CSC/CPE 138

COMPUTER NETWORK FUNDAMENTALS

Lecture 1_1: Computer Network and the Internet – Part 1

California State University, Sacramento
Fall 2024

Slide Courtesy: Computer Networking: A Top-Down Approach, Kurose Ross, 8th Edition

About the Course

Instructor:	Dr. Syed Badruddoja
Class Time and Location:	Tu,Th, 10:30 AM – 11:45 AM, Alpine Hall 156
Office Hours (Online):	Tu,Th, 2:30 PM – 4:00 PM
Office Hours Zoom Link:	https://csus.zoom.us/j/82588604485
Mode of Instruction:	In-person
E-mail:	badruddoja@csus.edu

Course Objectives

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- Explain the basic principles, architecture, layered models, and implementations of computer networks.
- Describe the details of important network protocols on different layers across the protocol stack.
- Apply reliable communication including the various methods for error detection, correction, retransmission, flow control, and congestion control.
- Explain the working mechanisms of routing, forwarding, internet addressing, and switching.
- Identify professional and ethical responsibilities, security issues and countermeasures.

Prerequisite and Materials

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Prerequisite

- Introduction to Systems Programming - CSC60,
- Data Structures and Algorithm Analysis - CSC130

Textbook

- Computer Networking: A Top-Down Approach, 7/8th edition, Kurose and Ross, Pearson, ISBN-10: 978013359414O, 1292405465 ISBN-13: 978-0133594140, 978-1292405469

Supplemental Materials

- Slides are adapted from Computer Networking: A Top-Down Approach, 8th edition, J.F Kurose and K.W. Ross
- Coding examples, online resources and Youtube videos

Grading Policy - Assignments

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Assignment Categories	Grade Percentage
In-Class Activity	5.0%
Homework & Programming	20.0%
Lab Assignment	15.0%
Project	10.0%
Midterm Exam	25.0%
Final Exam	25.0%
Total	100.0%

Grading Policy - Assignments

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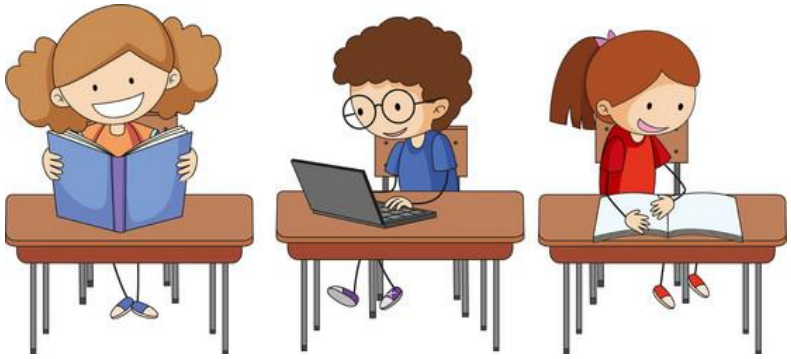

- In-Class activities
  - Quiz
  - Self-reflection
  - Think-pair-share
  - Prompt questions
  - Concept-Map
- Homework and Programming Assignments
- Lab Assignments
- Programming Project
- Exams

Submission Policy

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- Submission guidelines
  - Submit assignments on due date
  - Pdf files submission for homework
  - Code files submission for programs (zipped folder)
  - Recheck submission

- Late submissions will be penalized by the following rules.
  - 10% deduction for one day late submission.
  - 20% deduction for two days late submission.
  - 30% deduction for three days late submission.
  - 100% deduction from, 4^{th} day onwards

Other Policies in Syllabus

- Check emails and canvas regularly
- Make-up exams are not allowed
  - Exempted from extreme circumstances with evidence
  - Require instructor approval
- Syllabus may be modified in the semester
  - Any changes to the syllabus will be communicated

Tentative Class Schedule

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Week	Date	Materials to Cover	Remarks	Textbook Chapters
1	8/26 – 1/30	Computer Networks and The Internet	-	1
2	9/2 – 9/6	Computer Networks and The Internet	ASSIGNMENT 1	
3	9/9 – 9/13	Application Layer	-	2
4	9/16 – 9/20	Application Layer	ASSIGNMENT 2	
5	9/23 – 9/27	Application Layer	-	
6	9/30 – 10/4	Transport Layer	LAB 1	3
7	10/7 – 10/11	Transport Layer	MID-TERM EXAM	
8	10/14 – 10/18	Transport Layer	LAB 2	
9	10/21 – 10/25	Network Layer: Data Plane	ASSIGNMENT 3	4
10	10/28 – 11/1	Network Layer: Data Plane	-	
11	11/4 – 11/8	Network Layer: Control Plane	ASSIGNMENT 4	5
12	11/11 – 11/15	Network Layer: Control Plane	-	
13	11/18 – 11/22	Link Layer	LAB 3	6
14	11/25 – 11/29	Link Layer	PROJECT SUBMISSION	
15	12/2 – 12/6	Network Security	-	8
16	12/9 – 12/13	-	FINAL EXAM	-

Getting Started:

Computer Network and the Internet

Overview

- The computer network
- Protocol and Internet
- Network infrastructure
- Access networks and physical media
- Packet switching versus circuit-switching

Fun Activity: Brainstorm Internet

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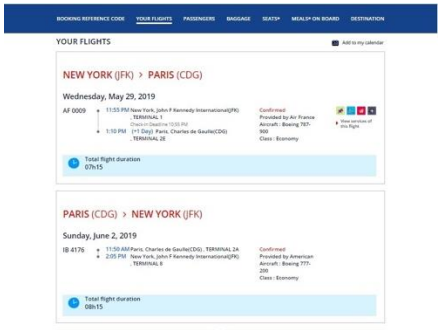
Parking

Ecommerce



Reservation

Training

Smart Home

TAB

Laptop

Connected-world

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

Web-enabled toaster +
weather forecaster

Tweet-a-watt:
monitor energy use

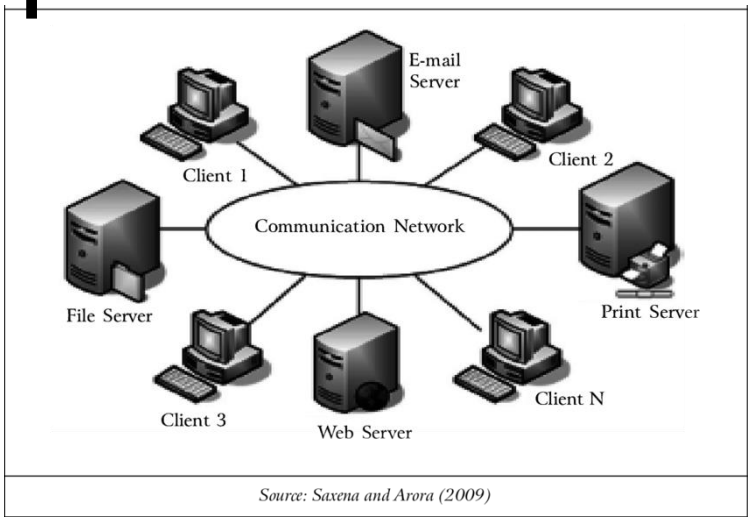
Smart
refrigerator

Streaming Services

sensorized,
bed
mattress

Internet phones

Introducing Computer Network



Source: Saxena and Arora (2009)

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

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

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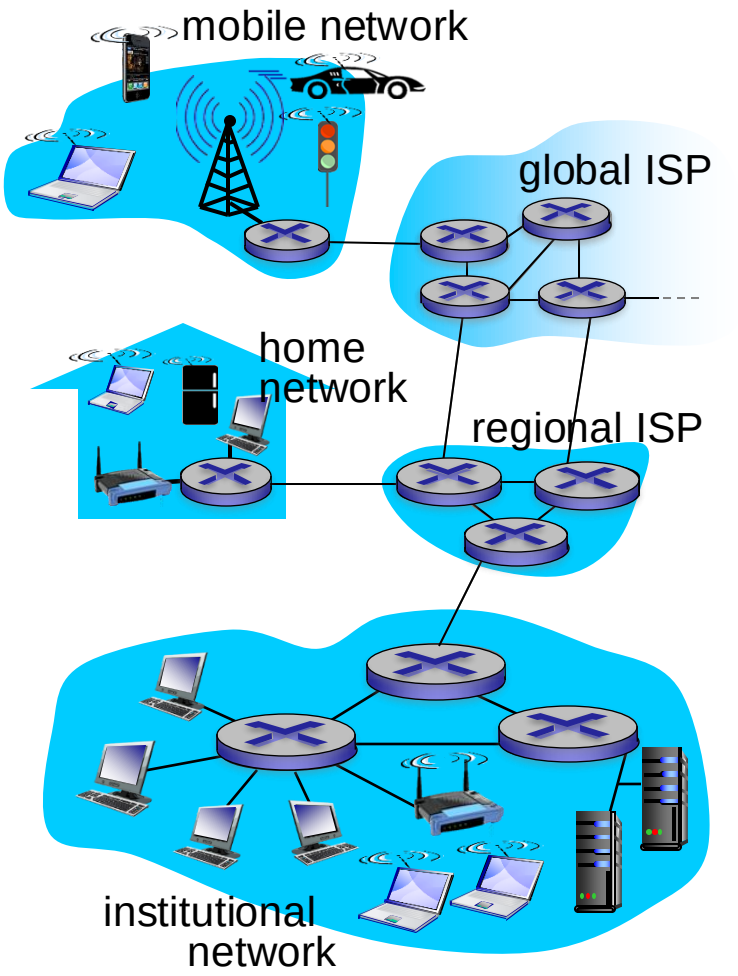
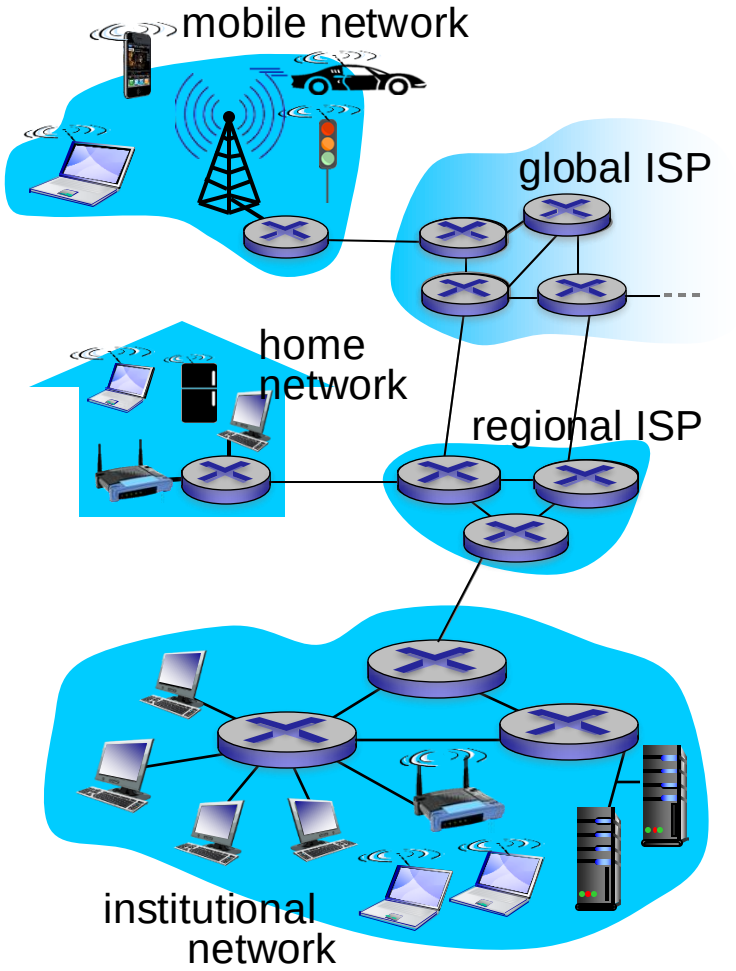
- billions of connected computing devices:
  - *hosts = end systems*
  - running *network apps*
- *communication links*
  - fiber, copper, radio, satellite
  - transmission rate: *bandwidth*
- *packet switches:* forward packets (chunks of data)
  - *routers* and *switches*



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

- *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

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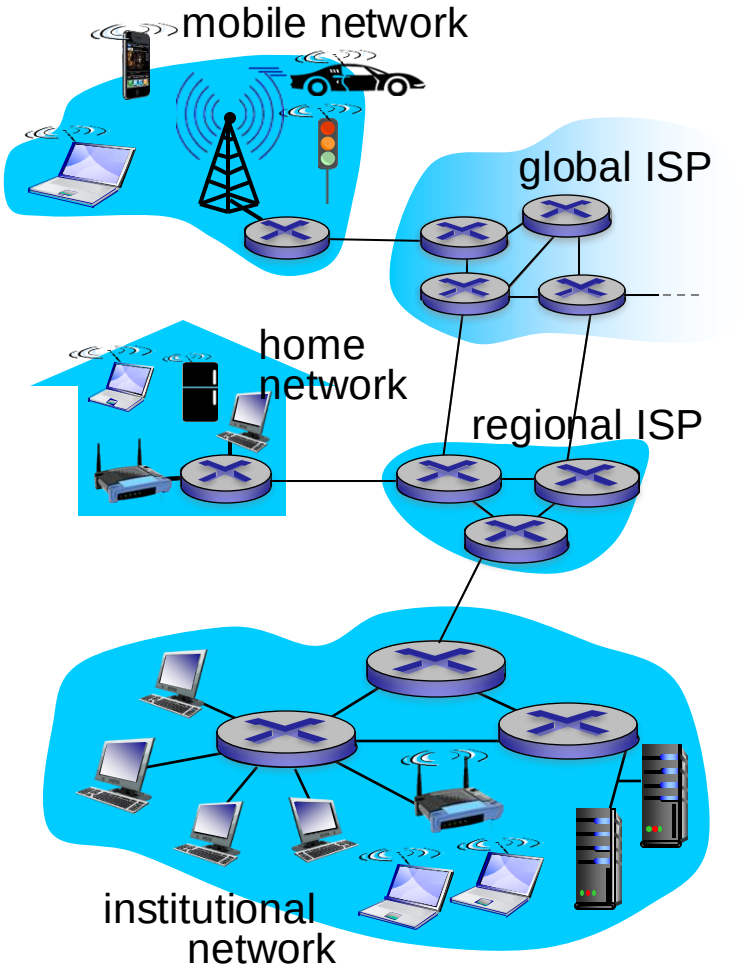
- *infrastructure that provides services to applications:*
  - Web, VoIP, email, games, e-commerce, social nets, …
- *provides programming interface to apps*
  - hooks that allow sending and receiving app programs to "connect" to Internet
  - provides service options, analogous to postal service



What's a protocol?

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human protocols:

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

… specific messages sent

… specific actions taken when messages received, or other events

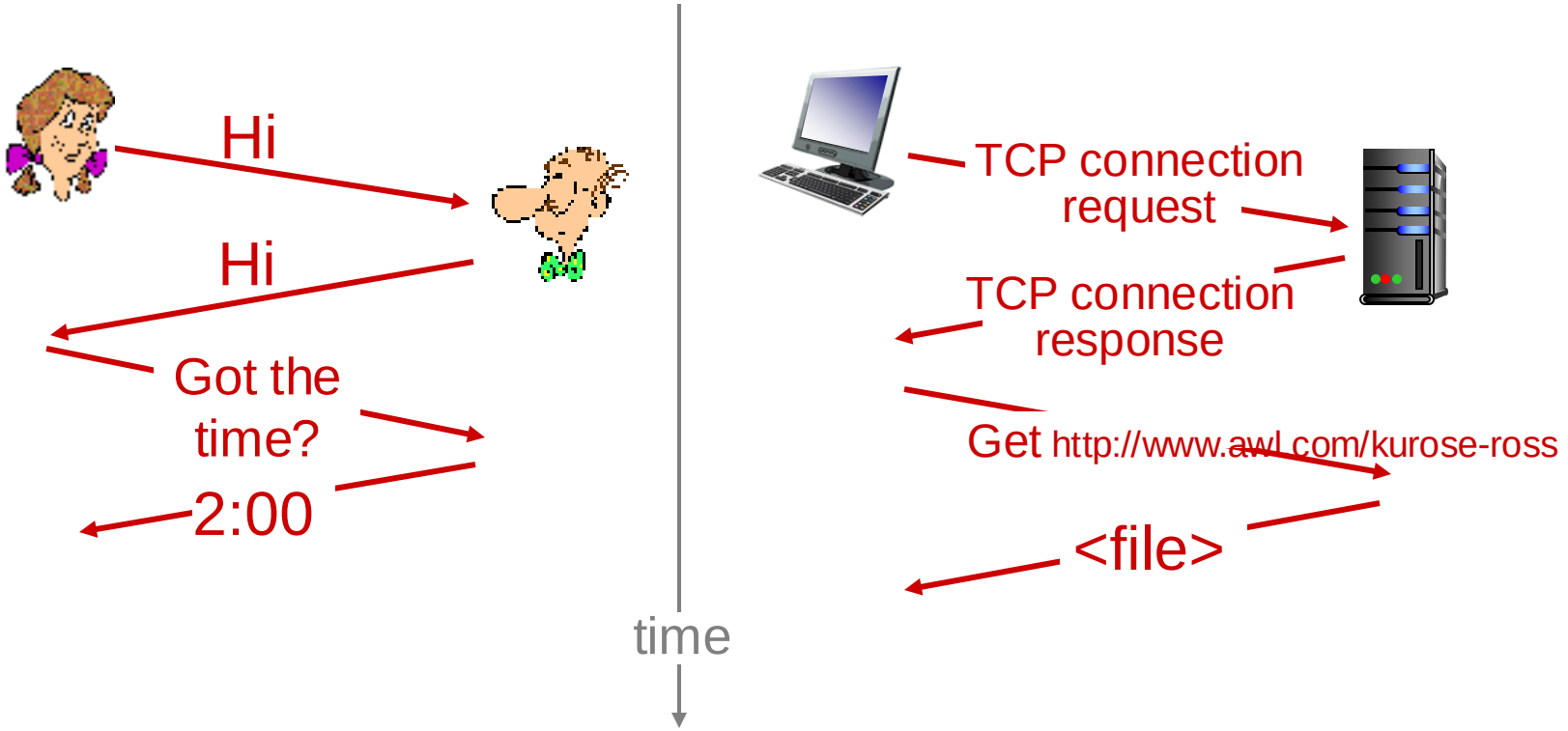
network protocols:

- 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?

Network Infrastructure

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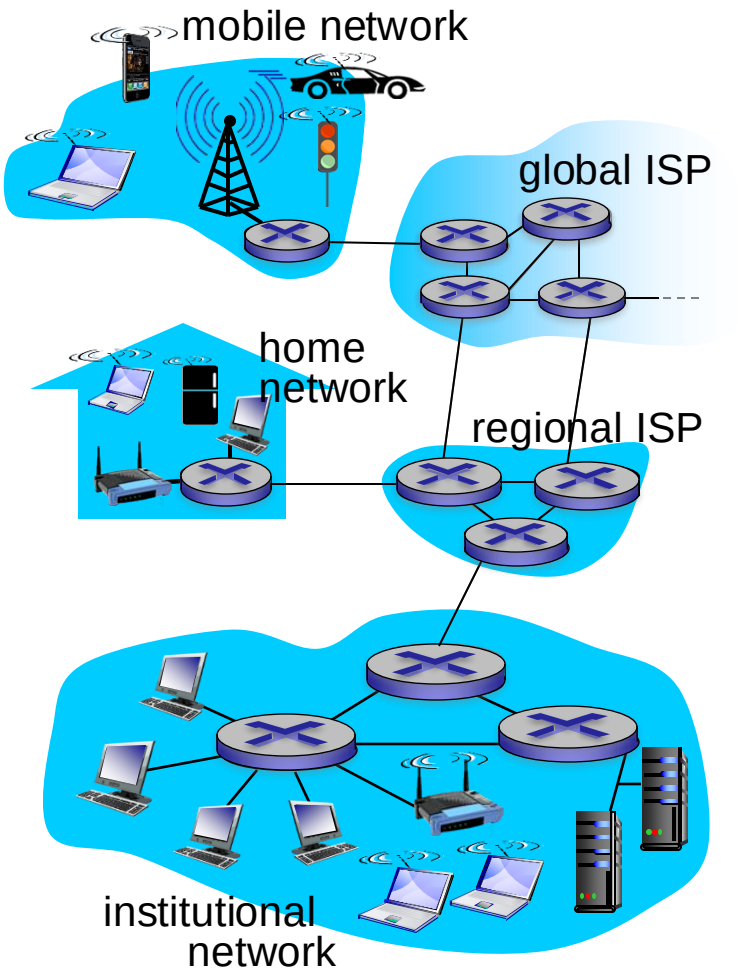
- *network edge:*
  - hosts: clients and servers
  - servers often in data centers
- *access networks, physical media:* wired, wireless communication links
- *network core:*
  - interconnected routers
  - network of networks



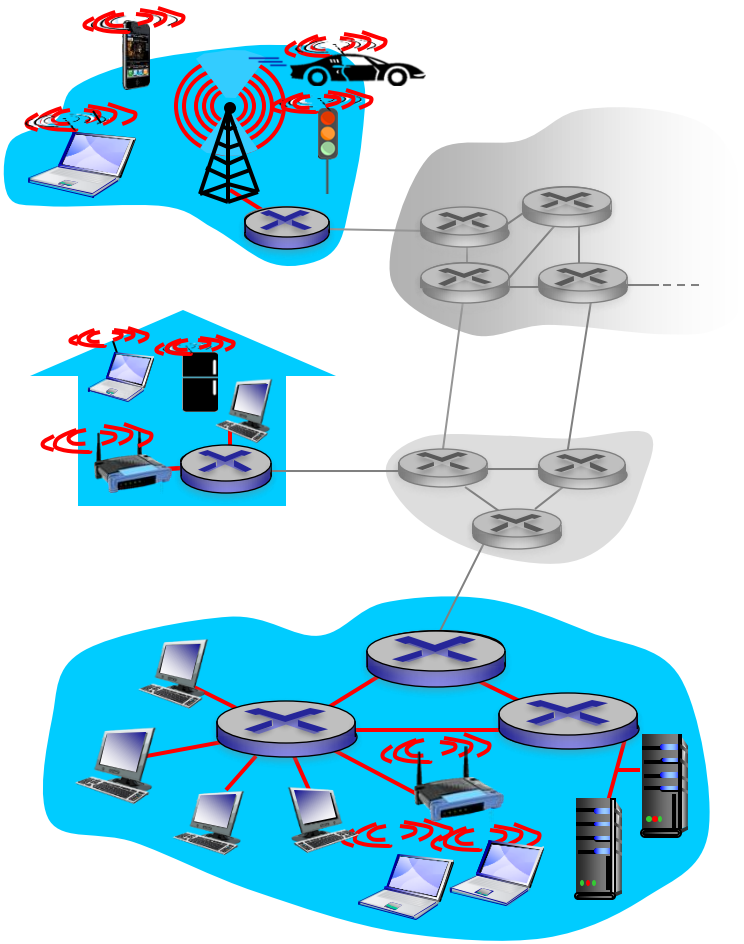
Access networks and physical media

Q: How to connect end systems to edge router?

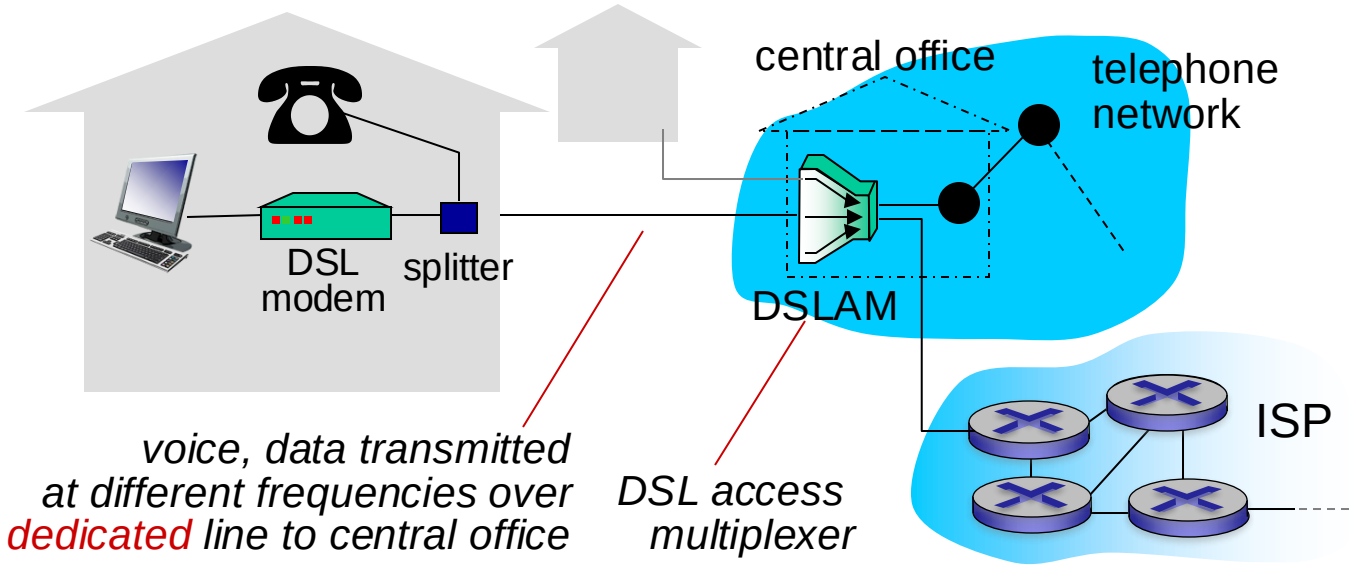
- residential access nets
- institutional access networks (school, company)
- mobile access networks

keep in mind:

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

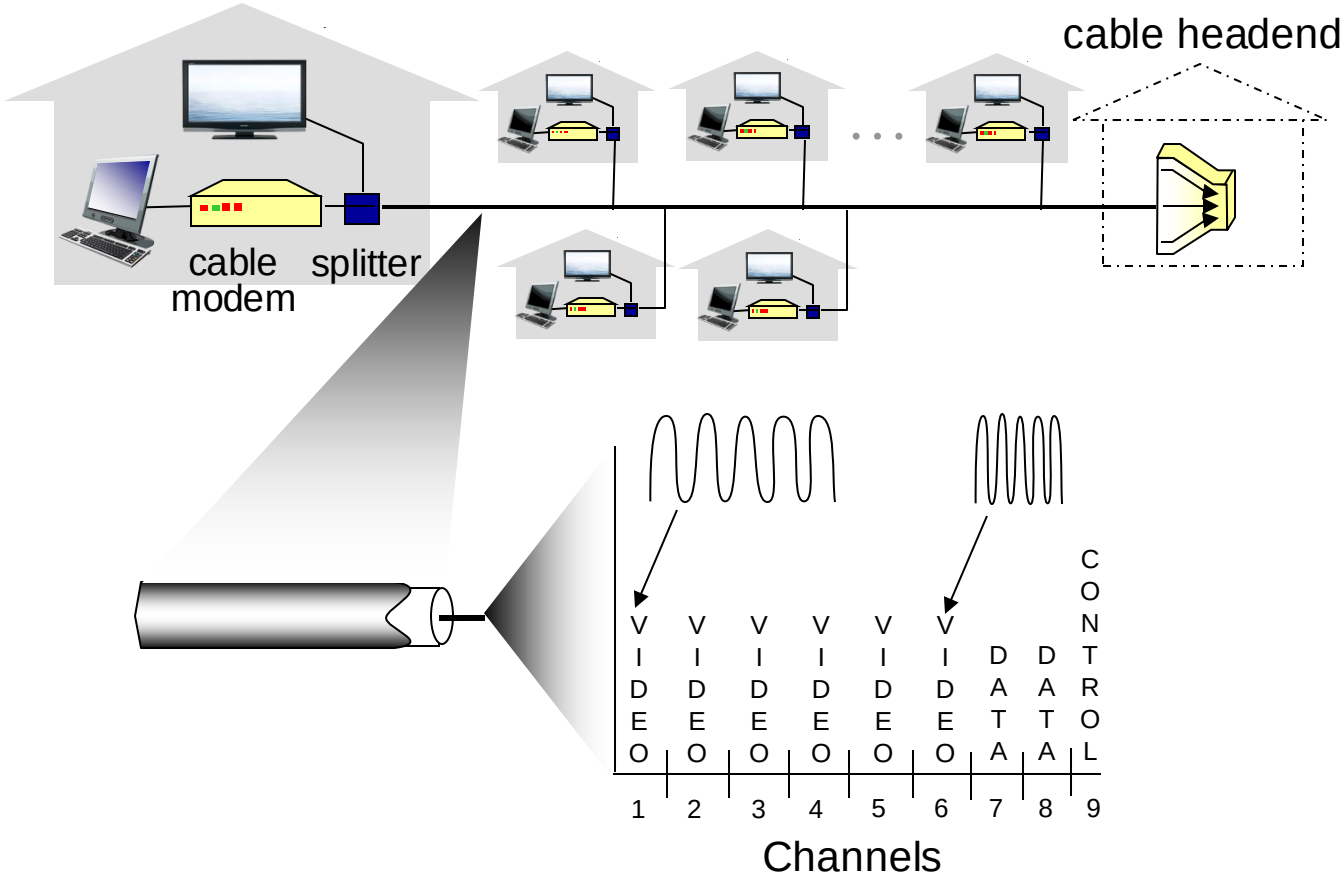


Access network: digital subscriber line (DSL)



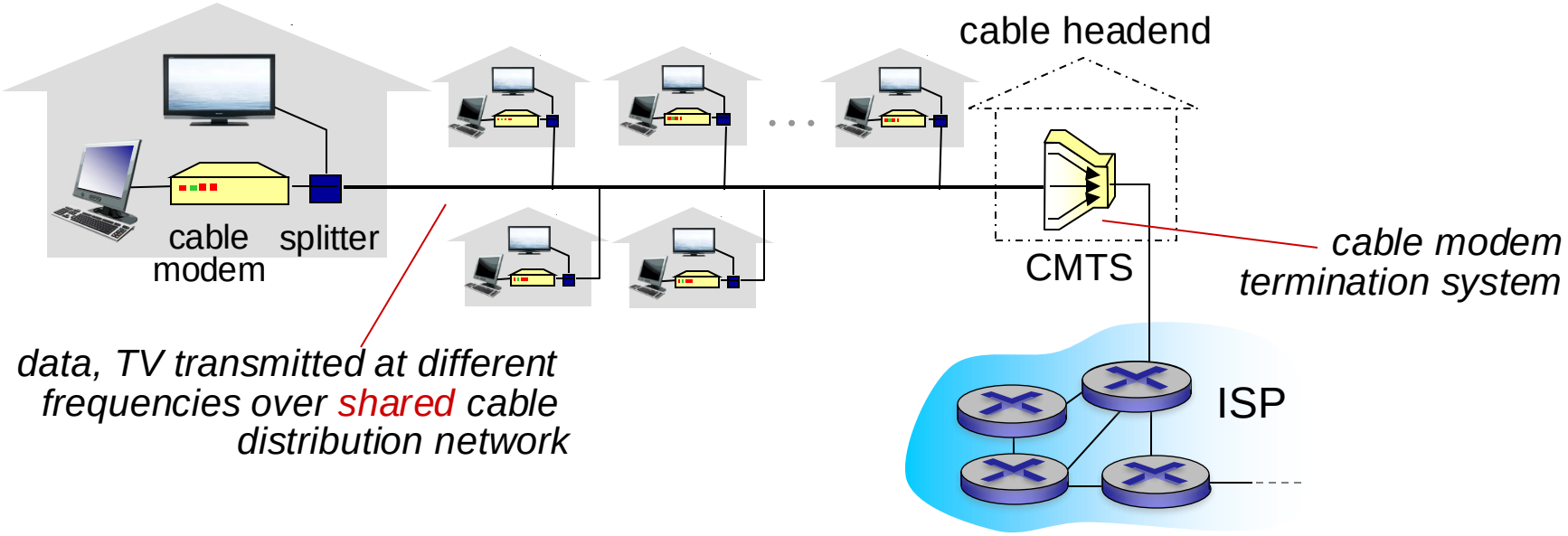
- use *existing* telephone line to central office DSLAM
  - data over DSL phone line goes to Internet
  - voice over DSL phone line goes to telephone net
- < 2.5 Mbps upstream transmission rate (typically < 1 Mbps)
- < 24 Mbps downstream transmission rate (typically < 10 Mbps)

Access network: cable network



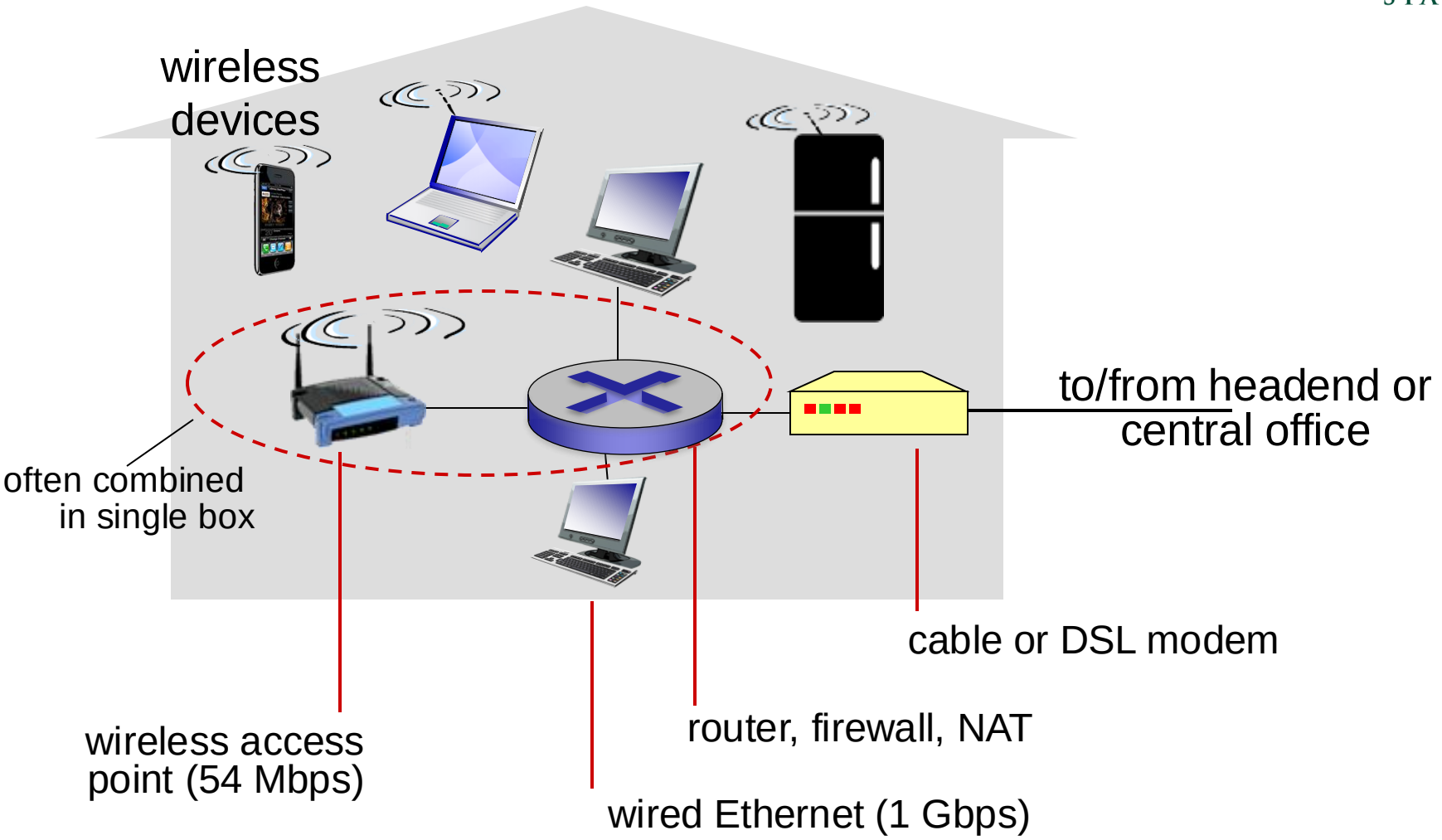
frequency division multiplexing: different channels transmitted in different frequency bands

Access network: cable network

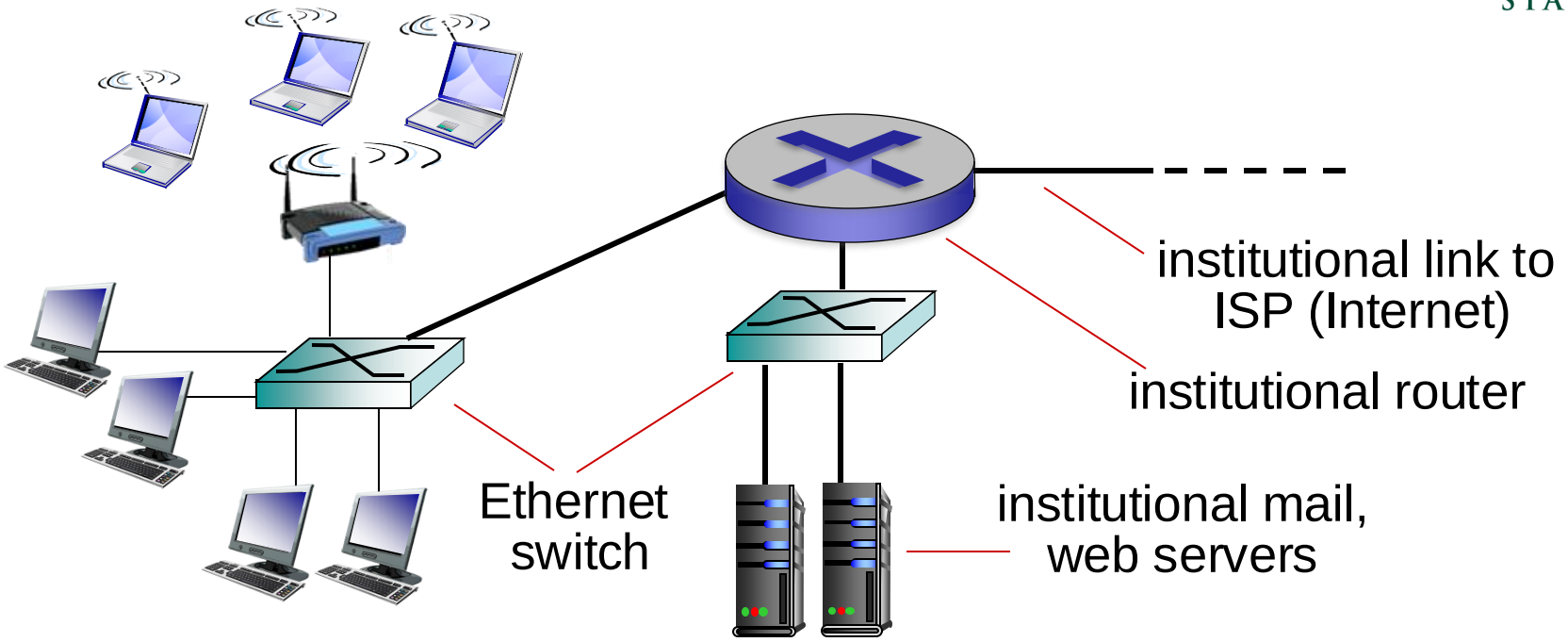


- HFC: hybrid fiber coax
  - asymmetric: up to 30Mbps downstream transmission rate, 2 Mbps upstream transmission rate.
- network of cable, fiber attaches homes to ISP router
  - homes *share access network* to cable headend
  - unlike DSL, which has dedicated access to central office

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

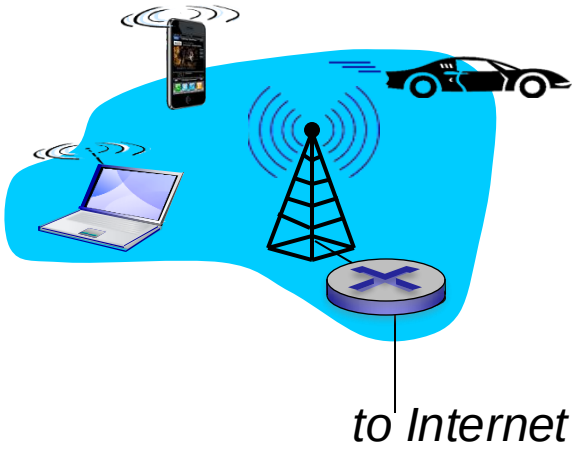
- shared *wireless* access network connects end system to router
  - via base station aka "access point"

wireless LANs:

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

wide-area wireless access

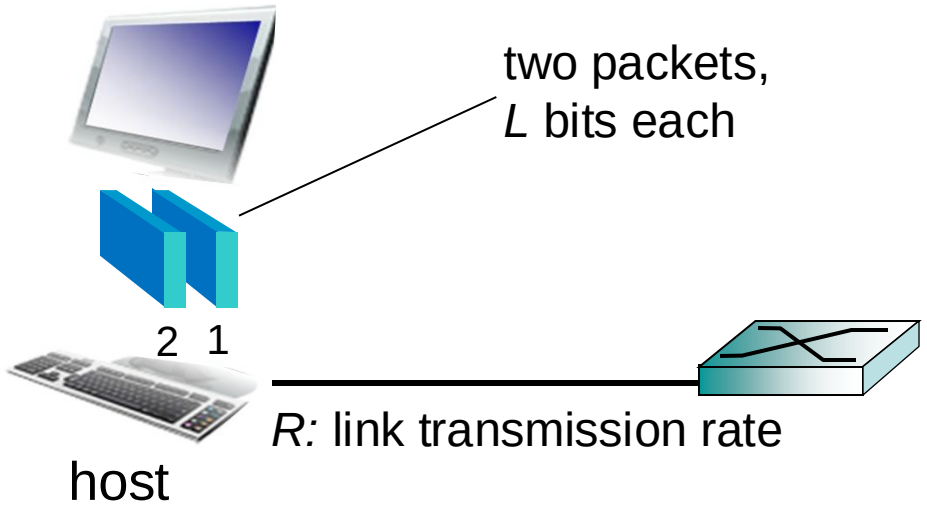
- provided by telco (cellular) operator, 10's km
- between 1 and 10 Mbps
- 3G, 4G: LTE



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

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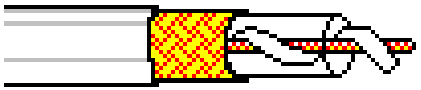
coaxial cable:

- 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

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- 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

Minute Paper

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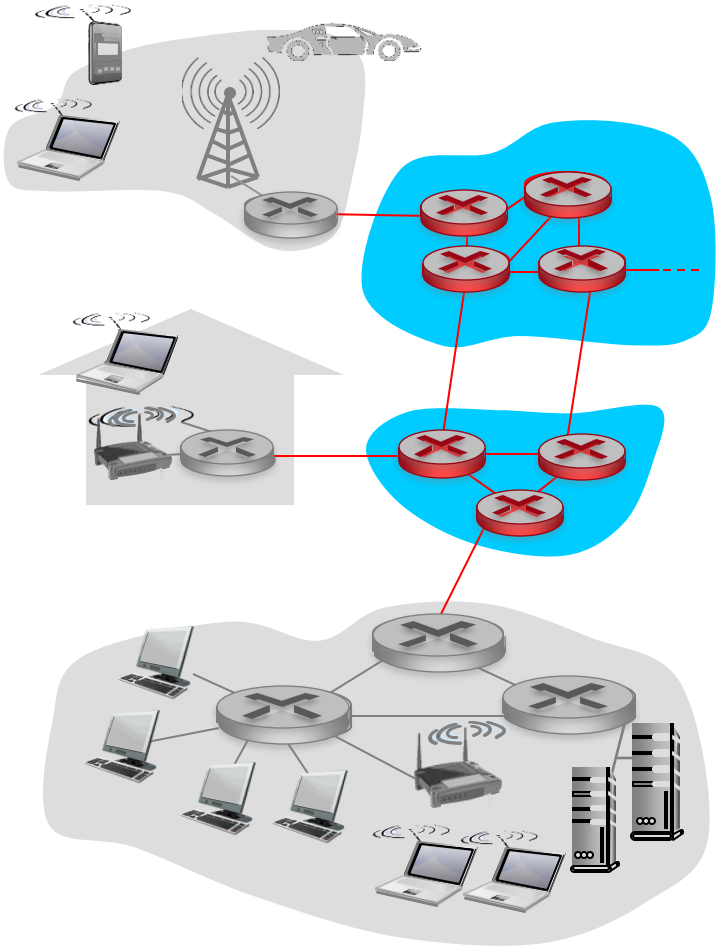
- Differentiate between Internet and Protocol?

- Identify the elements in hierarchical network infrastructure ?

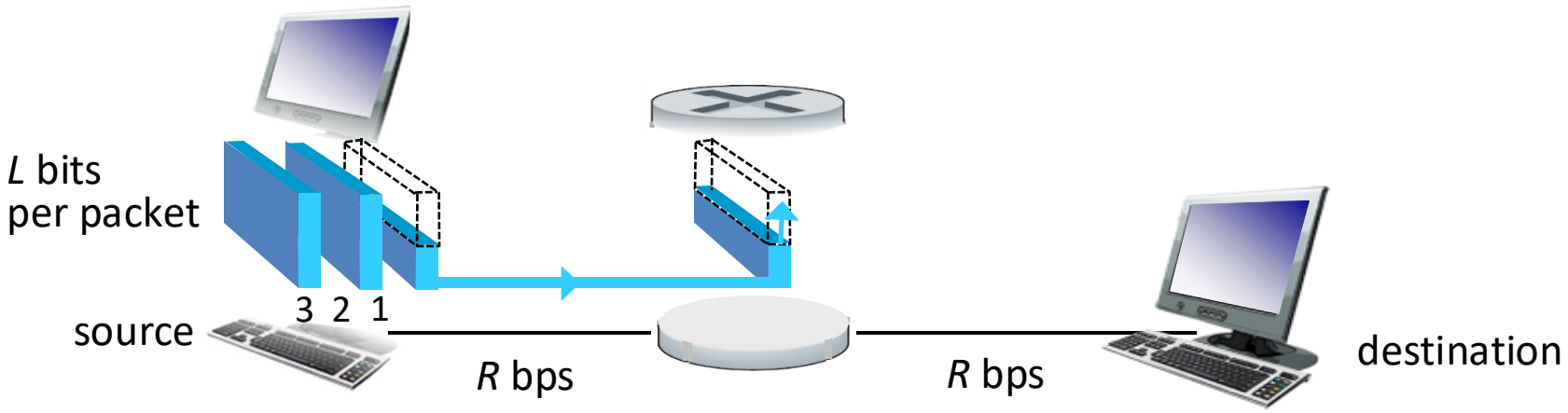
- Identify types of access networks and their use case in daily lives?

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



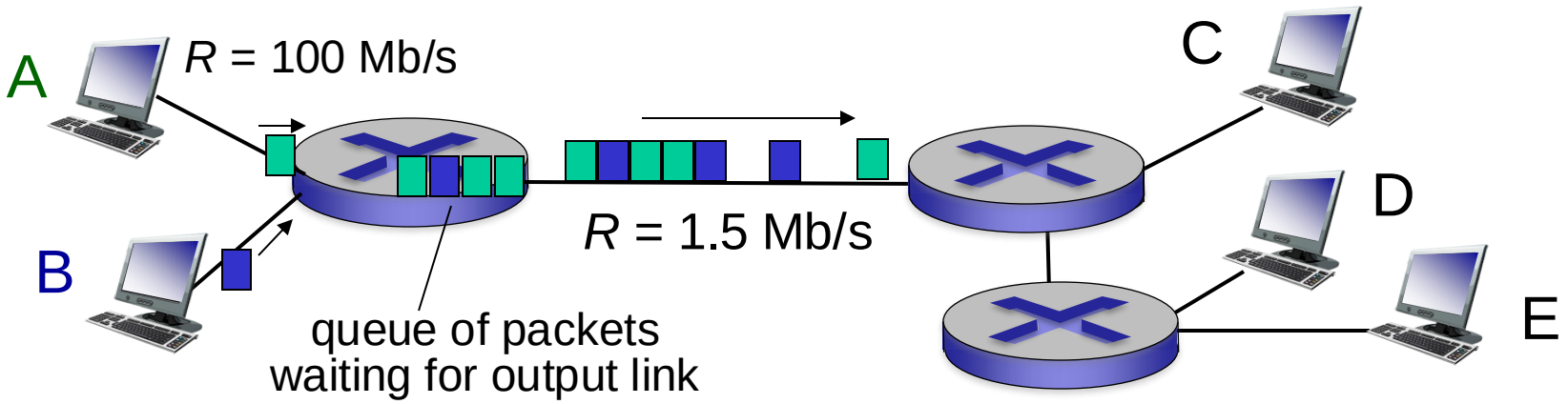
- takes *L*/*R* seconds to transmit (push out) *L*-bit packet into link at *R* bps
- *store and forward:* entire packet must arrive at router before it can be transmitted on next link
- end-end delay = 2*L*/*R* (assuming zero propagation delay)

one-hop numerical example:

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

more on delay shortly …

Packet Switching: queueing delay, loss



queuing and loss:

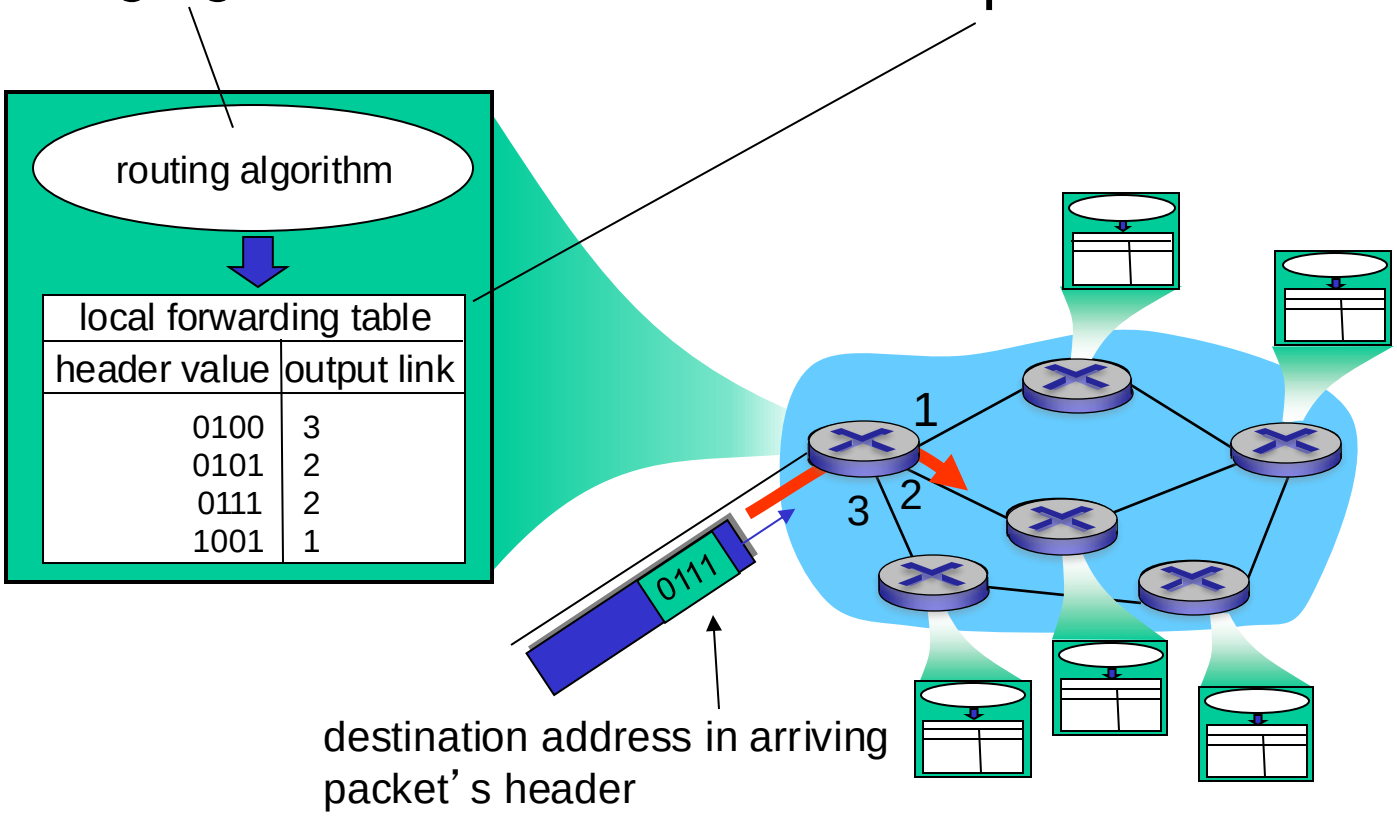
- if arrival rate (in bits) to link exceeds transmission rate of link for a period of time:
  - packets will queue, wait to be transmitted on link
  - packets can be dropped (lost) if memory (buffer) fills up

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

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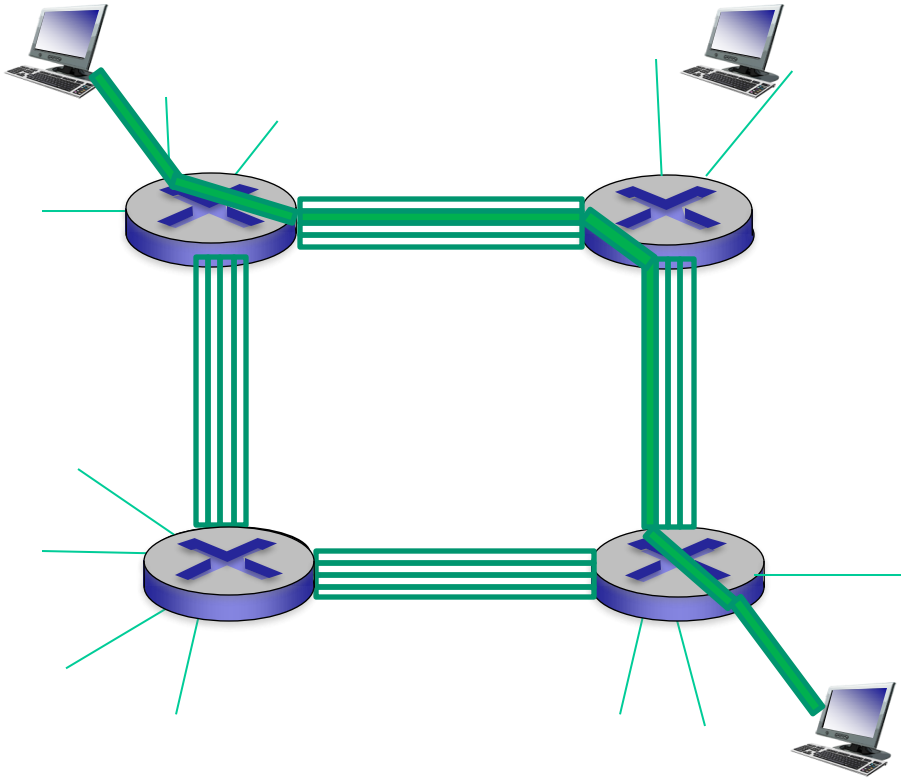
end-end resources allocated to, reserved for "call" between source & dest:

- 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



Minute Paper

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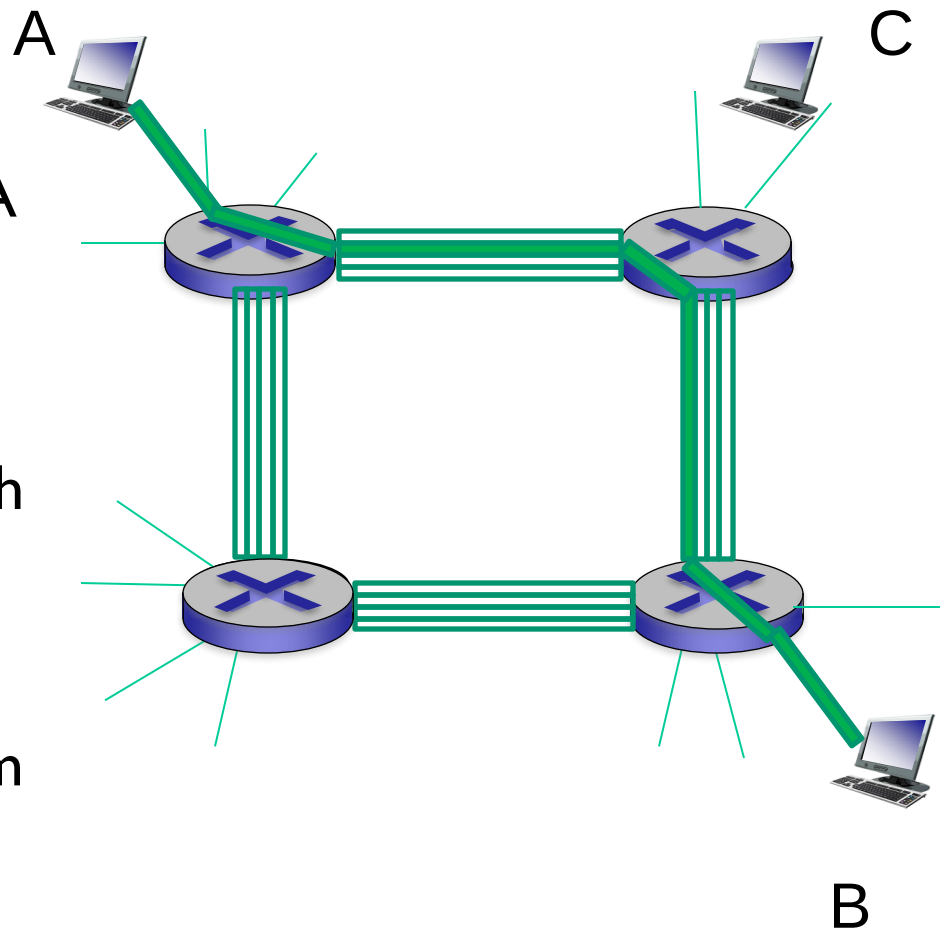
- How many circuits can be active from source computer A to destination computer B simultaneously?
- When can C communicate with B?
- Answers: 8 circuits can be active. C can communicate when one of the 8 circuits from A-B stops transmission

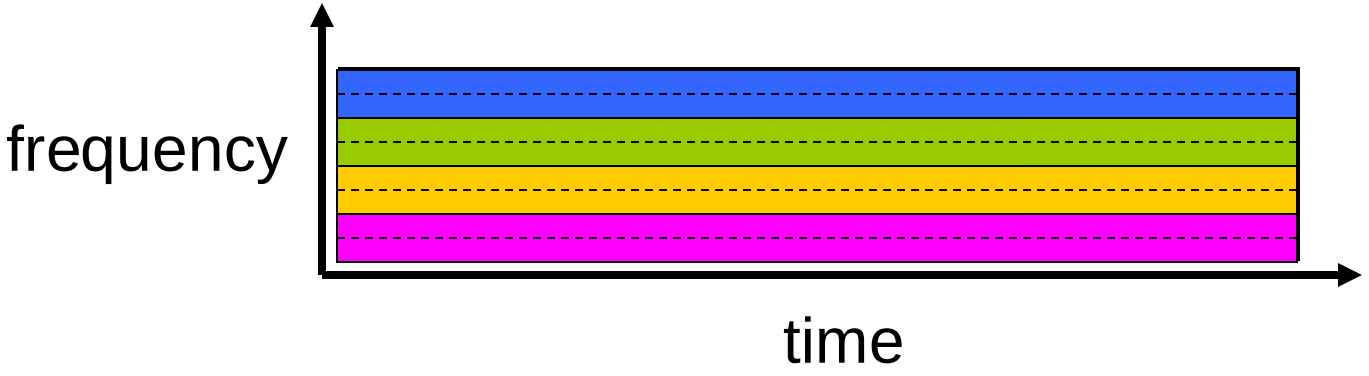


Circuit switching: FDM versus TDM

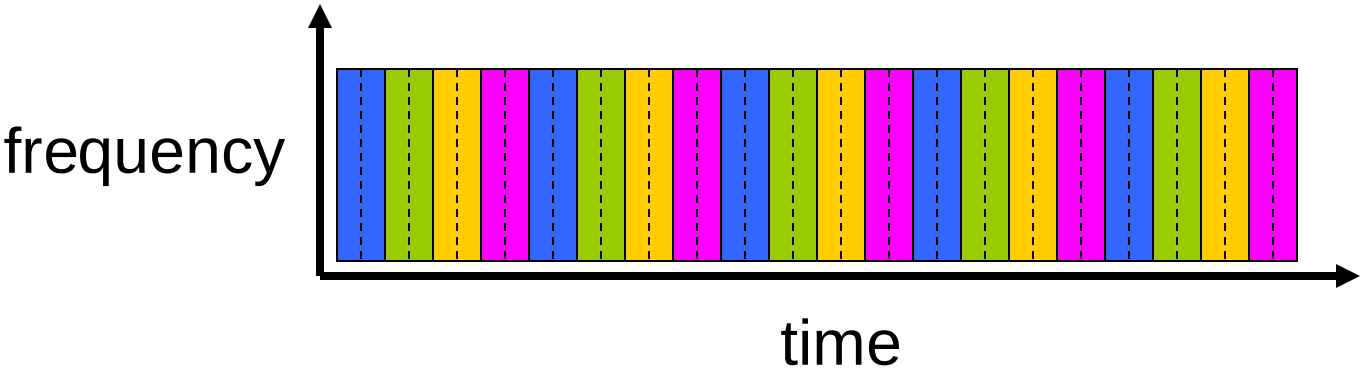
Example:

4 users

FDM



TDM



A Little more on TDM

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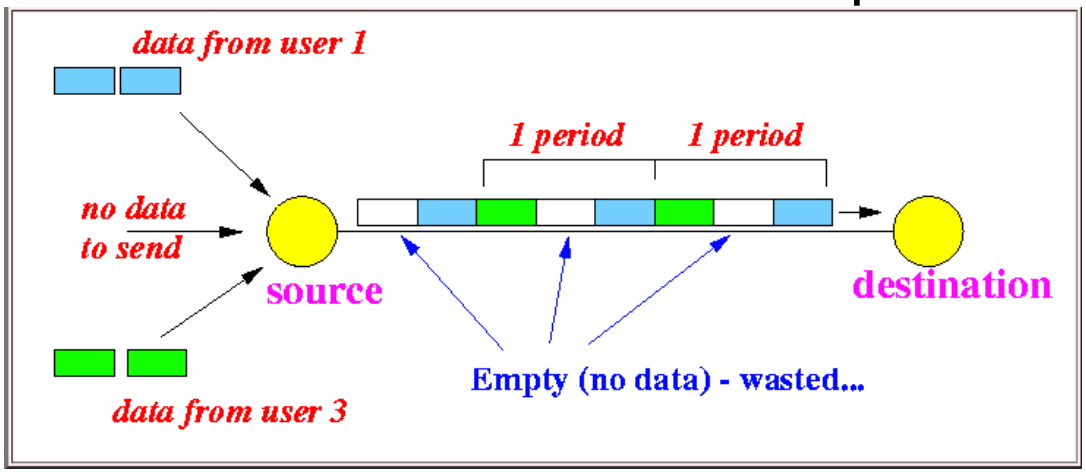
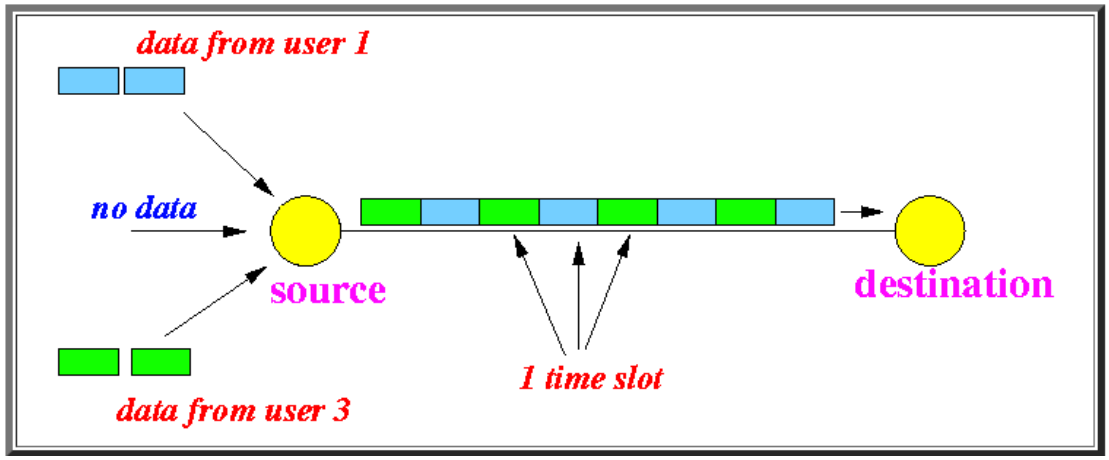
Synchronous TDM – Time is divided into periods of slots



Asynchronous TDM – No periods, anyone can send



Source: https://www.cs.emory.edu/~cheung/Courses/455/Syllabus/2-physical/multiplexing2.html

TDM : Example

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Suppose that you have a multiplexer (mux) with 2 different inputs at the following bit-rates: (A) 10 Kbps, (B) 8 Kbps, Using a fixed slot size in the frame, how would you organize a single asynchronous TDM link receiving the output of the mux?

Solution: Common slot size is 2 Kbps

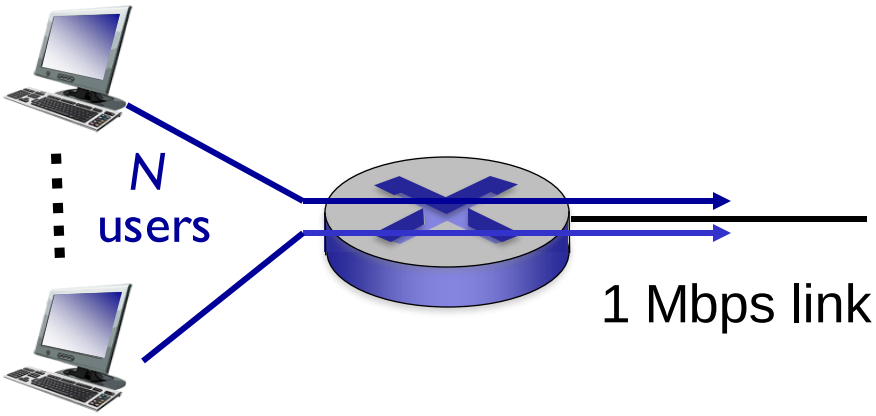
How about the below solution? Is it asynchronous?

Circuit Switching Vs Packet 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 can be active
- *packet switching:*
  - With 35 users, probability of 10 active at same time is less than .002 *

Q: how did we get value 0.002?

Efficiency of Packet-Switching Method

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Measuring probability of users being active

- Given
  - Total number of users = 35
  - The probability of a user being active = 0.1
- Find
  - Probability of 10 users simultaneously active

Solution :

Binomial probability distribution = $\binom{n}{x} p^x (1-p)^{n-x}$

$= \binom{35}{10} 0.1^{10} (1-0.1)^{35-10}$

$= 0.00131$

Note: $\binom{n}{x} = \frac{n!}{x!(n-x)!}$

DIY : Computing Binomial Probability

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Now consider a scenario where 20 users are using the packet switched line and users are active 10% of time.

A. Compute probability of 1 user being active

B. Compute the summative probability of up to 7 users being active simultaneously

C. Compute the probability that more than 7 of 20 users are transmitting at the same time.

DIY : Solutions

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A. Compute probability of 1 user being active

Binomial probability distribution = $\binom{n}{x} p^x (1-p)^{n-x}$

$= \binom{20}{1} 0.1^1 (1-0.1)^{20-1}$

$= 0.27017$

B. Compute the summative probability of any upto 7 (0,1,2, …7) users being active

Cumulative Binomial distribution for 0 through 7 users

$= \binom{20}{0} 0.1^0 (1-0.1)^{20-0} + \binom{20}{1} 0.1^1 (1-0.1)^{20-1} + \ldots\ldots$

$+ \binom{20}{7} 0.1^7 (1-0.1)^{20-7}$

$= 0.999584$

DIY : Solutions

C. Compute the probability of more than 7 of 20 users are transmitting at the same time.

= 1 – (summative probability of 7 users)

= 1 – 0.999584

= 0.000416

Packet switching versus circuit switching

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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

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- The computer network
- Protocol and Internet
- Network infrastructure
- Access networks and physical media
- Packet switching versus circuit-switching

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End of Lecture 1_1