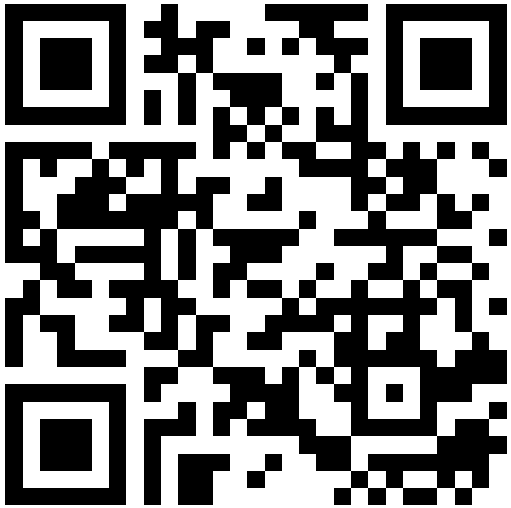
Computer Networks - LEIC-T



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Prof. Luis Pedrosa

A Note on Language

- Class materials will be in English
- I will speak in Portuguese
  - Special arrangements for foreign students

- Most technical terminology is in English
  - Helps with Google searches later on
- Most technical literature is in English
  - Research papers
  - The class book
- Good opportunity to practice
  - You'll likely need English in the workplace

Teachers

- **Prof. Luis Pedrosa** <luis.pedrosa@tecnico.ulisboa.pt>
  - Lectures
  - 2 Labs
- **Prof. Rui Cruz** <rui.s.cruz@tecnico.ulisboa.pt>
  - 2 Labs

Scheduling

Time	Mon	Tue	Wed	Thu	Fri
08:00					
			Lab L3 Zoom		Lab L4 1–3 / Zoom
09:00					
10:00				Lecture Zoom	
11:00					
					Lecture Zoom
12:00					
13:00					
14:00				Office Hours (Pedrosa) Zoom	Lab L5 1-3 / Zoom
15:00					
					Office Hours (Cruz) Zoom
16:00					
			Lab L2 Zoom		Office Hours (Pedrosa) Zoom
17:00					

Grading

- Exam (50%)
  - 1st Exam: 2021-01-25
  - 2nd Exam: 2021-02-08
- Lab work / Mini-projects (50%)
  - Individual
  - 2 mini-projects (30%, 15% each)
  - 5 best of 6 lab guides (20%, 4% each)
    - *Due the week after the lab*
- Check website (Fenix) for extra details

What you'll learn

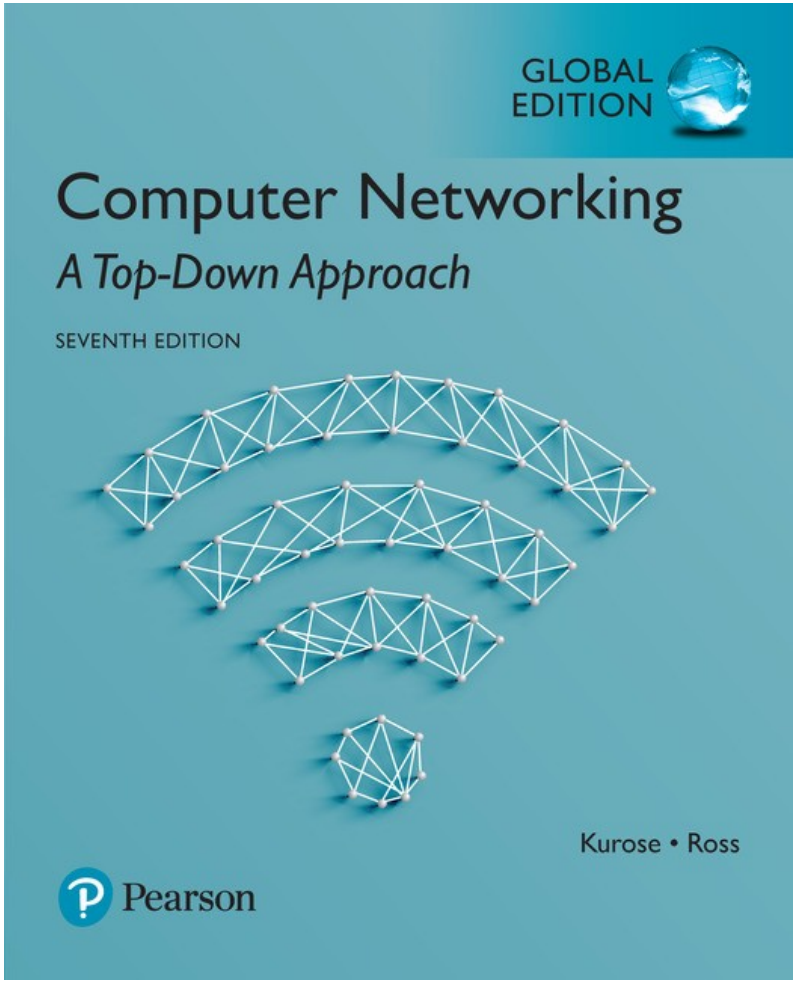
- Computer Networking Fundamentals
  - Design principles
  - Limitations & trade-offs
- Internet Architecture
- Emerging Networking Technologies
- Overview of common protocols / apps
- Details on select protocols / apps
- Some practical experience

What you won’t learn

- Web design, web-services, etc.
  - From our point of view, it’s just another app
- Network planning & deployment
  - This could be its own course
- How to configure a Cisco ME3800X
  - Focus on principles, not specific equipment

Textbook

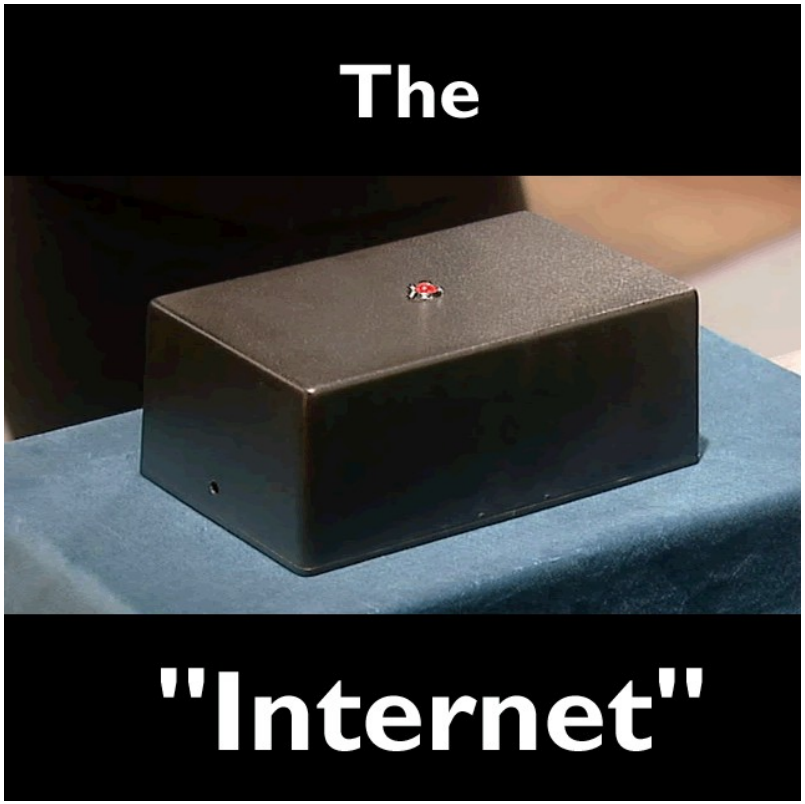
- Computer Networking: A Top-Down Approach (7th Edition)
  J. Kurose, K. Ross
  2017
- Don't get older editions
  - They miss material we'll cover
  - Even on the exam
- Also the basis for these slides and some labs



Today's Class

- What is the Internet?
- Network edge
  - End systems, access networks, links
- Network core
  - packet switching, circuit switching
- Textbook sections 1.1 - 1.3

What is the Internet?



Show of Hands:

- A: Network of Connected Computers – 20 votes
- B: Network of Networks – 12 votes
- C: Data flowing between computers – 2 votes
- D: All the above – 27 votes

What do you think?

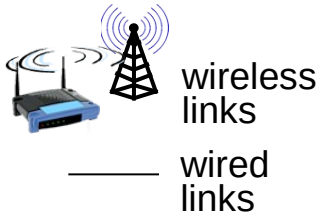
Introduction

our goal:

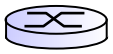
- get "feel" and terminology
- more depth, detail *later* in course
- approach:
  - use Internet as example

What's the Internet: nuts and bolts

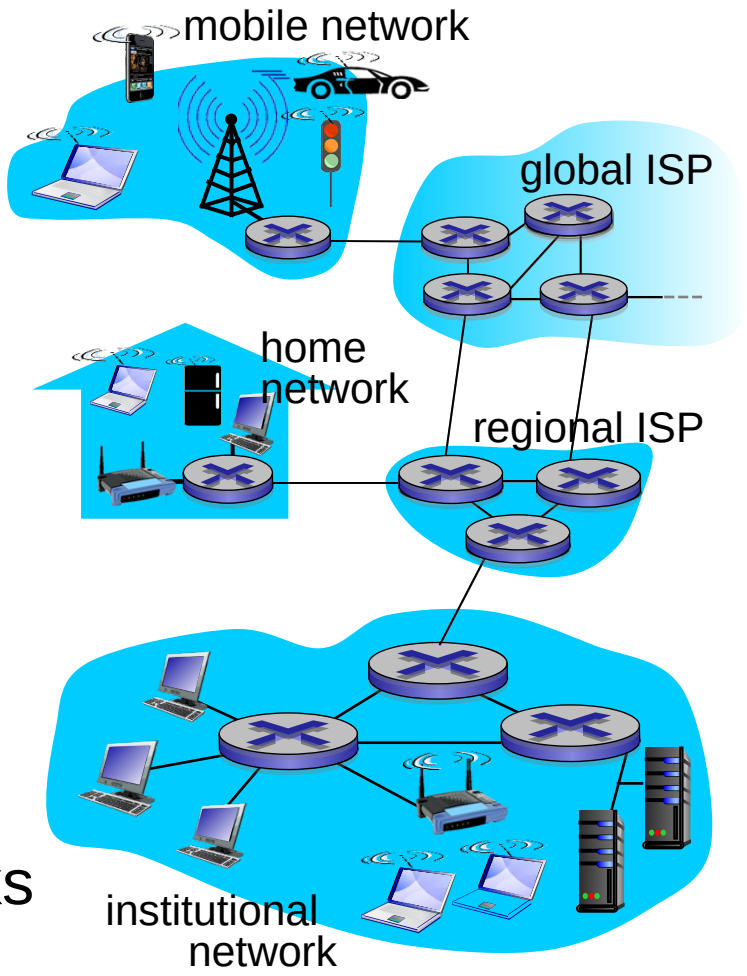
- billions of connected computing devices:
  - *hosts* = *end systems*
  - running *network apps*



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



- *packet switches:* forward packets (chunks of data)
  - *routers* and *switches*



“Fun” Internet-connected devices

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

Web-enabled toaster + weather forecaster

Tweet-a-watt:
monitor energy use

Internet
refrigerator

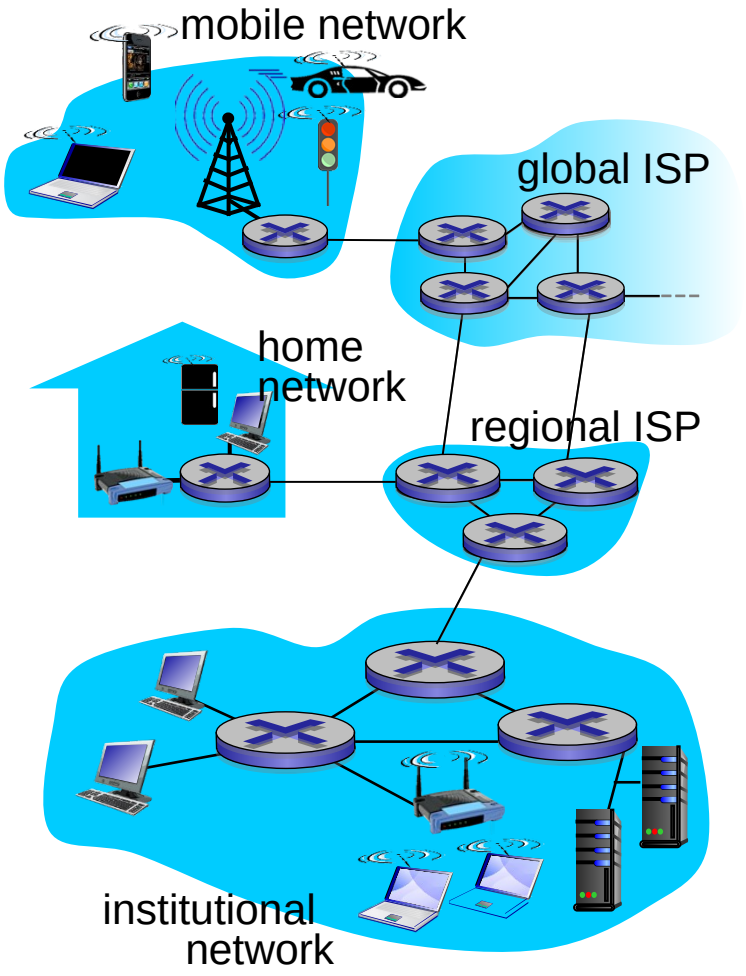
Slingbox: watch,
control cable TV remotely

sensorized,
bed
mattress

Internet phones

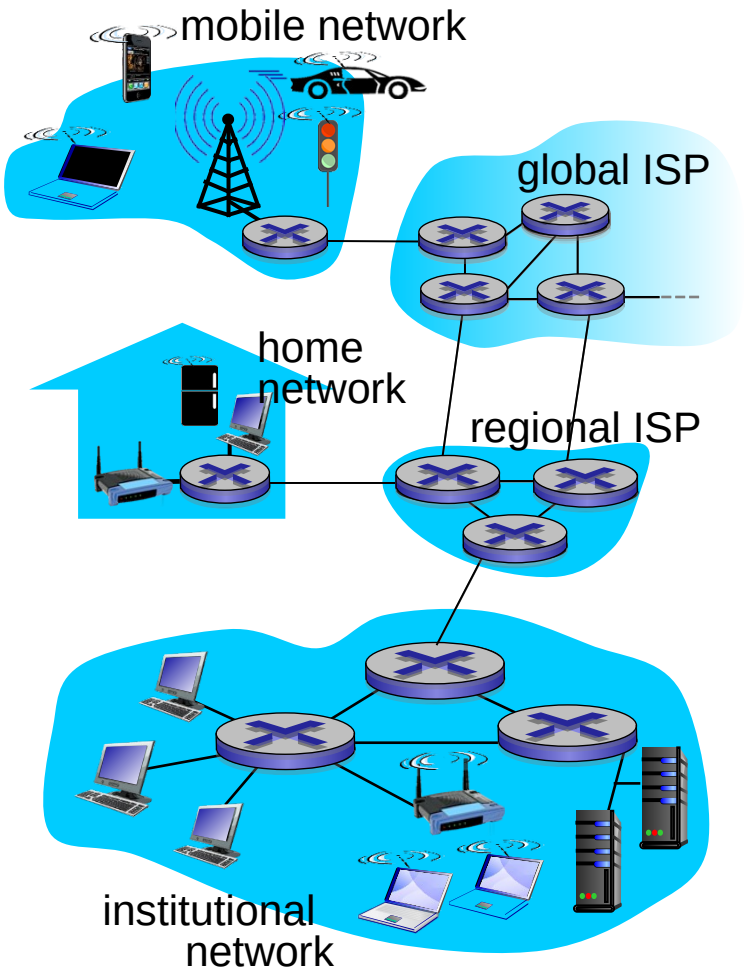
What's the Internet: nuts and bolts

- *Internet:* "network of networks"
  - Interconnected ISPs
- *protocols* control sending, receiving of messages
  - e.g., TCP, IP, HTTP, Skype, 802.11
- *Internet standards*
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force



What's the Internet: a service view

- *infrastructure that provides services to applications:*
  - Web, VoIP, email, games, e-commerce, social nets, …
- *provides programming interface to apps*
  - hooks that allow sending and receiving app programs to "connect" to Internet
  - provides service options, analogous to postal service



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

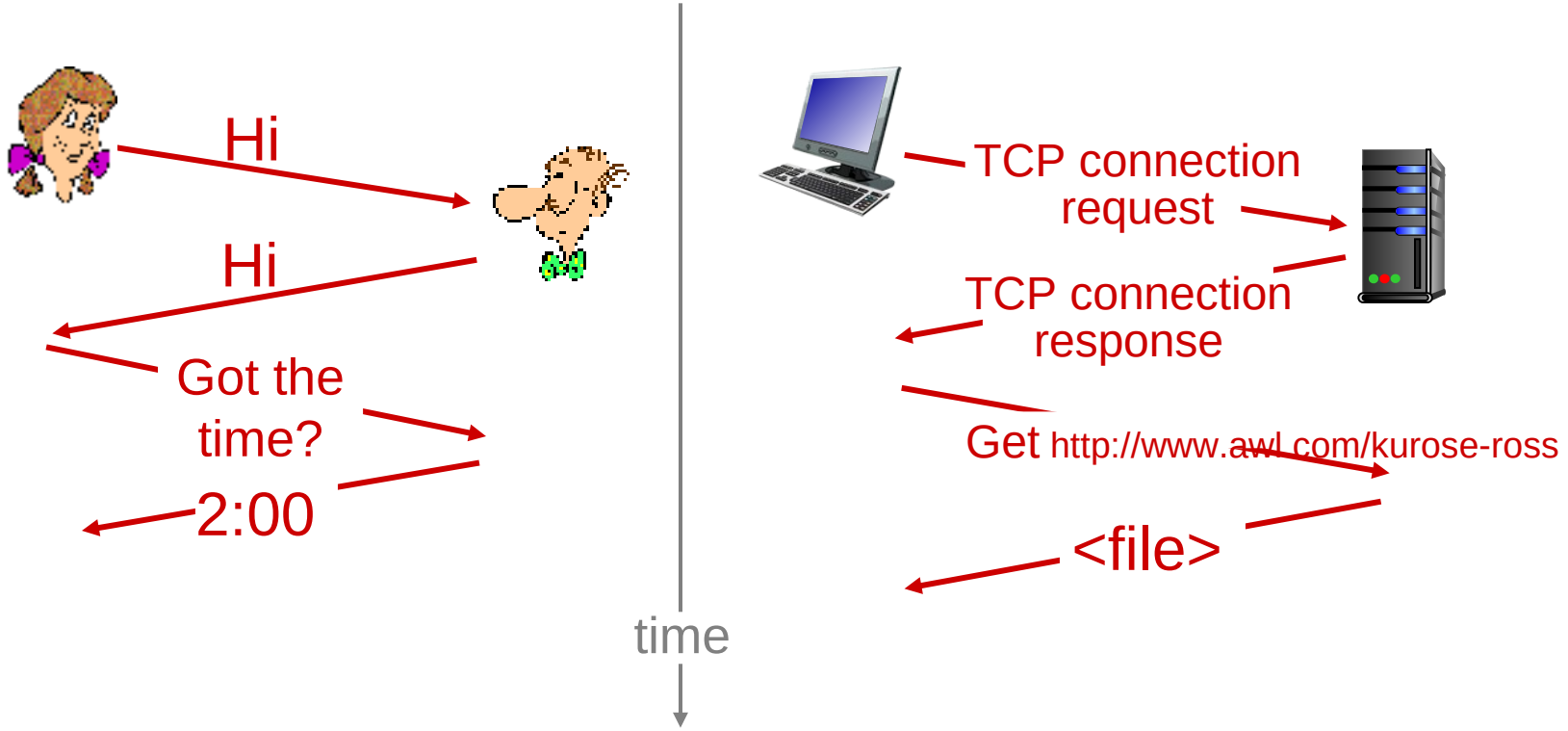
network protocols:

- 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, receipt

What's a protocol?

a human protocol and a computer network protocol:



Q: other human protocols?

Today's Class

- What is the Internet?
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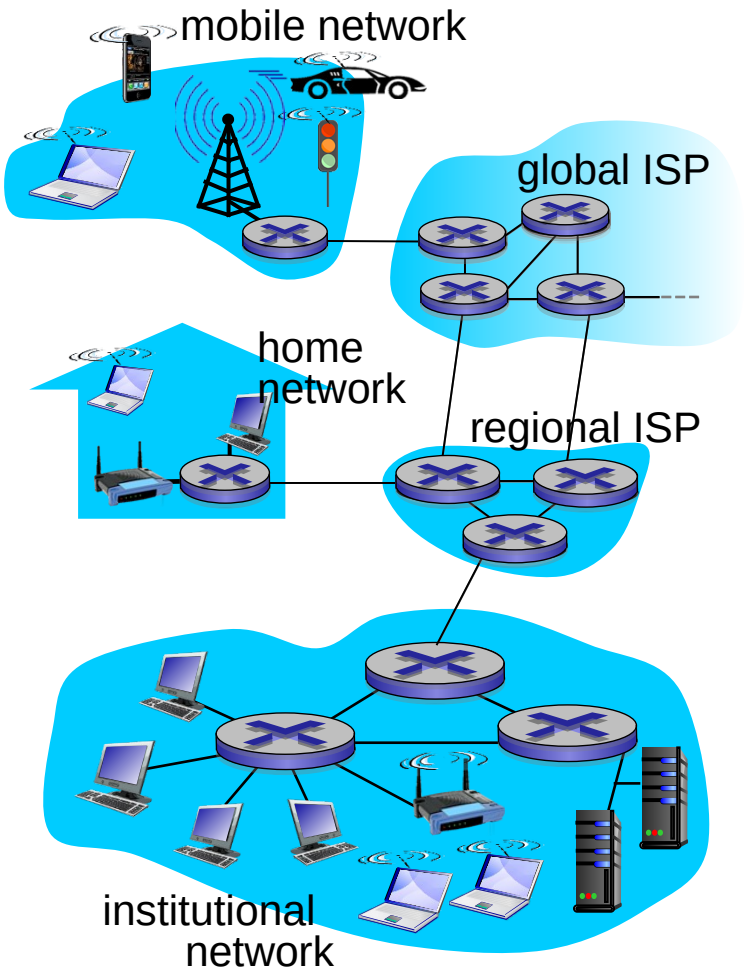
- Network core
  - packet switching, circuit switching

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



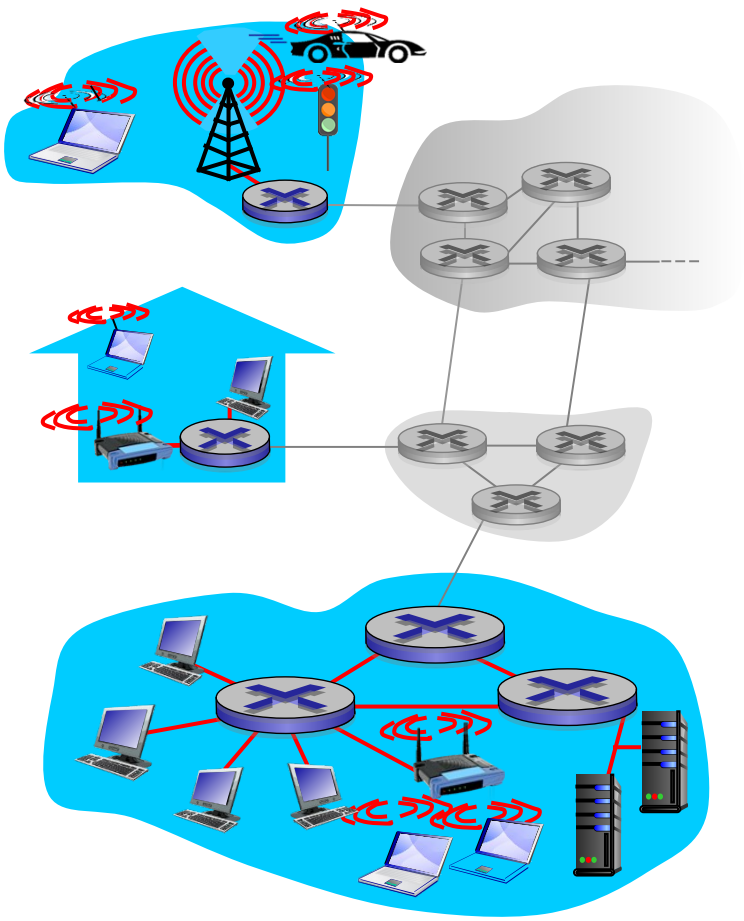
Access networks and physical media

Q: How to connect end systems to edge router?

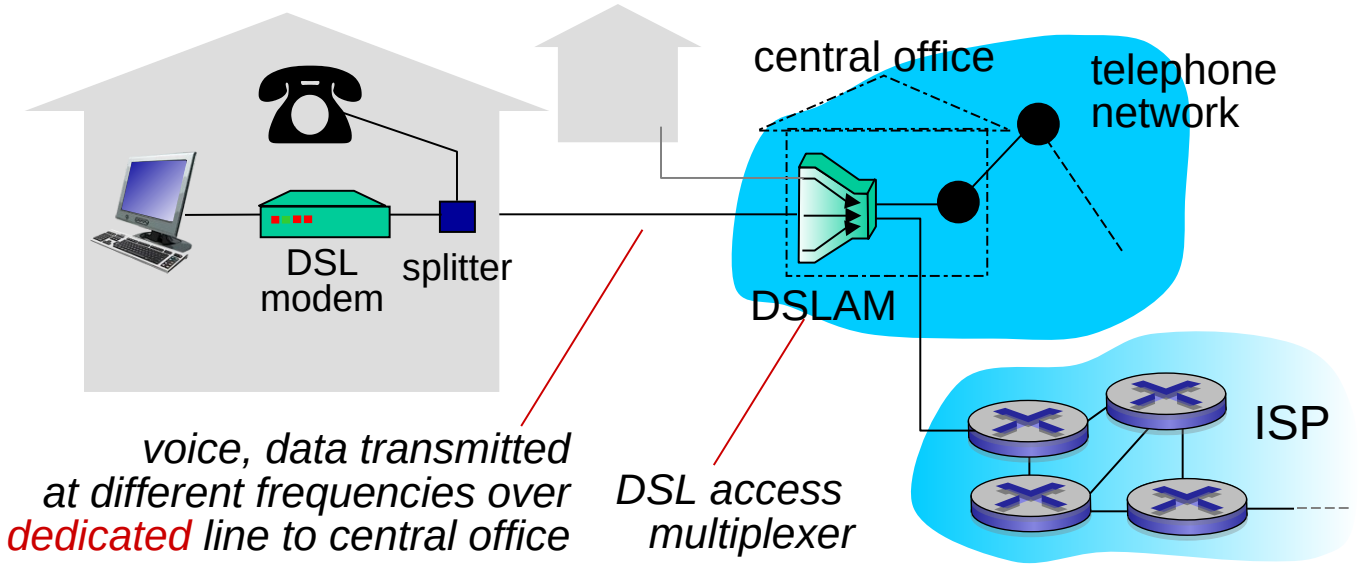
- residential access nets
- institutional access networks (school, company)
- mobile access networks

keep in mind:

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

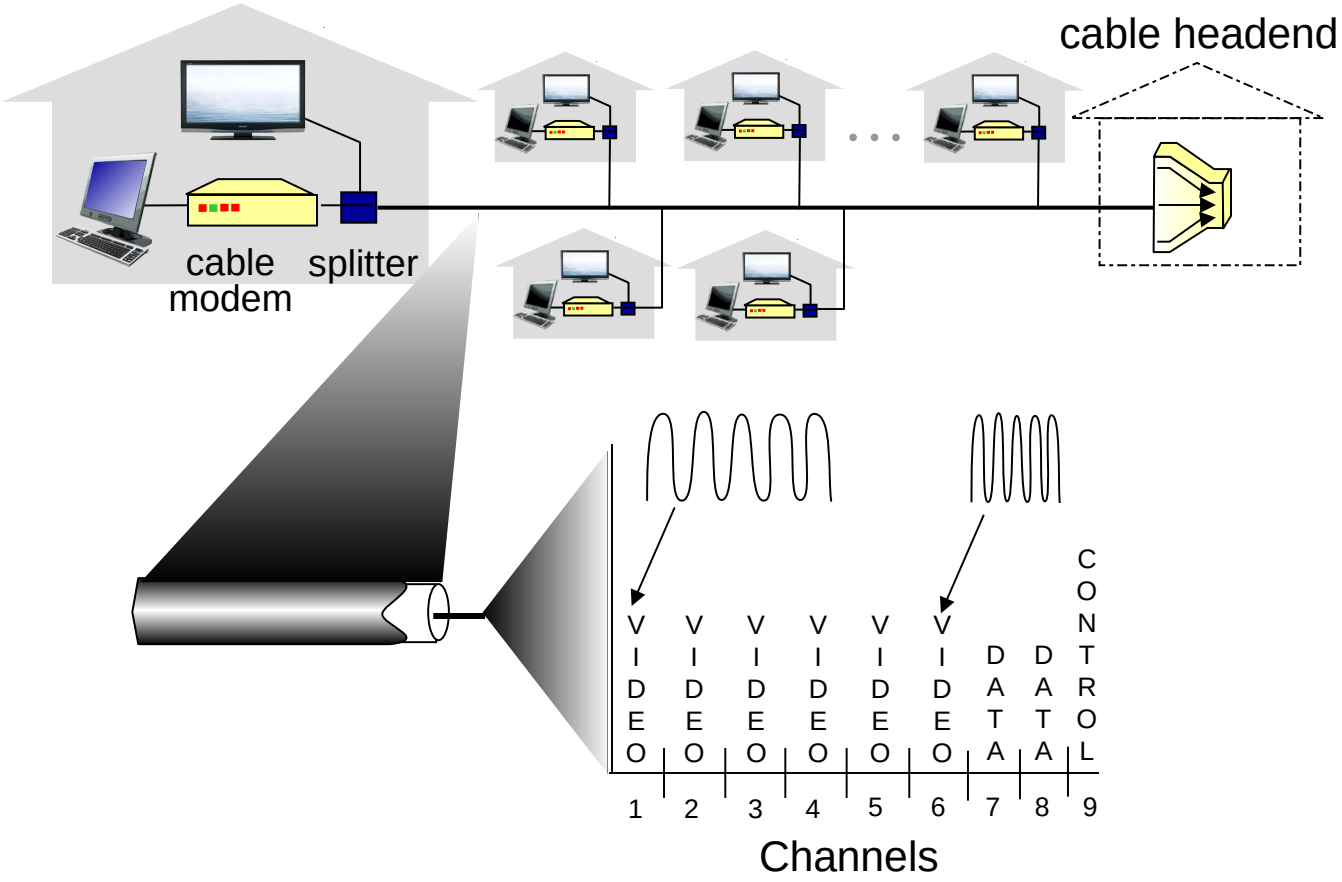


Access network: digital subscriber line (DSL)



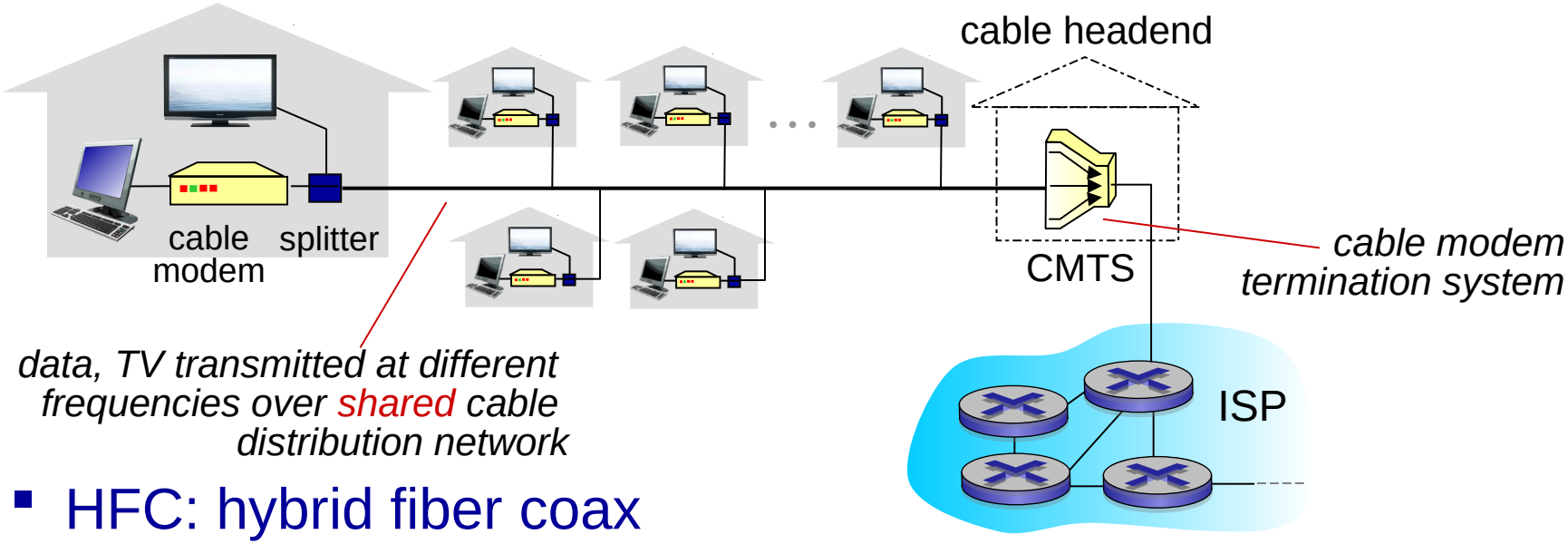
- use *existing* telephone line to central office DSLAM
  - data over DSL phone line goes to Internet
  - voice over DSL phone line goes to telephone net
- < 2.5 Mbps upstream rate (typically < 1 Mbps)
- < 24 Mbps downstream rate (typically < 10 Mbps)

Access network: cable network



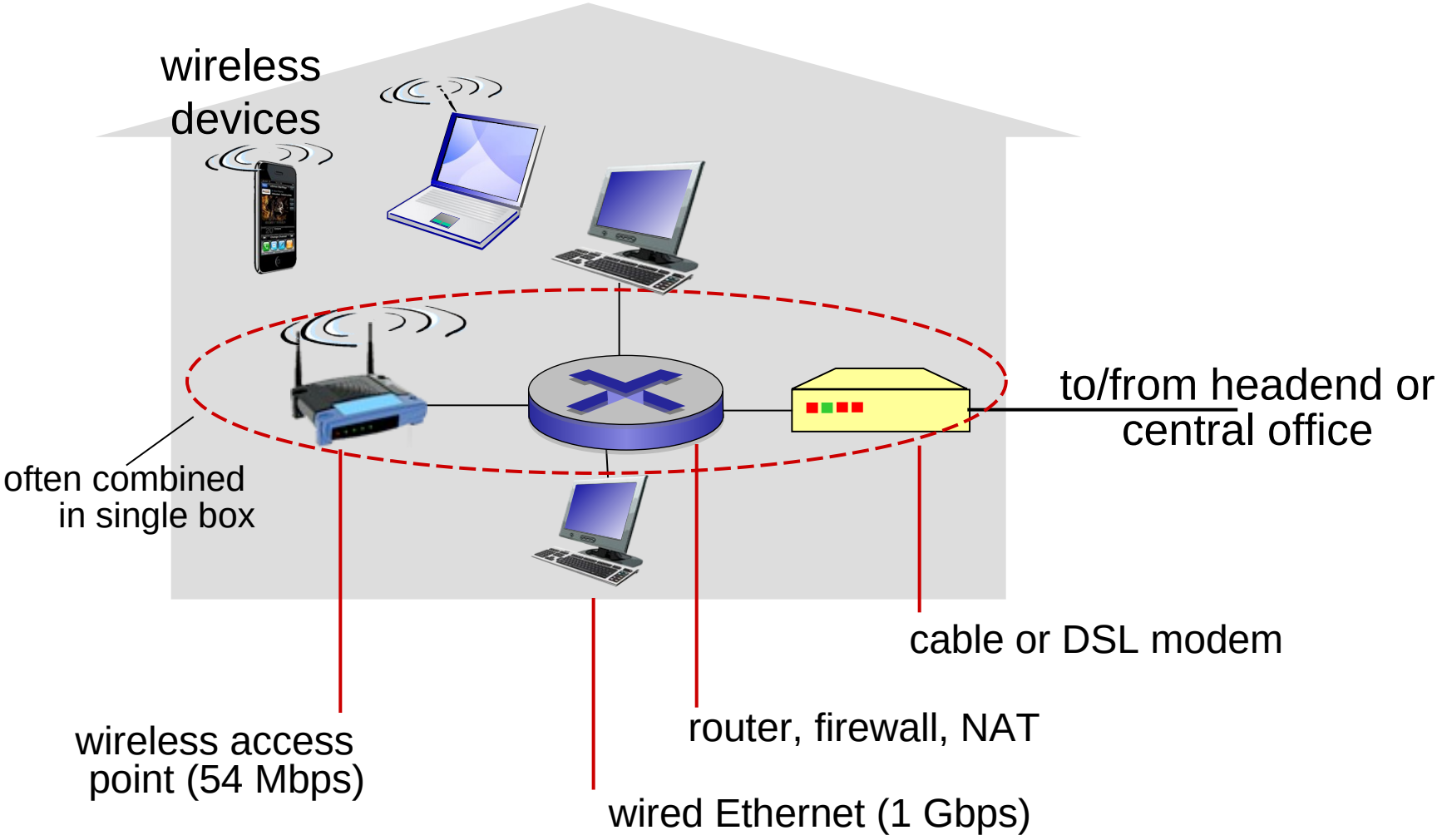
frequency division multiplexing: different channels transmitted in different frequency bands

Access network: cable network

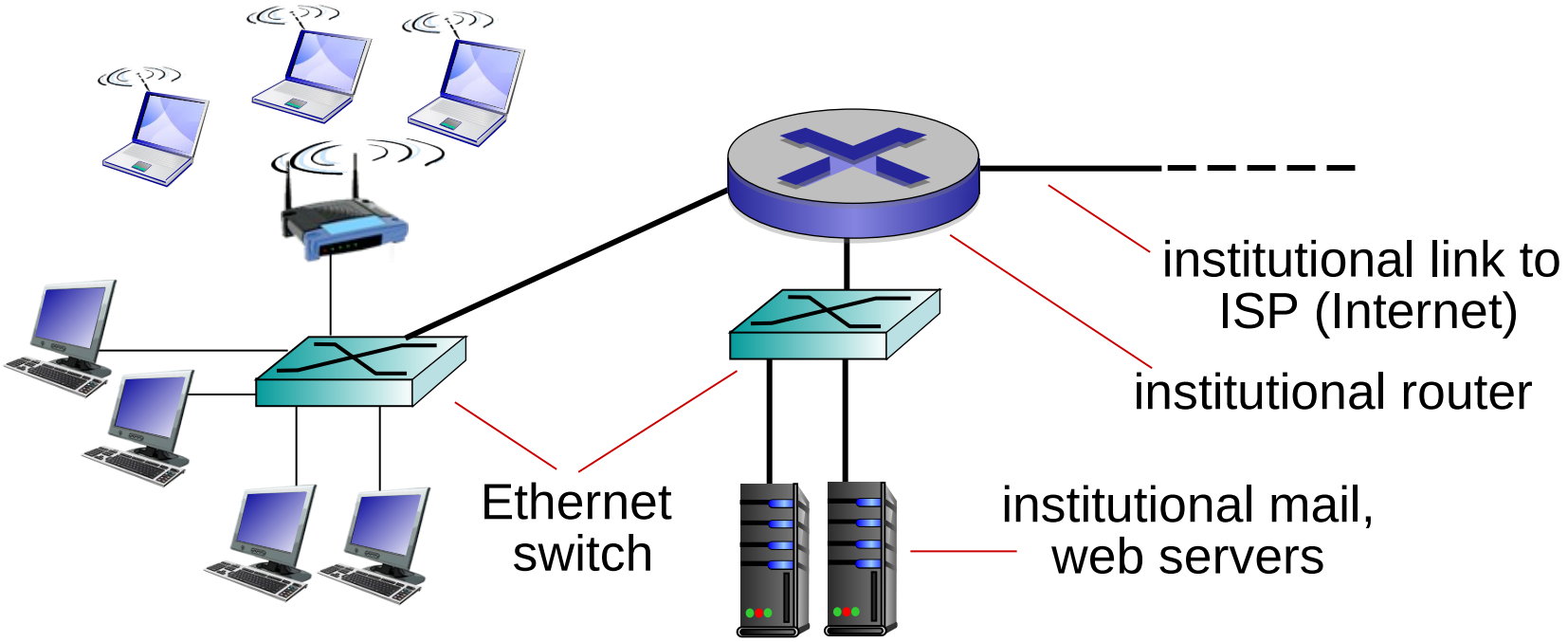


- HFC: hybrid fiber coax
  - asymmetric: up to 30Mbps downstream transmission rate, 2 Mbps upstream transmission rate
- network of cable, fiber attaches homes to ISP router
  - homes *share access network* to cable headend
  - unlike DSL, which has dedicated access to central office

Access network: home network



Enterprise access networks (Ethernet)



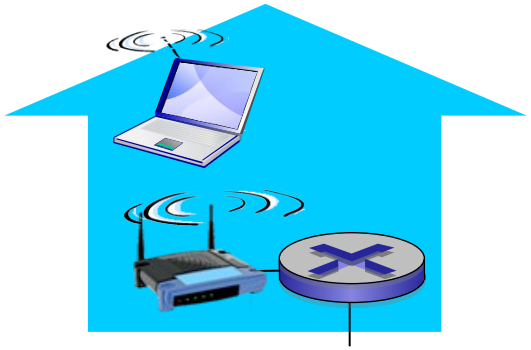
- typically used in companies, universities, etc.
- 10 Mbps, 100Mbps, 1Gbps, 10Gbps transmission rates
- today, end systems typically connect into Ethernet switch

Wireless access networks

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

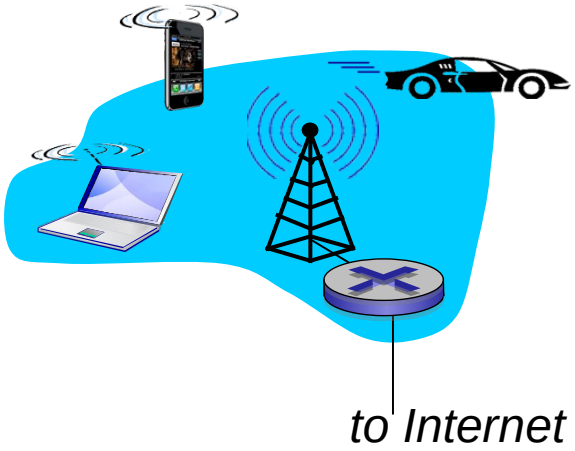
wireless LANs:

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



wide-area wireless access

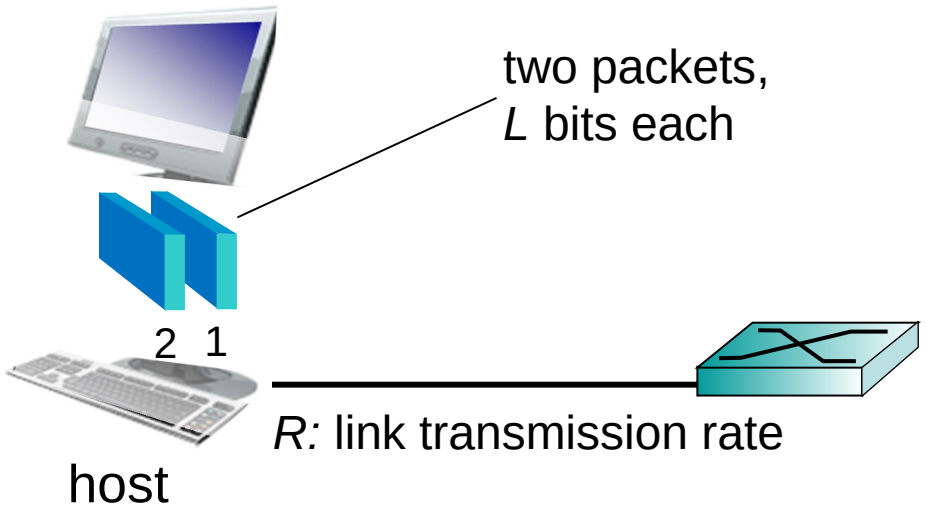
- provided by telco (cellular) operator, 10's km
- between 1 and 10 Mbps
- 3G, 4G: LTE



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*



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

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

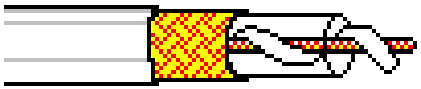
twisted pair (TP)

- two insulated copper wires
  - Category 5: 100 Mbps, 1 Gbps Ethernet
  - Category 6: 10Gbps

Physical media: coax, fiber

coaxial cable:

- two concentric copper conductors
- bidirectional
- 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 Gbps transmission rate)
- 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:

- terrestrial microwave
  - e.g. up to 45 Mbps channels
- LAN (e.g., WiFi)
  - 54 Mbps
- wide-area (e.g., cellular)
  - 4G cellular: ~ 10 Mbps
- satellite
  - Kbps to 45Mbps channel (or multiple smaller channels)
  - 270 msec end-end delay
  - geosynchronous versus low altitude

Today's Class

- What is the Internet?
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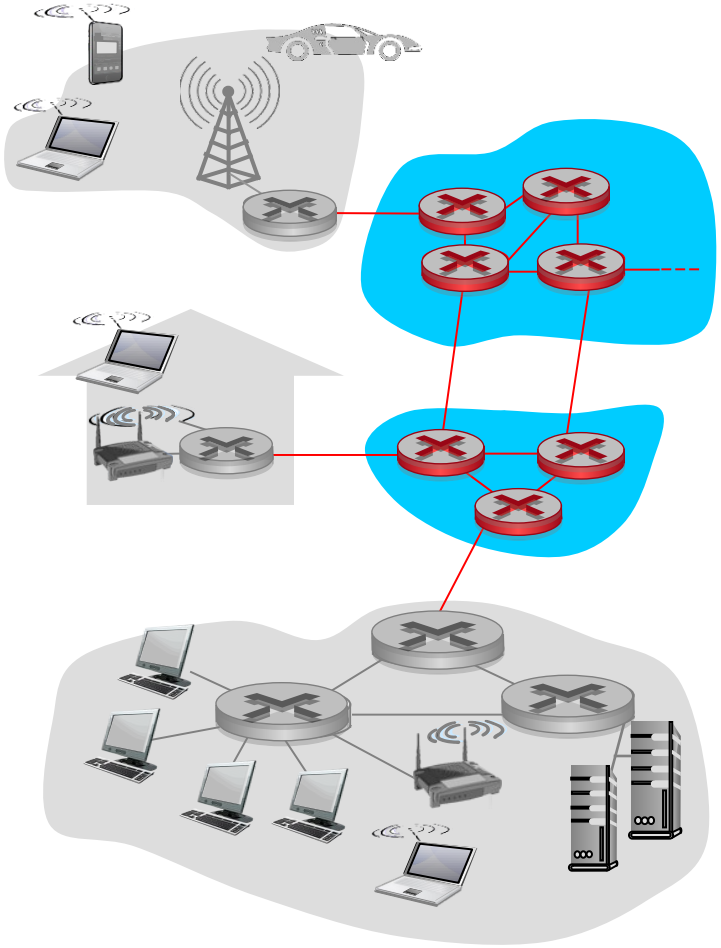
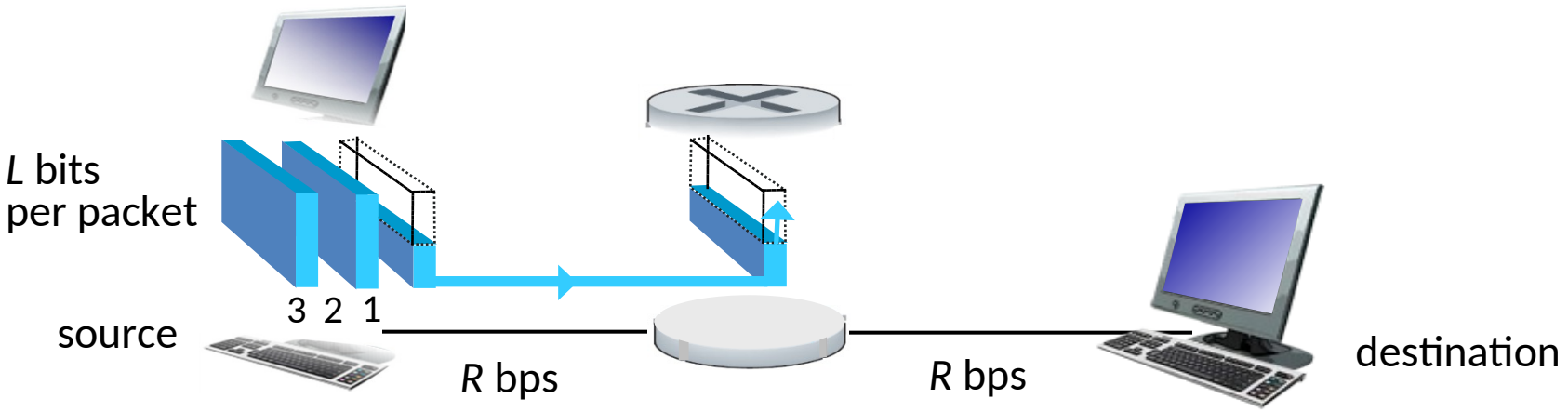
The network core

- mesh of interconnected routers
- 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



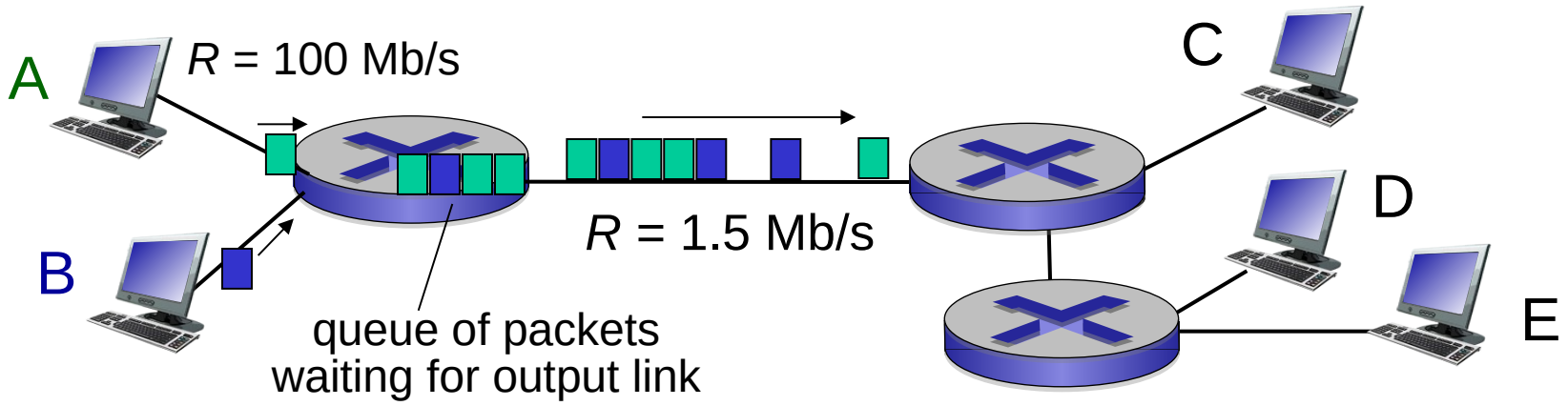
- takes L/R seconds to transmit L-bit packet into link at R bps
- *store and forward:* entire packet arrives at router before being transmitted on next link
- end-to-end delay = $2L/R$ (assuming zero propagation delay)

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:

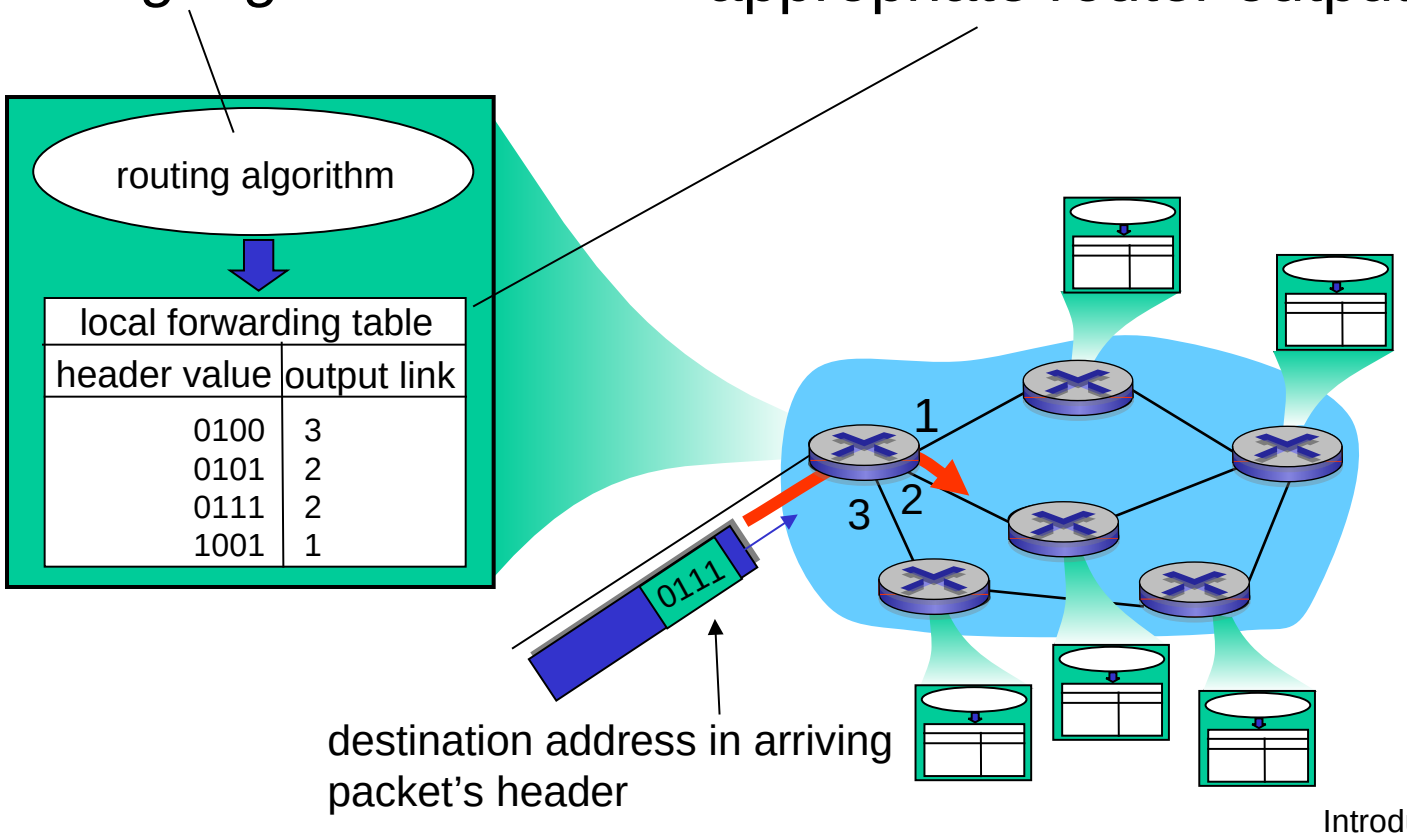
- if arrival rate (in bits) to link exceeds transmission rate of link for a period of time:
  - packets will queue, wait to be transmitted on link
  - packets can be dropped (lost) if memory (buffer) fills up

Two key network-core functions

routing: determines source-destination route taken by packets

- *routing algorithms*

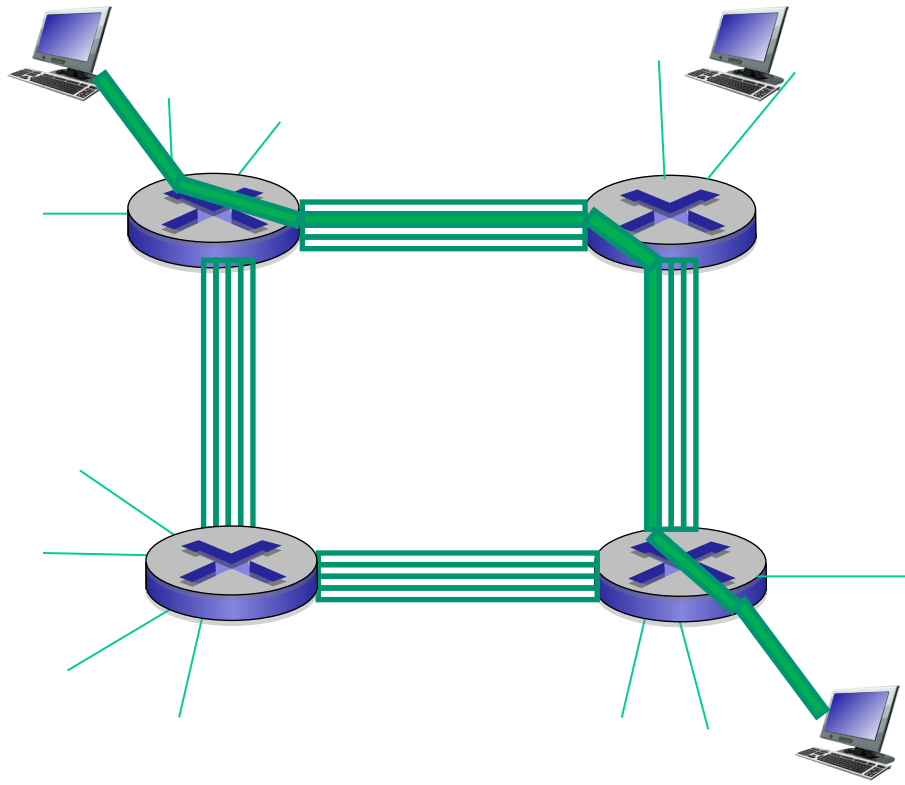
forwarding: move packets from router's input to appropriate router output



Alternative core: circuit switching

end-end resources allocated to, reserved for "call" between source & dest:

- in diagram, each link has four circuits.
  - call gets 2nd circuit in top link and 1st circuit in right link.
- dedicated resources: no sharing
  - circuit-like (guaranteed) performance
- circuit segment idle if not used by call *(no sharing)*
- commonly used in traditional telephone networks

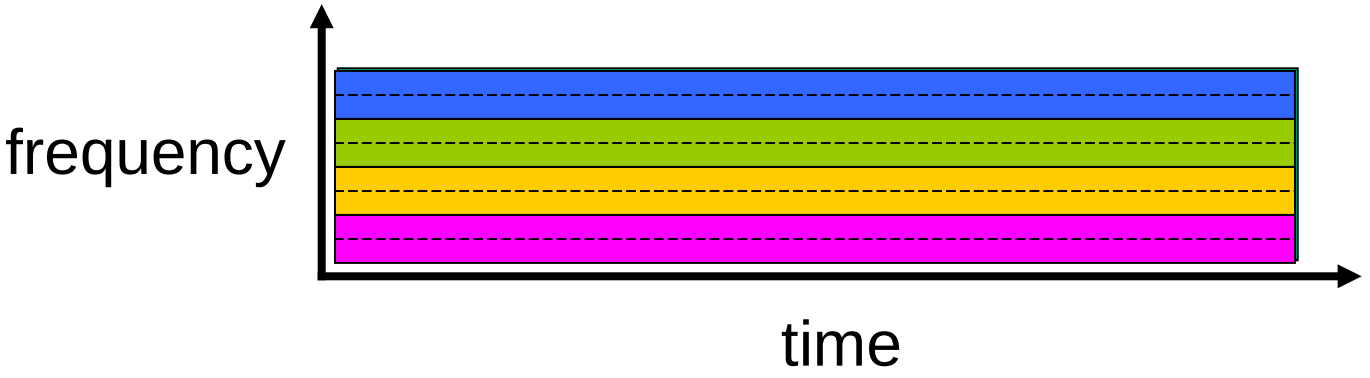


Circuit switching: FDM versus TDM

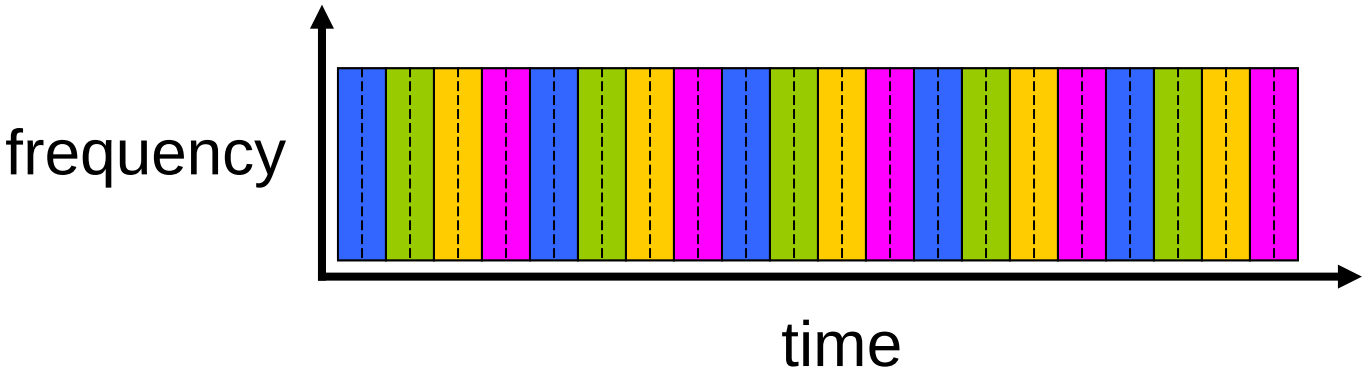
Example:

4 users

FDM



TDM

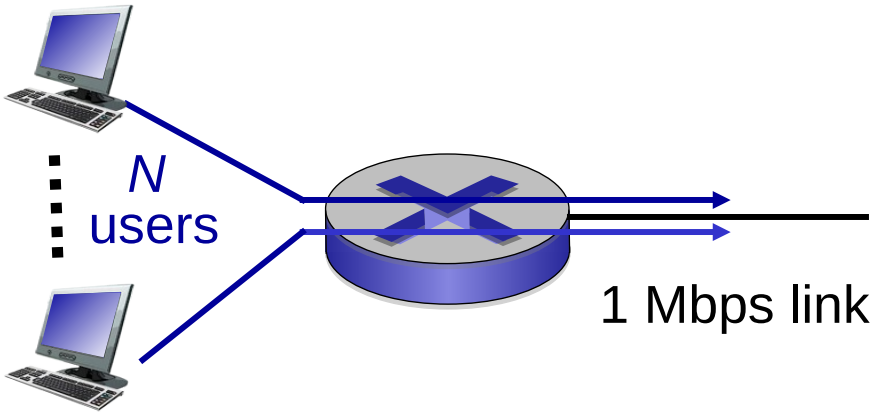


Packet switching versus circuit switching

packet switching allows more users to use network!

example:

- 1 Mb/s link
- each user:
  - 100 kb/s when "active"
  - active 10% of time



- *circuit-switching:*
  - 10 users
- *packet switching:*
  - with 35 users, probability > 10 active at same time is less than .0004 *

Q: what happens if > 35 users ?

Packet switching versus circuit switching

is packet switching a "slam dunk winner?"

- great for bursty data
  - resource sharing
  - simpler, no call setup
- excessive congestion possible: packet delay and loss
  - protocols needed for reliable data transfer, congestion control
- *Q:* How to provide circuit-like behavior?
  - bandwidth guarantees needed for audio/video apps
  - still an unsolved problem (chapter 7)

Q: human analogies of reserved resources (circuit switching) versus on-demand allocation (packet-switching)?

Summary

- What is the Internet?
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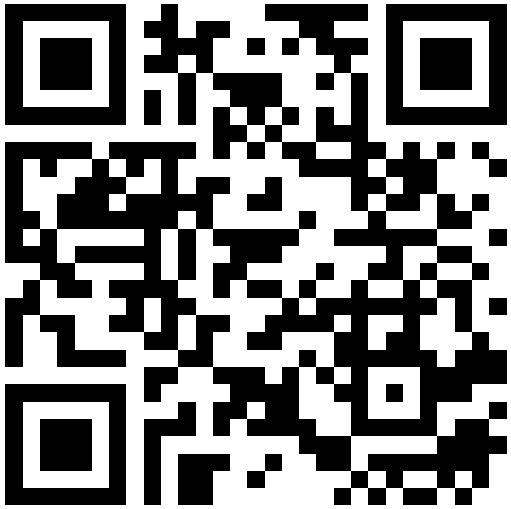
Next Class

- Network core
  - network structure
- Delay, loss, throughput in networks
- Protocol layers

Don’t Forget to Sign In!



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