COMP3270: Computer Networks
Fall 2017

Instructor: Ning Lu, HL 411, Tel. 250-828-5224

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Prerequisites: COMP 2130, COMP 2230. Knowledge of MATH 3020 (undergrad probability) would be helpful.

Meeting Time:

Lectures (Sept. 6 — Dec. 1)
4:30 pm - 5:20 pm on Mondays, Tuesdays, and Thursdays
OM 1762

Seminar/Lab
4:30 pm - 5:20 pm on Wednesdays, OM 1360

Office Hours (HL 411)
10:30 am – 11:20 am on Tuesdays and Thursdays

Grading:

10% Biweekly quizzes (5 quizzes)
15% Lab assignment (3 assignments)
20% Homework (5 assignments)
25% One midterm exam (paper-based)
30% Final exam (paper-based)

Note:

1. Quizzes will be on Thursdays, and will be based on the latest home assignments posted on the Moodle page. You must have a valid reason for missing a quiz, such as an illness or a job interview; otherwise you will get a zero for each missed quiz. You have to provide proof for any valid reason. The score for a quiz missed for a valid reason will be 80% of the full marks of the quiz.

2. Assignments have to be submitted on time; assignment submitted at any time up to one week after the due date will be graded at most 50% of the full marks; assignment submitted more than one week after the due date will be graded zero.

Materials:

Texts

- Course Notes (will be posted on Moodle after each lecture)

References

1. Behrouz A. Forouzan, Data Communications and Networking, fifth edition, McGraw-Hill, 2007
2. James F. Kurose and Keith W. Ross, Computer Networking – A Top Down Approach, 6th edition, Addison Wesley
3. D. Bertsekas and R. Gallager, Data Networks, Prentice Hall, 1992
4. R. Srikant and L. Ying. Communication Networks: An Optimization, Control and Stochastic Networks Perspective, Cambridge University Press, 2014 (advanced material)

Objectives of COMP 3270

1. To understand the fundamental concepts in computer networks

2. To understand the principles and practice of designing, analyzing, and operating networks.

How to do well in the course?

- Attend lectures!
- Participate in discussions, and read the corresponding lecture notes after class
- Understand, not have to memorize!
  - Consider yourself as the designer to please both the users (guaranteed service) and your boss (reduced cost)
  - KEEP Question on "Why do we need it? "
  - Think about the networks around you: cellular networks on the street, Internet at home, WiFi in the building, …

Topics

- Introduction to Computer Networks
- Network Performance
- Physical Layer: Fundamentals of Digital Transmission
- Data Link Layer: Error Control, Retransmission Protocols, Medium Access Control (MAC)
- Network Layer: IP addressing, Routing
- Transport Layer: TCP, UDP, Flow control and Congestion control
- Application Layer: HTTP, DNS, MQTT
- Special topic: Engineering data center networks

A note about the slides

Some of the slides were originally prepared by Kurose and Ross based on their book *Computer Networking: A Top Down Approach*.

Some of the slides were originally prepared by Prof. Sherman Shen based on his course ECE 358 at the University of Waterloo.

I have added more slides and edited some.

T1: Introduction

Objectives: What is computer network? Why computer network? How it works, how good it is

1.1 What is computer network?

Examples of computer network

The Internet

Network structure: edge and core

1.2 Why computer networks

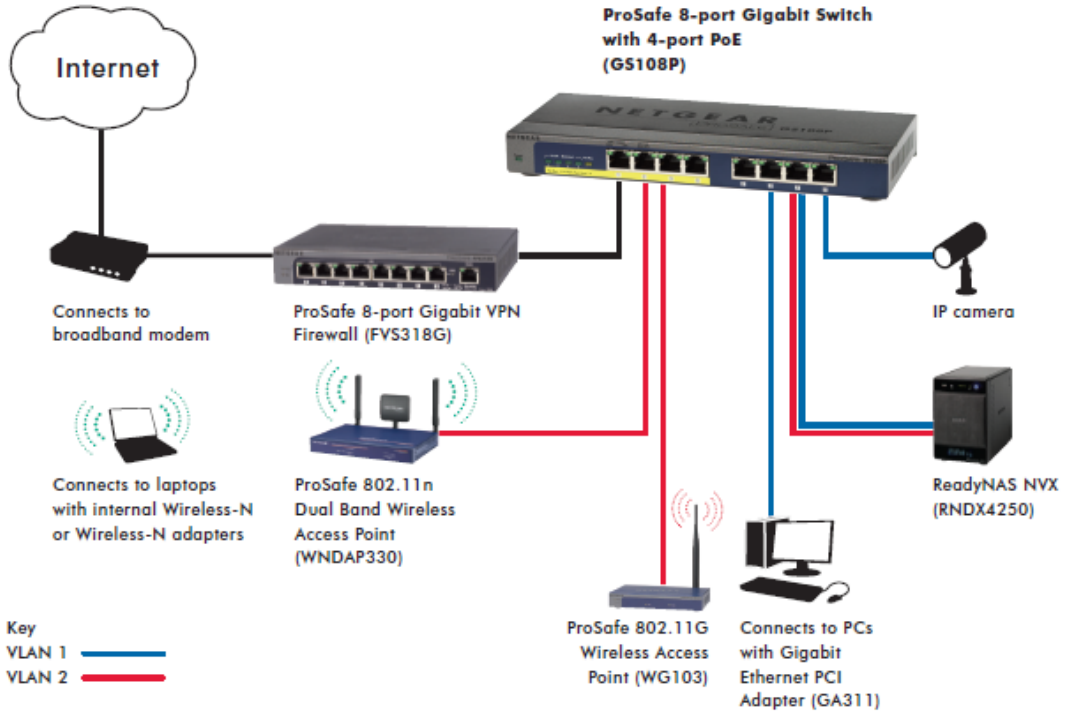
1.3 The way networks work

1.4 Performance metrics:

Delay, loss and throughput in packet-switched networks

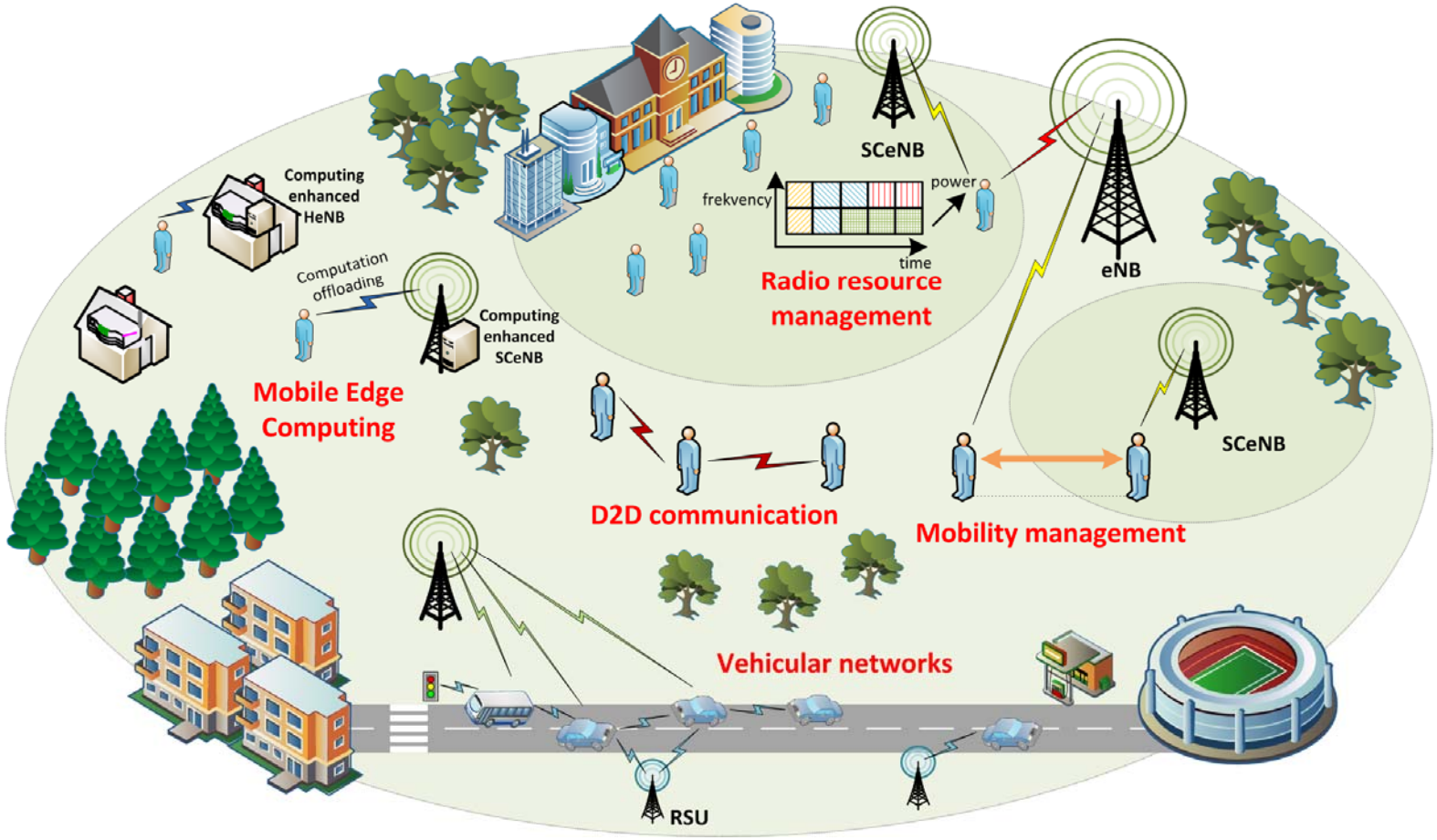
Examples of Computer Network

- Local area (802.3) network



Examples of Computer Network

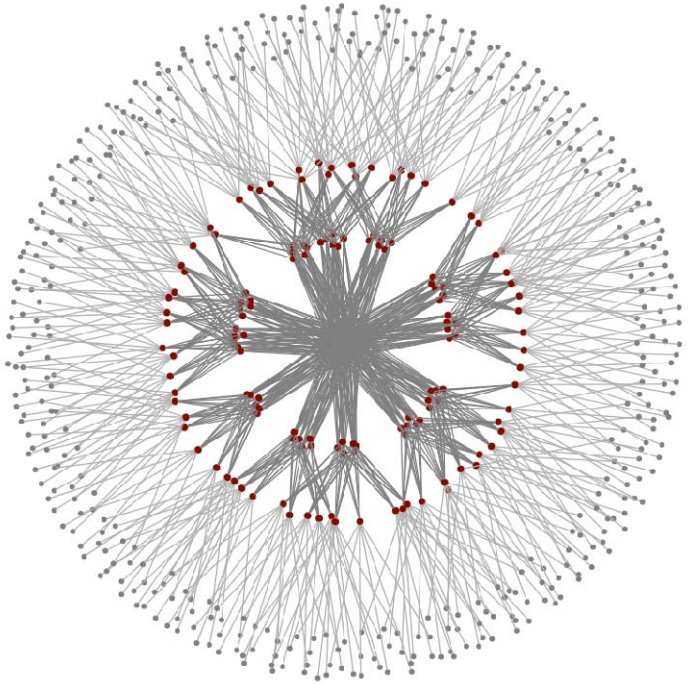
- Wireless network



https://www.youtube.com/watch?v=Q8Cn47L8FRQ

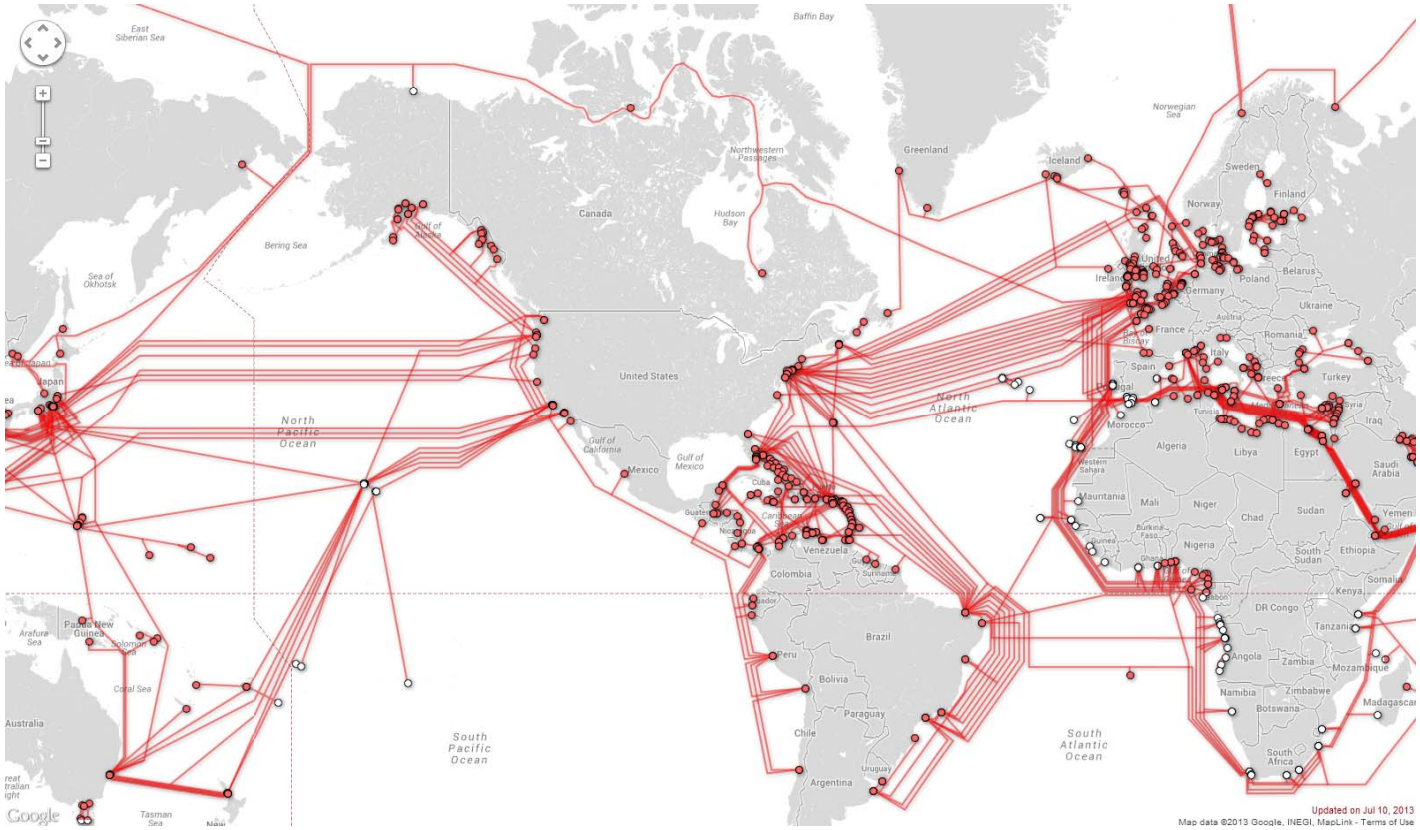
Examples of Computer Network

- Data center network



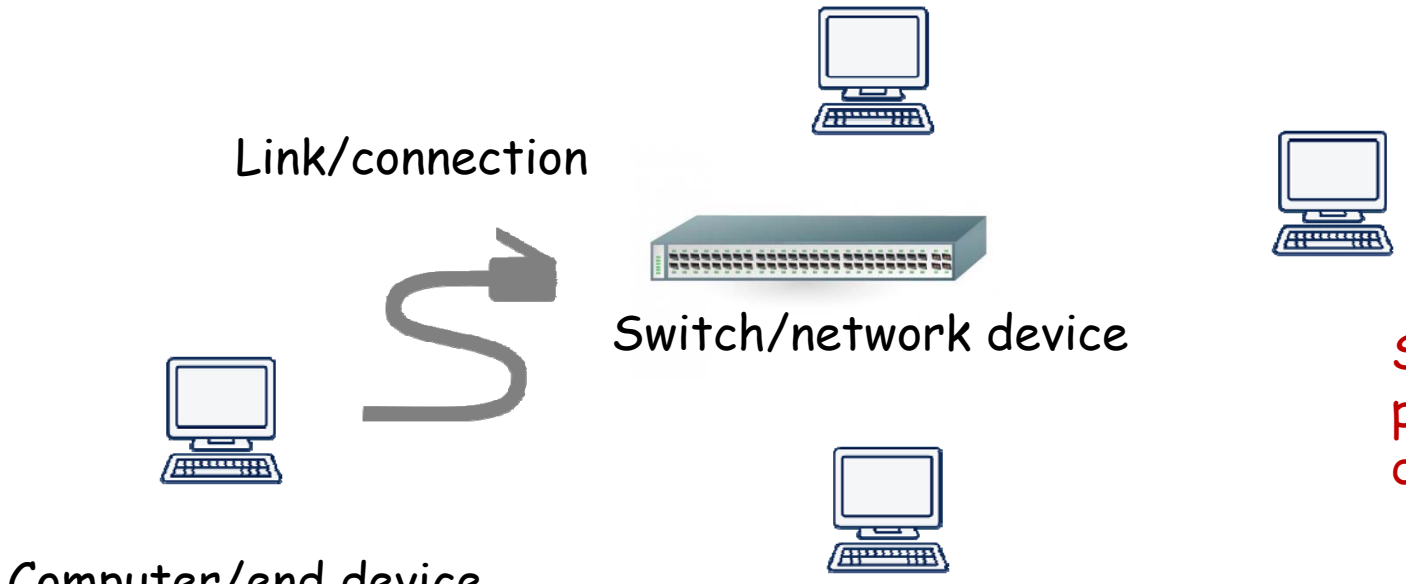
Examples of Computer Network

- Undersea Internet backbone



What is Computer Network

A computer network or data network is a telecommunications network which allows computers to exchange data.



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Definition of Internet

The **Internet** is a global system of interconnected computer networks that use the standard **Internet** protocol suite (TCP/IP) to link several billion devices worldwide and exchange information.

The Internet

- Early 1990s
  - Internet Service providers (ISP)
  - 1994: World Wide Web (WWW) & Web browser
- Number of devices

Internet: "nuts and bolts" view (1)

PC

server

wireless laptop

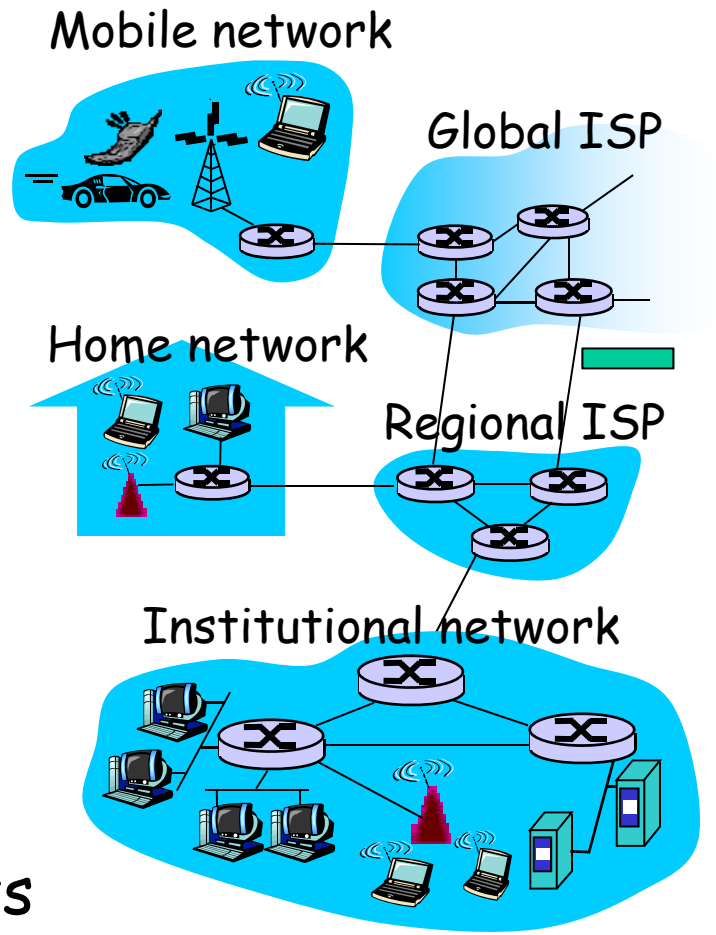
cellular handheld

access points

wired links

router

- Millions of connected computing devices: hosts = end systems running network apps
- Communication links
  - fiber, copper, radio, satellite
  - transmission rate = bandwidth
- Routers: forward packets (chunks of data)



Internet: "nuts and bolts" view (2)

- Internet: "network of networks"
  - loosely hierarchical
- Internet permits the reliable exchange of information with low cost
- Protocols control sending, receiving of msgs

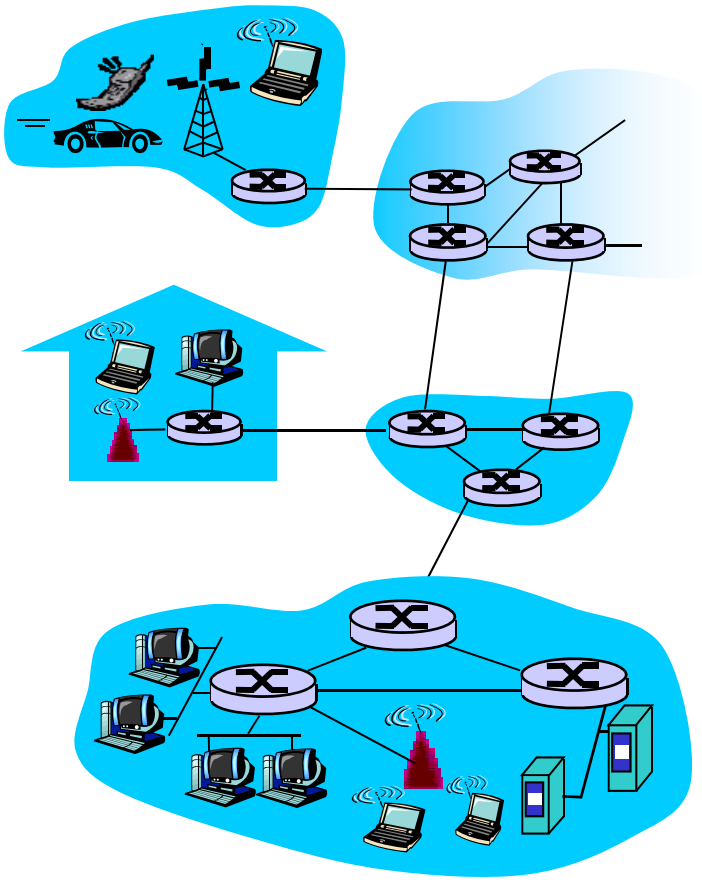
(it is important that everyone agrees on what each and every protocol does)

- Internet standards
  - RFC: Request For Comments
  - IETF: Internet Engineering Task Force

Internet: a service view

- Communication infrastructure enables distributed applications:
  - Web, VoIP, email, games,
  - e-commerce, file sharing

- Communication services provided to apps:
  - reliable data delivery from source to destination
  - "best effort" (unreliable) data delivery



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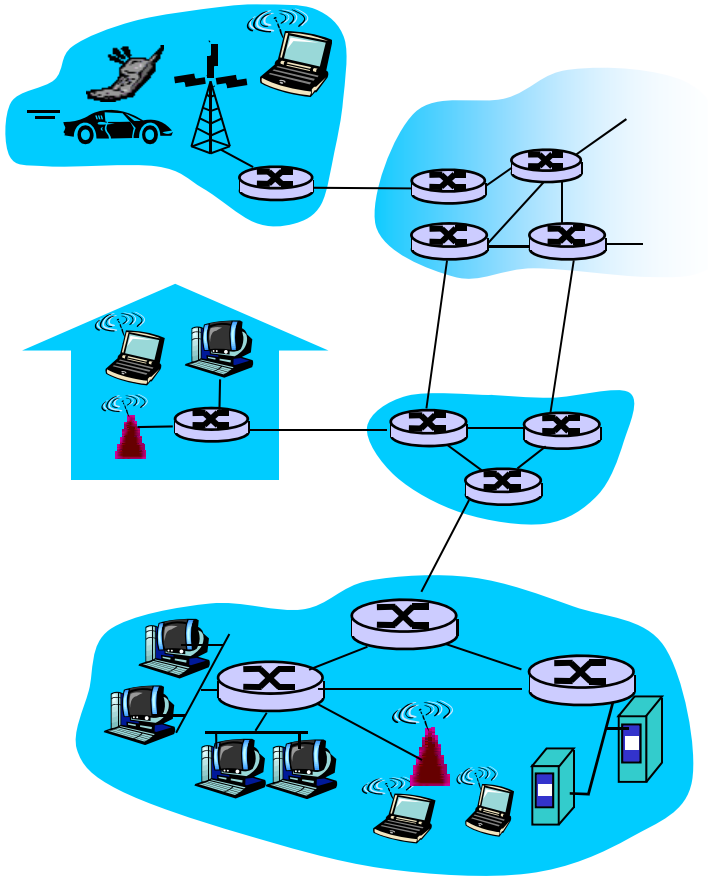
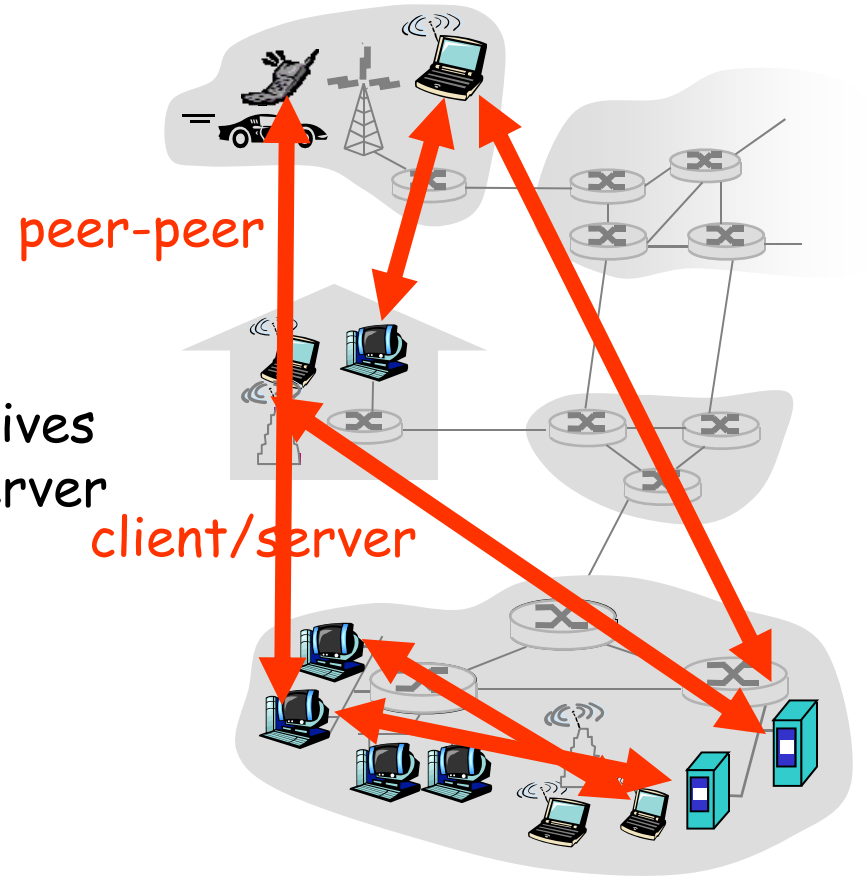
A closer look at network structure:

- **Network edge:**
  applications and hosts
- **Access networks, physical media:**
  wired, wireless communication links
- **Network core:**
  - interconnected routers
  - network of networks



The network edge:

- End systems (hosts):
  - run application programs
  - e.g. Web, email
  - at "edge of network"
- Client/server model
  - client host requests, receives service from always-on server
  - e.g. Web browser/server; email client/server
- Peer-peer model:
  - minimal (or no) use of dedicated servers
  - e.g. Skype, BitTorrent



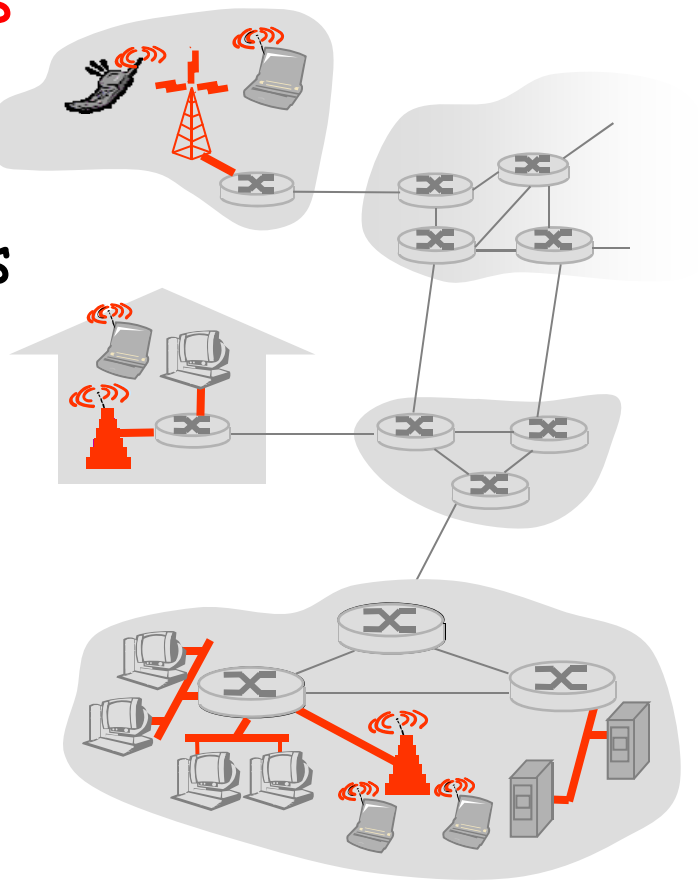
Access networks and physical media

Q: How to connect end systems to edge router?

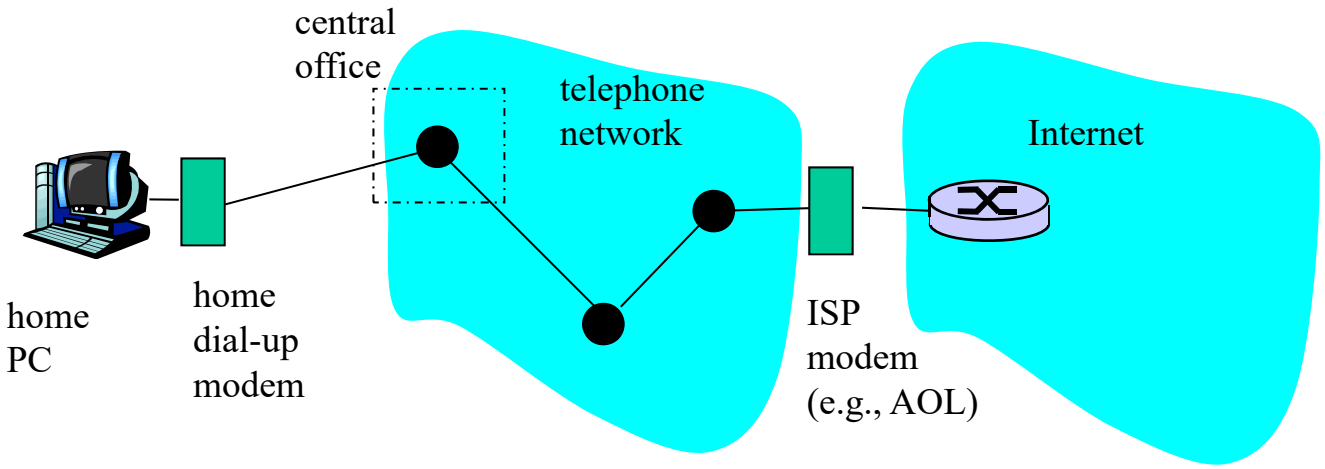
- residential access networks
- institutional access networks (school, company)
- mobile access networks

Keep in mind:

- bandwidth (bits per second) of access network?
- shared or dedicated?

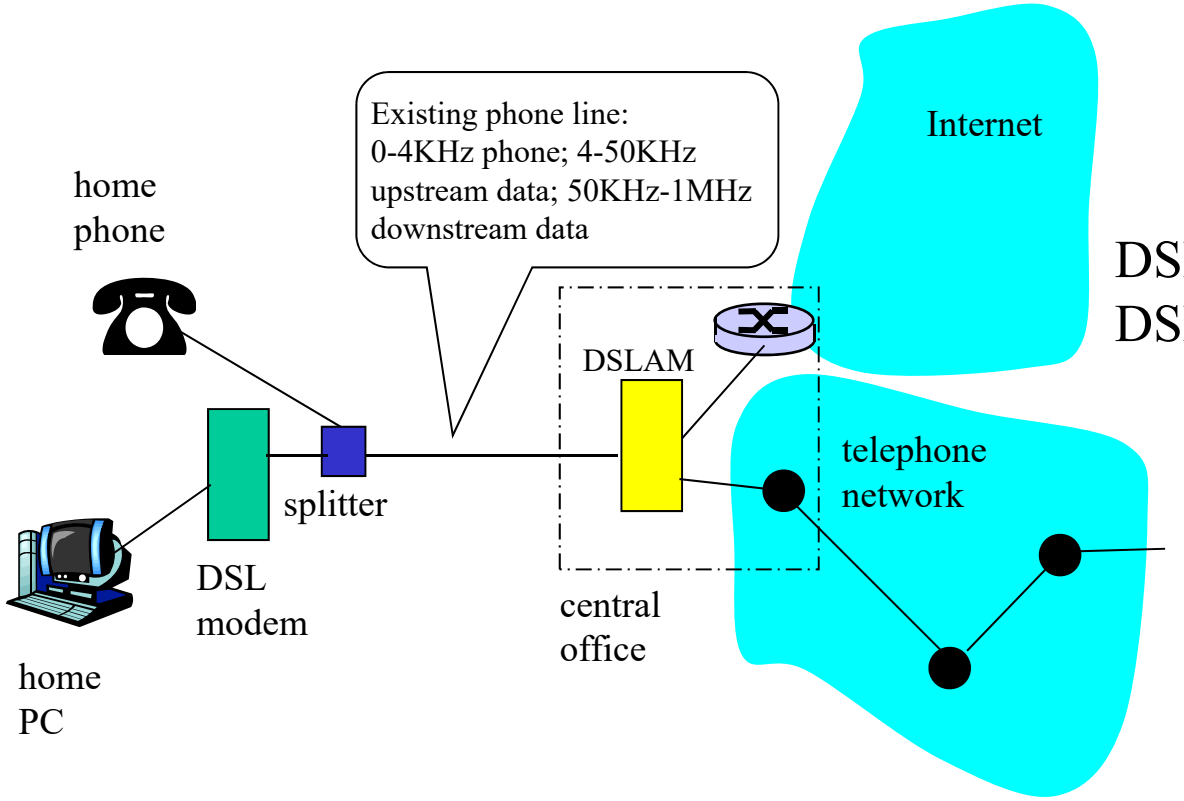


Dial-up Modem



- uses existing telephony infrastructure
  - home directly-connected to central office
- up to 56Kbps direct access to router (often less)
- can't surf, phone at same time: not "always on"

Digital Subscriber Line (DSL)



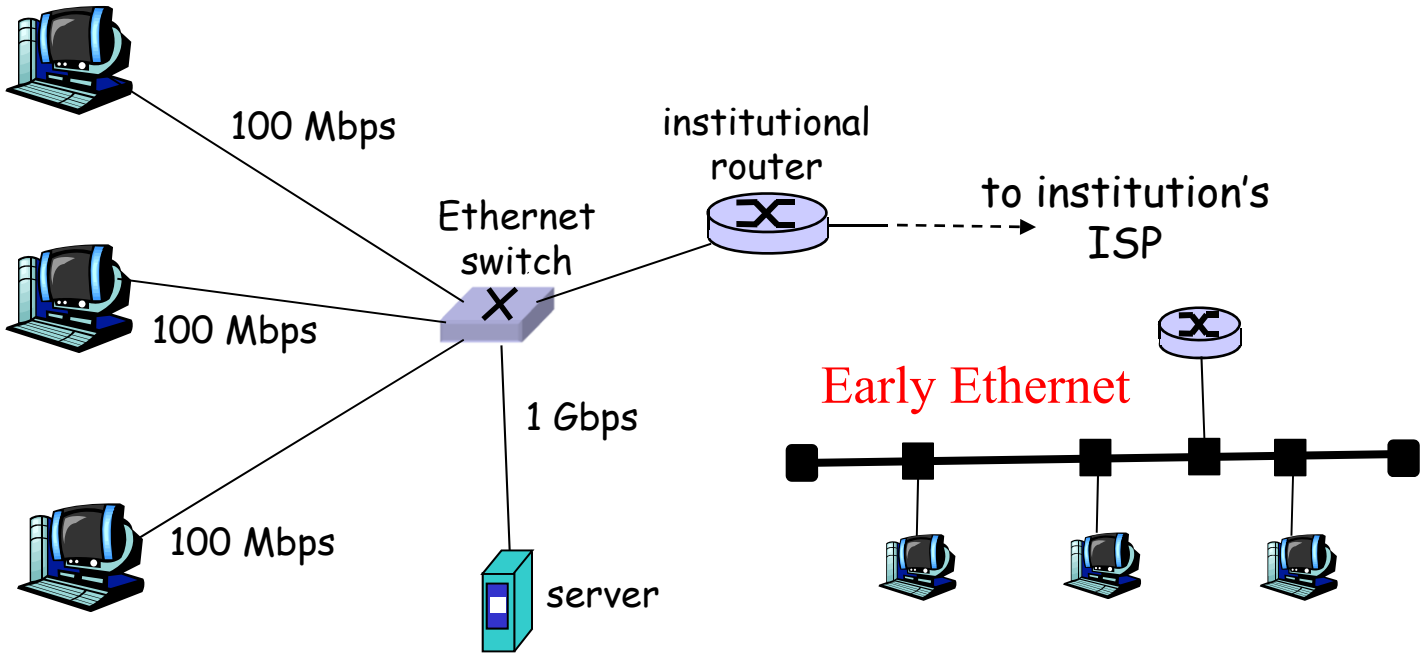
DSLAM:
DSL Access Multiplexer

- uses existing telephone infrastructure
- up to 1 Mbps upstream (today typically < 256 kbps)
- up to 8 Mbps downstream (today typically < 1 Mbps)
- dedicated physical line to telephone central office

Residential access: cable modems

- uses cable TV infrastructure, rather than telephone infrastructure
- HFC: hybrid fiber coax
  - asymmetric: up to 30Mbps downstream, 2 Mbps upstream
- Network of cable, fiber attaches homes to ISP router
  - homes share access to router
  - unlike DSL, which has dedicated access

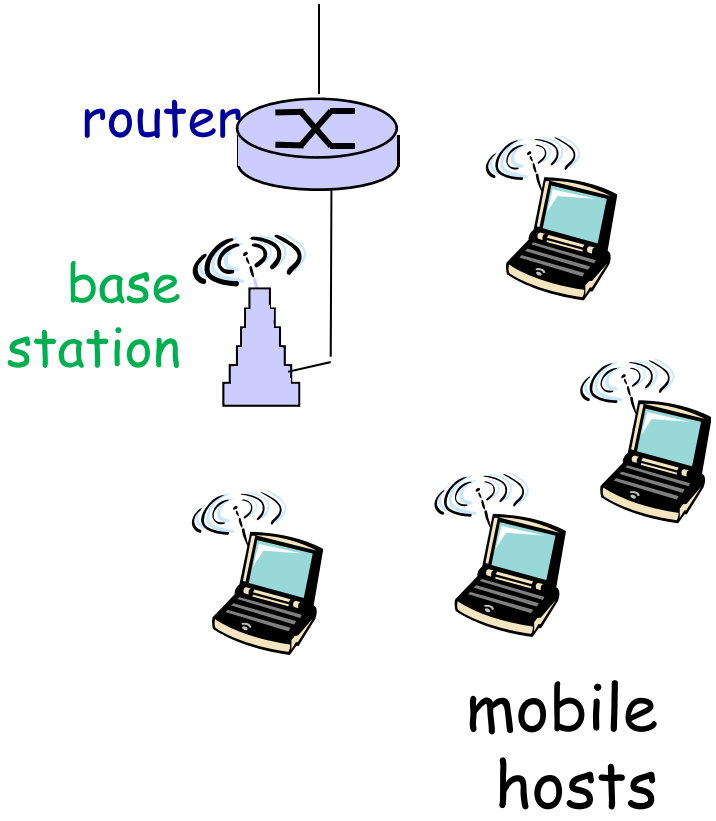
Ethernet Internet access



- typically used in companies, universities, etc
- 10 Mbps, 100Mbps, 1Gbps, 10Gbps Ethernet
- Question: How do nodes efficiently share the medium?

Wireless access networks

- Shared wireless access network connects end system to router
  - via base station aka "access point"
- Wireless LANs:
  - 802.11b/g (WiFi): 11 or 54 Mbps
- Wider-area wireless access
  - Cellular network



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

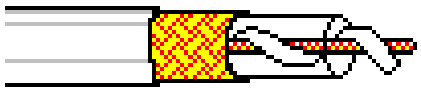
Twisted Pair (TP)

- two insulated copper wires
  - Category 3: traditional phone wires, 10 Mbps Ethernet
  - Category 5: 100Mbps Ethernet

Physical Media: coax, fiber

Coaxial cable:

- two concentric copper conductors
- bidirectional
- baseband:
  - single channel on cable
  - legacy Ethernet
- broadband:
  - multiple channels on cable
  - HFC



Fiber optic cable:

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

Physical media:

Radio:

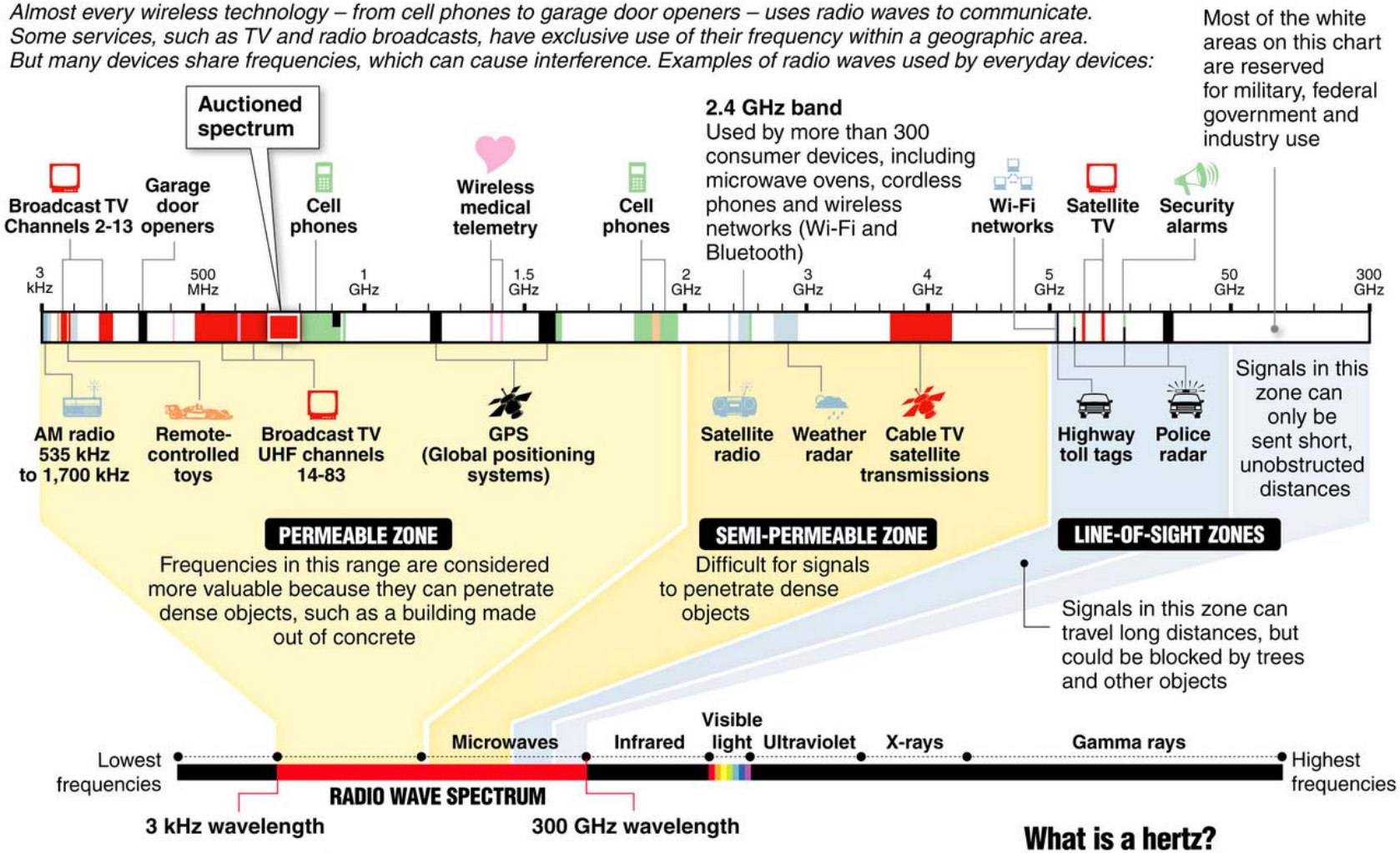
- signal carried in electromagnetic spectrum
- no physical "wire"
- bidirectional
- propagation environment effects:
  - reflection
  - obstruction by objects
  - interference

Radio link types:

- microwave
  - e.g. up to 45 Mbps channels
- LAN (e.g., WiFi)
  - 11Mbps, 54 Mbps
- wide-area (e.g., cellular)
  - 3G cellular: ~ 1 Mbps
- satellite
  - Kbps to 45Mbps channel (or multiple smaller channels)
  - 270 msec end-end delay
  - geosynchronous versus low altitude

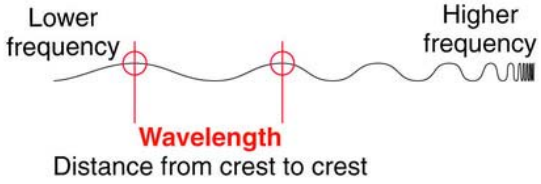
Inside the radio wave spectrum

Almost every wireless technology – from cell phones to garage door openers – uses radio waves to communicate. Some services, such as TV and radio broadcasts, have exclusive use of their frequency within a geographic area. But many devices share frequencies, which can cause interference. Examples of radio waves used by everyday devices:



The electromagnetic spectrum

Radio waves occupy part of the electromagnetic spectrum, a range of electric and magnetic waves of different lengths that travel at the speed of light; other parts of the spectrum include visible light and x-rays; the shortest wavelengths have the highest frequency, measured in hertz



What is a hertz?

One hertz is one cycle per second. For radio waves, a cycle is the distance from wave crest to crest

1 kilohertz (kHz) = 1,000 hertz

1 megahertz (MHz) = 1 million hertz

1 gigahertz (GHz) = 1 billion hertz

Source: New America Foundation, MCT, Howstuffworks.com
Graphic: Nathaniel Levine, Sacramento Bee