, 10Gbps
  - WiFi: wireless access points at 11, 54, 450 Mbps

# 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)



# Host: sends *packets* of data

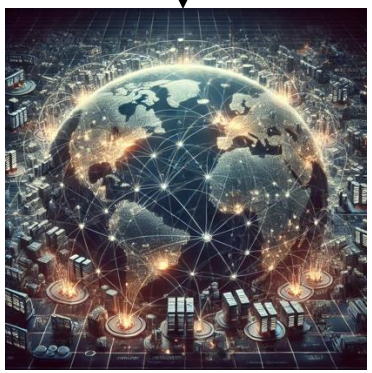
host sending function:

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

App Data

101101101010101001101111……. Bits

Packet 1 Packet 2

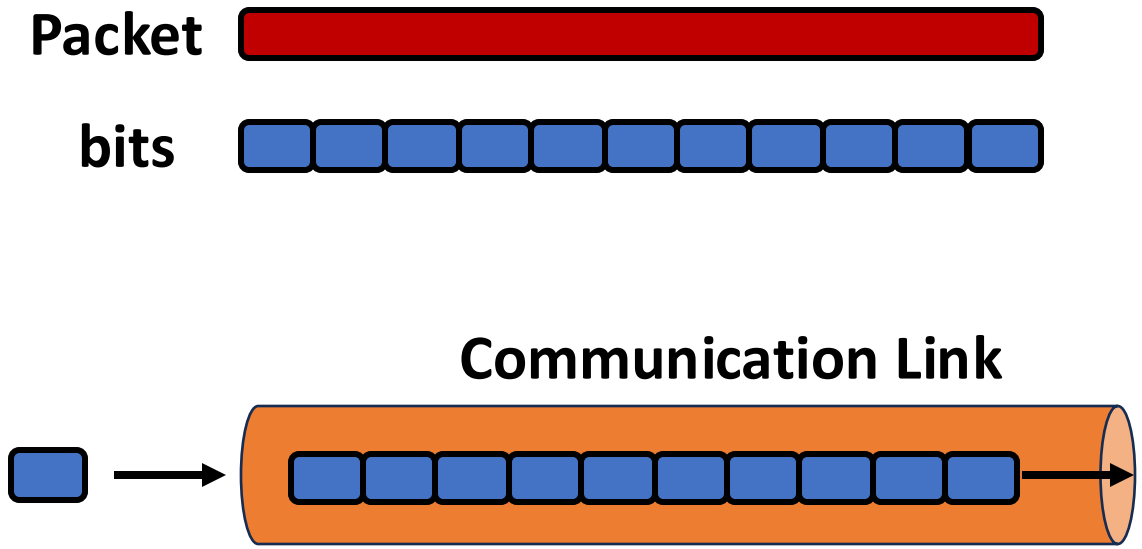


Network

# Host: sends *packets* of data

host sending function:

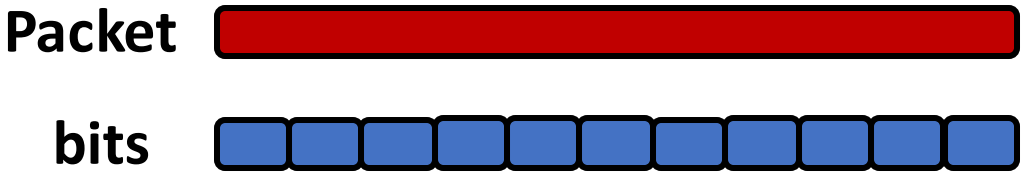
- takes application message
- breaks into smaller chunks, known as *packets*, of length *L* bits
- transmits packet into access network at *transmission rate R*
  - link transmission rate, aka link *capacity, aka link bandwidth*

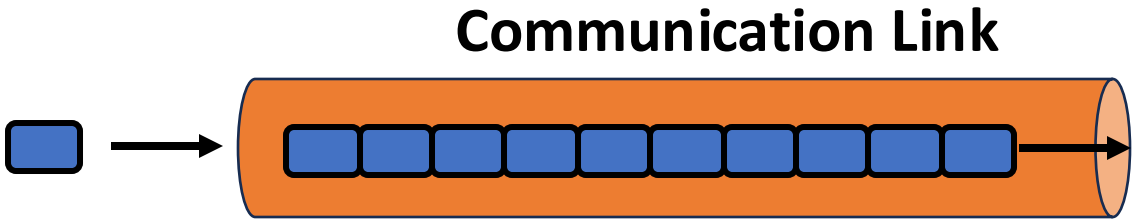



What's the transmission rate R, link capacity or link bandwidth?

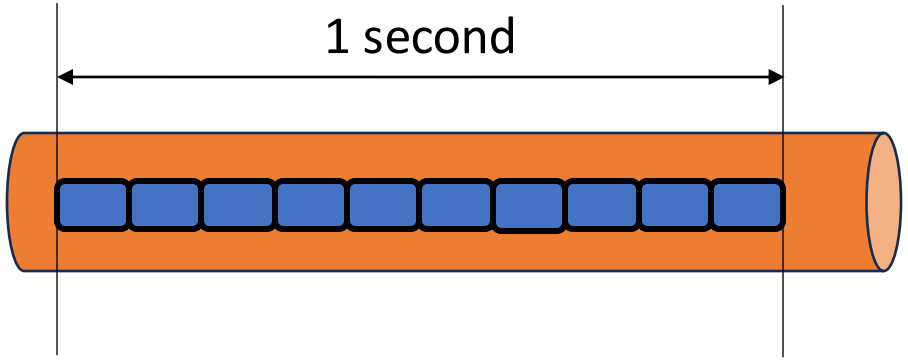
# Host: sends *packets* of data

Link *transmission rate R, aka Link Capacity, aka link bandwidth*

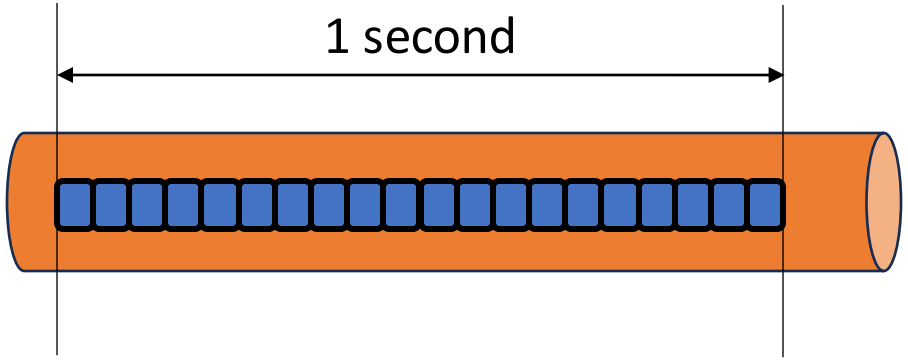



**Link capacity: 10 bit/sec**




**Link capacity: 20 bit/sec**

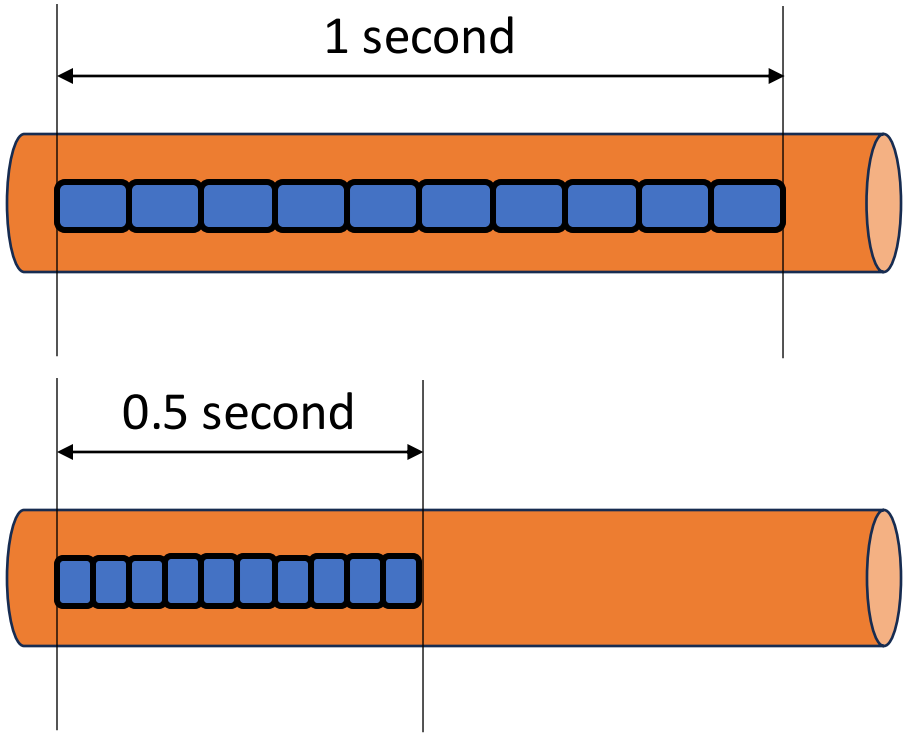


# Host: sends *packets* of data

Link *transmission rate R, aka Link Capacity, aka link bandwidth*

Packet transmission delay

- How long it takes for transmitting all the bits into the network or communication link




**A packet with 10 bits**

**10 bits**

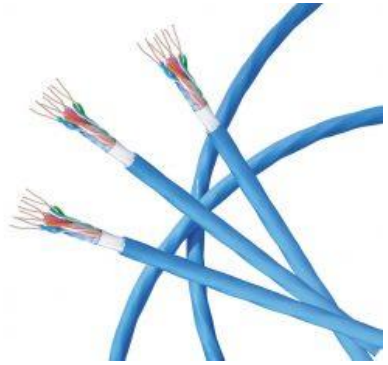
$$\text{packet transmission delay} = \text{time needed to transmit } L\text{-bit packet into link} = \frac{L \text{ (bits)}}{R \text{ (bits/sec)}}$$

# Communication 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



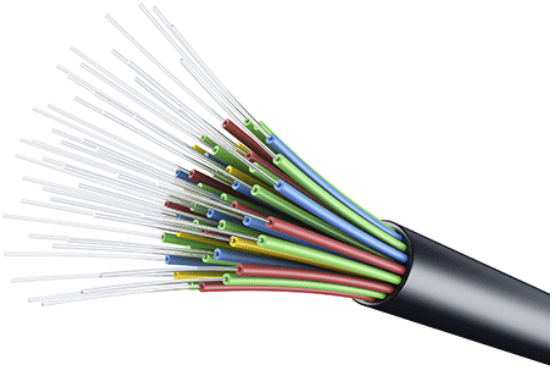
# Communication Links: physical media

## 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 wireless spectrum
- no physical "wire"
- broadcast, "half-duplex" (sender to receiver)
- propagation environment effects:
  - reflection
  - obstruction by objects
  - Interference/noise

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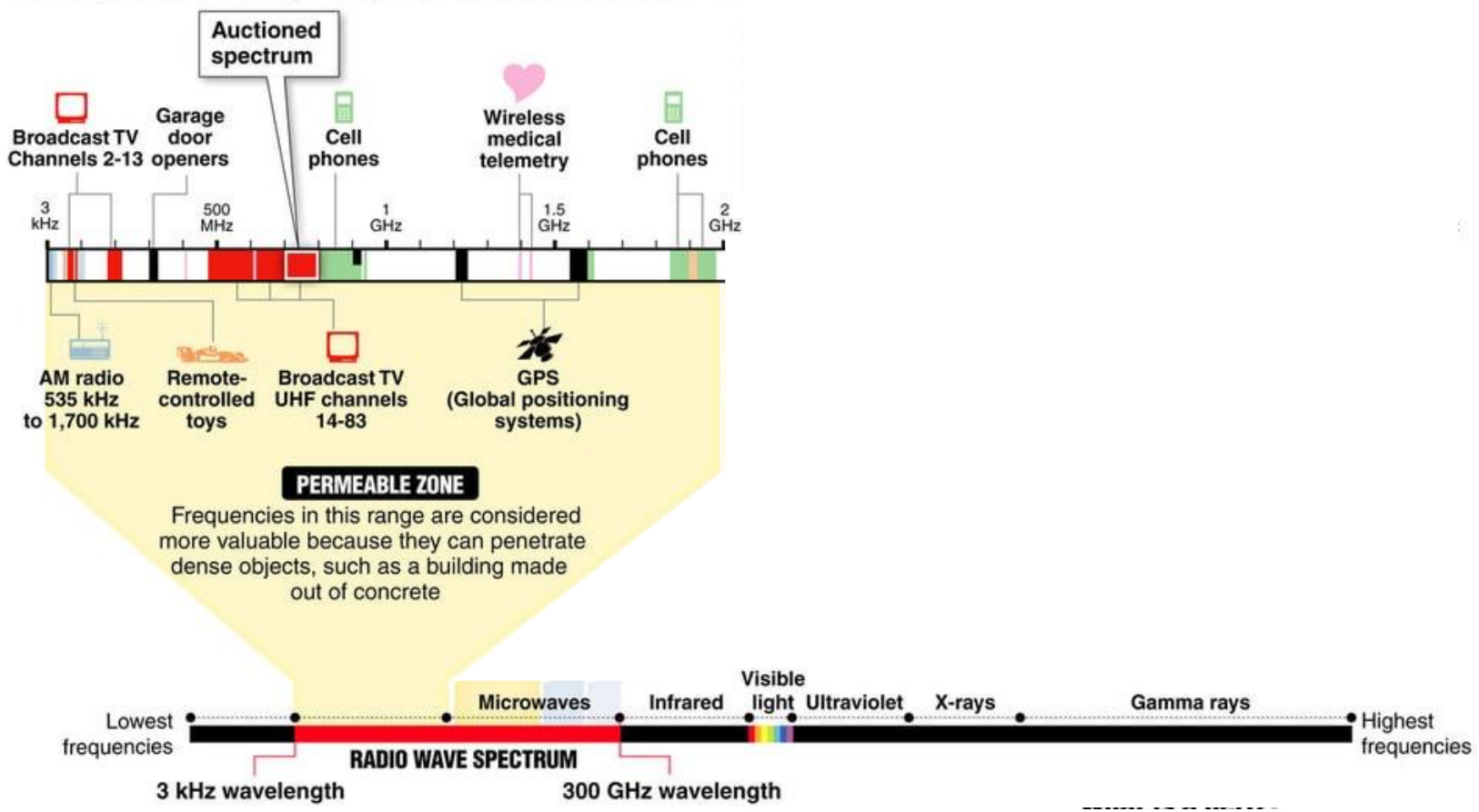
  - Interference/noise

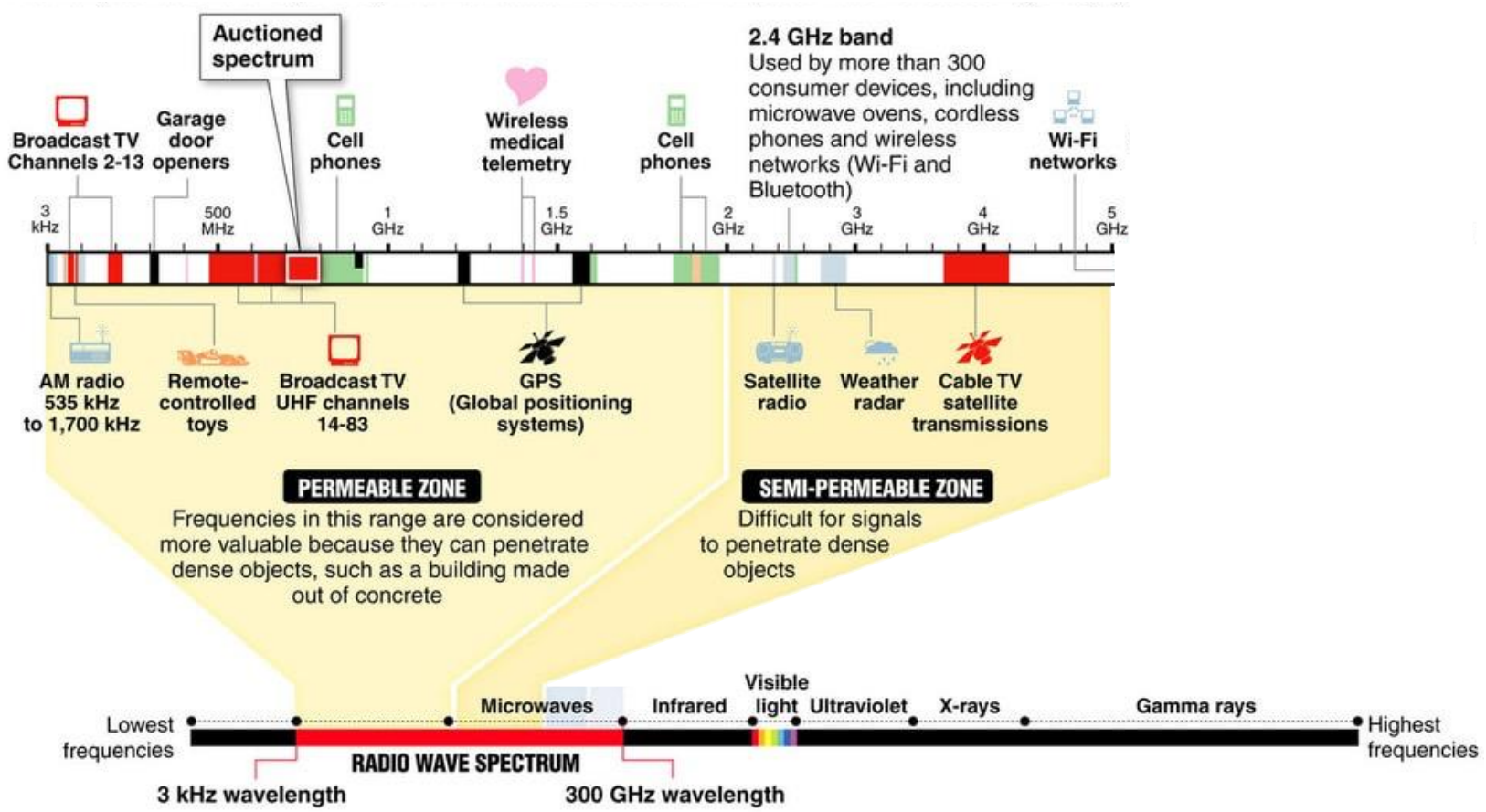
## Radio link types:

- 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
- satellite
  - up to 45 Mbps per channel
  - 270 msec end-end delay

# Wireless Spectrum



# Wireless Spectrum



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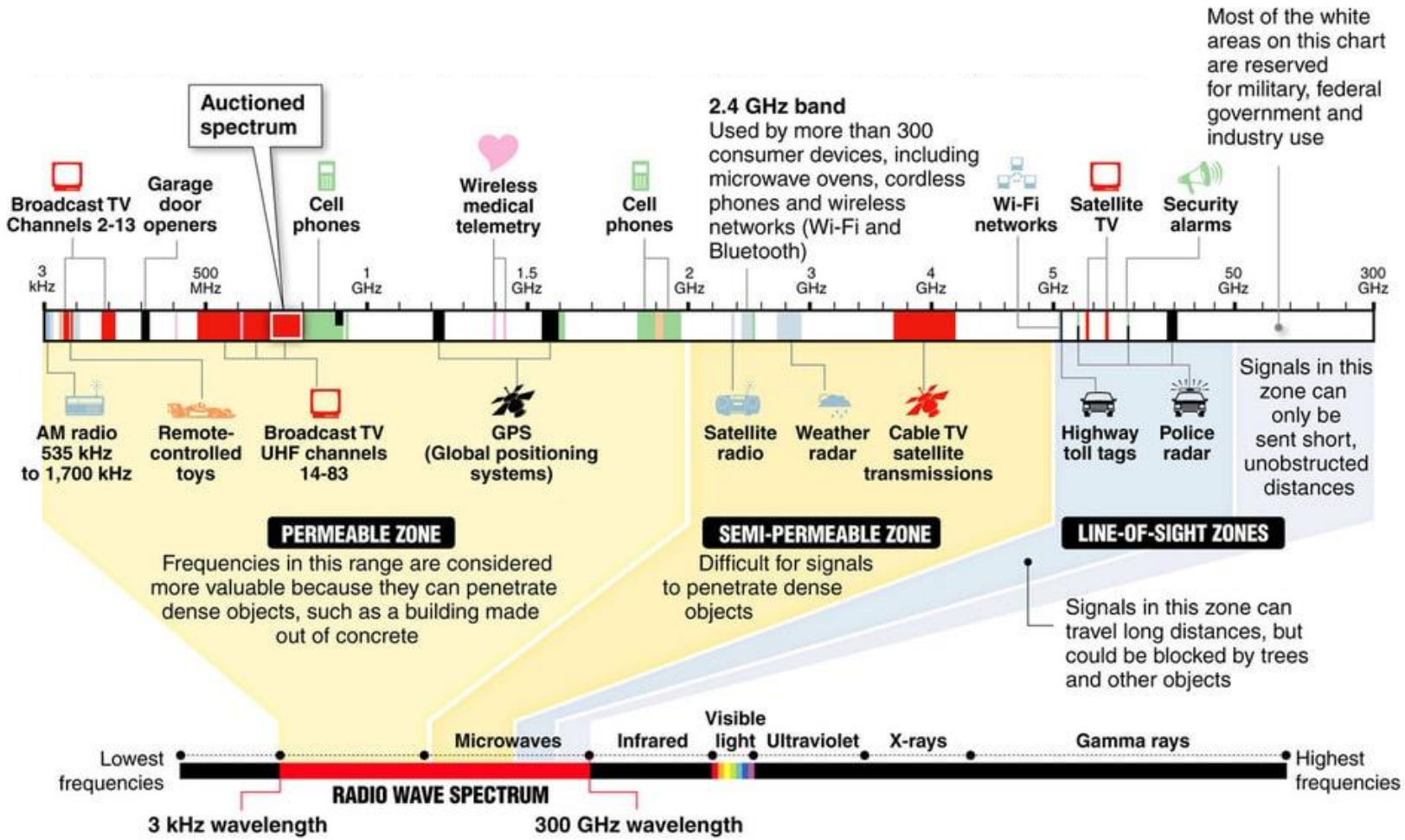

# Wireless Spectrum

*MID-BAND SPECTRUM AUCTION —*

## Verizon and AT&T dominate spectrum auction, spending combined $69 billion

**Top two carriers buy licenses nationwide, outspending T-Mobile and US Cellular.**

JON BRODKIN - 2/25/2021, 11:14 AM

Verizon and AT&T dominated the US government's latest spectrum auction, spending a combined $68.9 billion on licenses in the upper 3GHz band.

Verizon's winning bids totaled $45.45 billion, while AT&T's came in at $23.41 billion. T-Mobile was third with $9.34 billion as the three biggest wireless carriers accounted for the vast majority of the $81.17 billion in winning bids, the Federal Communications Commission said in results released yesterday. US Cellular, a regional carrier, was a distant fourth in spending, at $1.28 billion, but came in third, ahead of T-Mobile, in the number of licenses won.