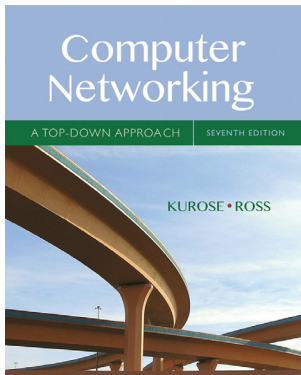


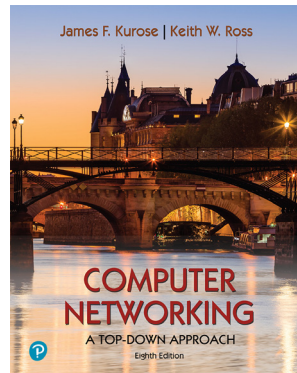
Chapter 1

Introduction

Courtesy to the textbooks' authors and Pearson Addison-Wesley because many slides are adapted from the following textbooks and their associated slides.



Jim Kurose, Keith Ross,
“Computer Networking: A Top
Down Approach”, 7th Edition,
Pearson, 2016.



Jim Kurose, Keith Ross,
“Computer Networking: A Top
Down Approach”, 8th Edition,
Pearson, 2020.

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Chapter 1: introduction

Chapter goal:

- Get “big picture” and “feelings”
 - Introduction to terminology
 - more depth, detail later in course
- Use Internet as an example

Overview/roadmap:

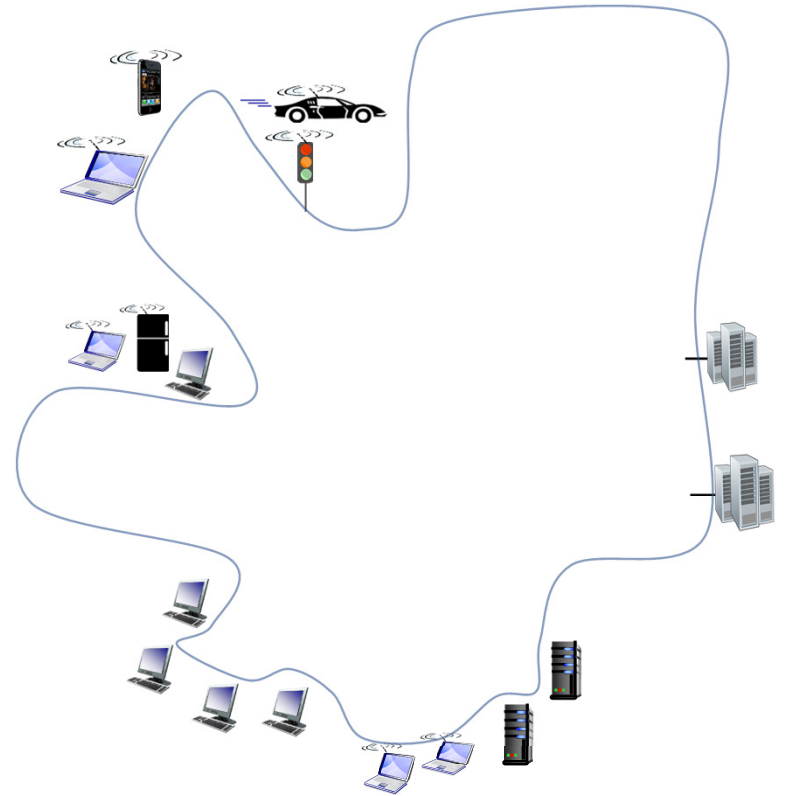
- What is the Internet?
 - **Network edge**: hosts, access network, physical media
 - **Network core**: packet/circuit switching, internet structure
 - What is a protocol?
- Performance
 - loss, delay, throughput
- Protocol layers, service models
- Security
- History

The Internet: a “nuts and bolts” view



Billions of connected *devices*:

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



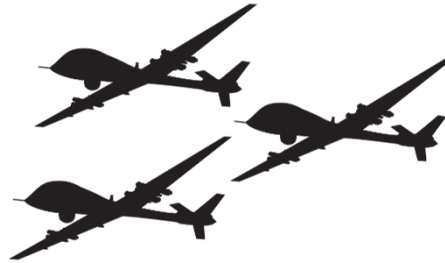
“Fun” Internet-connected devices



Amazon Echo



smart phone



UAV or UAV fleet



Tweet-a-watt:
monitor energy use



smart
bracelet



Security Camera



Slingbox: remote
control cable TV



VR/AR devices



smart
watch



bikes



cars



Internet phones



Gaming devices



sensorized,
bed mattress



scooters

The Internet: a “nuts and bolts” view



Billions of connected *devices*:

- *end systems* = *hosts*
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Routers/switches: forward packets (chunks of data)

- *routers, switches*

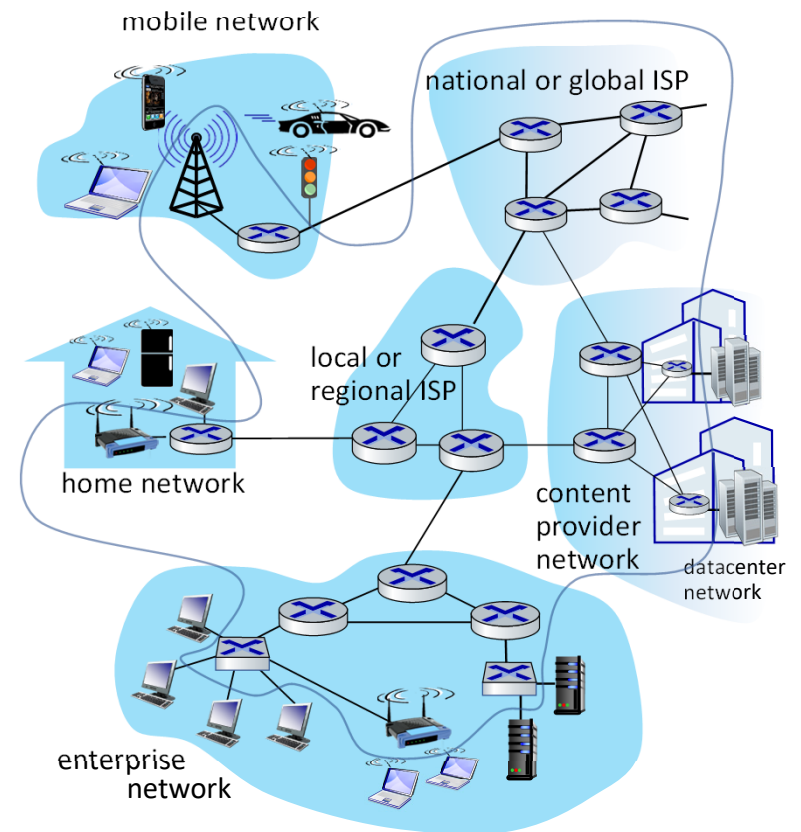


Communication links

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

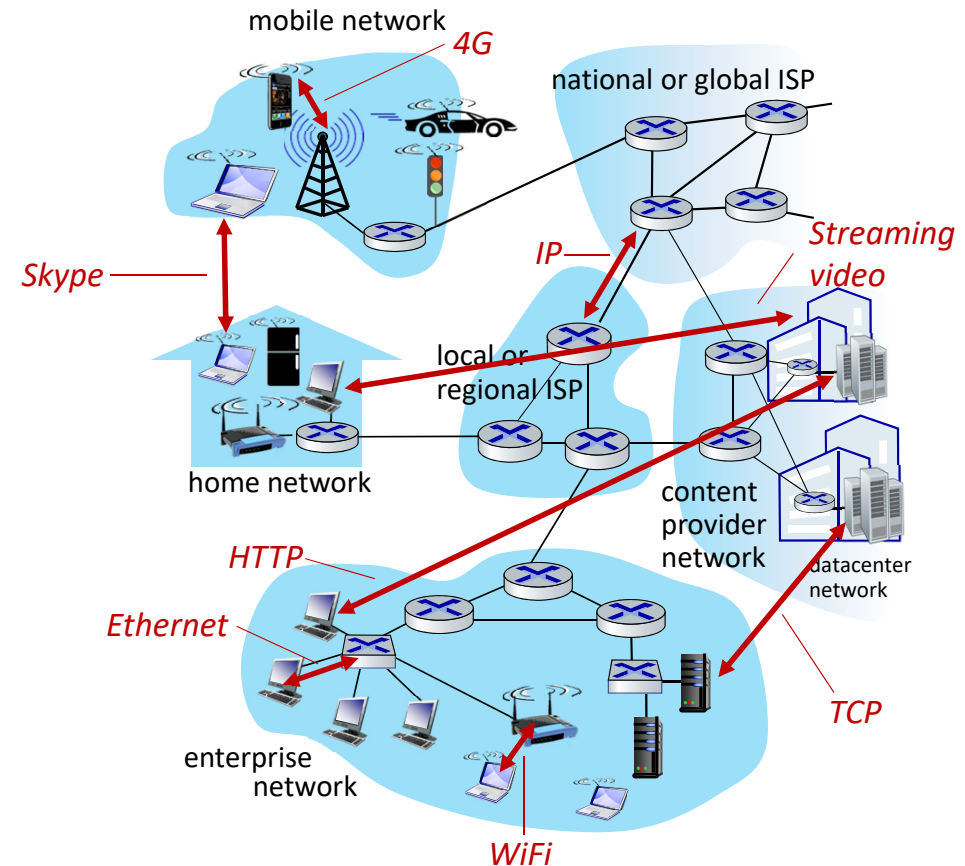
Networks

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



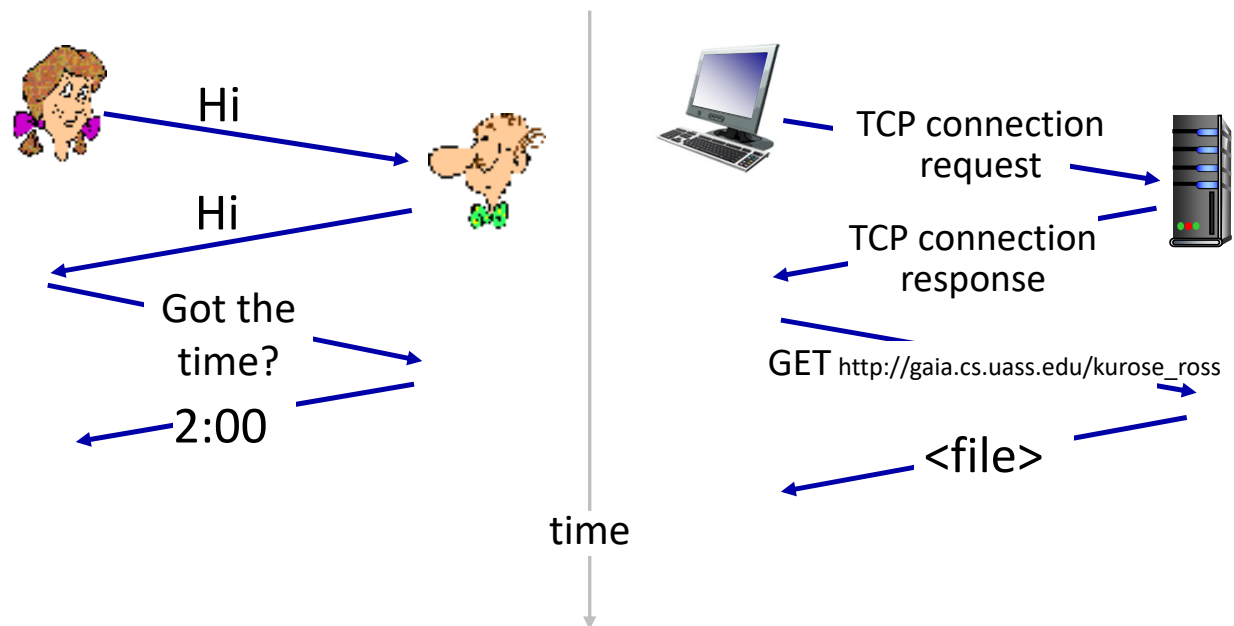
The Internet: a “nuts and bolts” view

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



What's a protocol?

A human protocol and a computer network protocol:



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*

Chapter 1: roadmap

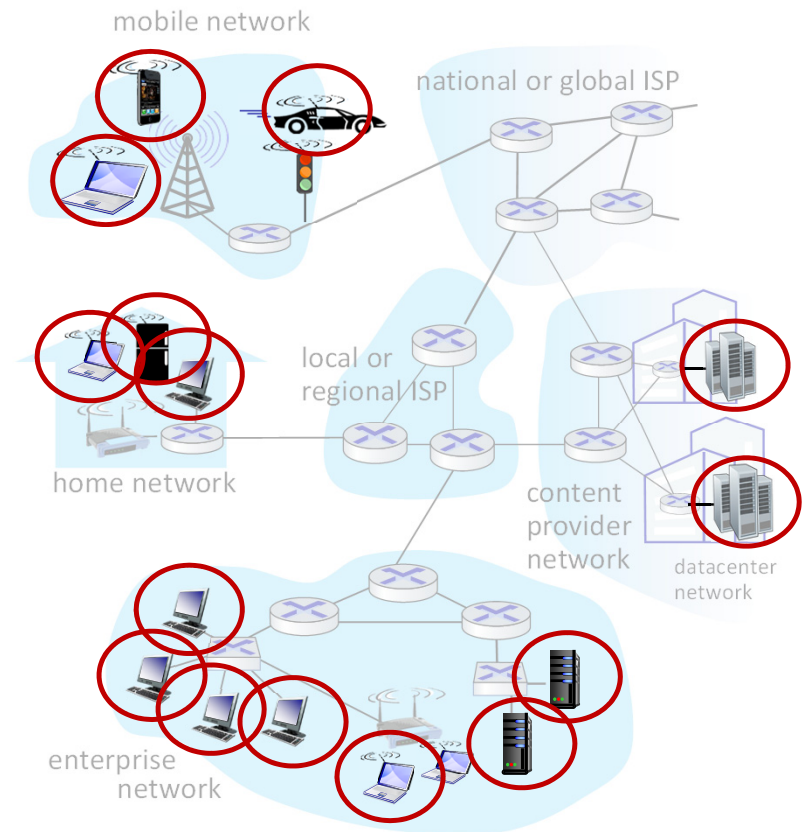
- What *is* the Internet?
- What *is* a protocol?
- **Network edge:** hosts, access network, physical media
- Network core: packet/circuit switching, internet structure
- Performance: loss, delay, throughput
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Network edge vs. network core

Network edge:

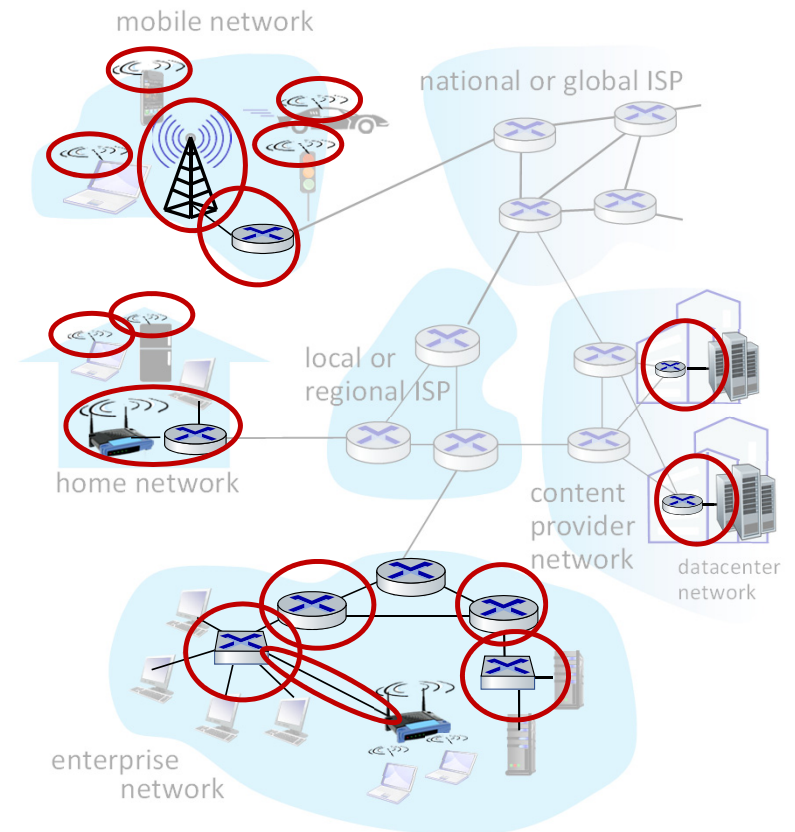
- hosts: clients and servers
 - servers often in data centers
- access network
 - the network that physically connects an end system to the first router (aka edge router)
 - wired, wireless communication links



Network edge vs. network core

Network edge:

- hosts: clients and servers
 - servers often in data centers
- access network
 - the network that physically connects an end system to the first router (aka edge router)
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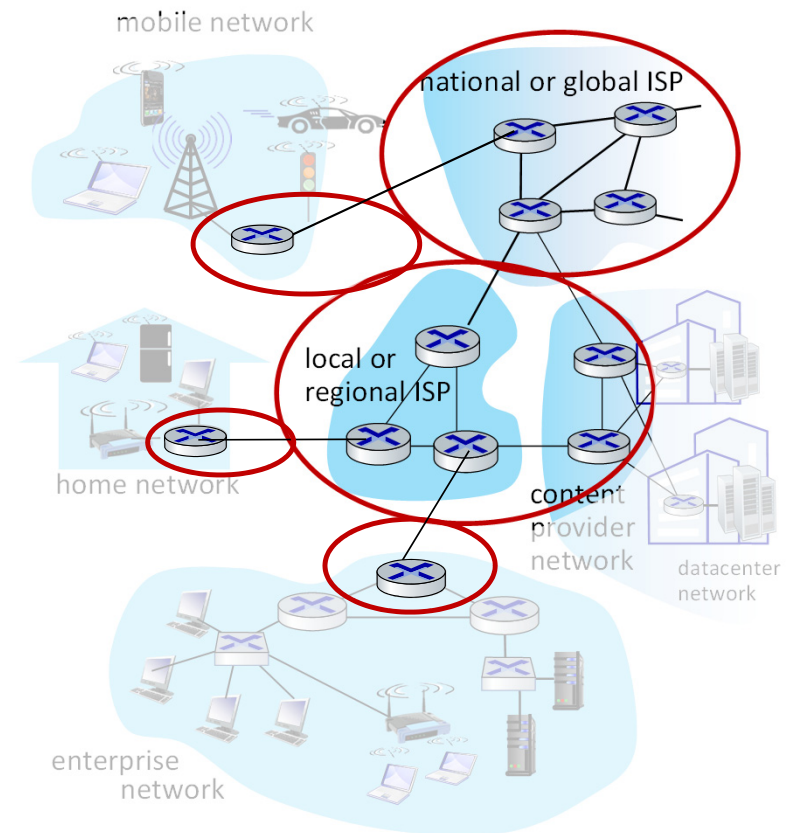
Network edge vs. network core

Network edge:

- hosts: clients and servers
 - servers often in data centers
- access network
 - the network that physically connects an end system to the first router

Network core:

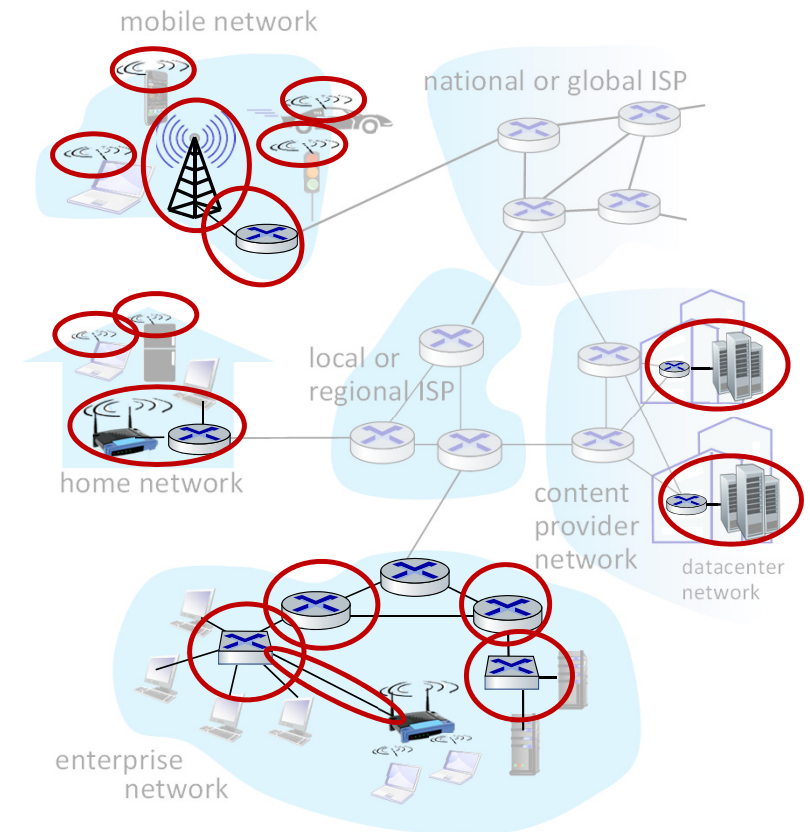
- interconnected routers
- network of networks



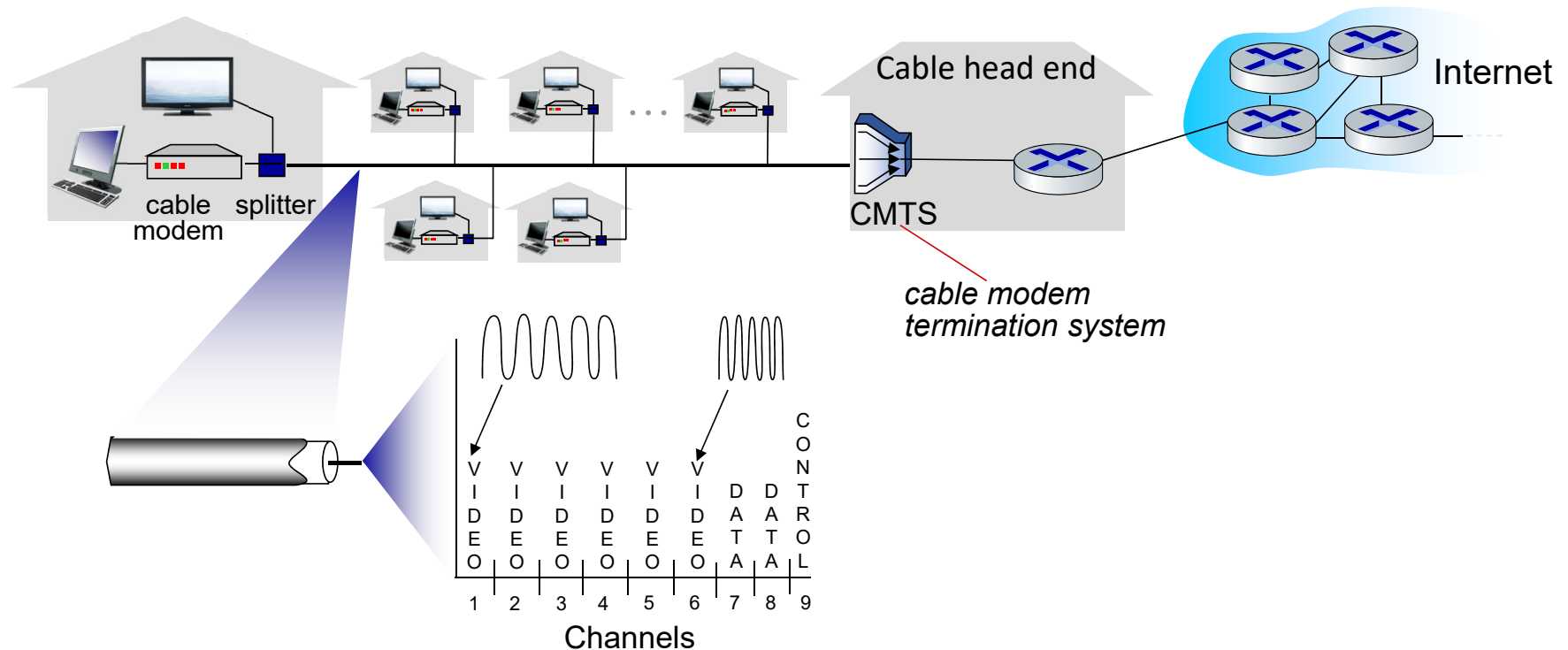
Access networks

Q: How to connect end systems to edge router?

- residential access networks
 - DSL (digital subscriber line)
 - Cable
 - with multiple wired and wireless devices
- institutional access networks (school, company)
- mobile access networks (WiFi, 4G/5G)

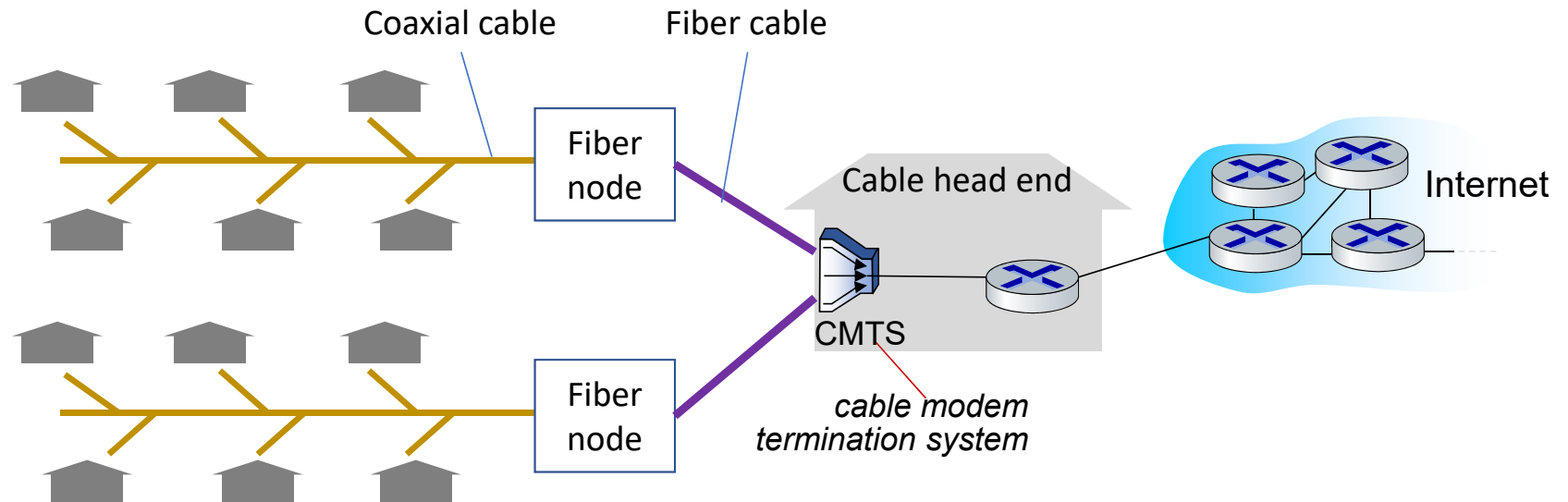


Access networks: cable-based access



- cable Internet access makes use of existing cable TV infrastructure
- *frequency division multiplexing (FDM)*: different channels transmitted in different frequency bands
- homes *share* access network to cable headend and ISP

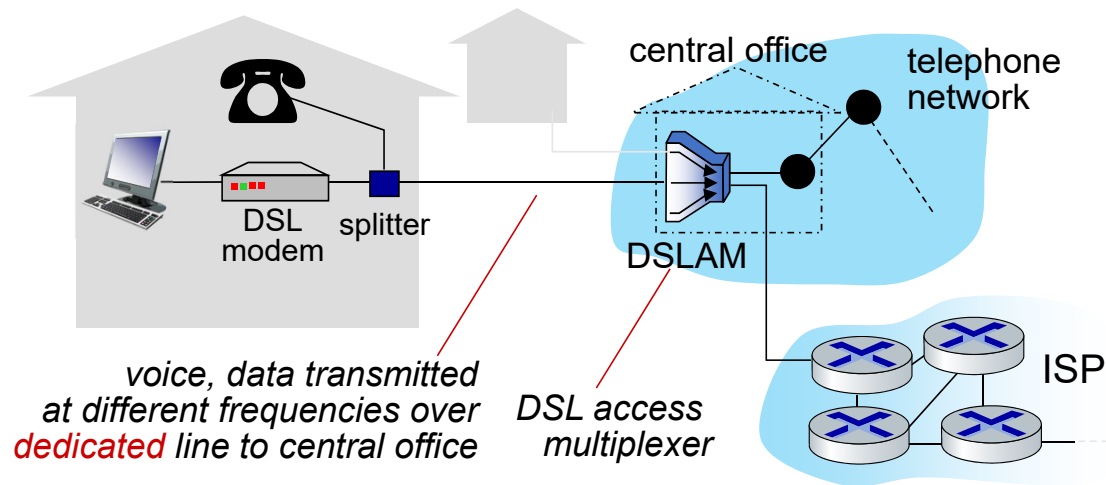
Access networks: cable-based access



■ HFC: hybrid fiber coax

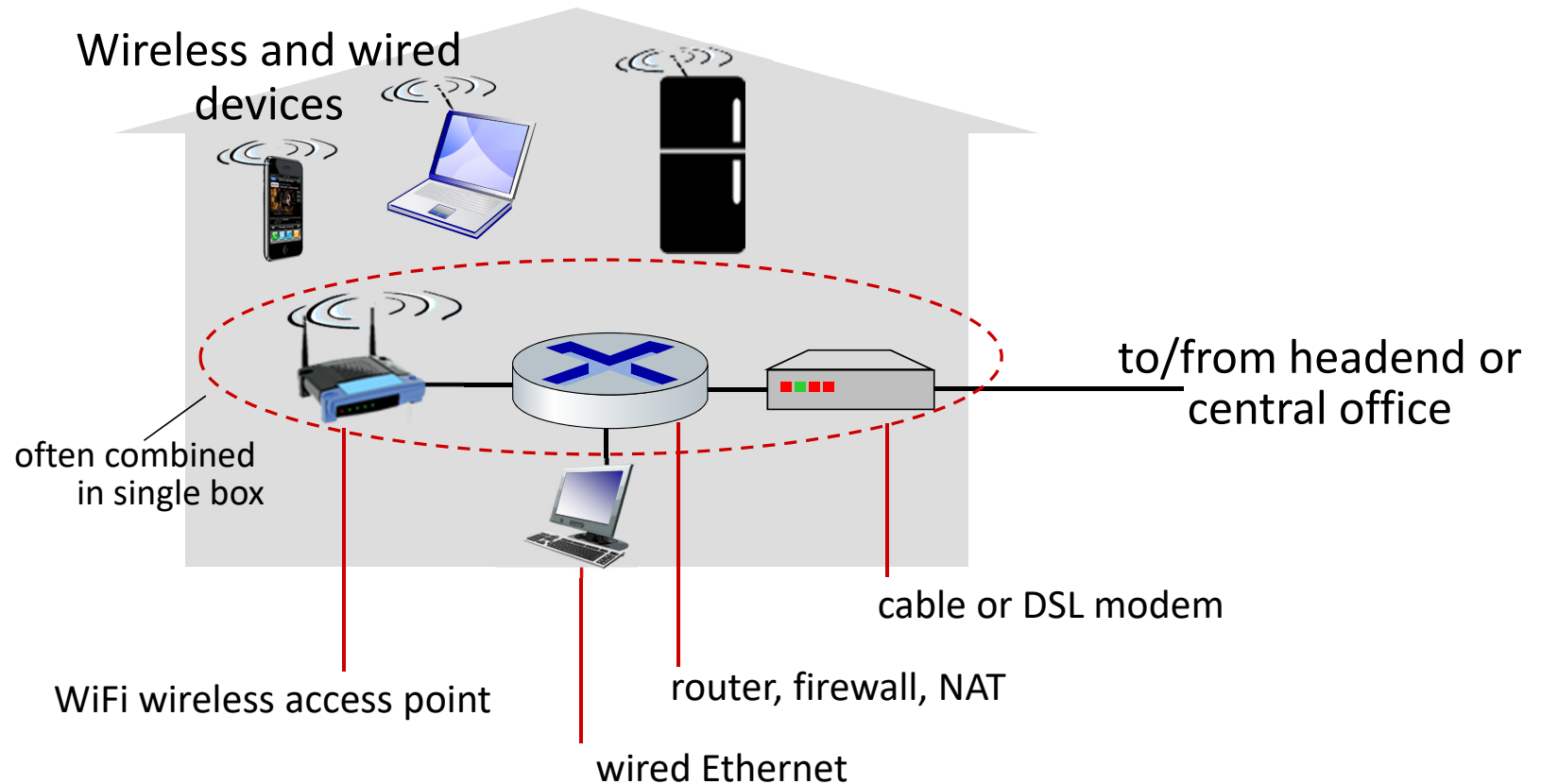
- asymmetric: up to 40 Mbps – 1.2 Gbps downstream transmission rate, 30-100 Mbps upstream transmission rate
- network of cable and fiber attaches homes to ISP router
 - homes *share access network* to cable headend

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 for each line
- 3.5-16 Mbps **dedicated** upstream transmission rate for each line

Access networks: home networks



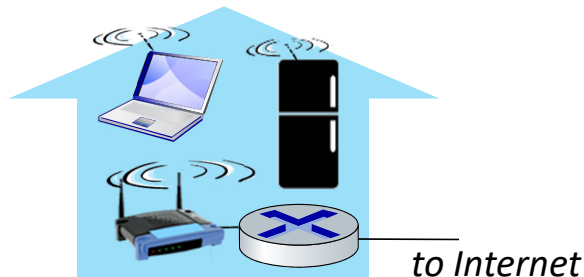
Wireless access networks

Shared *wireless* access network connects end system to router

- via base station aka “access point”

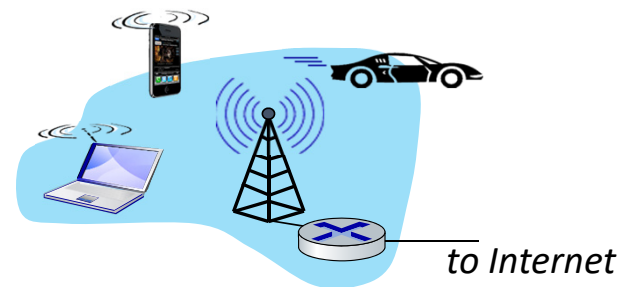
Wireless local area networks (WLANs)

- typically within or around building (~100 ft)
- 802.11b/g/n/ac/ax (WiFi): 11, 54, 450, 1560, 2400 Mbps tx rate

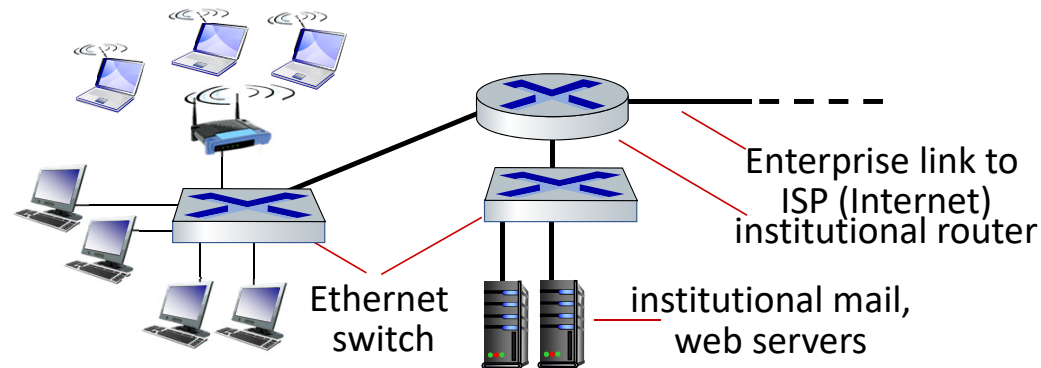


Wide-area cellular access networks

- provided by mobile, cellular network operator (10's km)
- 10's or 100's Mbps (5G peak: 20Gbps)
- 4G/5G cellular networks (6G coming)



Access networks: enterprise networks



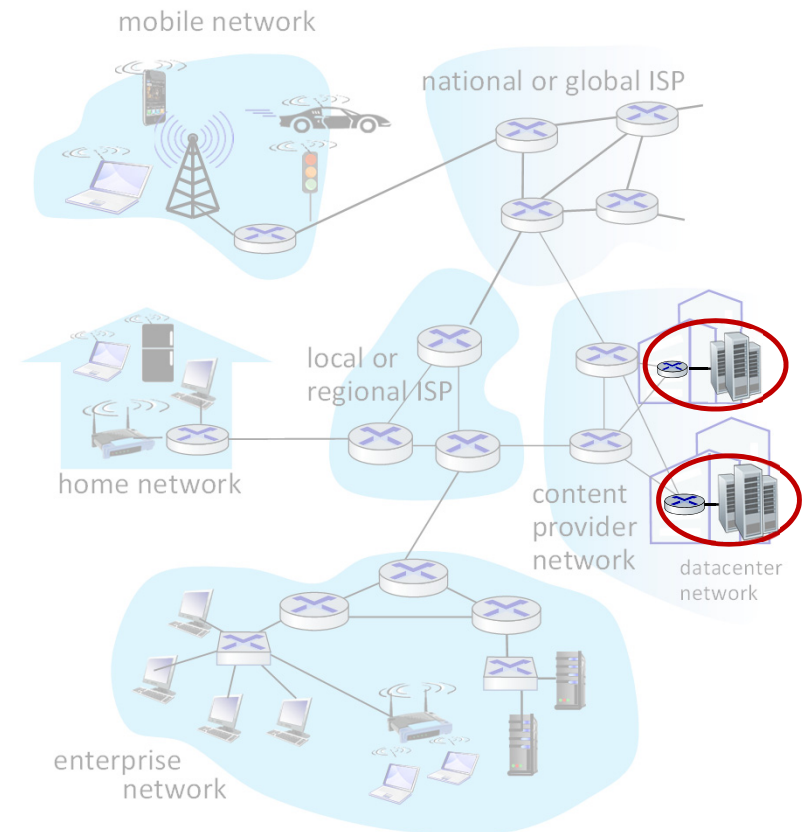
- companies, universities, etc.
- mix of wired, wireless link technologies, connecting a mix of switches and routers (we'll cover differences shortly)
 - Ethernet: wired access at 100Mbps, 1Gbps, 10Gbps
 - WiFi: wireless access points at 11, 54, 450, 1560, 2400 Mbps

Access networks: data center networks

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



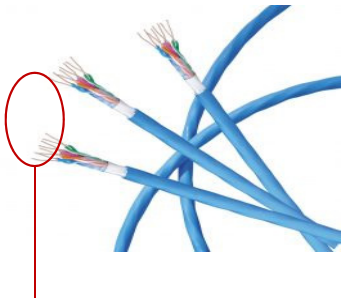
Courtesy: Massachusetts Green High Performance Computing Center (mghpcc.org)



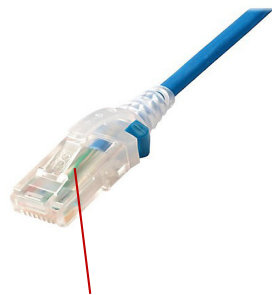
Links: wired media

■ Twisted pair (TP)

- two insulated copper wires
 - Category 5 (CAT. 5): 100 Mbps, 1 Gbps Ethernet
 - CAT. 6: 10 Gbps Ethernet
 - CAT. 8: 25/40 Gbps Ethernet



4 twisted pairs
(8 insulated copper wires)



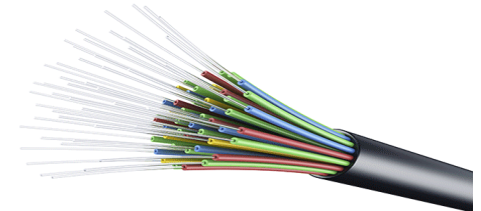
RJ45 connector

■ Coaxial cable



■ Fiber optic cable:

- high-speed operation:
 - 10's-100's Gbps
 - low error rate
- slow attenuation
- immune to electromagnetic noise



Links: wireless media

Wireless radio

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

Radio link types include:

- **wireless personal area network** (e.g., Bluetooth)
 - cable replacement
 - short distances
 - limited rates
- **wireless local area network** or **WLAN** (e.g., WiFi)
 - rate: 10-1000's Mbps
 - coverage: 10's of meters
- **wireless wide-area network** or **WWAN** (e.g., 4G/5G)
 - rate: 10's Mbps
 - coverage: 10's Km
- **satellite**
 - long end-to-end propagation delay
 - except for LEO satellites