CMPE 150/L : Introduction to Computer Networks

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Lecture 2

Class Administration Issues

Administrative Info

- Communication:
  - E-mail preferred.
  - Send e-mail to instructor AND TAs.

Introduction

Fundamental concepts, terminology
(Chapter 1)

Chapter 1: roadmap

1.1 what *is* the Internet?

1.2 network edge

- end systems, access networks, links

1.3 network core

- packet switching, circuit switching, network structure

1.4 delay, loss, throughput in networks

1.5 protocol layers, service models

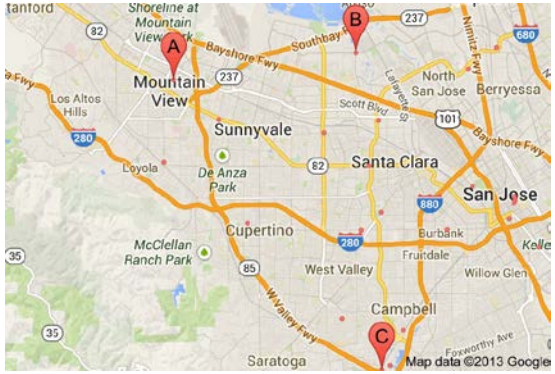
1.6 networks under attack: security

What is a network?

What is a network?

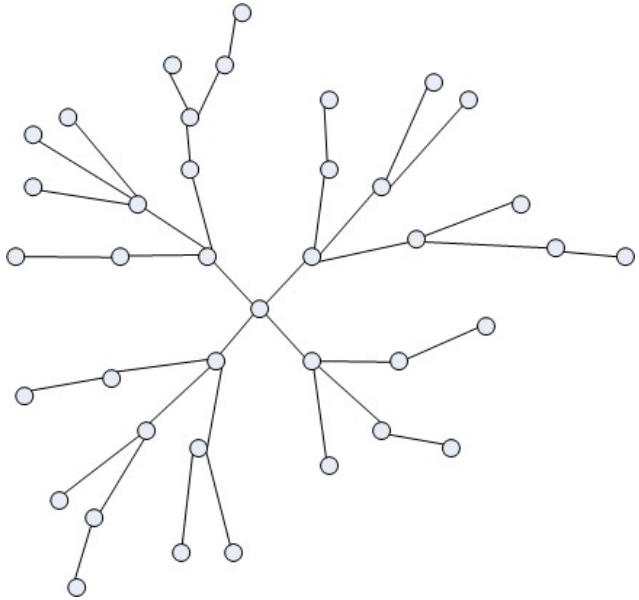
- Definition: "A group or system of interconnected people or things". [Google]
- Many types of networks. Examples?

Many types of networks



What is a computer network?

From Webopedia:
"A compute network is a group of two or more computer systems linked together."



What are the components of a computer (communication) network?

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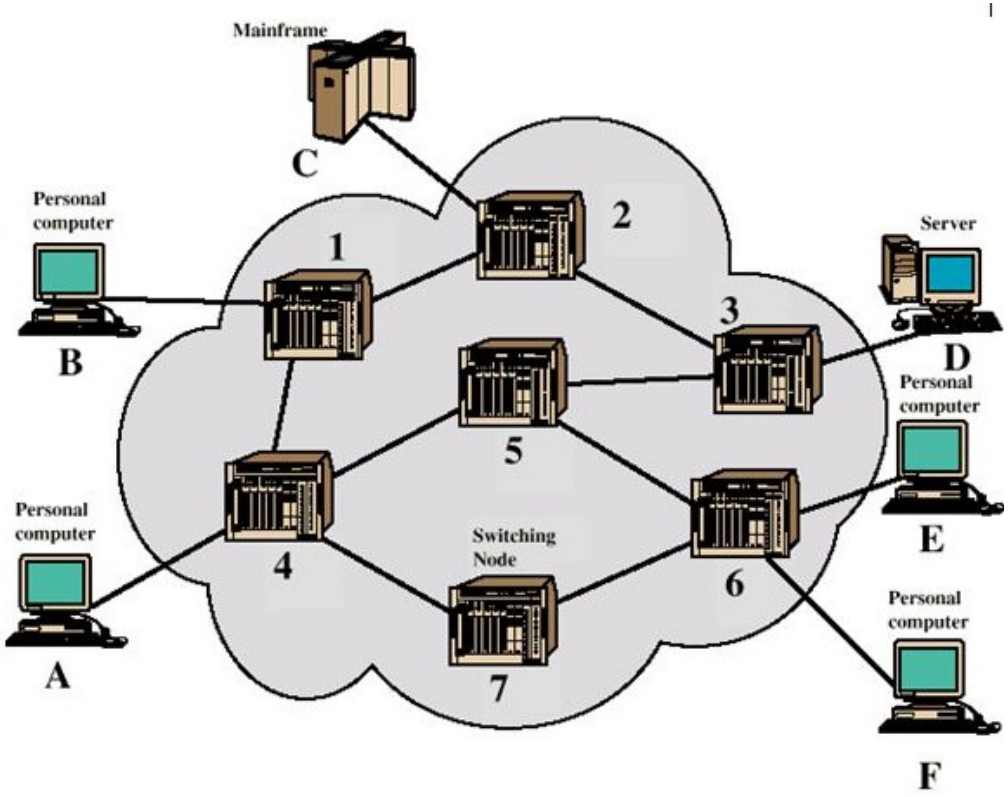
"How do you send text messages?"

What are the components of a computer (communication) network?

- Links, nodes, and
  - "terminals".
- What's the difference between "nodes" and "terminals"?

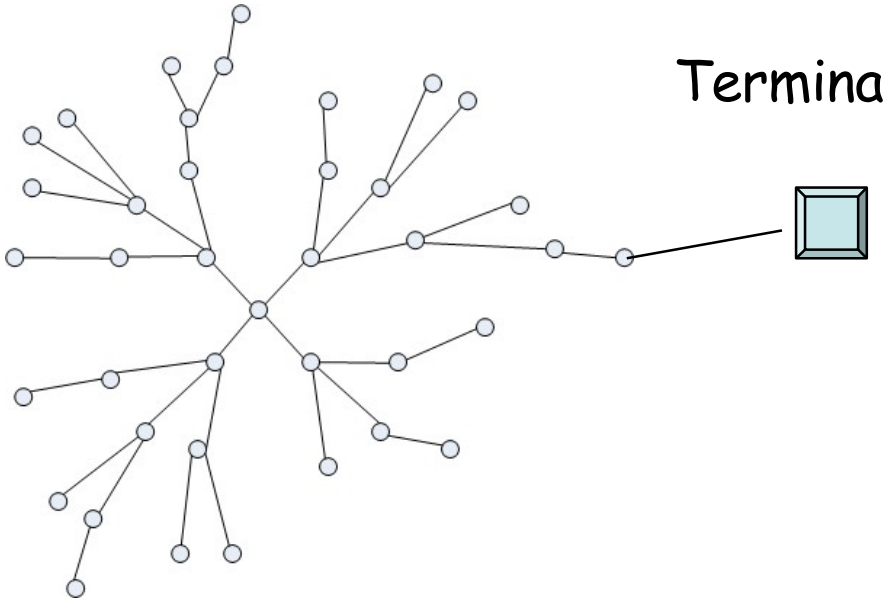
"How do you send text messages?"

Nodes and Terminals

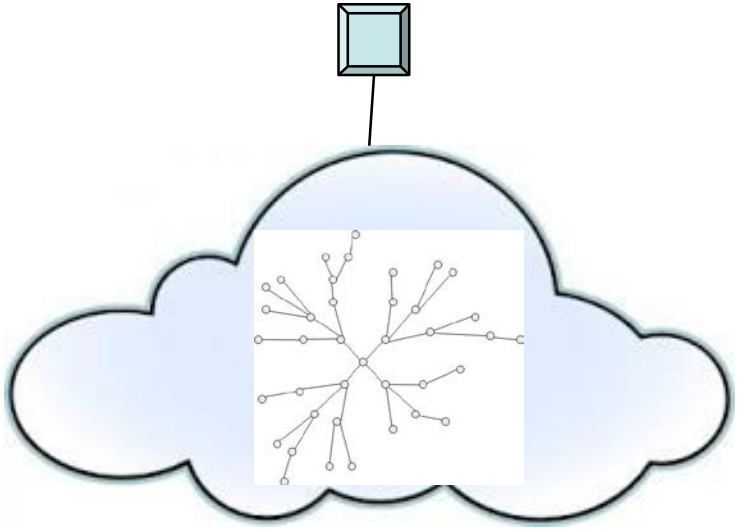


Source: K. Salah Module 3.4

Nodes and Terminals



Terminals = Hosts, End-User Devices



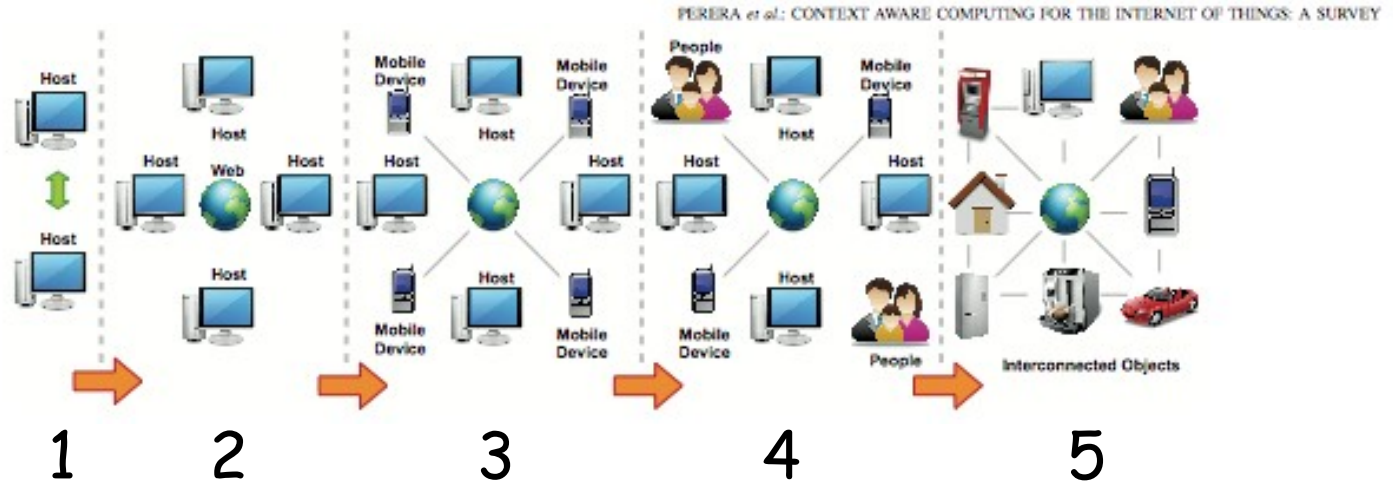
The Internet

- The Internet versus an internet?
- "internet" is an abbreviation of "internetwork".
  - Collection of interconnected networks, with no central administration or management.
  - A "network" has a single administrative authority.
- Intranetwork.

What made the Internet so popular?

What was the killer application ("killer app") of the Internet?
2nd killer application?
And more?

Internet Evolution



1: Connecting (few) computers: e-mail, file transfer, remote login.
2: Connecting larger number of computers: sharing information (WWW).
3: Connecting wireless and mobile devices.
4: Connecting people: social networks.
5: Connecting objects: Information-Centric Networks (ICNs), Internet of Things (IoT), Context-Aware Networking.

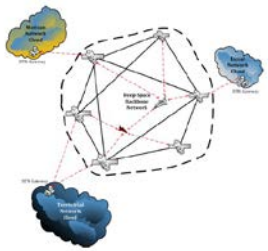
Internets of the future: a vision

"Sorry it's taking so long to load. I'm still on dial-up."

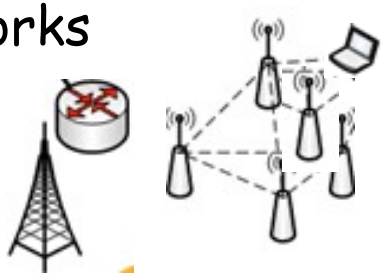
What does the future hold?

Internets of the future: a vision

Smart home

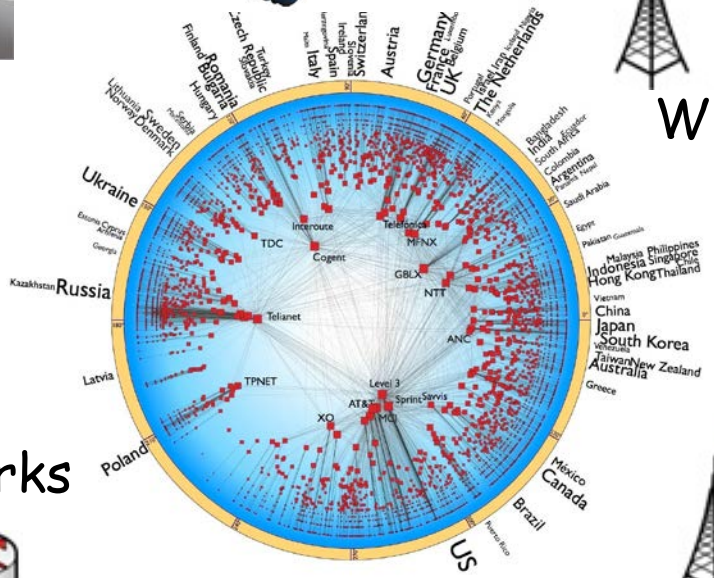


Interplanetary networks

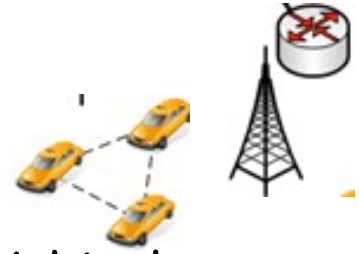


Wireless mesh network

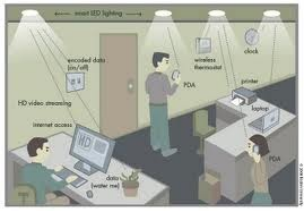
Mobile ad-hoc networks



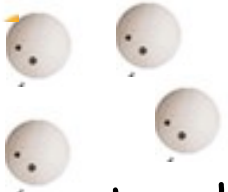
Smart grid



Vehicular networks



Smart office

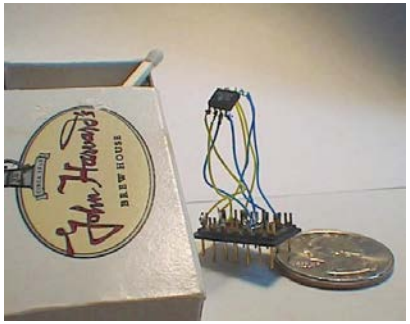


Sensor networks

"The Internet of Everything"

IP picture frame
http://www.ceiva.com/

Web-enabled toaster + weather forecaster



World's smallest web server
http://www-ccs.cs.umass.edu/~shri/iPic.html

Internet phones

Challenges

- Scalability
  - As of early 2013, ~1.5 billion connected PCs and ~1 billion Internet-enabled mobile phones.
  - By 2020, ~50-100 billion Internet-connected devices.
- Heterogeneity
  - Devices
  - Networks
  - Services
- Autonomy and administrative decentralization

What's the Internet?

What's the Internet: "Nuts and Bolts" View

PC

server

wireless laptop

cellular handheld

Millions of connected computing devices:
hosts = end systems
- Running *network apps*

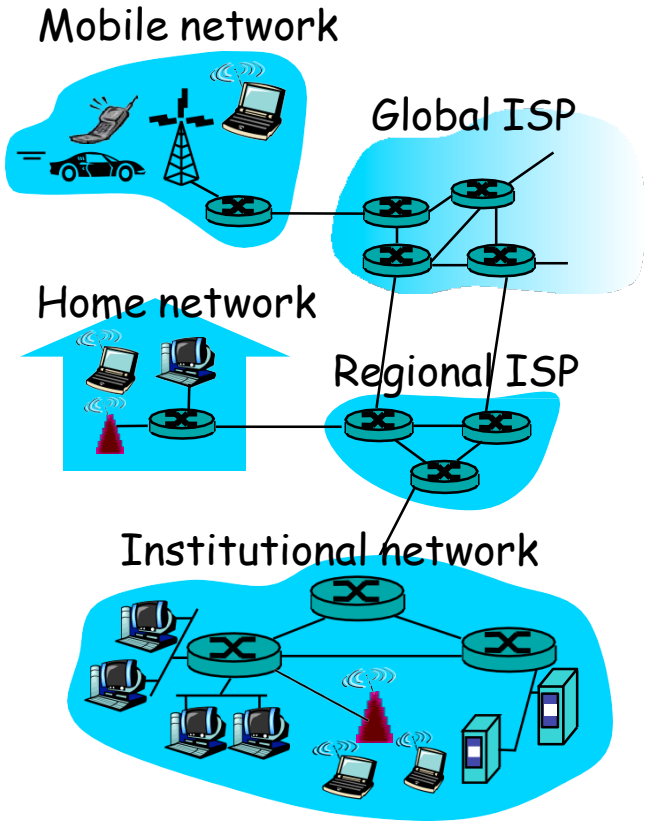
Access points

wired links

router

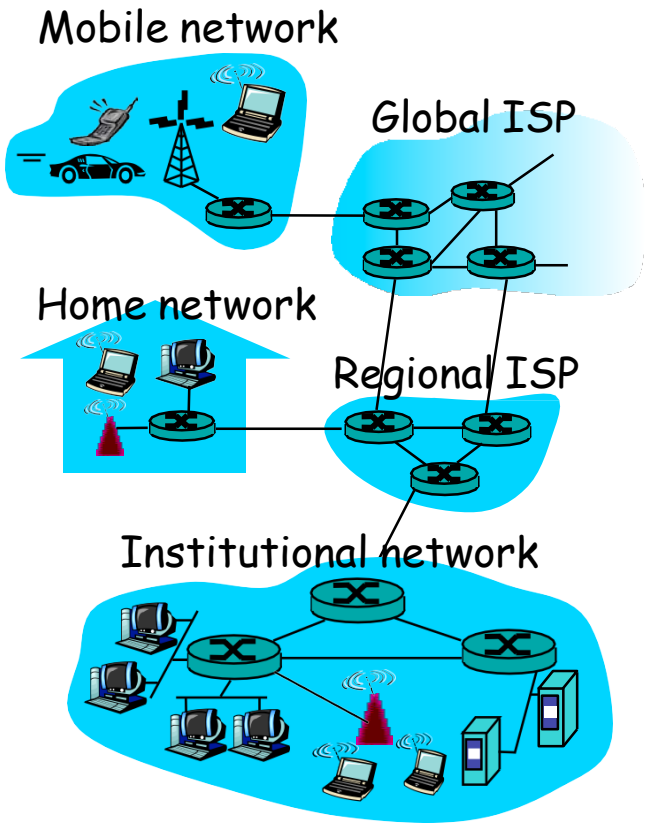
Connection links
Fiber, copper, radio, satellite

Routers:
Forward packets (chunks of data)



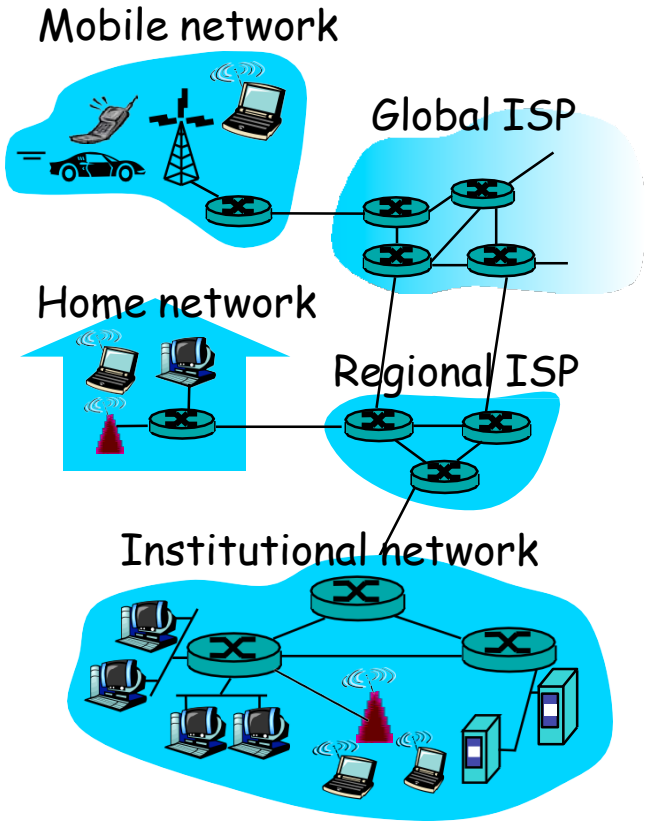
What's the Internet: "Nuts and Bolts" View

- *Internet:* "network of networks"
  - hierarchical



What's the Internet: "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



What's a protocol?

Human protocols:

- "What's the time?"
- "I have a question"
- Introductions.

… specific messages sent

… specific actions taken when messages received, or other events

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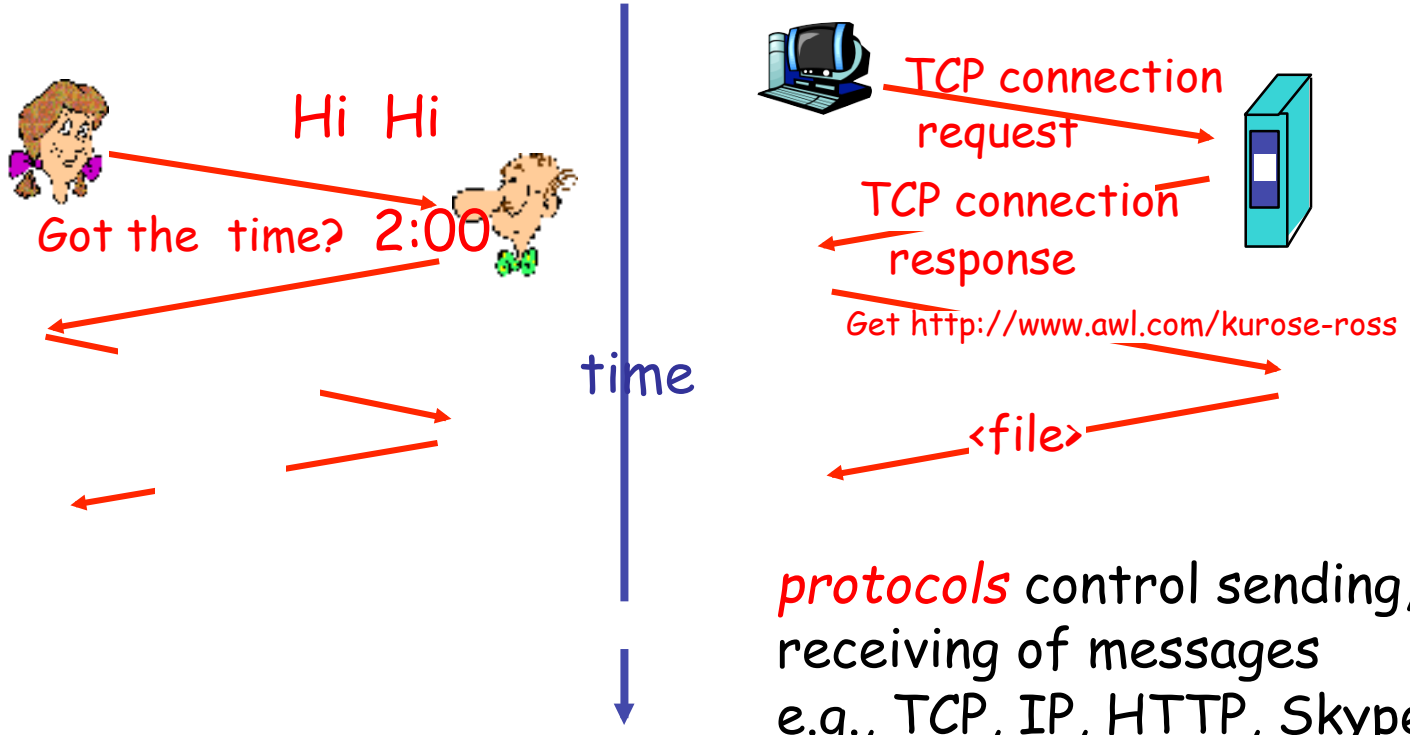
Network protocols:

- Machines rather than humans
- All communication activity in Internet governed by protocols

Protocols define format, order of messages sent and received among network entities, and actions taken on message transmission and receipt.

What's a protocol?

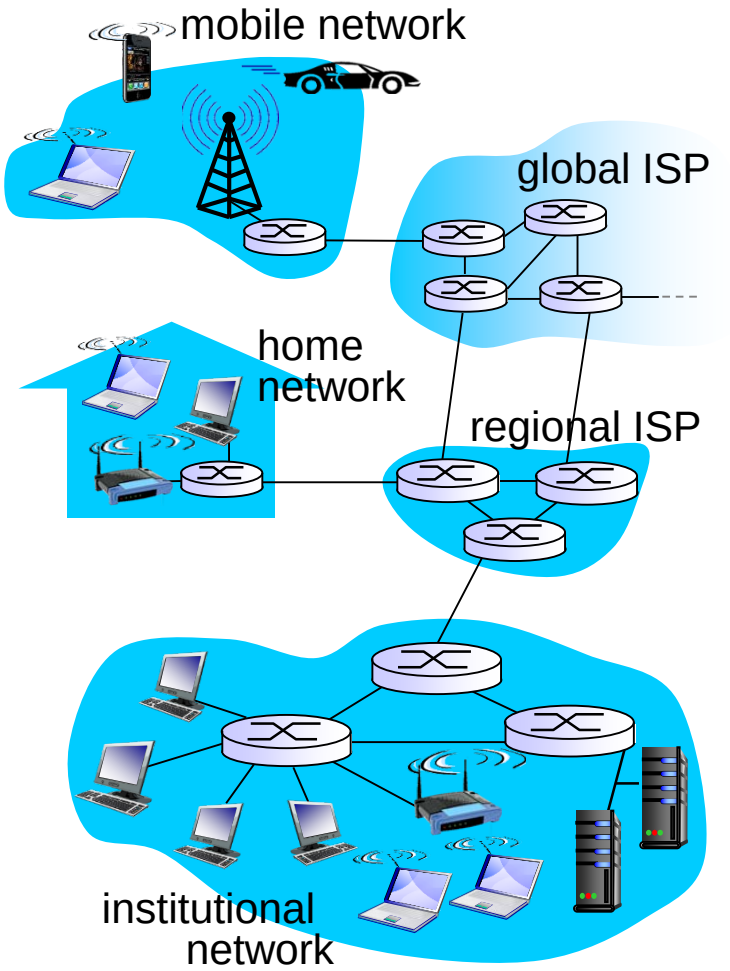
Human protocol and network protocol:



protocols control sending, receiving of messages
e.g., TCP, IP, HTTP, Skype, Ethernet

A closer look at network 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



Chapter 1: roadmap

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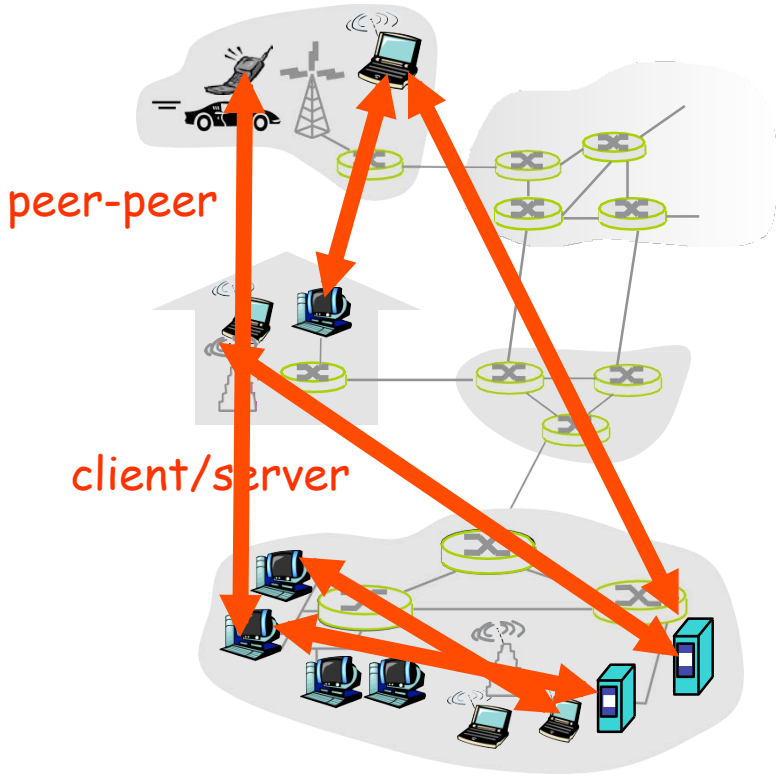
The Network Edge

- End systems (hosts):
  - run application programs
  - e.g. Web, email
  - at "edge of network"



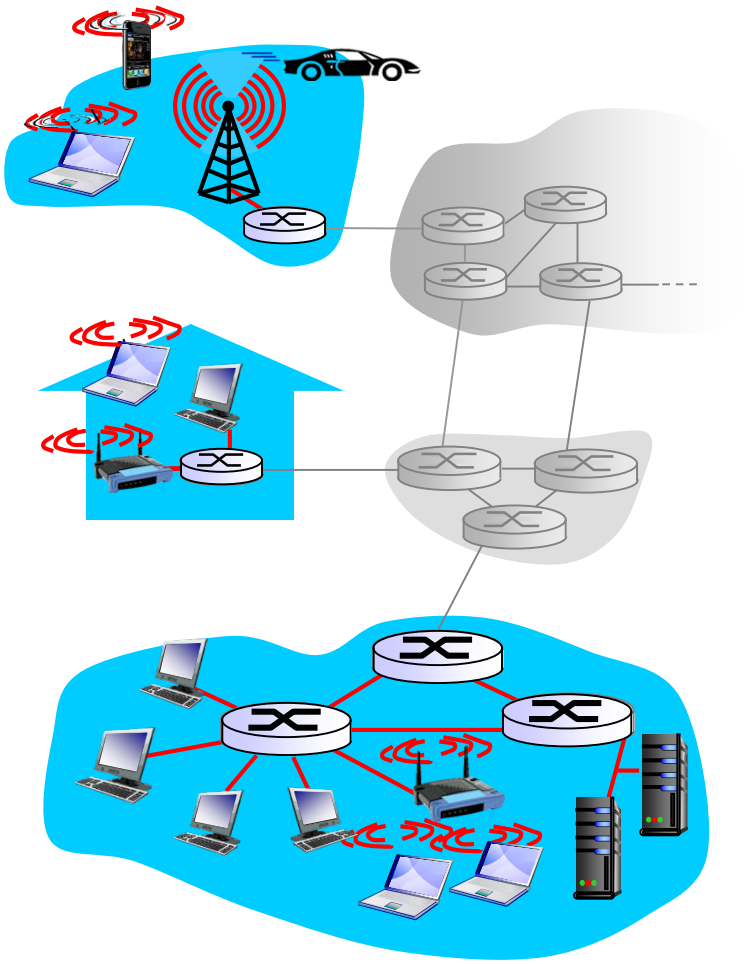
Access networks and physical media

Q: How to connect end systems to edge router?

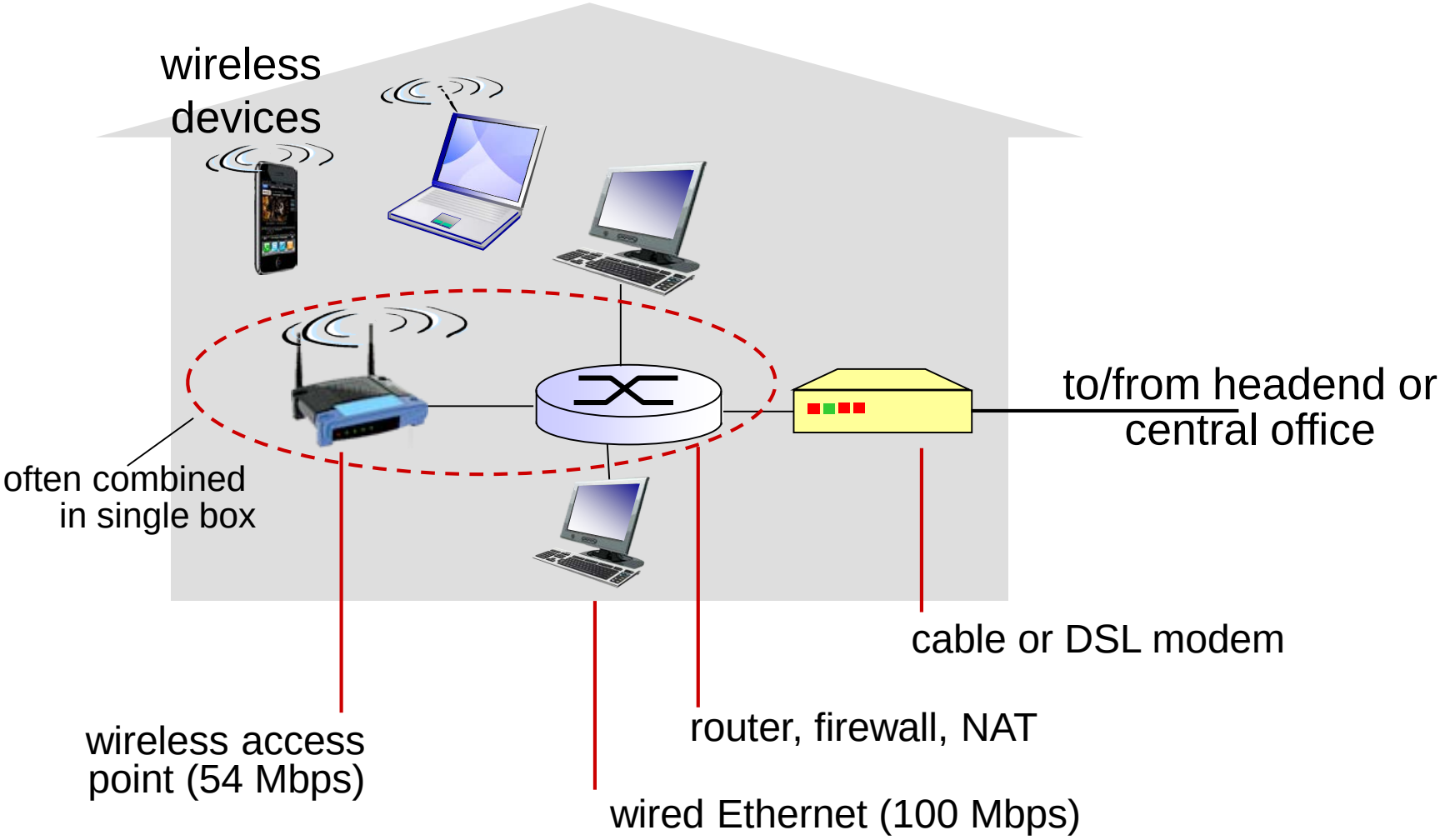
- residential access nets
- institutional access networks (school, company)
- mobile access networks

keep in mind:

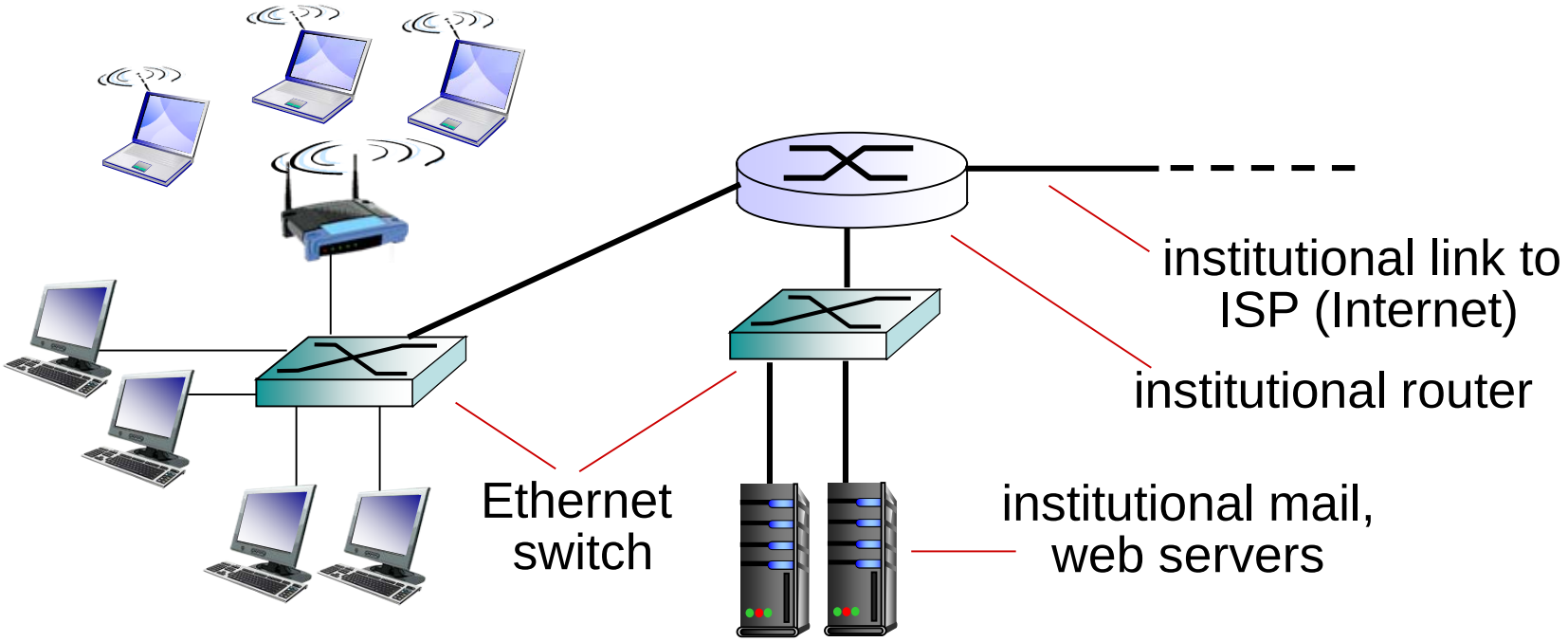
- bandwidth (bits per second) of access network?
- shared or dedicated?
- Bandwidth cap



Access net: home network



Enterprise access networks (Ethernet)



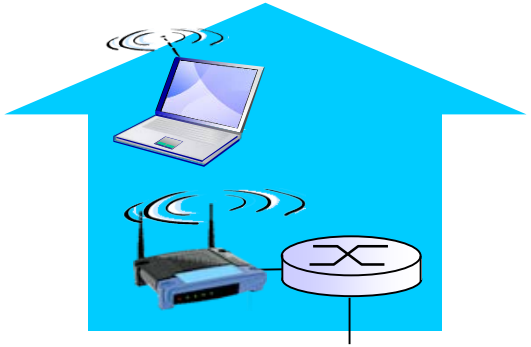
- typically used in companies, universities, etc
- 10 Mbps, 100Mbps, 1Gbps, 10Gbps transmission rates
- today, end systems typically connect into Ethernet switch

Wireless access networks

- shared *wireless* access network connects end system to router
  - via base station aka "access point"

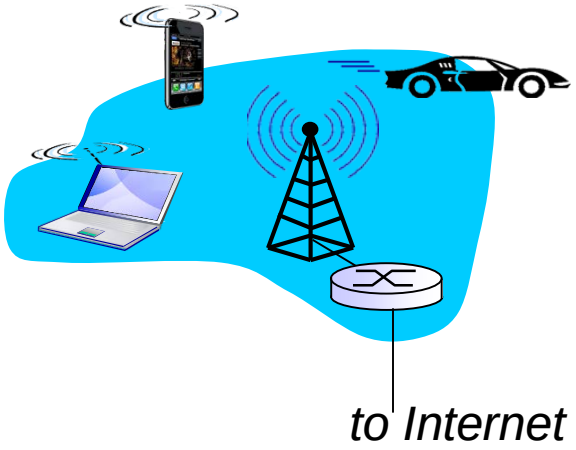
wireless LANs:

- within building (100 ft)
- 802.11b/g (WiFi): 11, 54 Mbps transmission rate



wide-area wireless access

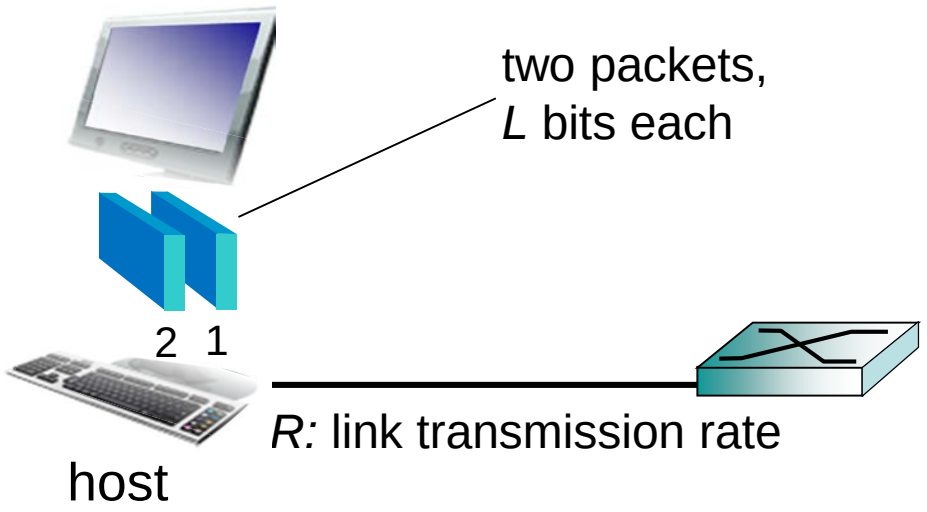
- provided by telco (cellular) operator, 10's km
- between 1 and 10 Mbps
- 3G, 4G: LTE



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*



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

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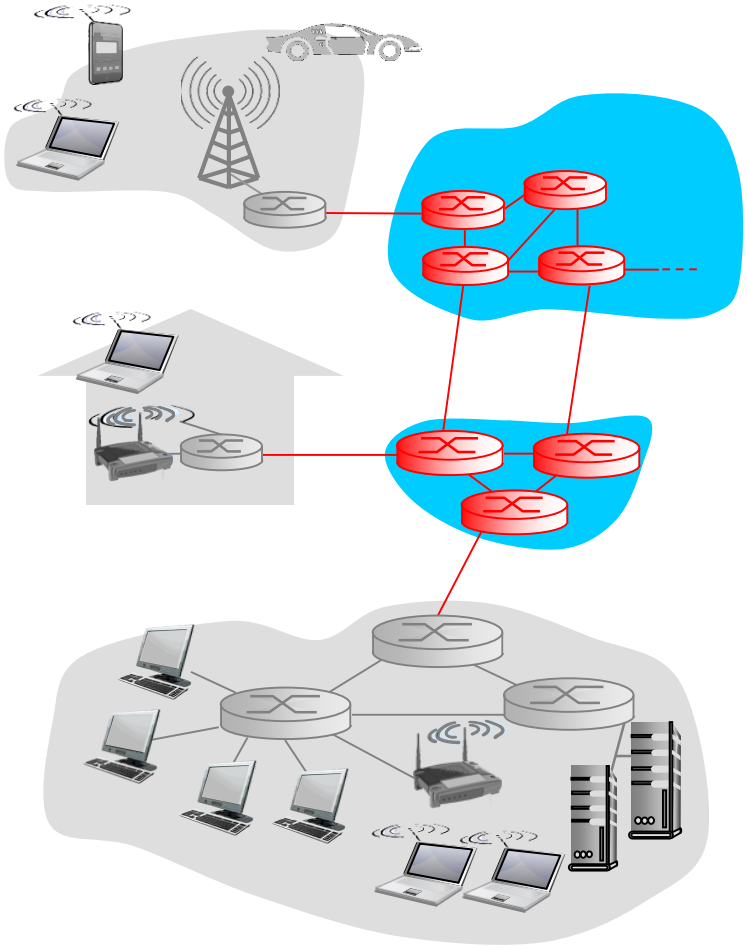
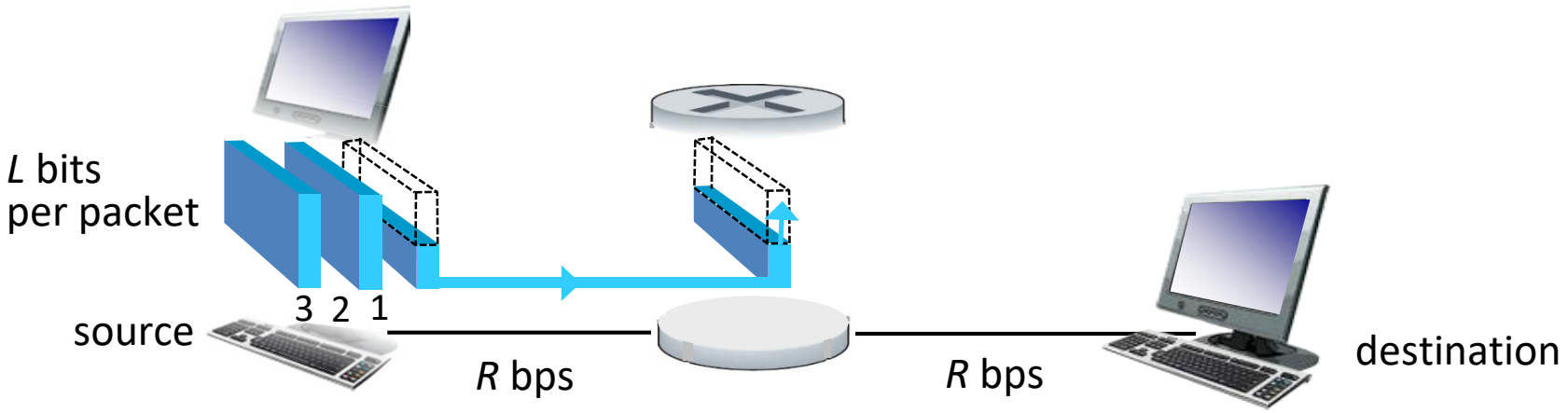
The network core

- mesh of interconnected routers
- https://www.youtube.com/watch?v=yU9oMOcRsuE
- packet-switching: hosts break application-layer messages into *packets*
  - forward packets from one router to the next, across links on path from source to destination
  - each packet transmitted at full link capacity



Packet-switching: store-and-forward



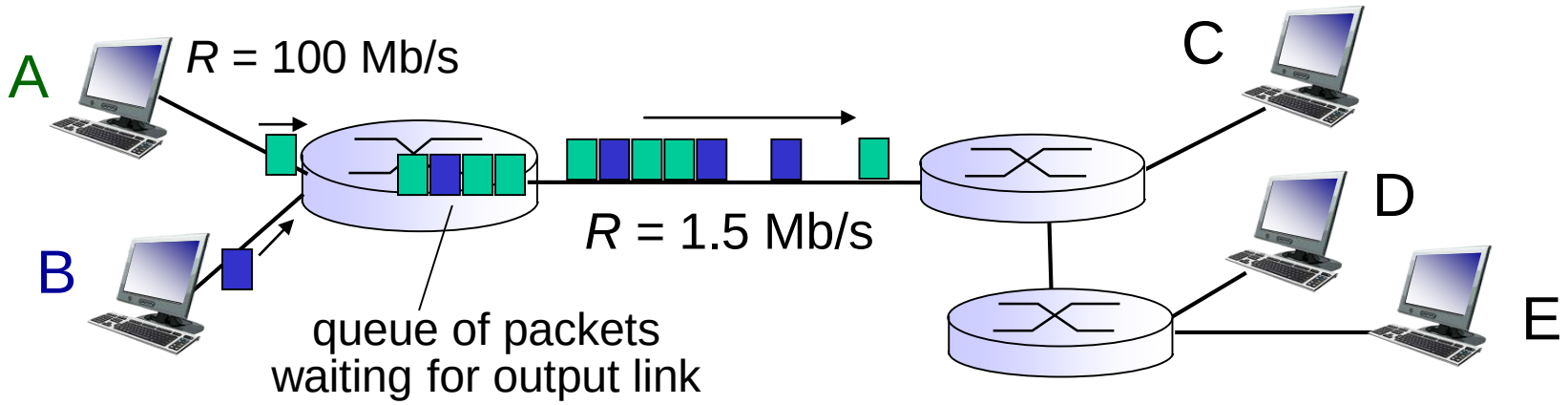
- takes *L*/*R* seconds to transmit (push out) *L*-bit packet into link at *R* bps
- *store and forward:* entire packet must arrive at router before it can be transmitted on next link
- end-end delay = 2*L*/*R* (assuming zero propagation delay)

one-hop numerical example:

- *L* = 7.5 Mbits
- *R* = 1.5 Mbps
- one-hop transmission delay = 5 sec

more on delay shortly …

Packet Switching: queueing delay, loss

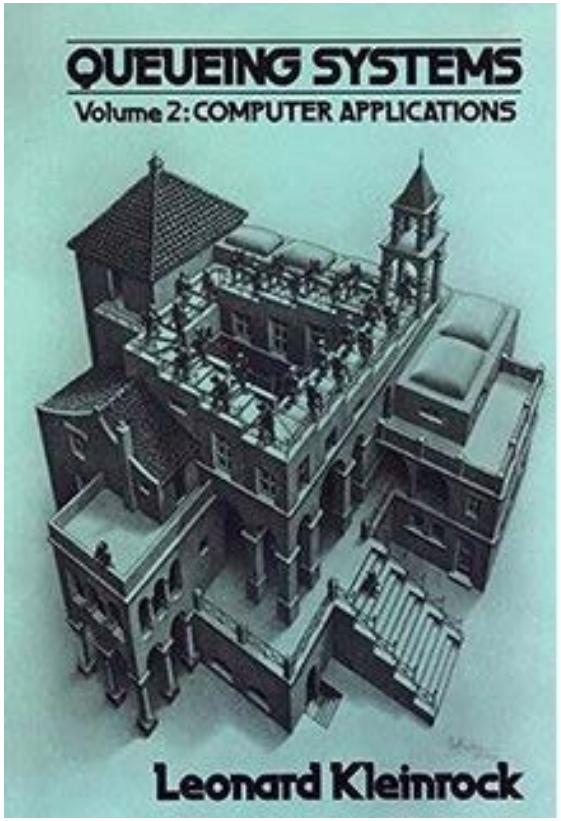


queuing and loss:

- If arrival rate (in bits) to link exceeds transmission rate of link for a period of time:
  - packets will queue, wait to be transmitted on link
  - packets can be dropped (lost) if memory (buffer) fills up

Mathematical background

Queuing theory:



Whenever $V(I) > 0$, then the system is said to be busy, and only when $V(I) = 0$ is the system said to be idle. The duration and location of these busy and idle periods are also quantities of interest.

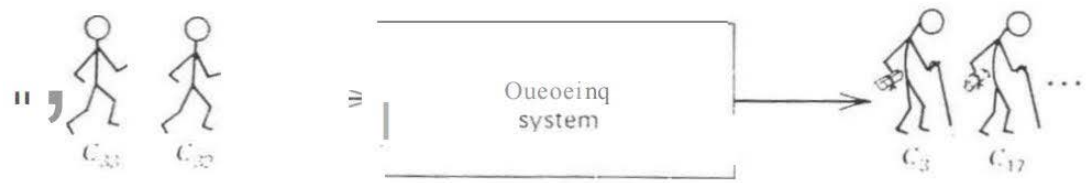


Figure 2.1 A general queueing system.

• The notation $\triangleq$ is to be read as "equals by definition."

Next class

- Please read Chapter 1.4-1.7 of your textbook BEFORE Class