This lecture will be recorded!

Welcome to

CS 3516:
Computer Networks

Prof. Yanhua Li

Time: 9:00am –9:50am M, T, R, and F
Zoom lecture
Fall 2020 A-term

Update

1. Lab assignment #1
   1. Starts today 9/1 and due on this Friday 9/4

2. Quiz #1
   1. This Thursday 9/3 (8:55AM – 9AM)
   2. Login to Zoom session while doing Quiz #1, so you can ask questions via Zoom chatbox.
   3. *Quiz topics (2 questions, 7 points):*
      1. Packet Switching,
      2. Circuit switching: (Time Division Multiplexing (TDM) and Frequency Division Multiplexing (FDM))
3. Preference of accessing AK219
   1. 91 students in Canvas
   2. 64 responses
   3. 17 "Yes" (prefer to access AK219)

Lecture 1: roadmap

1.1 what *is* the Internet?

"nuts and bolts" view

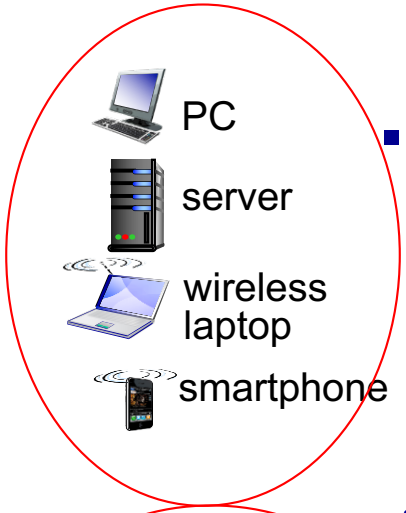
a service view

what's a protocol?

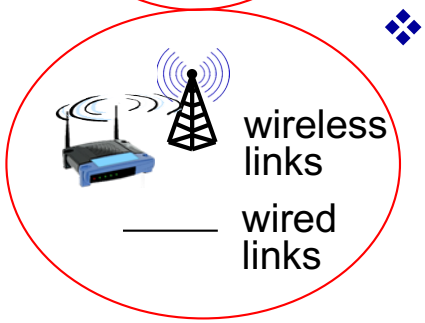
1.2 network edge

- hosts, access networks, physical media/links

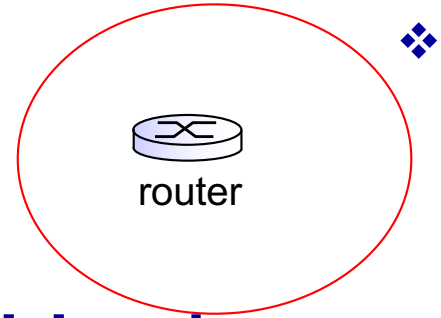
What's the Internet: "nuts and bolts" view



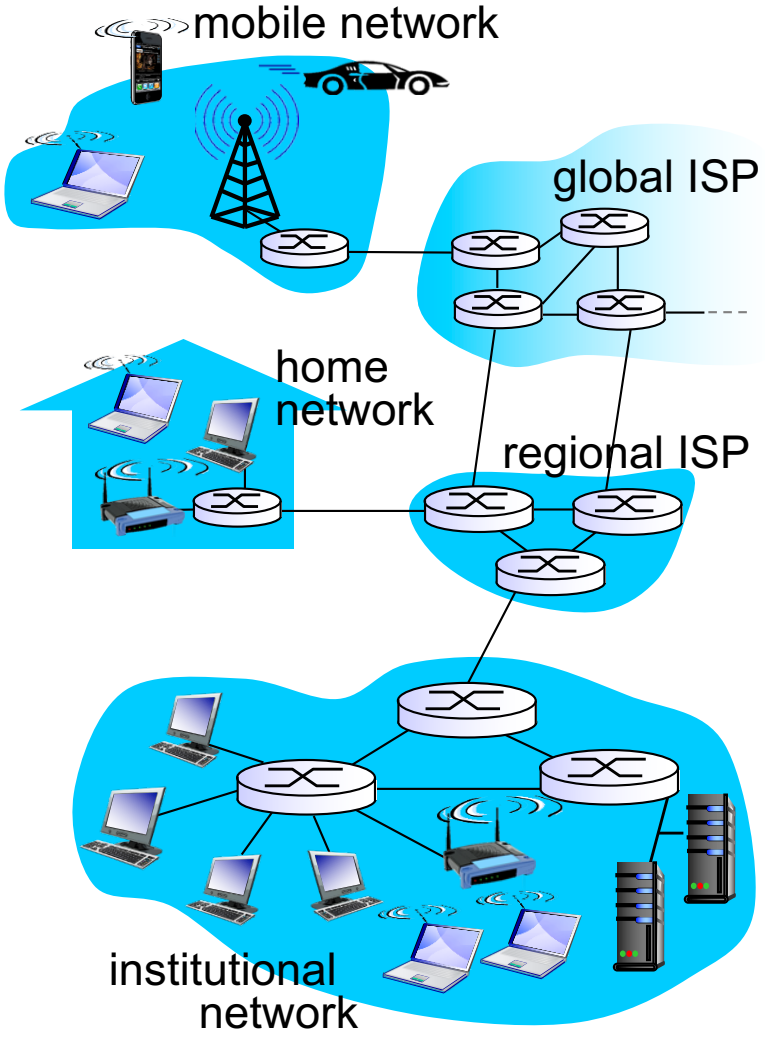
- millions of connected computing devices:
  - *hosts* = *end systems*
  - running *network apps*



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



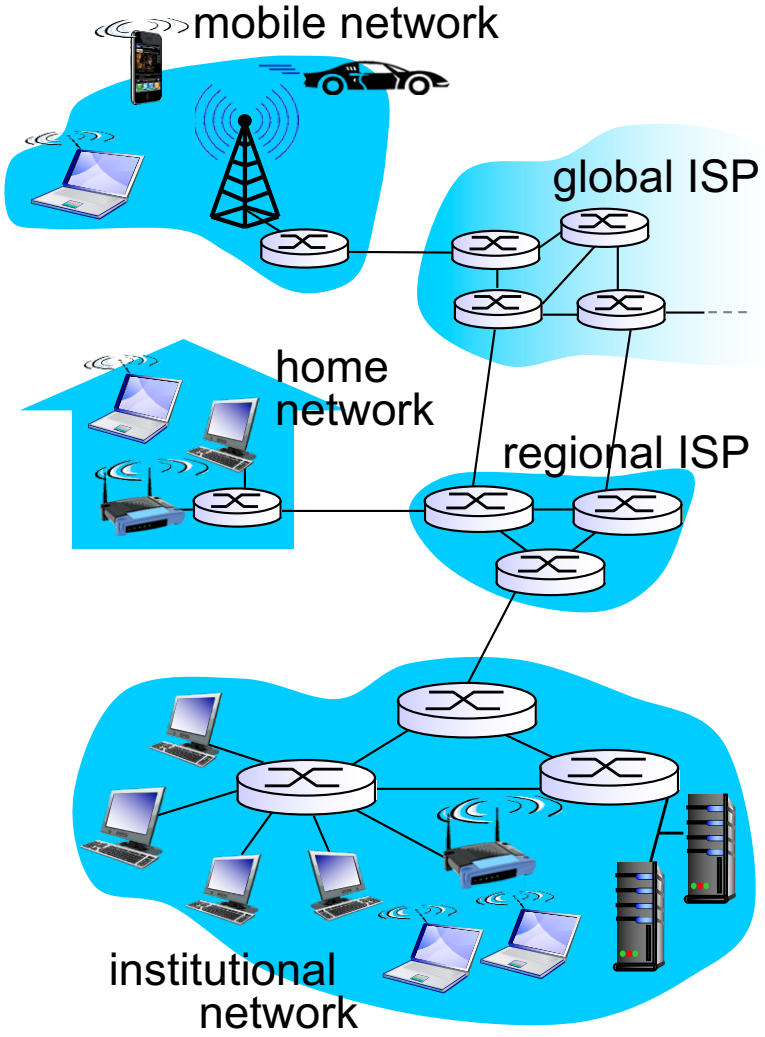
- *Packet switches:* forward packets (chunks of data)
  - *routers* and *switches*



Hardware components.

What's the Internet: "nuts and bolts" view

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



Software components.

Analogy to Road Networks

Software?

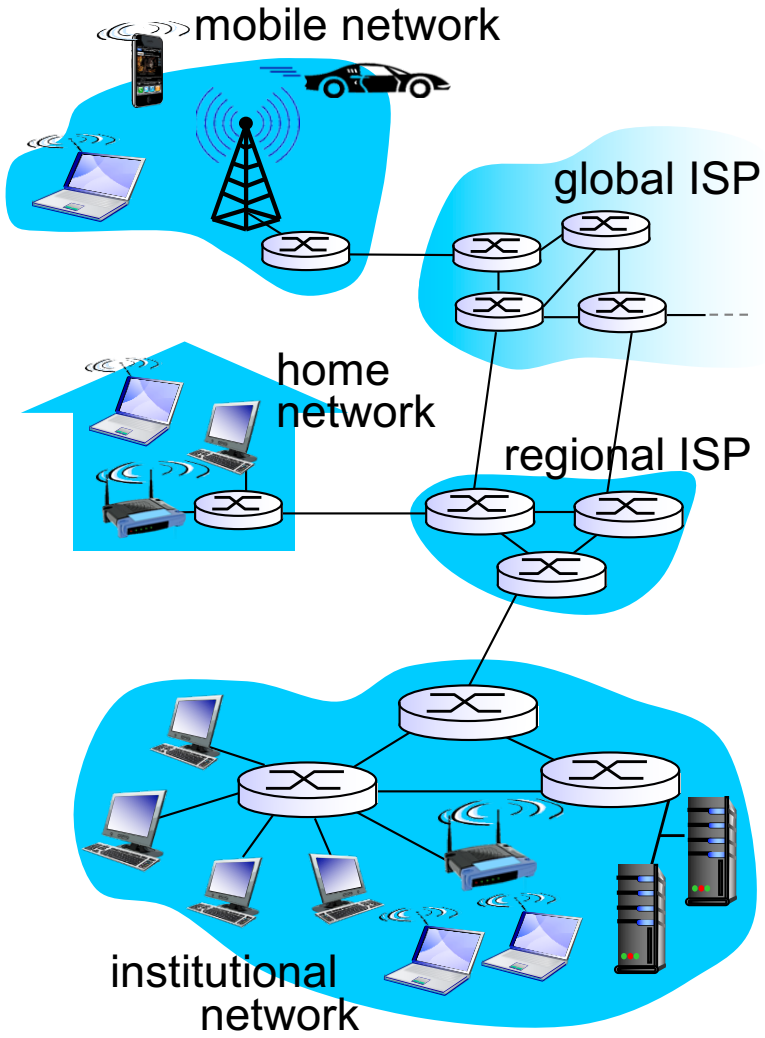
End systems=buildings

Packet switches=intersections

Links=road segments

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



Analogy to Post Service

What's a protocol?

human protocols:

- "what's the time?"
- "I have a question"
- introductions

… specific msgs sent

… specific actions taken when msgs received, or other events

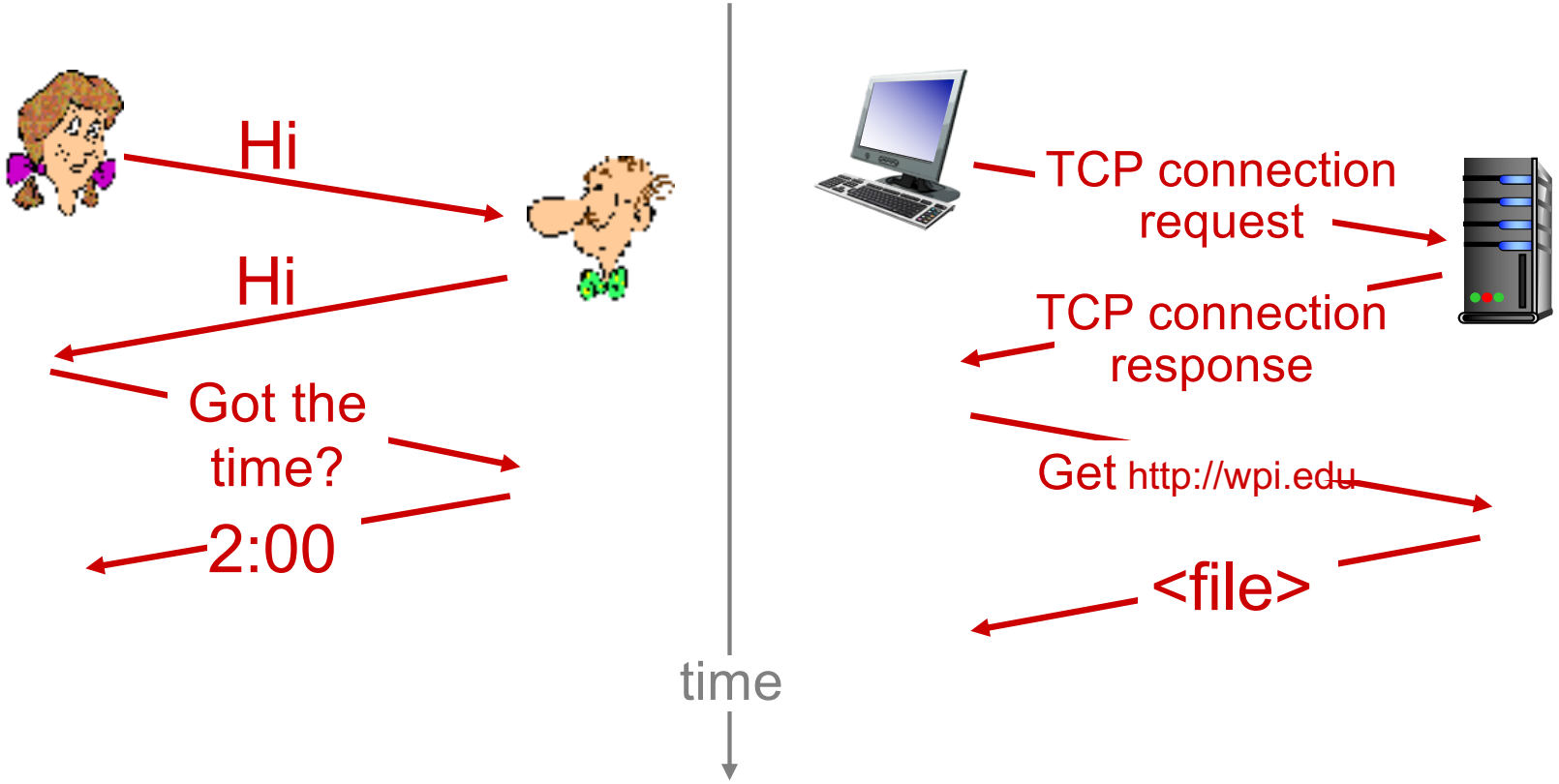
network protocols:

- machines rather than humans
- all communication activity in Internet governed by protocols

protocols define format, order of msgs sent and received among network entities, and actions taken on msg transmission, receipt

What's a protocol?

a human protocol and a computer network protocol:



Q: other human protocols?

Chapter 1: roadmap

1.1 what *is* the Internet?

1.2 network edge

- end systems, access networks, links

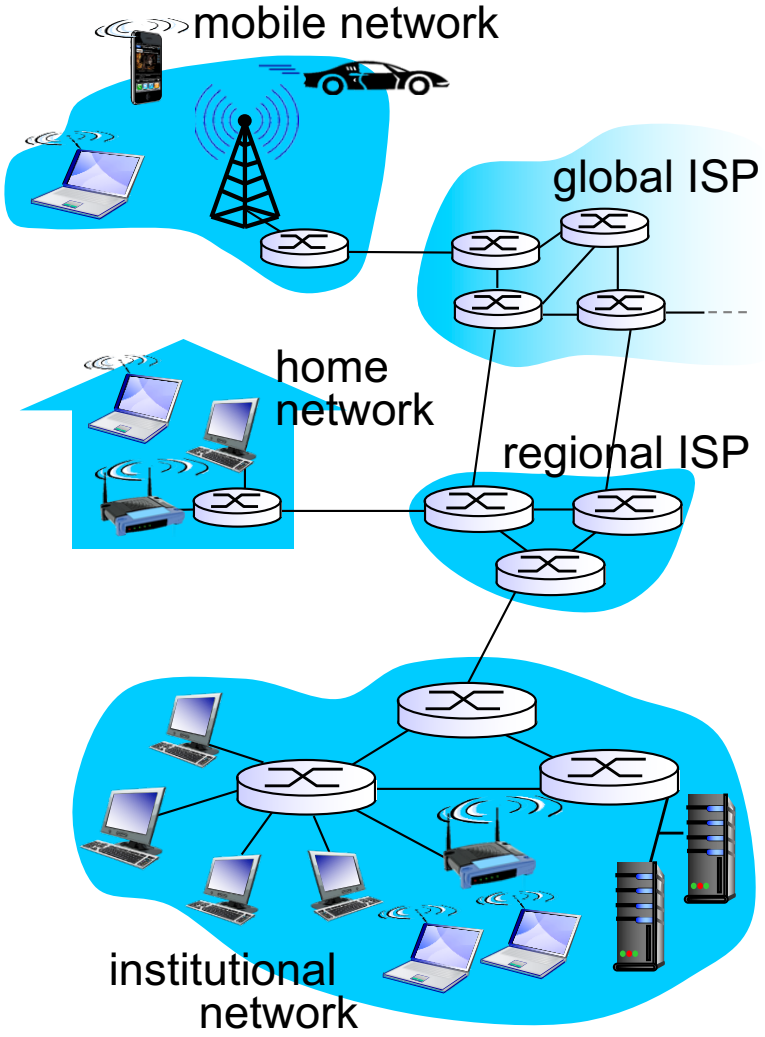
1.3 network core

- packet switching, circuit switching, network structure

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

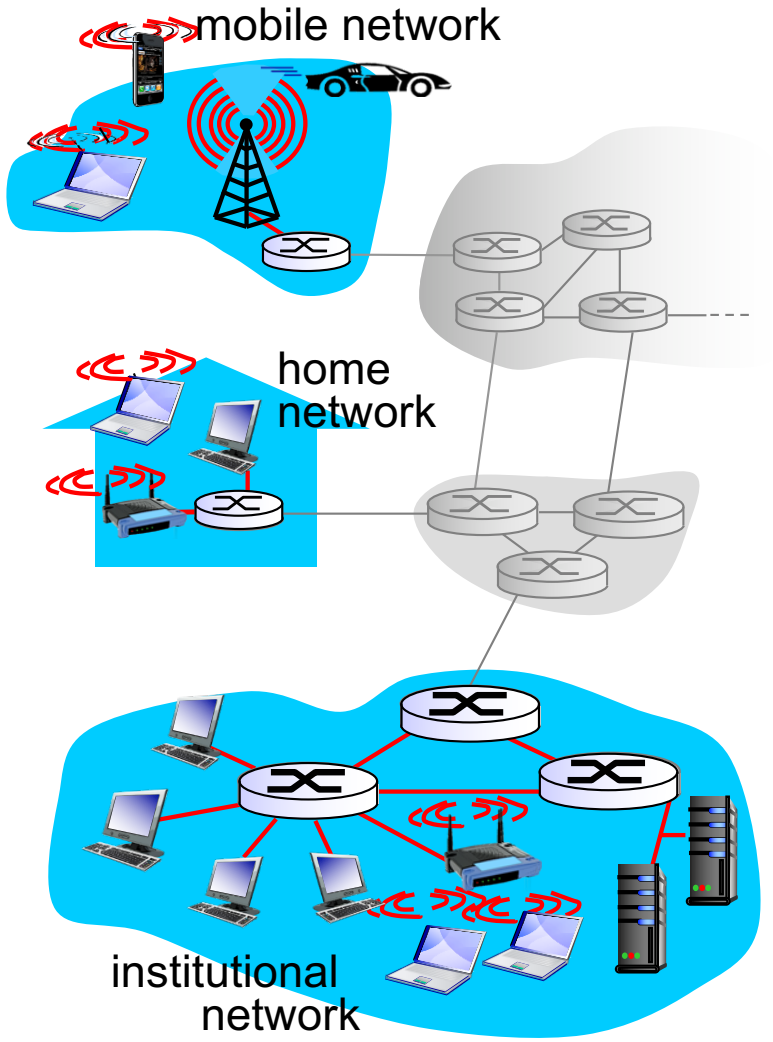
- *network core:*
  - interconnected routers
  - network of networks



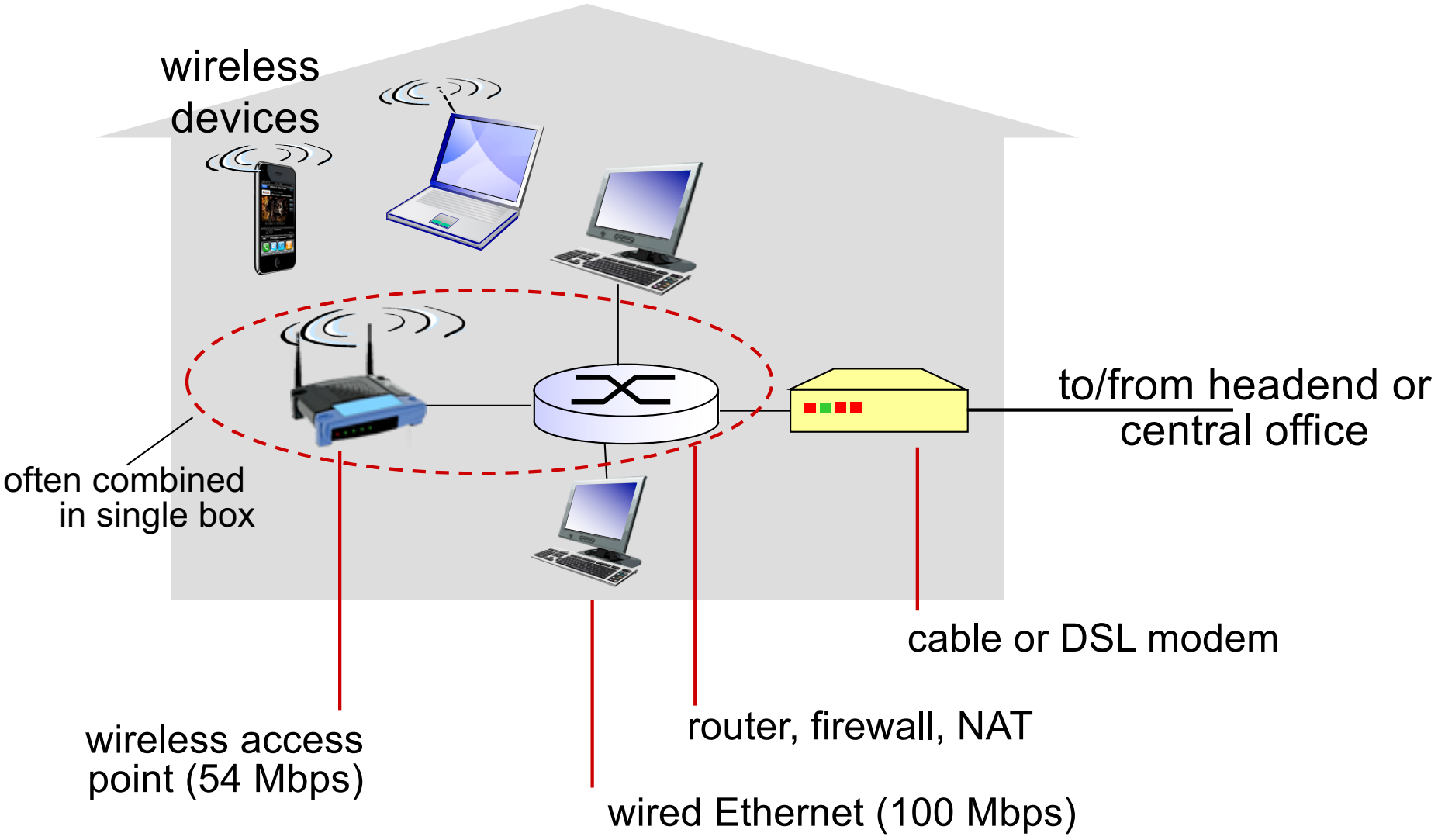
Access networks and physical media

Q: How to connect end systems to edge router?

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



Access net: home network



Chapter 1: roadmap

1.1 what is the Internet?

"nuts and bolts" view

service view

1.2 network edge

- end systems, access networks, links

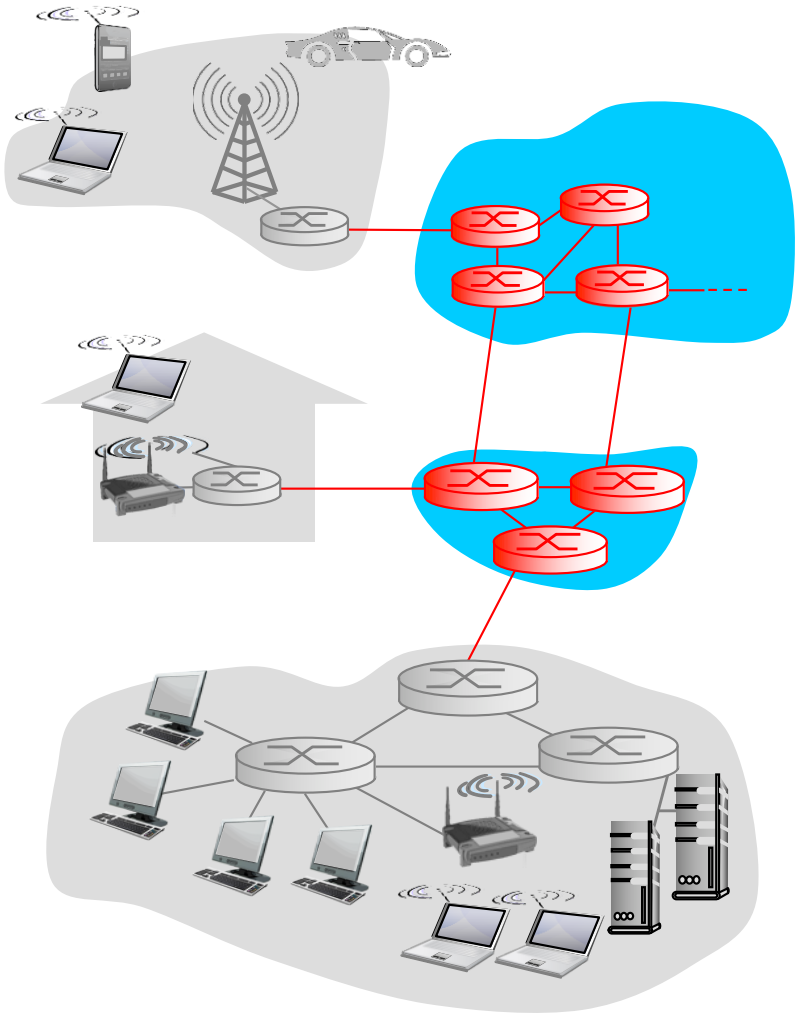
1.3 network core

- packet switching, circuit switching, network structure

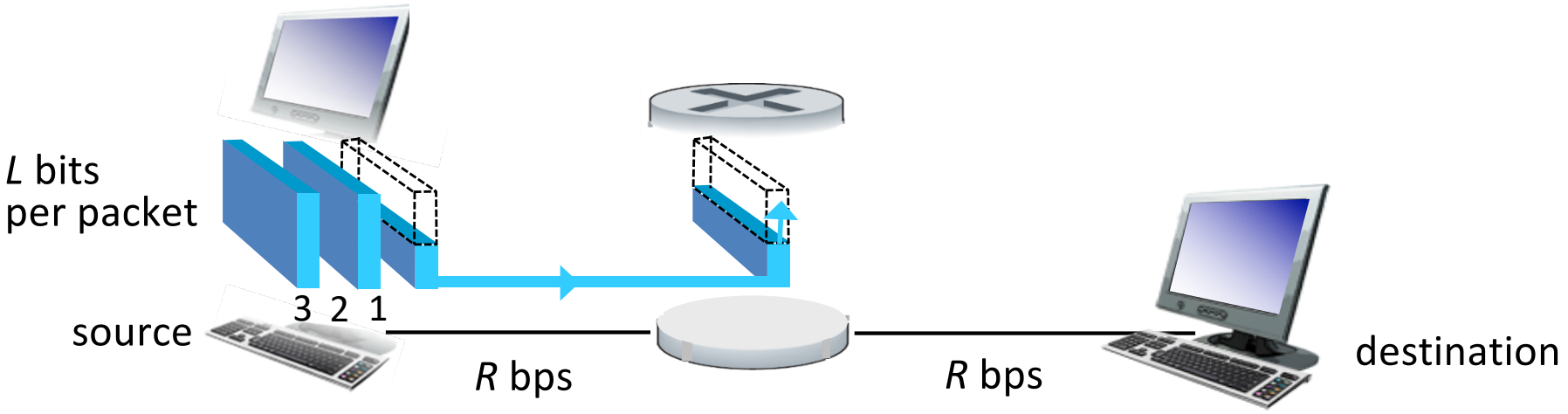
The network core

mesh of interconnected routers with three key aspects in network core

- Link: Switching, Resource allocation (chp 1.3)
- Node: Routing & Forwarding (to be discussed in Network layer chp 4)
- Network: Network Core Structure / Management / Coordination (chp 1.3)



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:

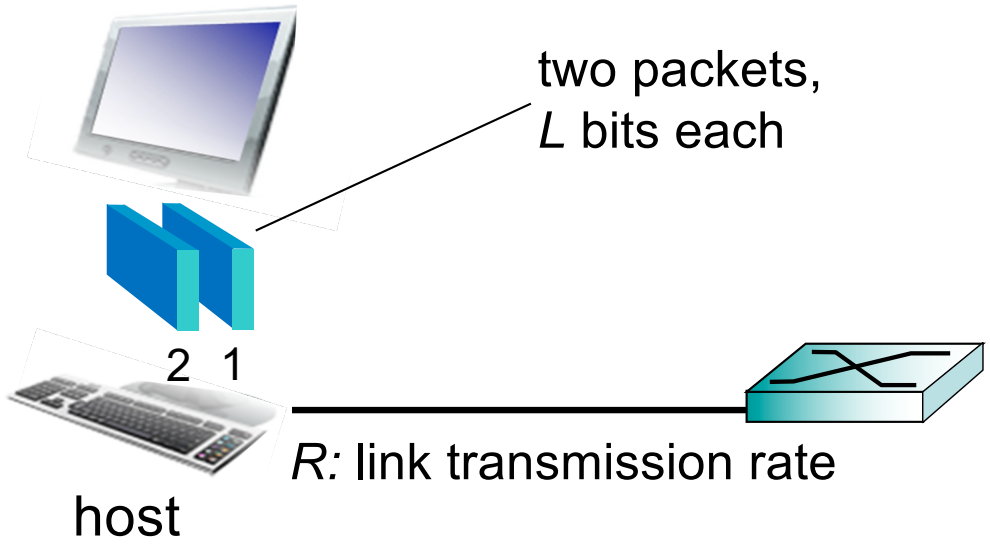
- *L* = 7.5 Mbits
- *R* = 1.5 Mbps
- one-hop transmission delay = 5 sec

more on delay shortly …

Host: sends *packets* of data

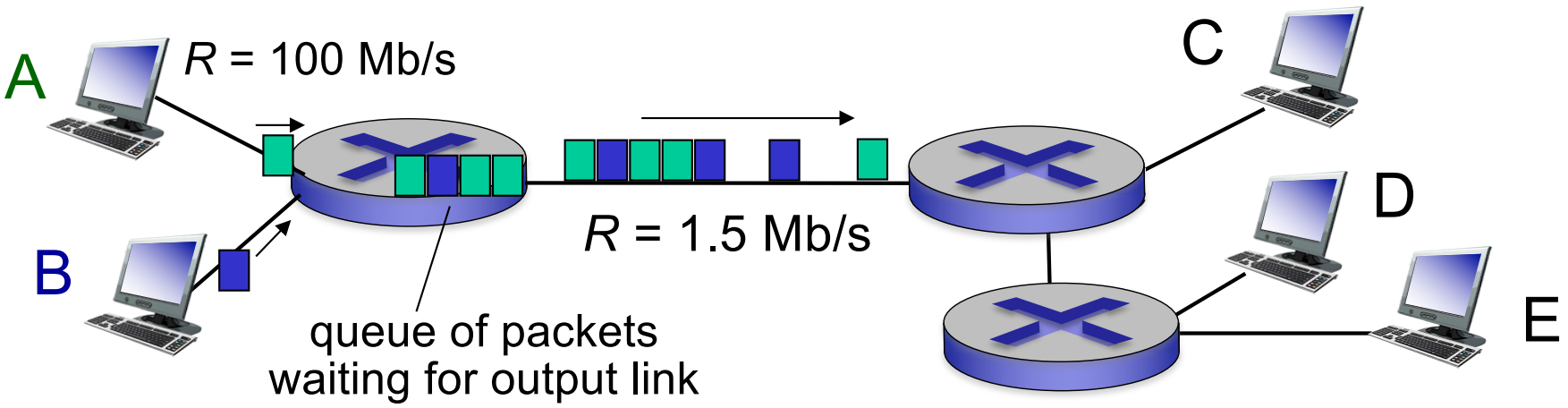
host sending function:

- 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*



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

Packet Switching: queueing delay, loss



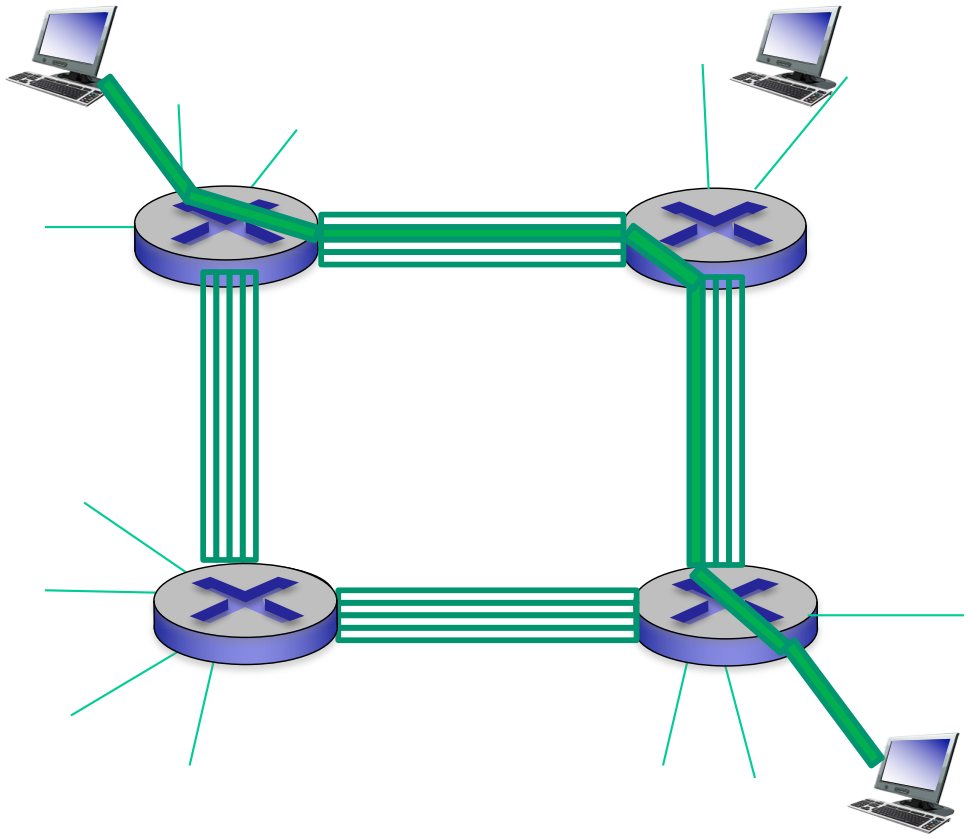
queuing and loss:

- 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

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



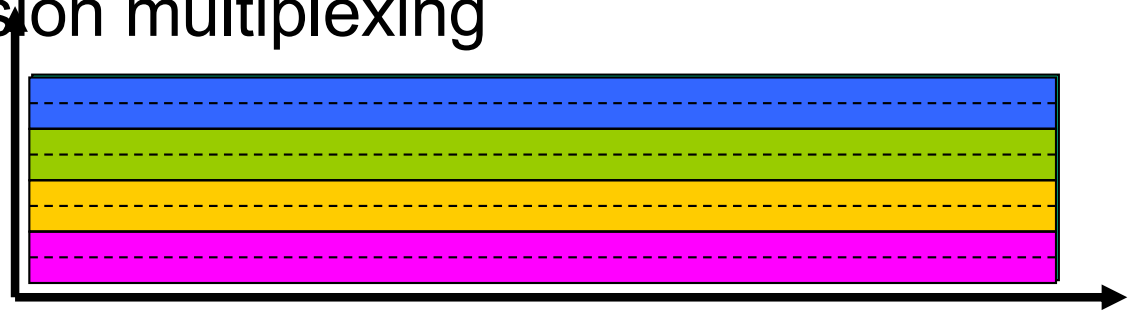
Circuit switching: FDM versus TDM

Example:

4 users

FDM

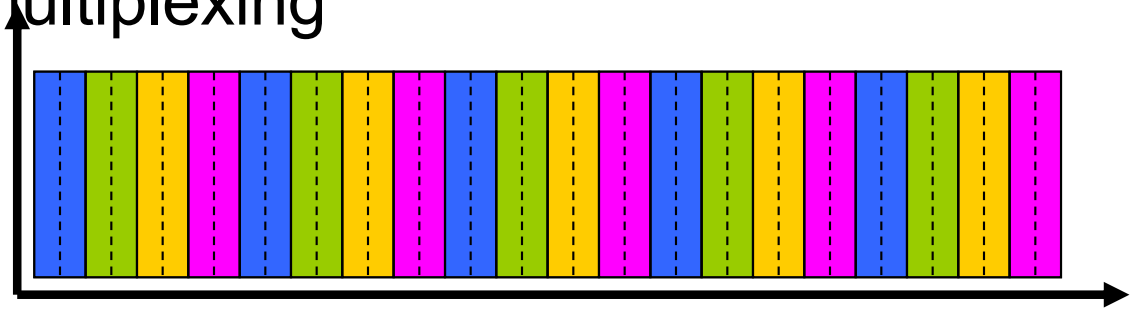
Frequency division multiplexing



Dedicated bandwidth

TDM

Time division multiplexing



Dedicated time slots

Analogy to Road Networks

End systems=buildings

Packet switches=intersections

Links=road segments

Packet switching versus circuit switching

is packet switching a "slam dunk winner?"

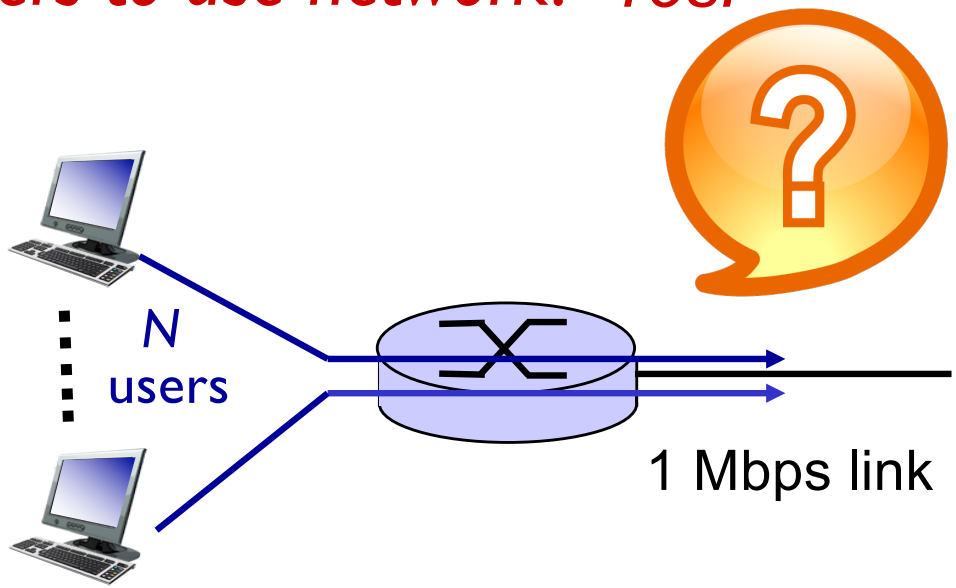
- Pros: great for bursty data (advantages)
  - resource sharing
  - simpler, no call setup
- Cons: excessive congestion possible:
  - packet delay and loss
  - protocols needed for reliable data transfer, congestion control

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

Like parking lots.

Packet switching versus circuit switching

packet switching allows more users to use network? Yes.



example:

- 1 Mbps link
- each user:
  - 250 kbps when "active"
  - active 10% of time

- *circuit-switching:*
  - 4 users
- *packet switching:*
  - with 5 users, probability of all active at same time is small

Q: probability of $u_1, u_2, u_3, ..., u_5$ are active? $(1/10)^5$

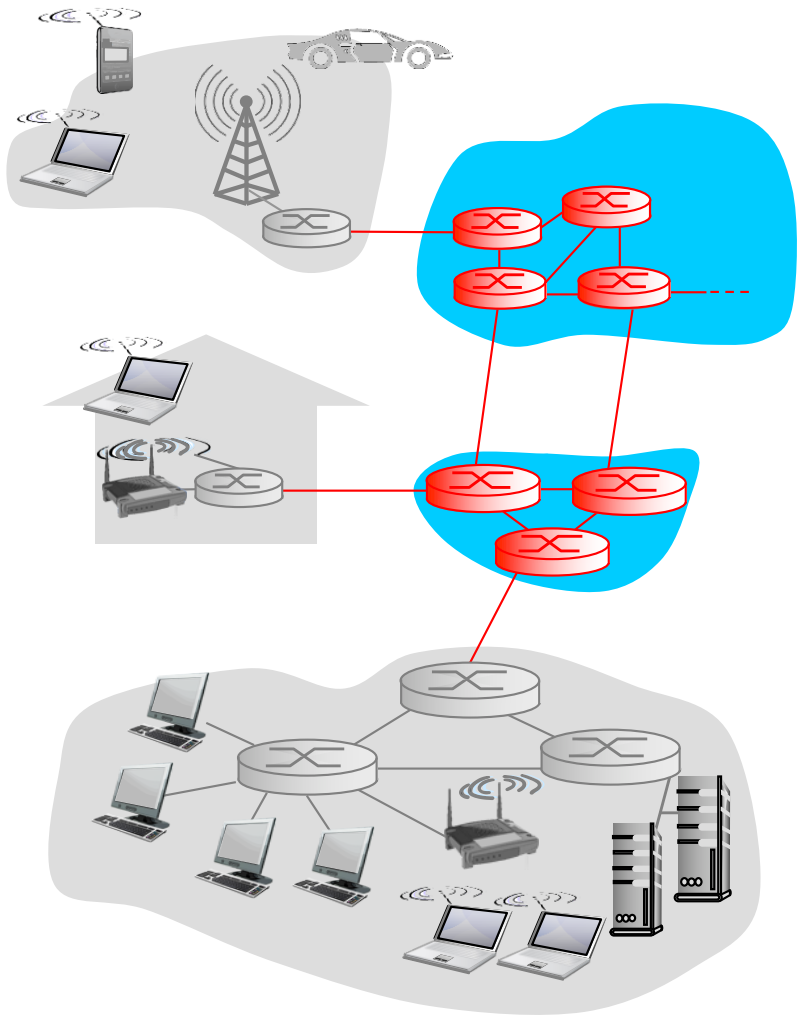
Q: probability of u_1, u_2, u_3, u_4 are active, u_5 is inactive

$(1/10)^4 * (9/10)$

The network core

Three key aspects in network core

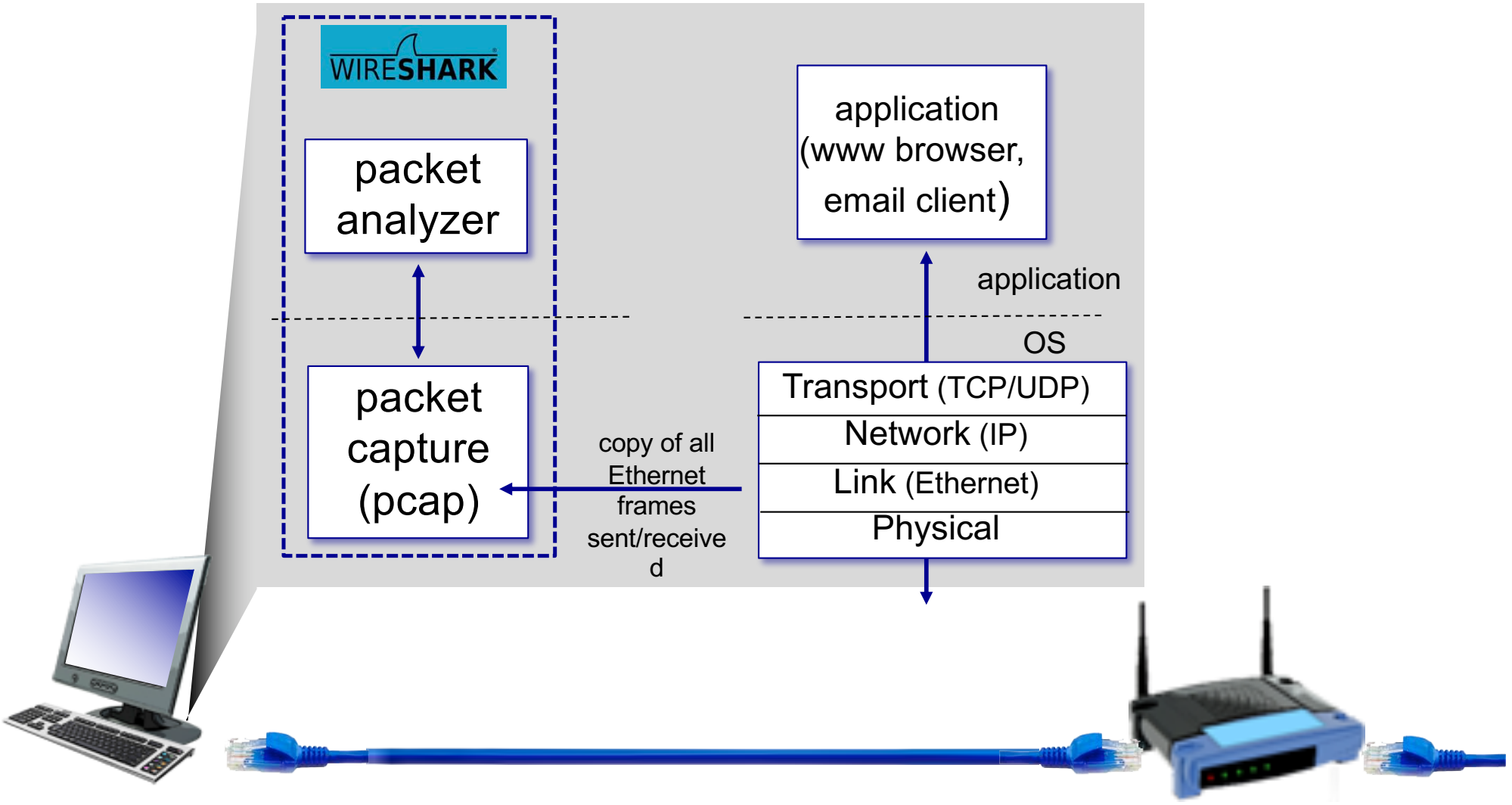
- Link: Switching, Resource allocation (chp 1.3)
- Node: Routing & Forwarding (to be discussed in Network layer chp 4)
- Network: Network Core Structure / Management / Coordination (chp 1.3)



Lab-assignment 1

Please watch my video Lecture-2-0901-Part2 for a demo

http://users.wpi.edu/~yli15/courses/CS3516Fall20A/labs/Lab1/lab1.html


WIRESHARK
packet analyzer
packet capture (pcap)
application (www browser, email client)
application
OS
Transport (TCP/UDP)
Network (IP)
Link (Ethernet)
Physical
copy of all Ethernet frames sent/received