# CSC/CPE 138

# COMPUTER NETWORKING FUNDAMENTALS

## Lecture 1_1

Department of Computer Science

Spring 2024

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

# About Me

Syed Badruddoja

- Ph.D. in Computer Science and Engineering, University of North Texas (UNT)
- Certification: Cisco Certified Internetwork Expert (CCIE Routing and Switching)
- Red Hat Certified Engineering (RHCE)
- Research : Blockchain for Artificial Intelligence
- Professional Experience: 14 Years
- Fun Fact: I play electric piano

# About the Course

| | |
|---|---|
| Instructor: | Dr. Syed Badruddoja |
| Office: | RVR3006 |
| Office Hours (Online): | Tuesday and Thursday |
| | 2:30 PM – 4:00 PM |
| Office Hours Zoom Link: | https://csus.zoom.us/j/84636285529 |
| Office Telephone: | 916-278-7328 |
| Mode of Instruction: | In-person |
| E-mail: | badruddoja@csus.edu |

# Course Description

- Overview, structure, concepts, principles, and protocols of computer networking.
- Network architecture, OSI reference model, TCP/IP protocol stack, layering, protocols and encapsulation.
- Introduce socket programming fundamentals and test knowledge through programming assignments.
- End-to-end communication, multiplexing and demultiplexing, reliable data transfer, flow control, and congestion control.
- Internet protocol (IP) addressing, routing algorithms and internet routing designs.
- Switching concepts, LAN topologies, link layer error corrections and how the underlaying hardware works in switches.
- Security components and their implications in computer networks.

# Course Objectives

- 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

**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: 9780133594140, 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

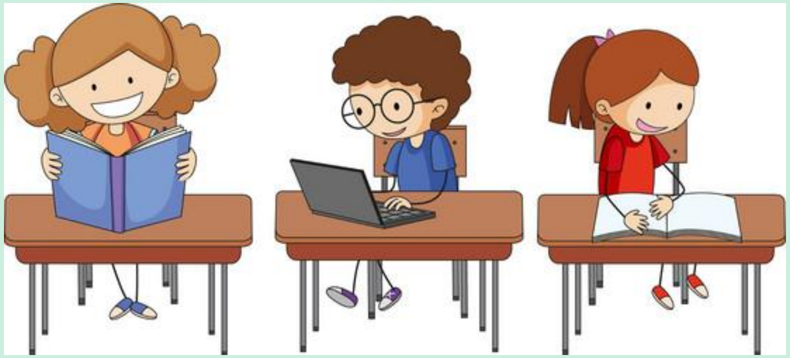
| | |
|---|---|
| In-Class Activity | 5.0% |
| Homework and Programming | 20.0% |
| Lab | 20.0% |
| Project | 10.0% |
| Midterm Exam | 20.0% |
| Final Exam | 25.0% |
| Total | 100.0% |

# Grading Policy - Grades

| Letter Grade | Percentage |
|---|---|
| A | 93-100% |
| A- | 90-92% |
| B+ | 87-89% |
| B | 83-86% |
| B- | 80-82% |
| C+ | 77-79% |
| C | 73-76% |
| C- | 70-72% |
| D+ | 67-69% |
| D | 60-66% |
| F | 0-59% |

# Grading Policy - Assignments

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



# Submission Policy

- 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.
  - 15% deduction for one day late submission.
  - 30% deduction for two days late submission.
  - 45% deduction for three days late submission.
  - 100% deduction from, 4th day onwards

# University and Department Policy

- Prerequisite Proof
- Attendance Policy
- Repeat Policy
- Drop Policy
- Acceptable Student Behavior

# 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

# Other Policies in Syllabus

- Students with Disabilities
  - Contact DAC and provide documentation

- Academic Honesty
  - Submit your own work
  - Discuss problems with friends and classmates
  - Follow the "Policy of Academic Integrity"
  - Beware of plagiarism penalties

# Additional Comments

- Communicate with instructor on any problems relating to assignments before the due date
- Use the feedback effectivity to do better on your next assignment
- Focus on depth of your learning
- Reach out to instructor if you do not understand any topic taught in class
- Feel free to discuss your learning difficulties
- Take the advantage of office hours to seek help and guidance

# Tentative Class Schedule

| Week | Date | Materials to Cover | Remarks |
|---|---|---|---|
| 1 | 1/22 – 1/26 | Computer Networks and The Internet | LAB1 |
| 2 | 1/29 – 2/2 | Computer Networks and The Internet | - |
| 3 | 2/5 – 2/9 | Application Layer | ASSIGNMENT 1 |
| 4 | 2/12 – 2/16 | Application Layer | - |
| 5 | 2/19 – 2/23 | Application Layer | LAB2 |
| 6 | 2/26 – 3/1 | Transport Layer | ASSIGNMENT 2 |
| 7 | 3/4 – 3/8 | Transport Layer | - |
| 8 | 3/11 – 3/15 | Transport Layer | MID-TERM EXAM |
| 9 | 3/25 – 3/29 | Network Layer: Data Plane | ASSIGNMENT 3 |
| 10 | 4/1 – 4/5 | Network Layer: Data Plane | - |
| 11 | 4/8 – 4/12 | Network Layer: Control Plane | LAB3 |
| 12 | 4/15 – 4/19 | Network Layer: Control Plane | ASSIGNMENT 4 |
| 13 | 4/22 – 4/26 | Link Layer | - |
| 14 | 4/29 – 5/3 | Link Layer | PROJECT SUBMISSION |
| 15 | 5/6 – 5/10 | Network Security | - |
| 16 | 5/13 – 5/17 | - | FINAL EXAM |

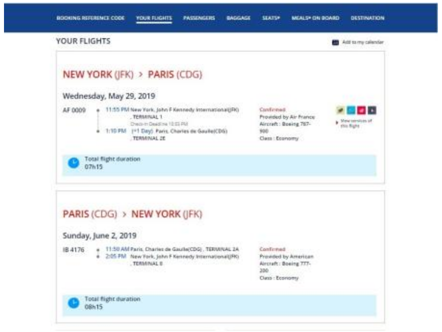
# Important Dates

| | |
|---|---|
| **March 18-24,2024** | Spring Recess |
| **April 1, 2024** | Cesar Chavez Birthday Observed (Holiday, Campus Closed) |
| **May 10,2024** | Last Day of Instruction |
| **May 13-17,2024** | Final Exam Week, TBD by College Official Final Exam Schedule |

# Fun Activity: Brainstorm Internet

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

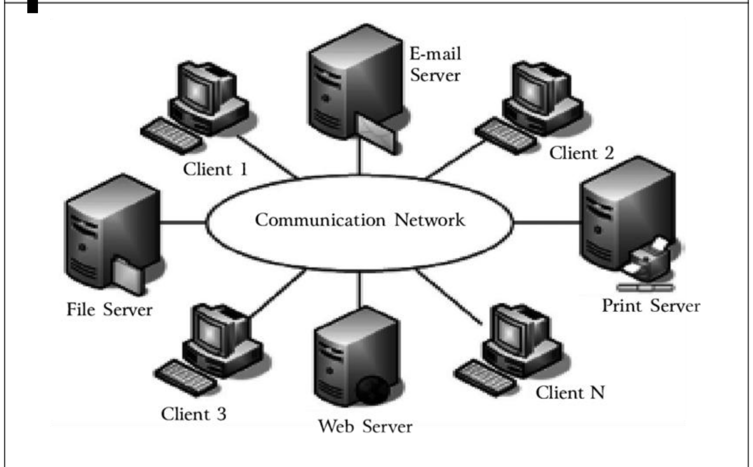
Smart
refrigerator

Streaming Services

sensorized,
bed
mattress

Internet phones

# Introducing Computer Network

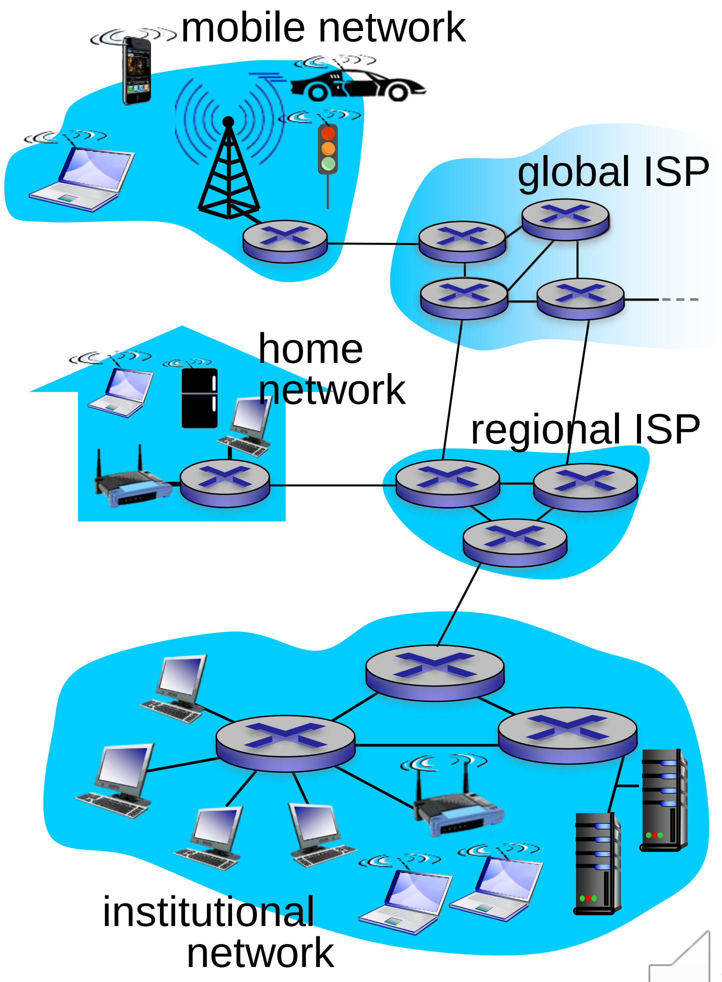



*Source: Saxena and Arora (2009)*

- 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

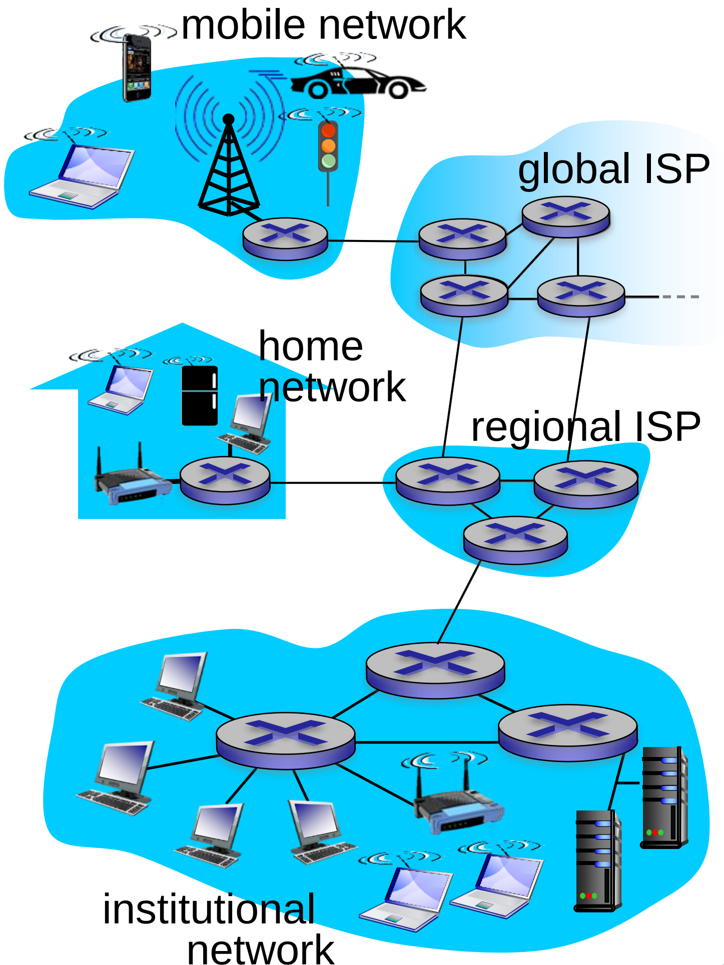
# What's the Internet: "nuts and bolts" view

- 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*



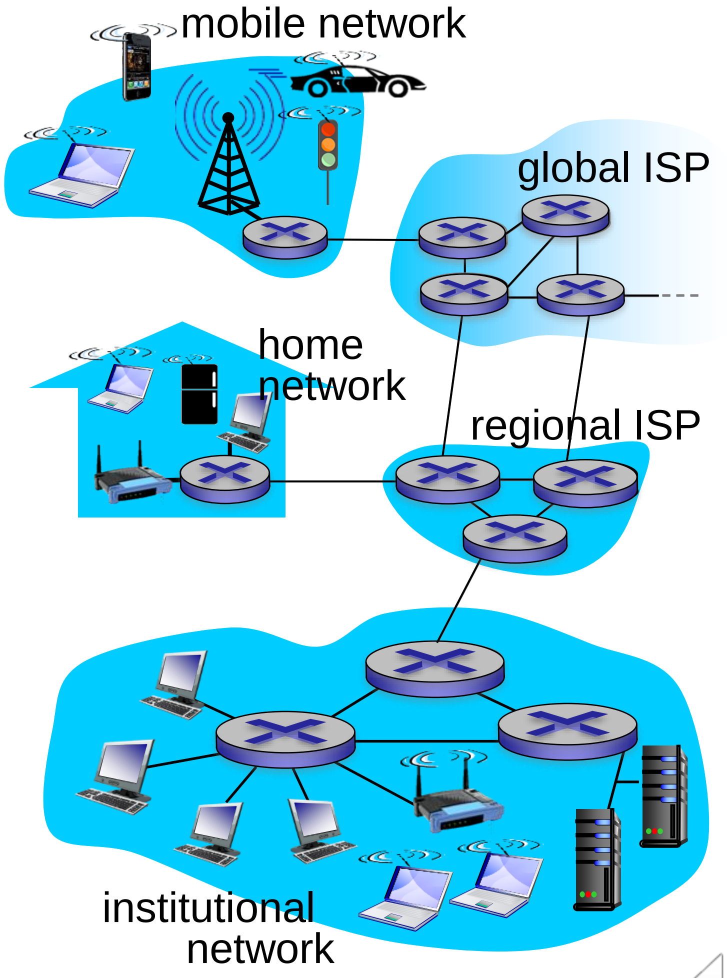
# What's the Internet: "nuts and bolts" view

- *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

- *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

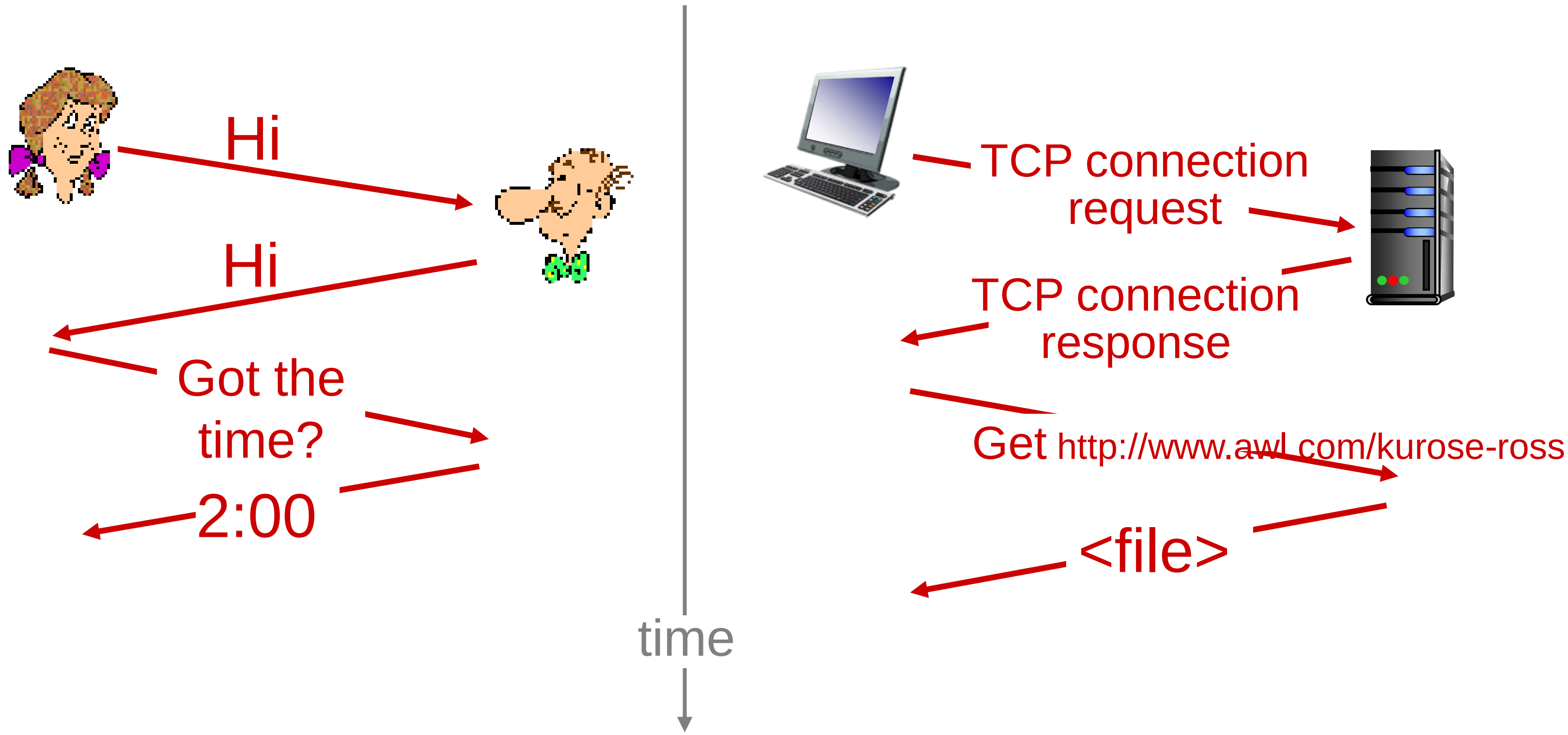
*network protocols:*

- 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?

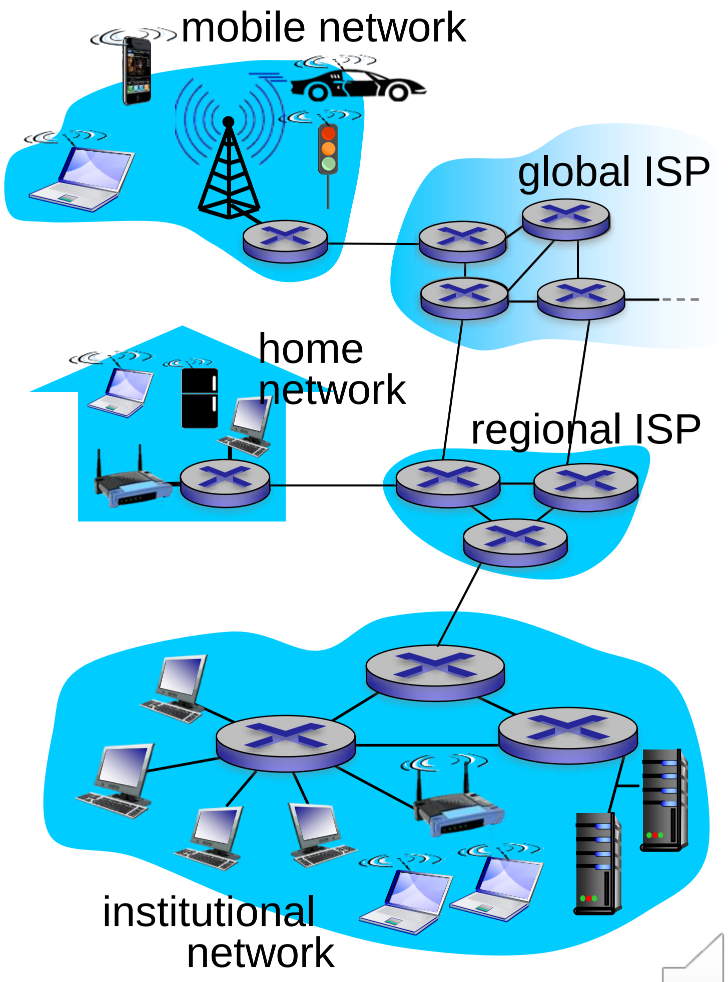
a human protocol and a computer network protocol:




*Q:* other human protocols?

# Network Infrastructure

- *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



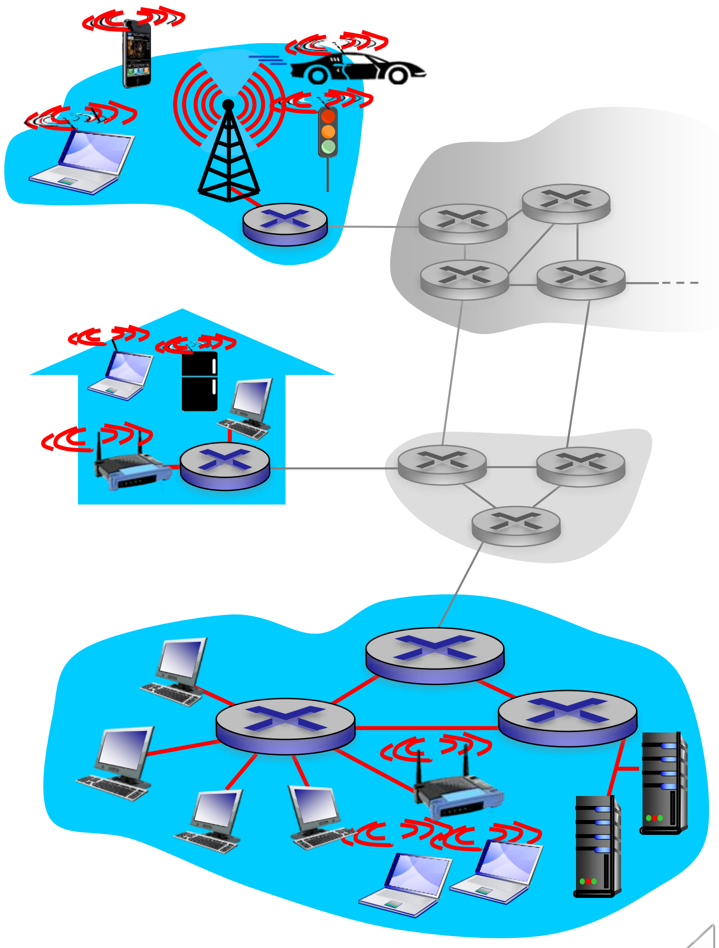
# Access networks and physical media

*Q: How to connect end systems to edge router?*

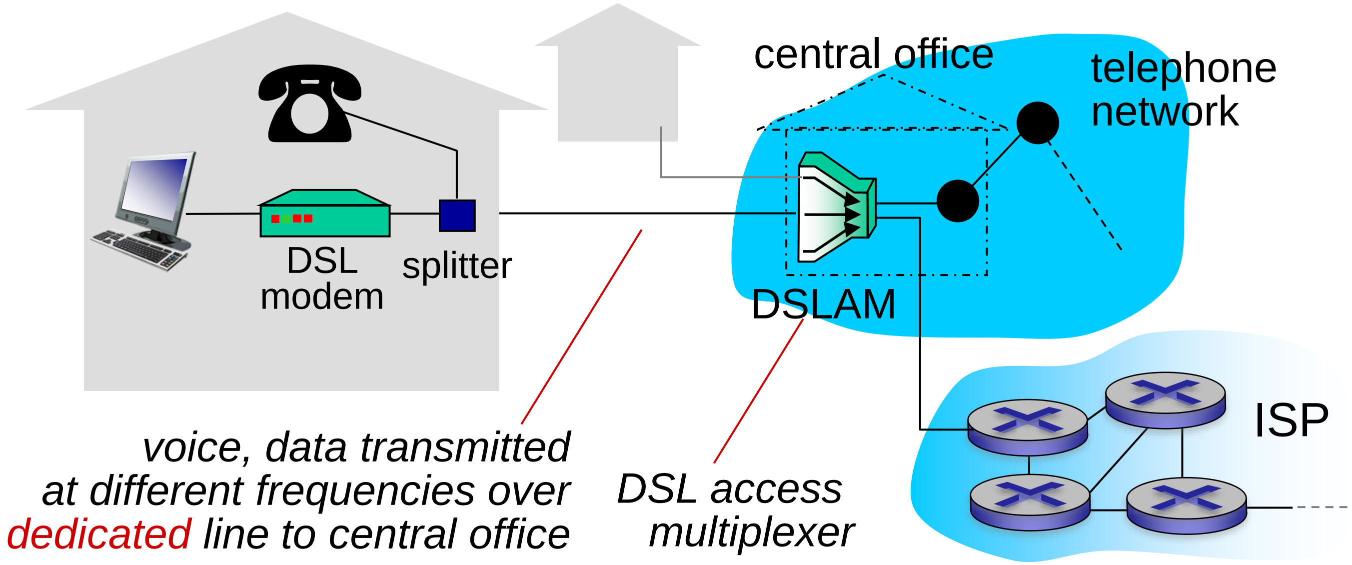
- residential access nets
- institutional access networks (school, company)
- mobile access networks

*keep in mind:*

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

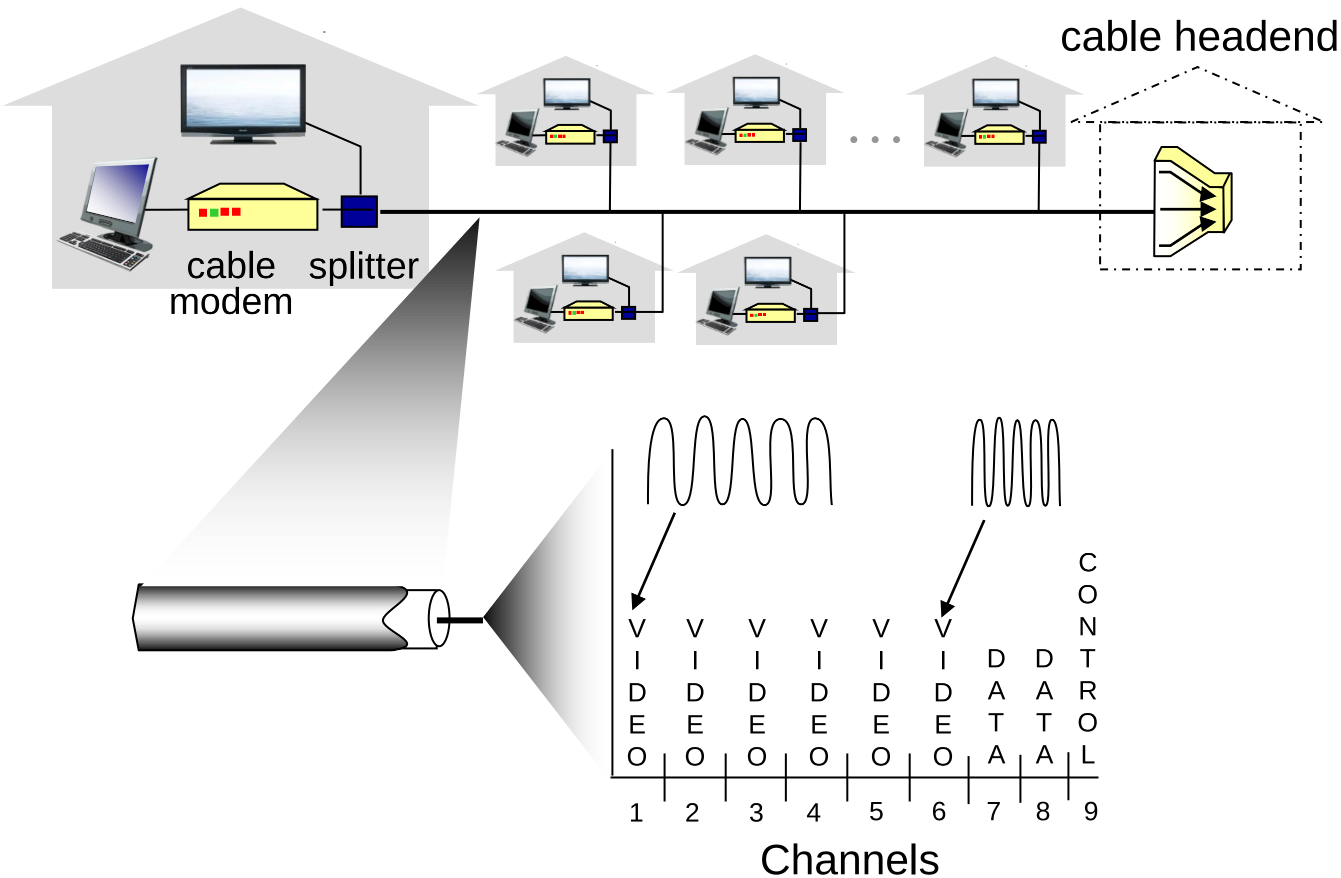


# Access network: digital subscriber line (DSL)



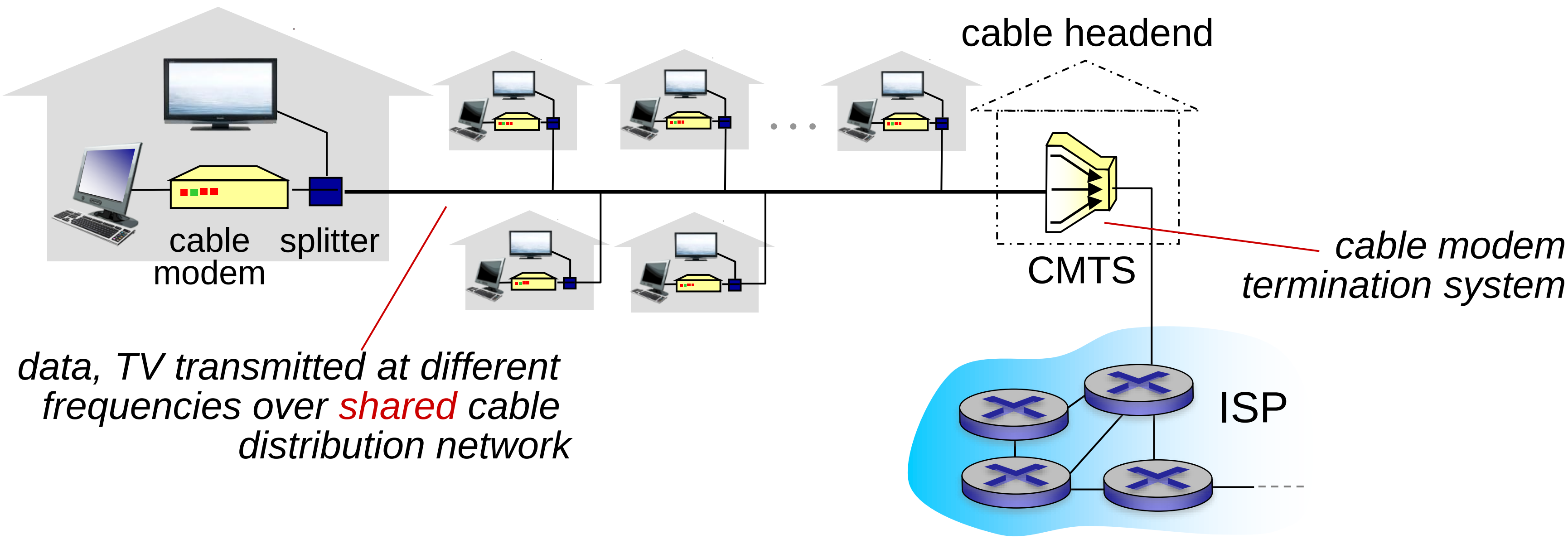

- use *existing* telephone line to central office DSLAM
  - data over DSL phone line goes to Internet
  - voice over DSL phone line goes to telephone net
- < 2.5 Mbps upstream transmission rate (typically < 1 Mbps)
- < 24 Mbps downstream transmission rate (typically < 10 Mbps)

# Access network: cable network



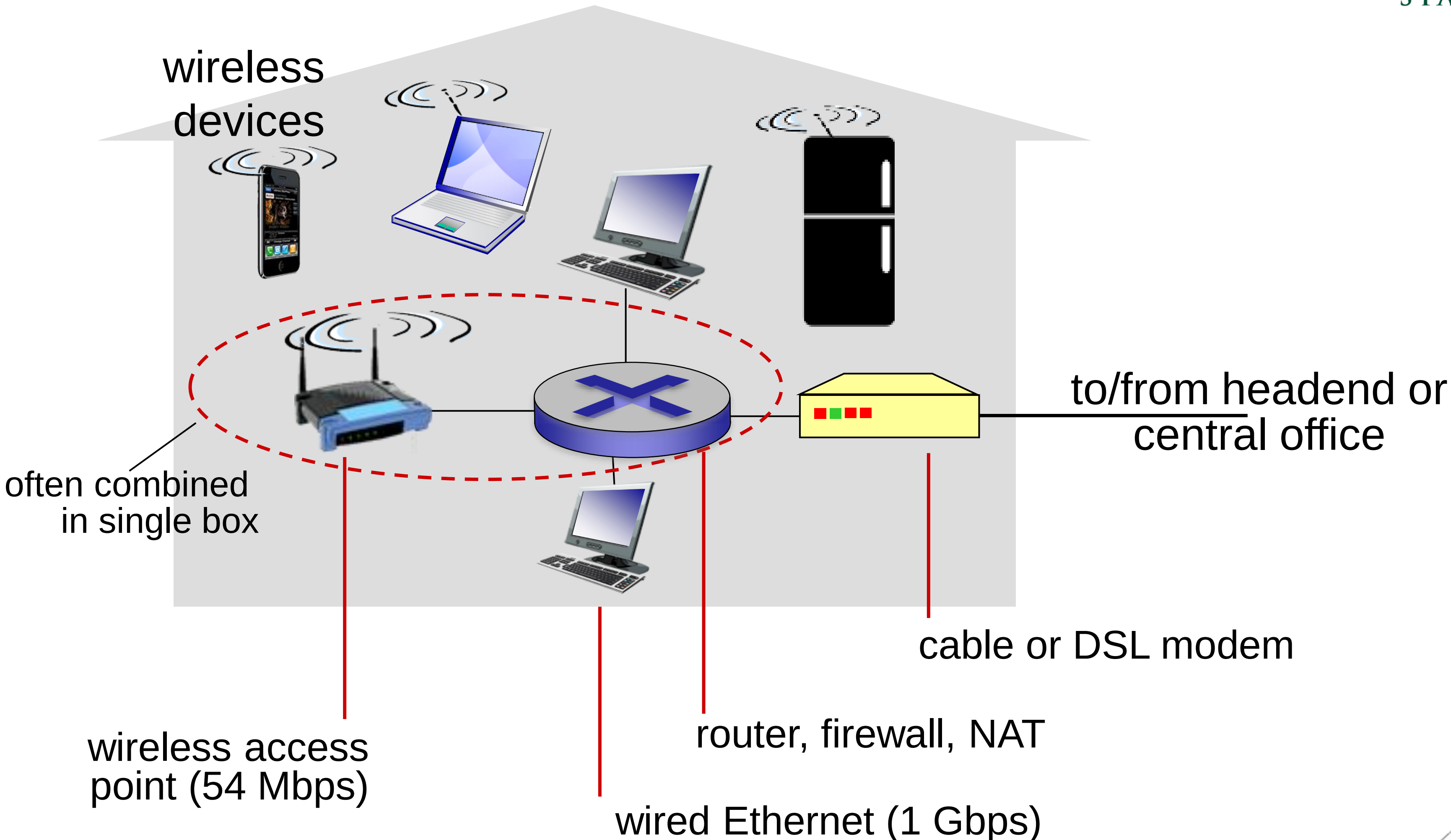

*frequency division multiplexing:* different channels transmitted in different frequency bands

# Access network: cable network

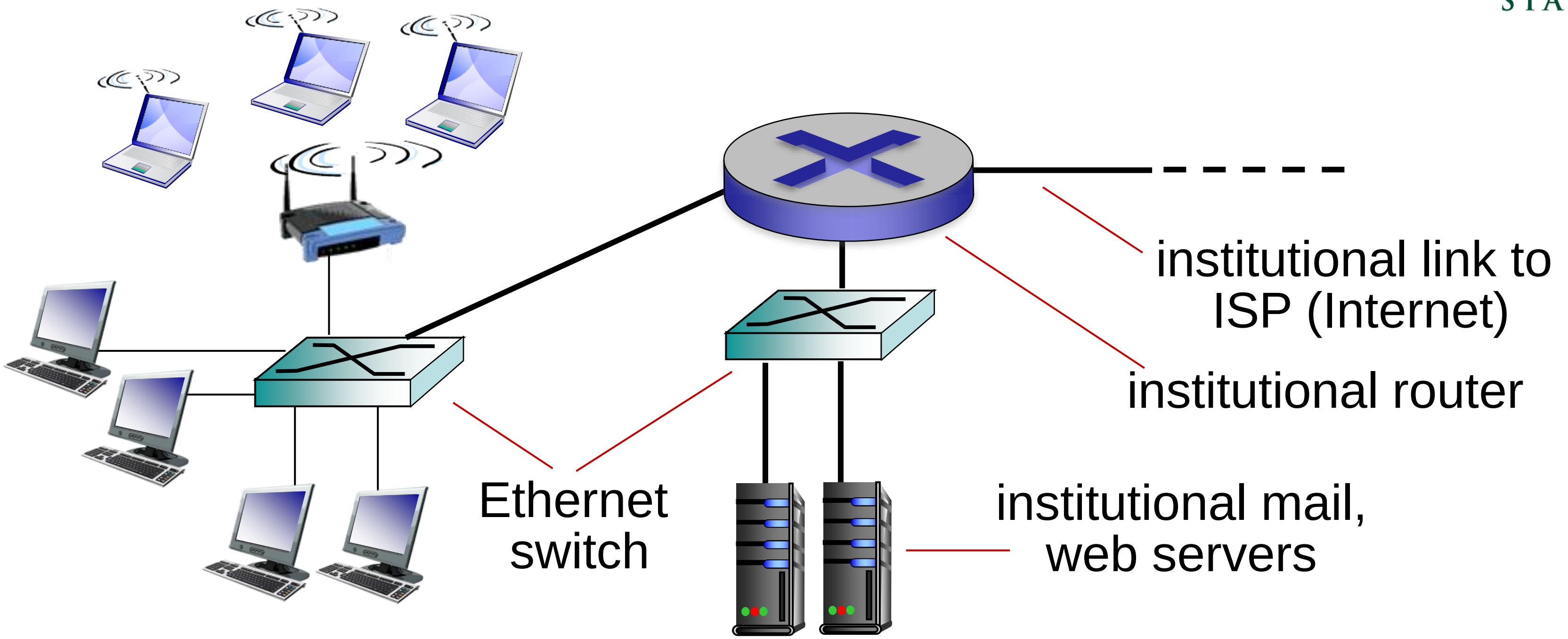



- HFC: hybrid fiber coax
  - asymmetric: up to 30Mbps downstream transmission rate, 2 Mbps upstream transmission rate.
- network of cable, fiber attaches homes to ISP router
  - homes *share access network* to cable headend
  - unlike DSL, which has dedicated access to central office

# Access network: home network



# Enterprise access networks (Ethernet)



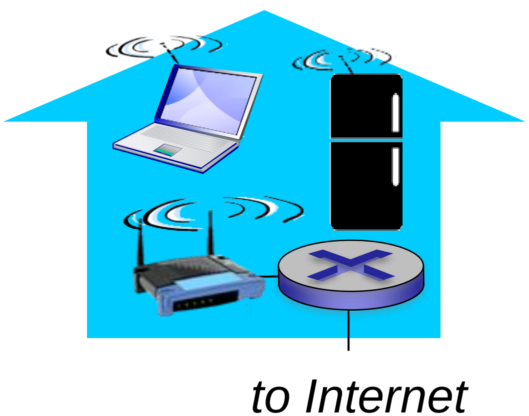

- typically used in companies, universities, etc.
- 10 Mbps, 100Mbps, 1Gbps, 10Gbps transmission rates
- today, end systems typically connect into Ethernet switch

# Wireless access networks

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

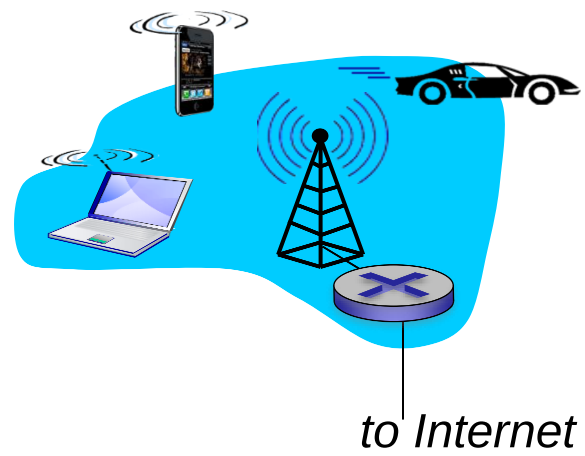
*wireless LANs:*

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




wide-area wireless access

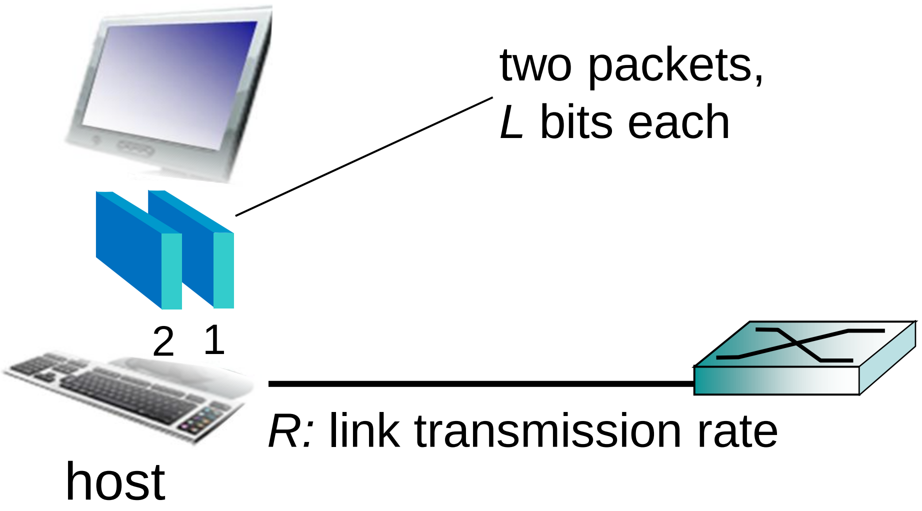
- provided by telco (cellular) operator, 10’s km
- between 1 and 10 Mbps
- 3G, 4G: LTE



# 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*




| packet transmission delay | = | time needed to transmit *L*-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

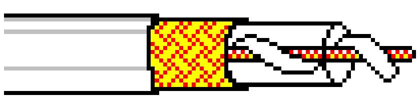
*twisted pair (TP)*

- 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

# Minute Paper

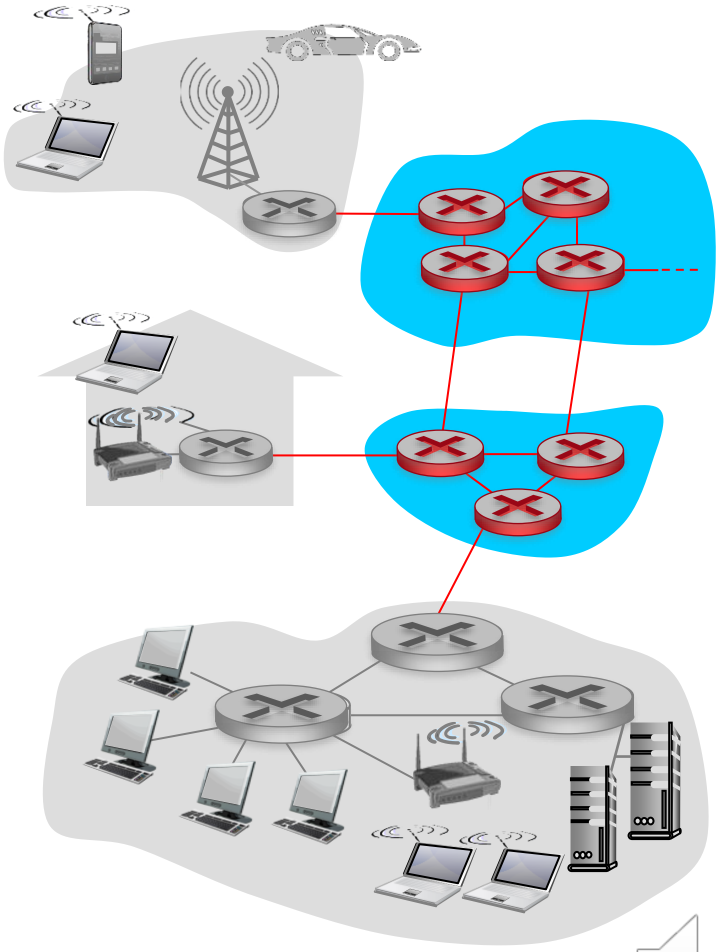
- Differentiate between Internet and Protocol?

- Identify the elements in hierarchical network infrastructure ?

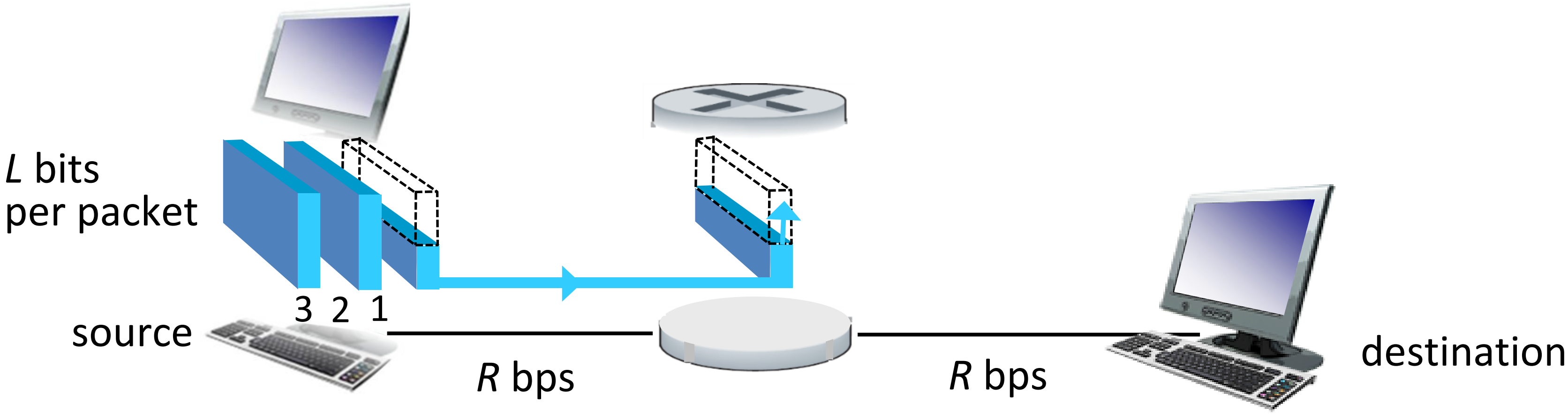
- Identify types of access networks and their use case in daily lives?

# 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



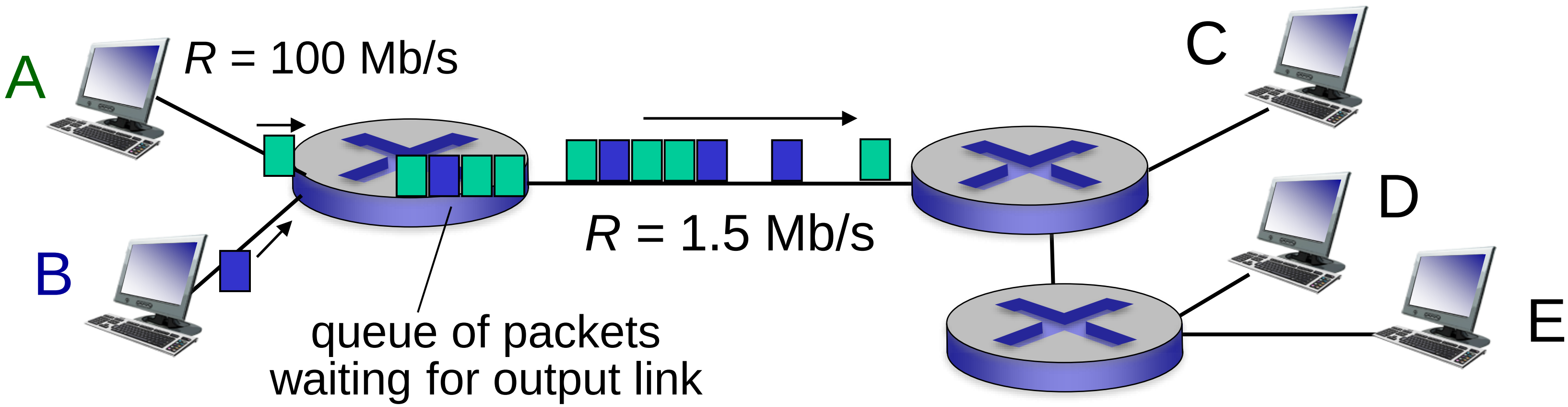

- takes *L*/*R* seconds to transmit (push out) *L*-bit packet into link at *R* bps
- *store and forward:* entire packet must arrive at router before it can be transmitted on next link
- end-end delay = 2*L*/*R* (assuming zero propagation delay)

*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:

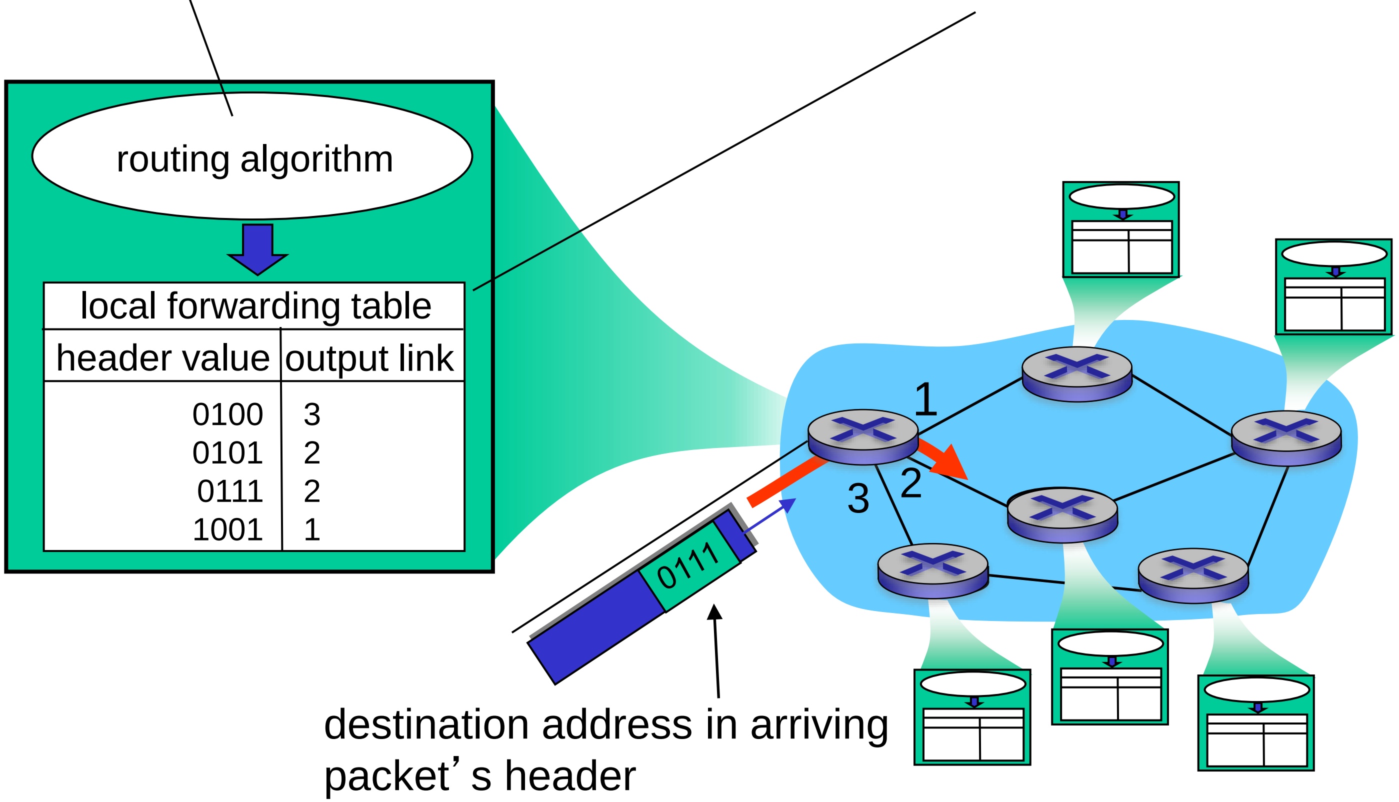
- if arrival rate (in bits) to link exceeds transmission rate of link for a period of time:
  - packets will queue, wait to be transmitted on link
  - packets can be dropped (lost) if memory (buffer) fills up

# Two key network-core functions

*routing:* determines source-destination route taken by packets

- *routing algorithms*

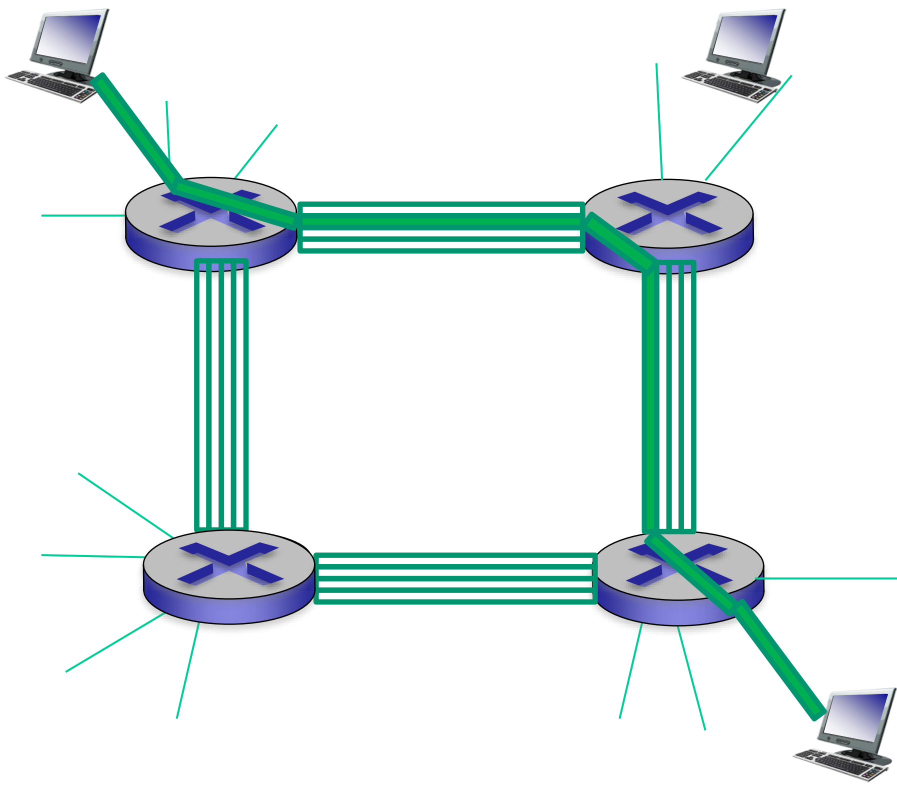
*forwarding:* move packets from router's input to appropriate router output



# Alternative core: circuit switching

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

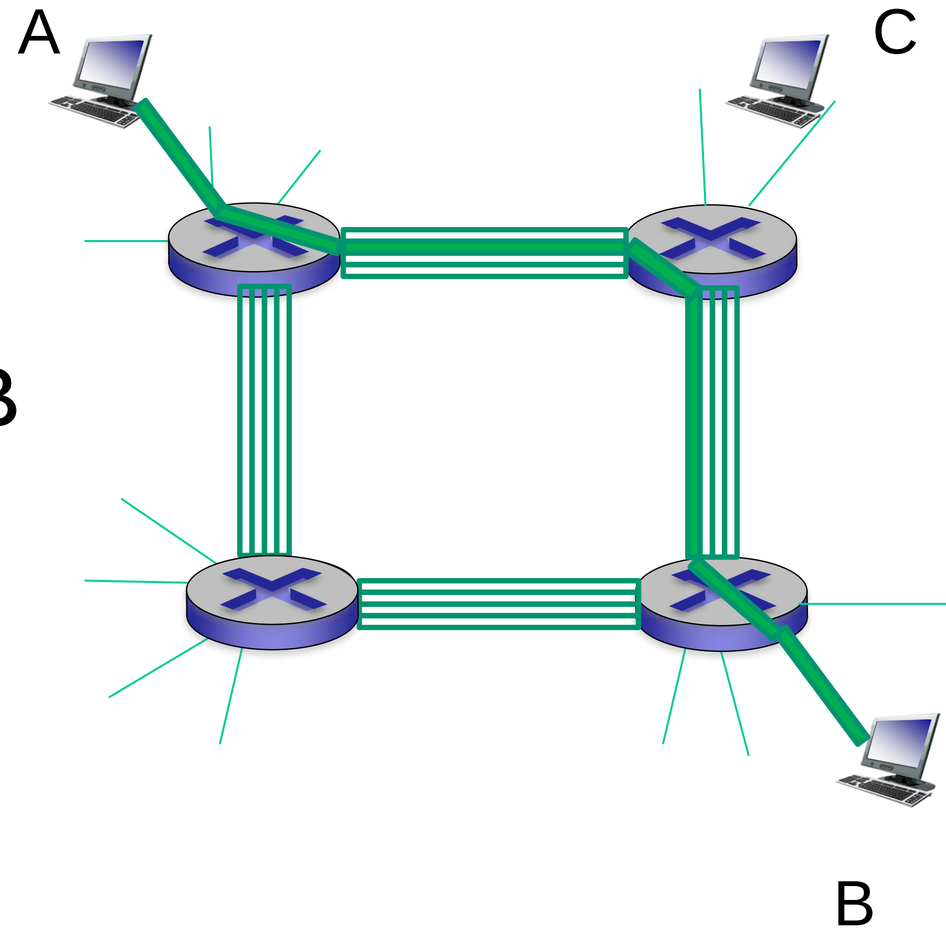
- in diagram, each link has four circuits.
  - call gets 2nd circuit in top link and 1st circuit in right link.
- dedicated resources: no sharing
  - circuit-like (guaranteed) performance
- circuit segment idle if not used by call *(no sharing)*
- commonly used in traditional telephone networks



# Minute Paper

- How many circuits can be active from source computer A to destination computer B simultaneously?

- When can C communicate with B?

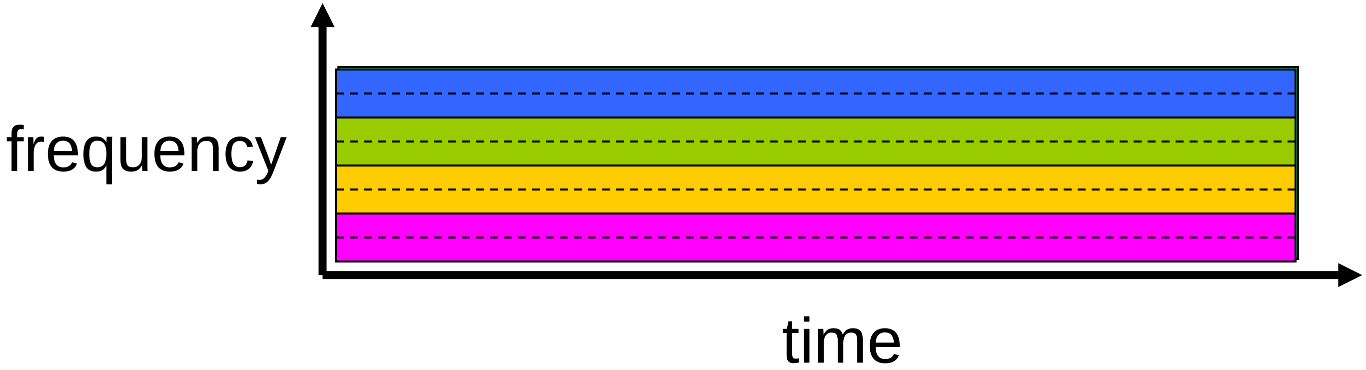


# Circuit switching: FDM versus TDM

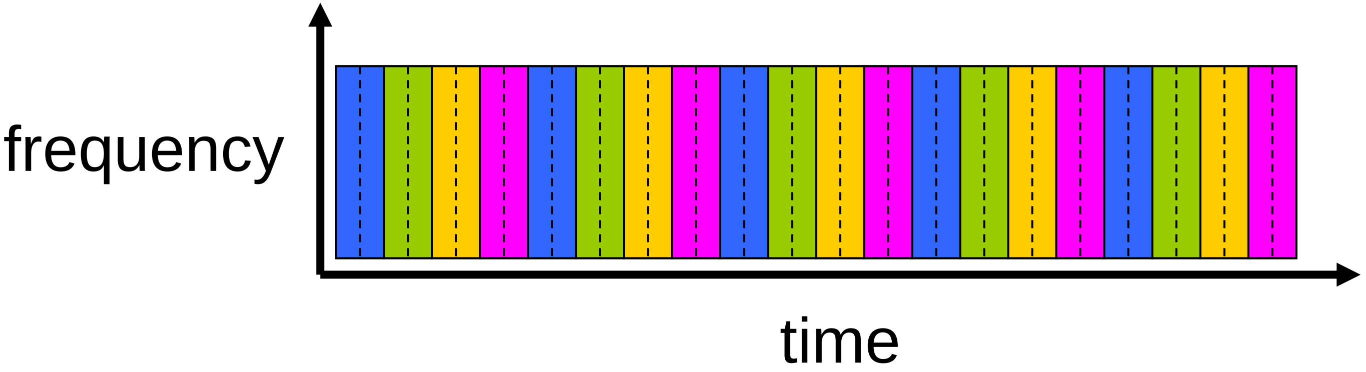
Example:

4 users

FDM

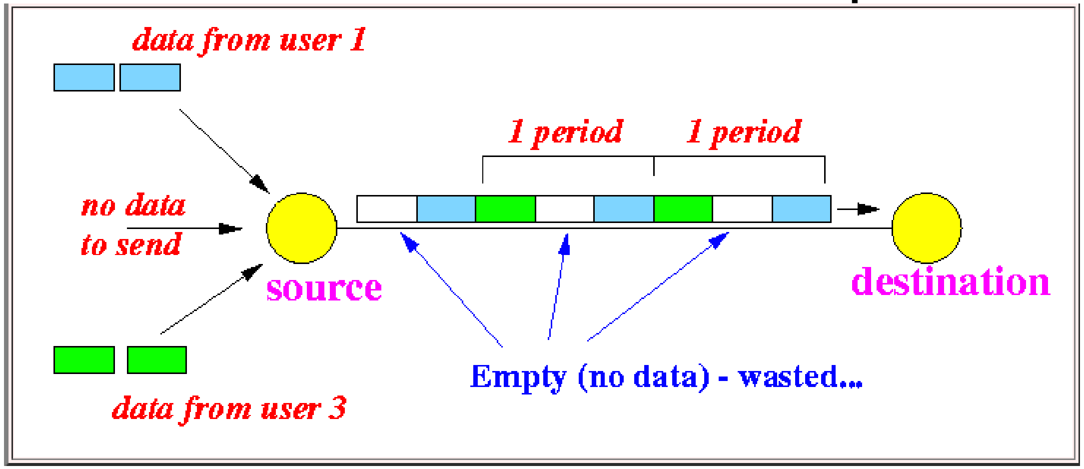



TDM

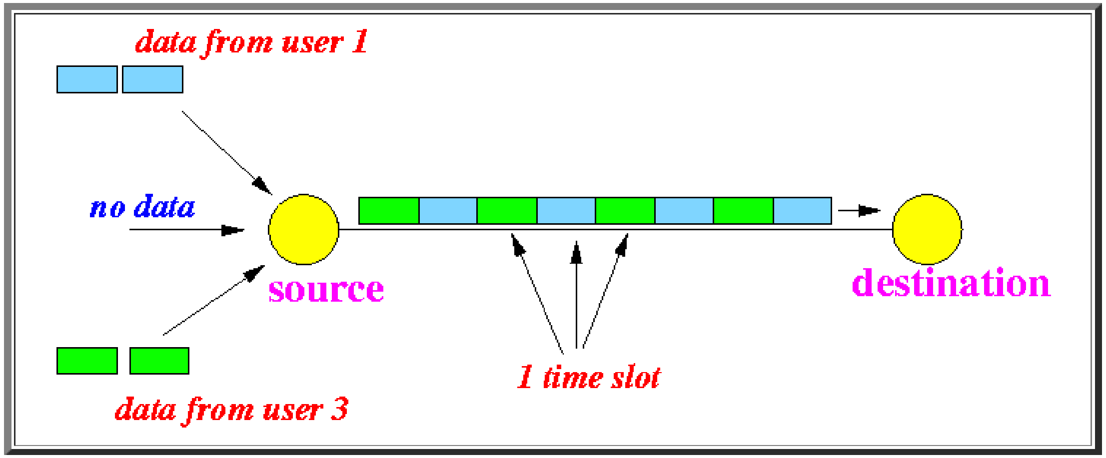


# A Little more on TDM

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

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

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| A | A | A | A | A | B | B | B | B |

Or

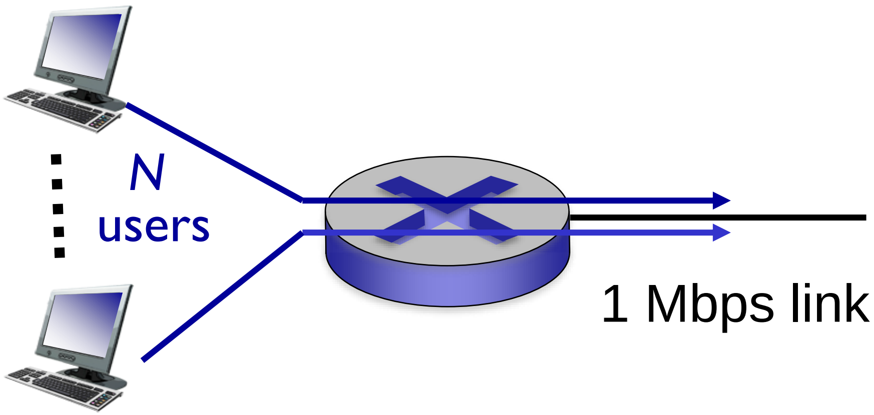
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| A | B | A | B | A | B | A | B | A |

# 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

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

SACRAMENTO STATE

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

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

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

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

= 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

SACRAMENTO STATE

## 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)?

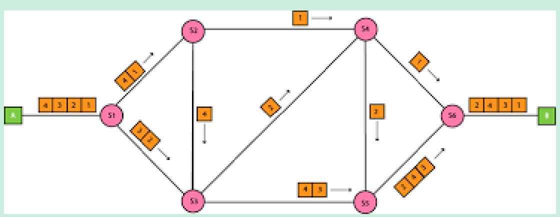
# Summarize Lecture 1_1

## Internet

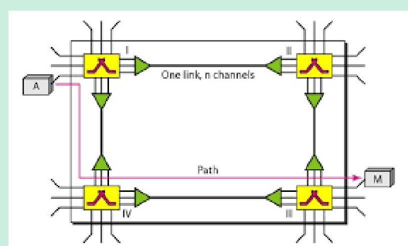
## Protocol


## Infrastructure: Edge, Core Access Network

## Packet - Switching



## Circuit- Switching




## Binomial Distribution:

$$\binom{n}{x}\, p^x (1-p)^{n-x}$$

# End of Lecture 1_1