CS 332:
Computer Networks
Introduction

Professor Doug Szajda

Before we do anything else:

- Names:
- The course website: https://cmsc332-fall-2025.github.io/
- Slides: I will post them. Not always before class.

Thanks!

- I've taught this course many times, the most recent being Fall 2021. Each time calls for a rethinking of the topics and new material.
- Much of the material I'll use in the course has been supplied by Professor Patrick Traynor of the University of Florida
  - In fact, some assignments, almost all of the slides, etc, are taken word for word.

Thanks!

- I don't feel bad about this: Patrick took this course with me at UR in the Spring of 2001.
  - So in a sense, it's payback! (And some of the material was originally mine!)
- Some of the material in these slides is also taken from the instructor material from your text
- So the authors, Jim Kurose and Keith Ross, deserve credit for them

A recurring theme

- I don't always like the images Patrick chose for his slides. So I replace some.
- The question: Is an image from me or from Patrick? Something to ponder…

What's this all about?

The Silk Road:
Silk, spices, horses, diamonds
Religion, technology, culture and disease
Shut down around 1400 due to fall of Mongols

A Modern Day Silk Road

- We live with nearly constant access to the most extensive system ever built by human beings.
  - *We may never build anything bigger.*
- The Internet quickens the exchange of ideas, goods, news, and improves the quality of life for a large portion of the world's population.
  - And as we've seen, such instant exchange of information can also cause harm
- It even impacts you where you least expect it.
  - E.g. Shipping/Supply Chain Management/Appliances

A Modern Day Silk Road

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  - *We may never build anything bigger.*
- The Internet quickens the exchange of ideas, goods, news, and improves the quality of life for a large portion of the world's population.
- And think of what may have been had we not had it during the COVID pandemic!

Why Do I Need This Course?

- As engineers and scientists, you need to understand the underpinnings of our global communications networks.

- With this information, you will be able to help design and implement the next generation of networked systems.

- As everything "comes online", you need to understand the implications (both good and bad) and architecture of these systems.

Goals

- My Goal: *To provide students with the tools to evaluate current, and develop new, networked systems.*
  - Networking Fundamentals
  - Recognize trade-offs between different technologies.
  - Design and implement software with a communications interface.
  - Prepare you for advanced work in this area.

- I love this material and want to help you all love it too.
- But know that we go beyond just "how the Internet works" to *why* it works the way it does!

What Topics Will We Cover?

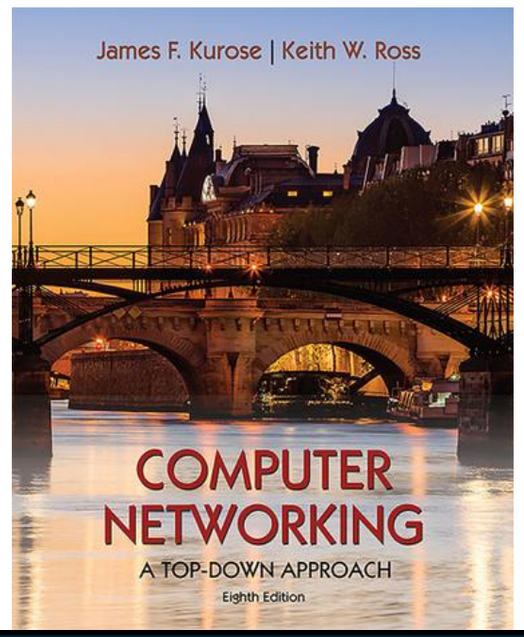
- This is an introductory course, so you will get a bit of everything:
  - TCP, IP, UDP, DNS, BGP, Email, P2P, Routing Algorithms, Congestion Control, Queuing Fundamentals, Network Management, Wireless, Cellular, Security, Ethics and lots more… (including some new protocols that are gaining widespread use)
- I will be maintaining the course at: https://cmsc332-fall-2025.github.io/
- Assignments, slides and other information will be made available there.

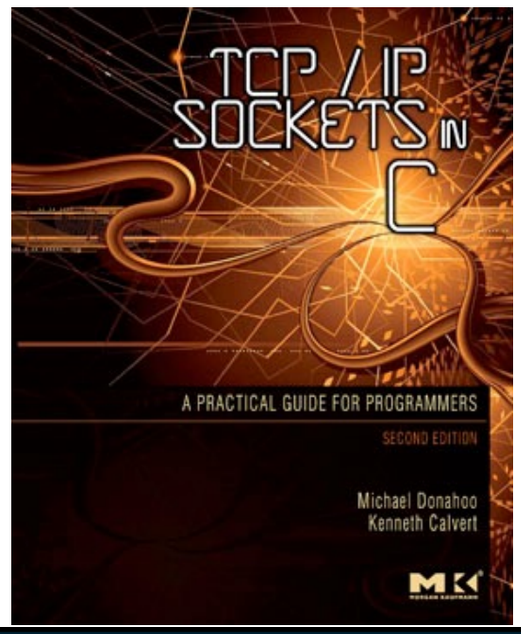
What Topics Will We Cover?

- I will also be creating a course Slack group
  - I urge you to take advantage of that to communicate with me or with each other
  - But please be aware, that I won't be responding instantaneously

Textbooks

- There are two *required* books for this class:
  - Computer Networking: A Top-Down Approach (8th edition)
  - TCP/IP Sockets in C: Practical Guide for Programmers
- Readings will come from the first; projects will be made easier using the second.





Assignments/Workload

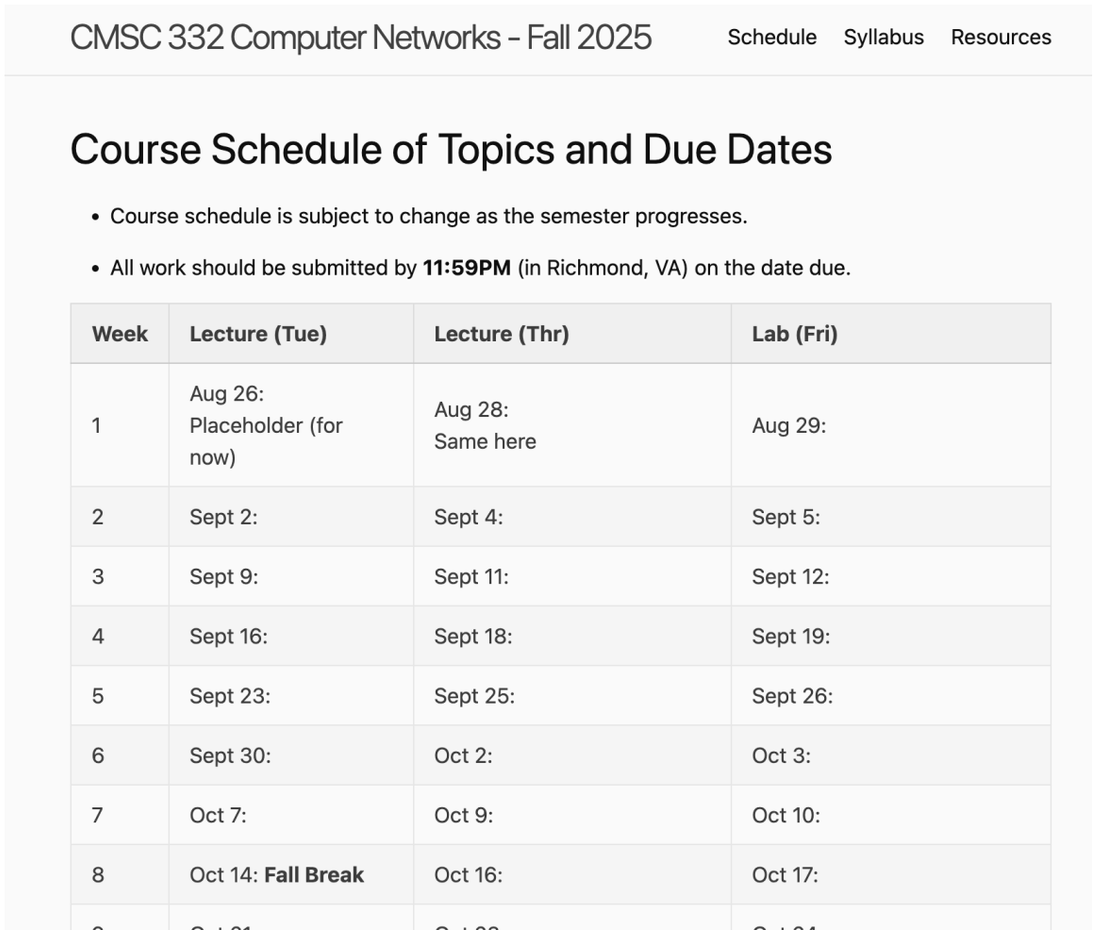
- There will be a reading assignment for nearly every class.
  - Reading must be done *before* the class period.
- We will have a total of *four* homework assignments:
  - Problems will come from the book and the professor.
  - Check the website.
- We will also do *four* programming projects:
  - All programming must be done in C or C++

Course Calendar

- The course calendar contains a listing of readings, assignments, and deadlines (or at least will as I add to it).

- The page also contains links to additional readings.

- Check frequently! There will be changes! Students are responsible (*I will do my best to make announcements*).



CMSC 332 Computer Networks - Fall 2025 Schedule Syllabus Resources

Course Schedule of Topics and Due Dates

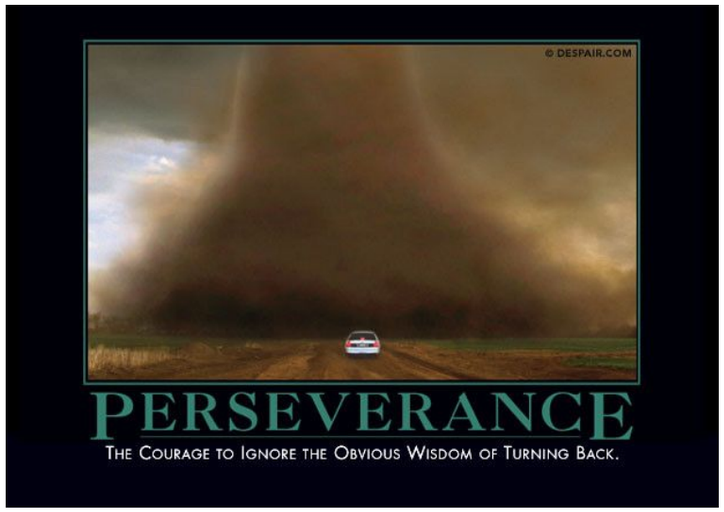
- Course schedule is subject to change as the semester progresses.
- All work should be submitted by **11:59PM** (in Richmond, VA) on the date due.

Week	Lecture (Tue)	Lecture (Thr)	Lab (Fri)
1	Aug 26: Placeholder (for now)	Aug 28: Same here	Aug 29:
2	Sept 2:	Sept 4:	Sept 5:
3	Sept 9:	Sept 11:	Sept 12:
4	Sept 16:	Sept 18:	Sept 19:
5	Sept 23:	Sept 25:	Sept 26:
6	Sept 30:	Oct 2:	Oct 3:
7	Oct 7:	Oct 9:	Oct 10:
8	Oct 14: **Fall Break**	Oct 16:	Oct 17:

Expectations

- This is going to be *a challenging course*. The key to success is sustained effort. Failure to keep up with readings and assignments will result in a poor understanding of the material, which is not what any of us wants.

- So what do we get for all our hard work?
  - Perhaps a step toward helping to change the world (hopefully for the better)...



Grading

- Two midterms, let's discuss
- Final Exam
- Four programming projects
  - The last one typically a more involved group project
- Perhaps a few labs
- Perhaps some ungraded homework
- Why the hand waving? Because I'm changing my grading structures and still thinking through how I'd like to do it. More on this in the coming weeks.

Lateness

- Exams are take home with a strict due date/time
- Projects will be submitted via Github Classroom.
  - You'll check out a starter repo, just as you all did in CS 240
- Late assignments are assessed a 10% per-day late penalty, with a maximum of four days.
- Students with legitimate reasons should contact the professor before the deadline to apply for an extension.
  - Failure to start on time is YOUR issue!

Academic Integrity

- Academic dishonesty, whether from *cheating*, *copying*, *fabricating results* or through *any other dishonest practice* will not be tolerated.
  - I take this personally - you should too.
- I assume by default that you are honest. Please don't disappoint me.

Course Outline

- Introduction to Networking (Chapter 1)
- Application layer (Chapter 2)
- Transport layer (Chapter 3)
- Network layer (Chapters 4 & 5)
- Link layer (some physical layer topics) (Chapter 6)
- Wireless, Mobility and Android (Chapter 7)
- Network security (Chapter 8)

So this is a networks class…

- What might that mean?
- Well, before we can answer the questions we'll consider, perhaps we should consider what questions we need to ask.
- Thought experiment. You have two devices, A and B, connected by two wires. One in each direction. These wires transmit information in binary. Messages can be transmitted from A to B or from B to A at any time. What kind of questions to you need to ask and solve in order to make this work?
  - Break into groups of 2 to discuss.

So this is a networks class…

- What might that mean?
- Well, before we can answer the questions we'll consider, perhaps we should consider what questions we need to ask.
- Another question: You now have many devices. Not all are directly connected to each other, but there is a path from any device to any other device. What questions do you need to ask and answer now?
  - Have at it. Hint: Networks are systems for transporting data. Thinking of other types of transportation systems might be helpful here.

Chapter 1: Roadmap

1.1 What is the Internet?

1.2 Network edge

1.3 Network core

1.4 Delay & loss in packet-switched networks

1.5 Protocol layers and their service models

1.6 Networks Under Attack

1.7 History of Computer Networking and the Internet

1.8 Summary

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

millions of connected computing devices:

hosts = end systems

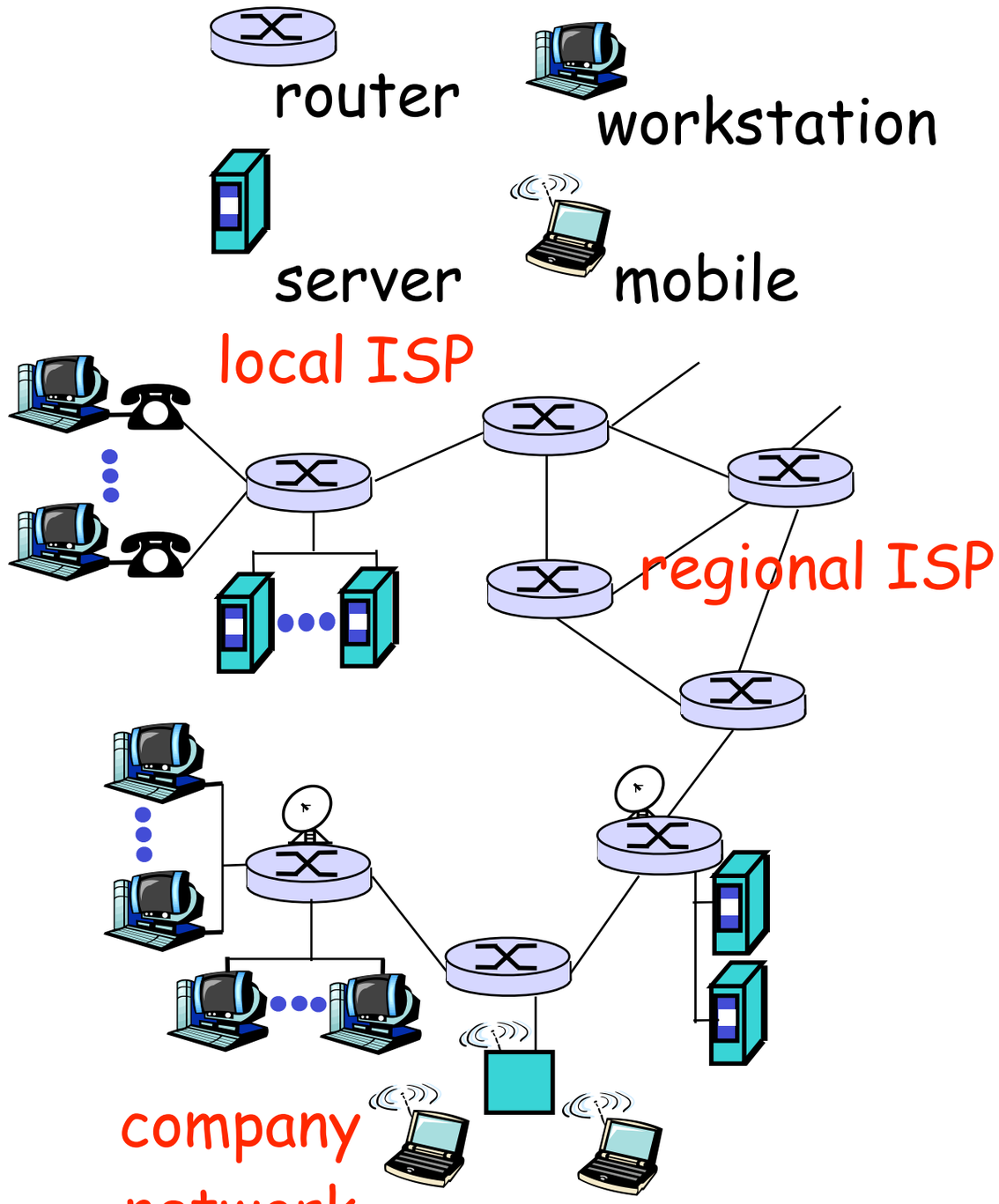
running network apps

communication links

fiber, copper, radio, satellite

transmission rate = **bandwidth**

routers: forward packets (chunks of data)



Cool Internet Appliances

"Fun" Internet-connected devices

Amazon Echo

Internet refrigerator

IP picture frame

Pacemaker & Monitor

Tweet-a-watt: monitor energy use

bikes

cars

scooters

Security Camera

Slingbox: remote control cable TV

Web-enabled toaster + weather forecaster

AR devices

Fitbit

diapers

Internet phones

Gaming devices

sensorized, bed mattress

Others?

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

protocols control sending, receiving of msgs

e.g., TCP, IP, HTTP, FTP, PPP

Internet:
"network of networks"

loosely hierarchical

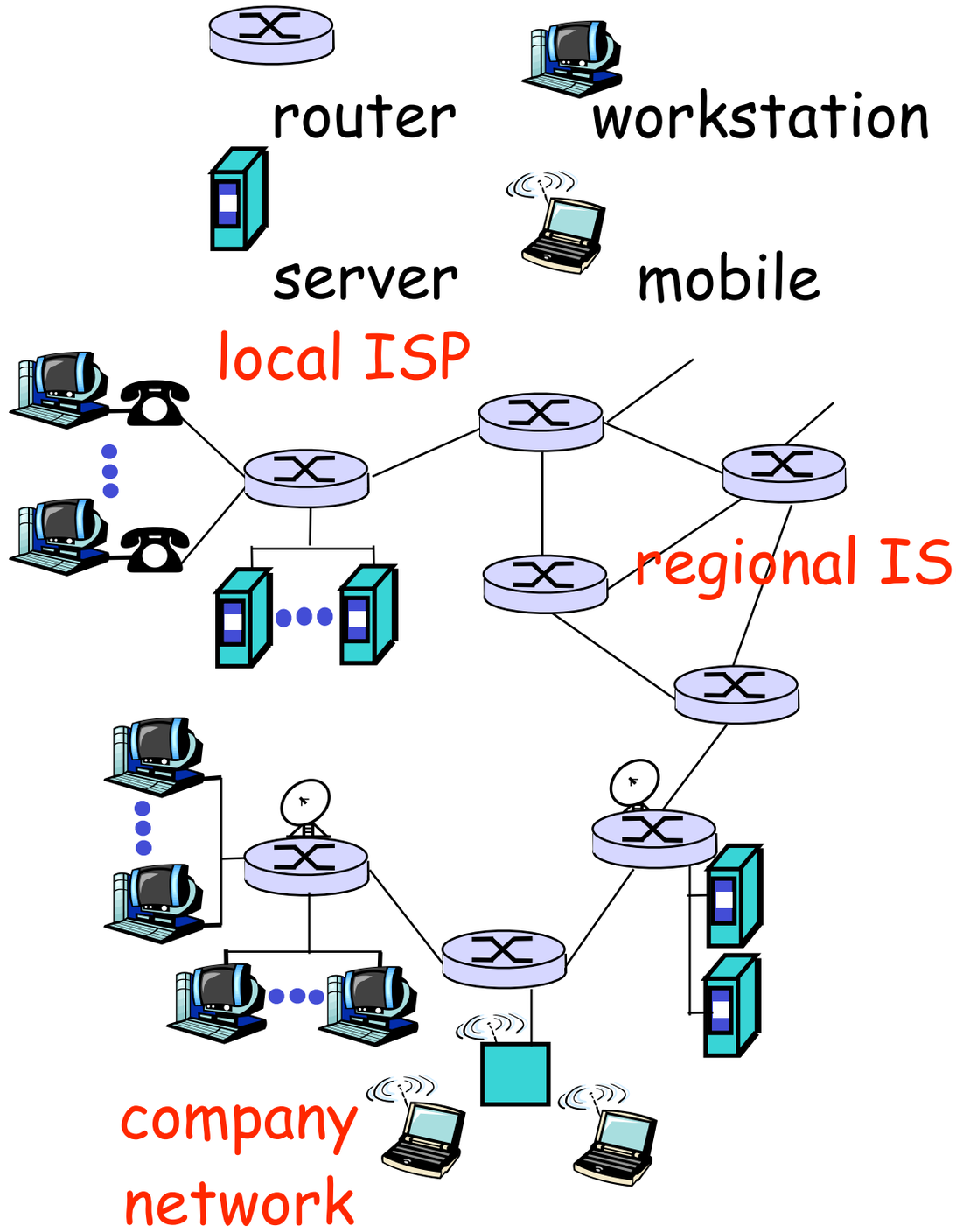
public Internet versus private intranet

Internet standards

RFC: Request for comments

IETF: Internet Engineering Task Force

(Check out IETF website)



What's the Internet: A Service View

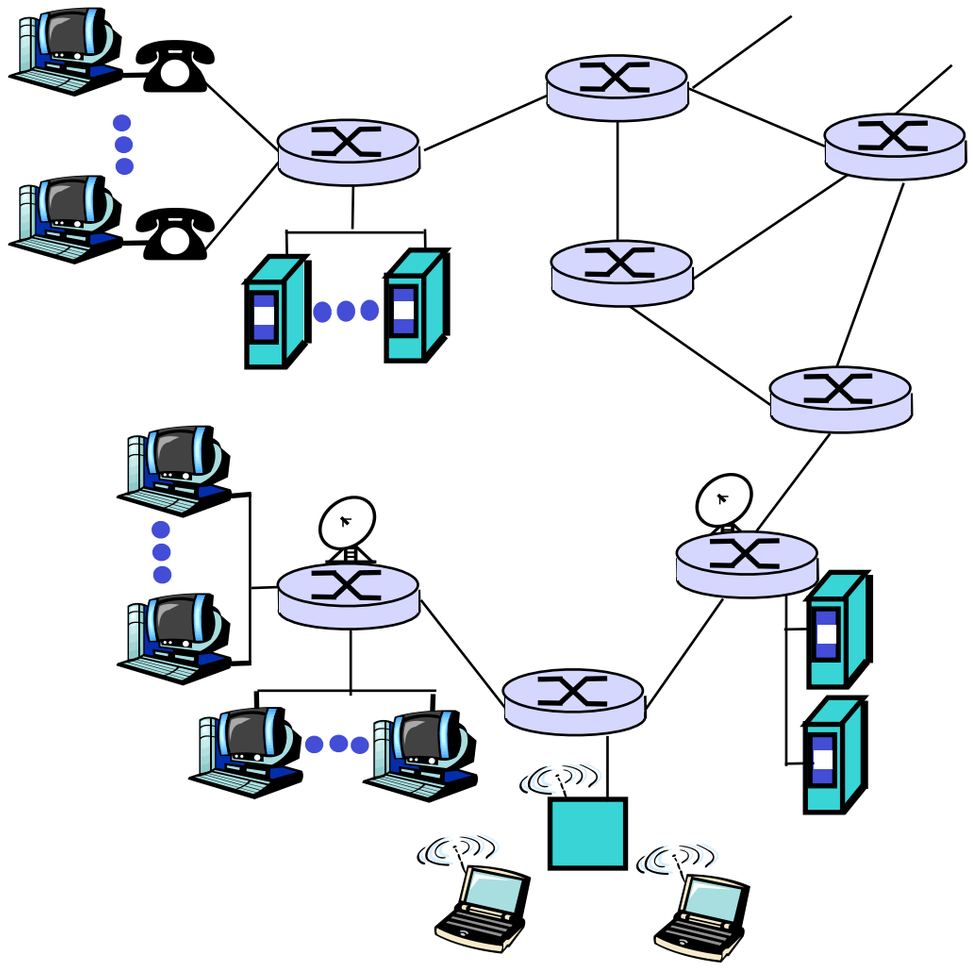
communications infrastructure enables distributed applications:

Web, email, games, e-commerce, file sharing, conferencing (Zoom)

communication services provided to apps:

Connectionless unreliable

connection-oriented reliable



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

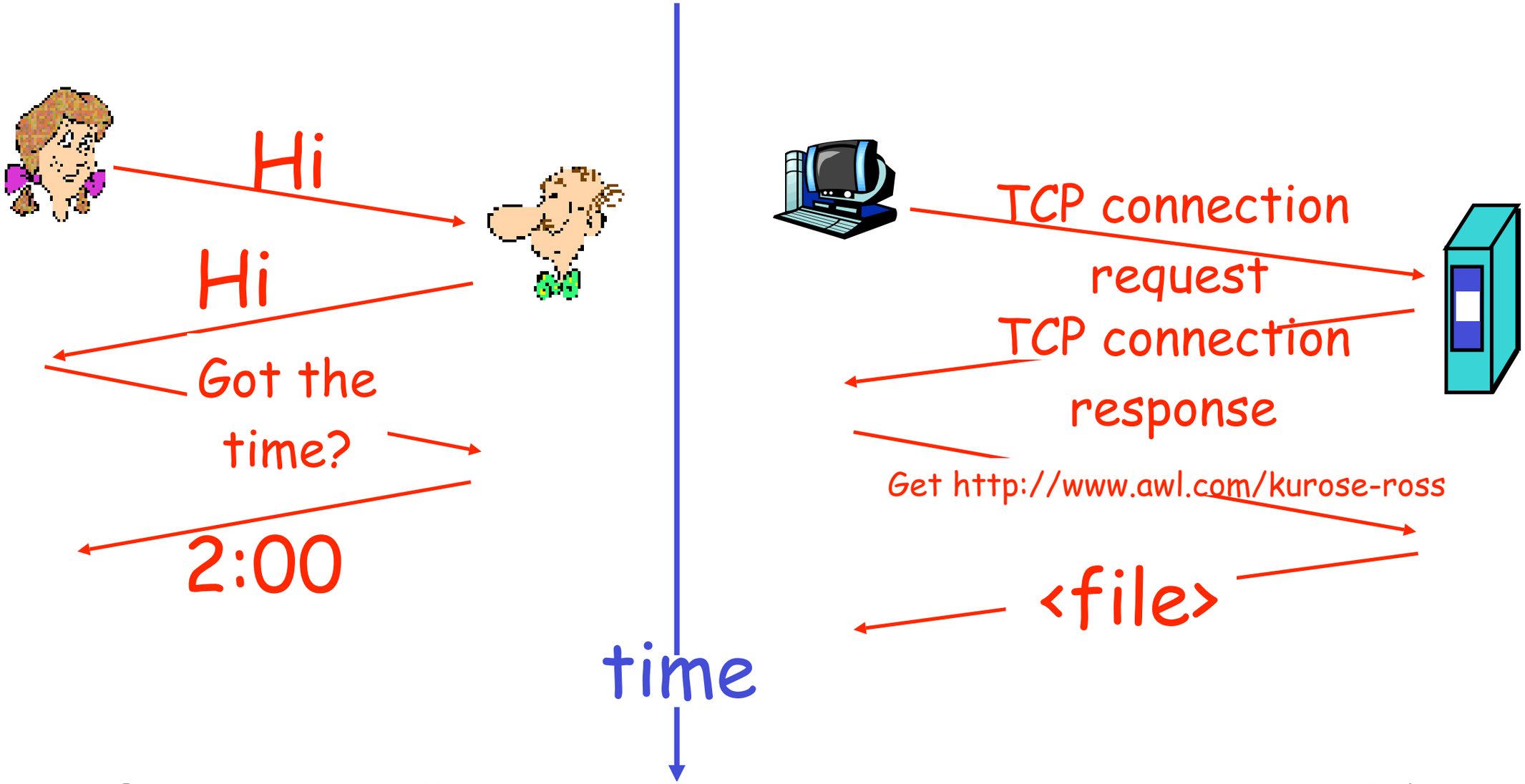
network protocols:

- 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?

- Example: A human protocol and a computer protocol:



- Question: What are some other human protocols?

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A Closer Look at Network Structure:

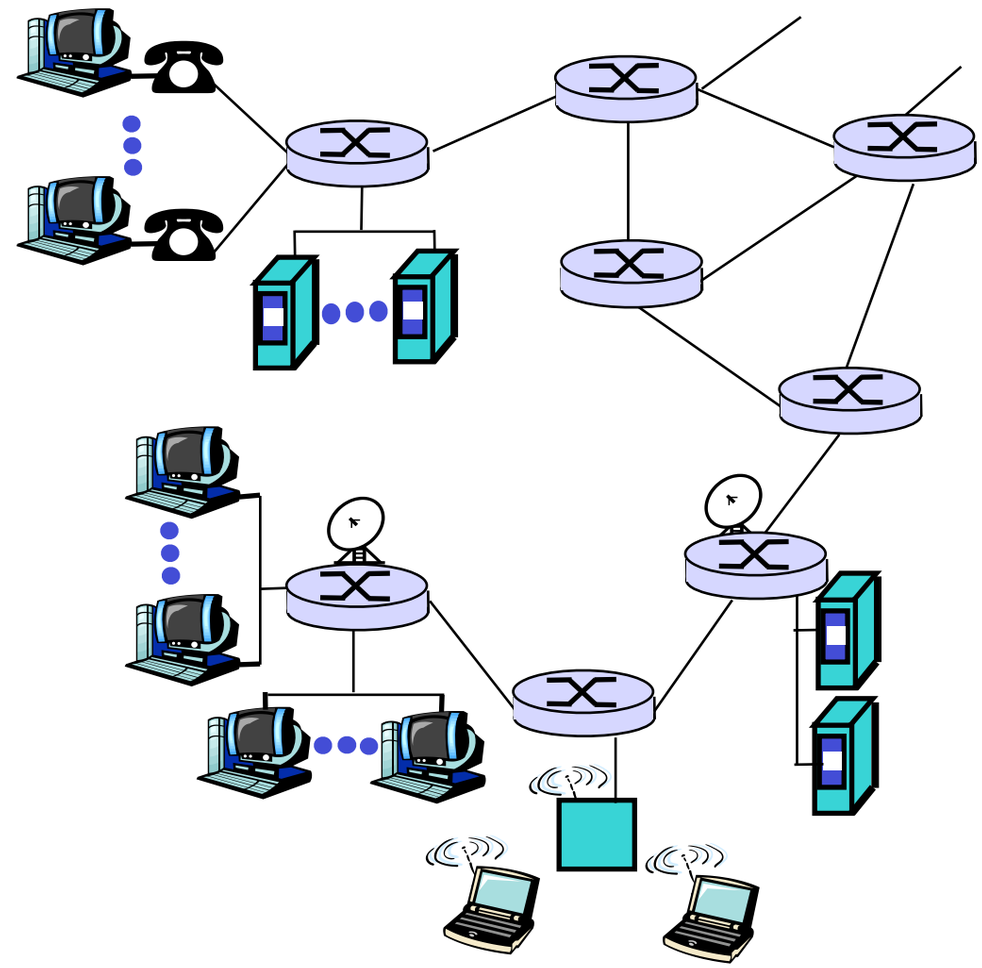
- network edge:

applications and hosts

- network core:
  - routers
  - network of networks

- access networks, physical media:

communication links



- Guided vs unguided

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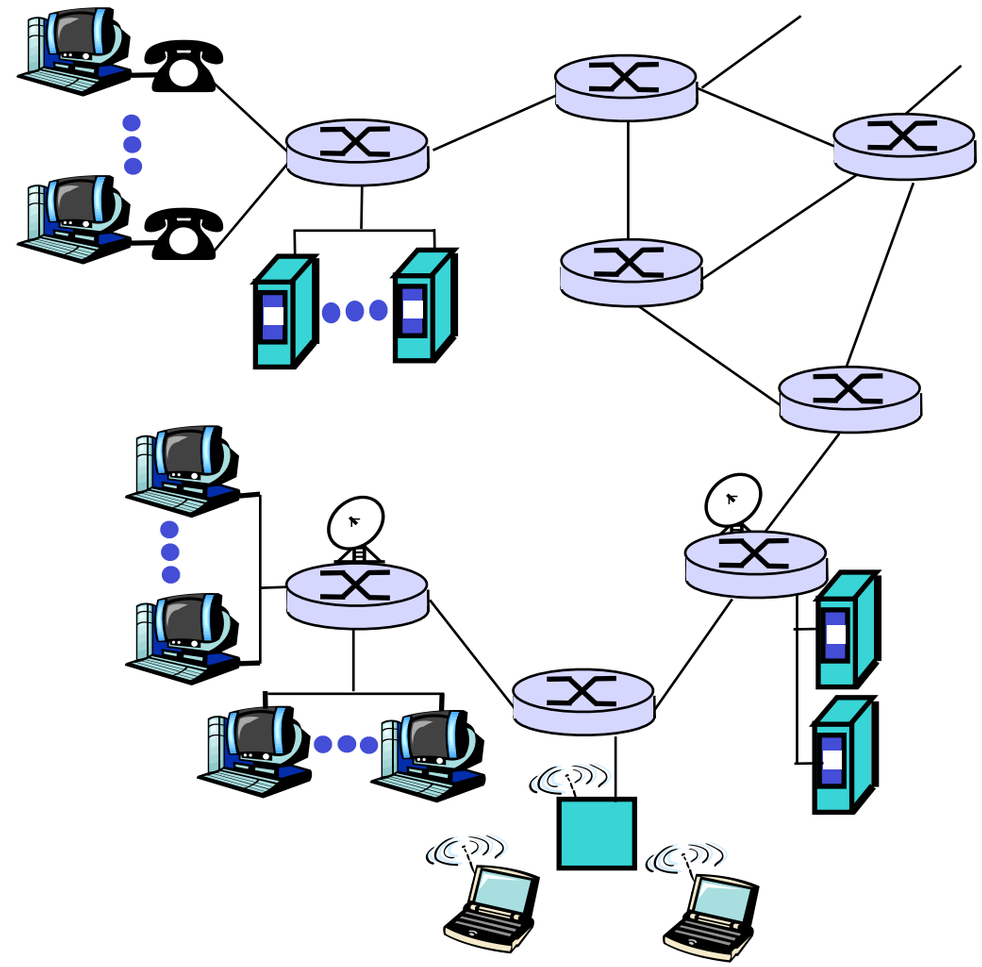


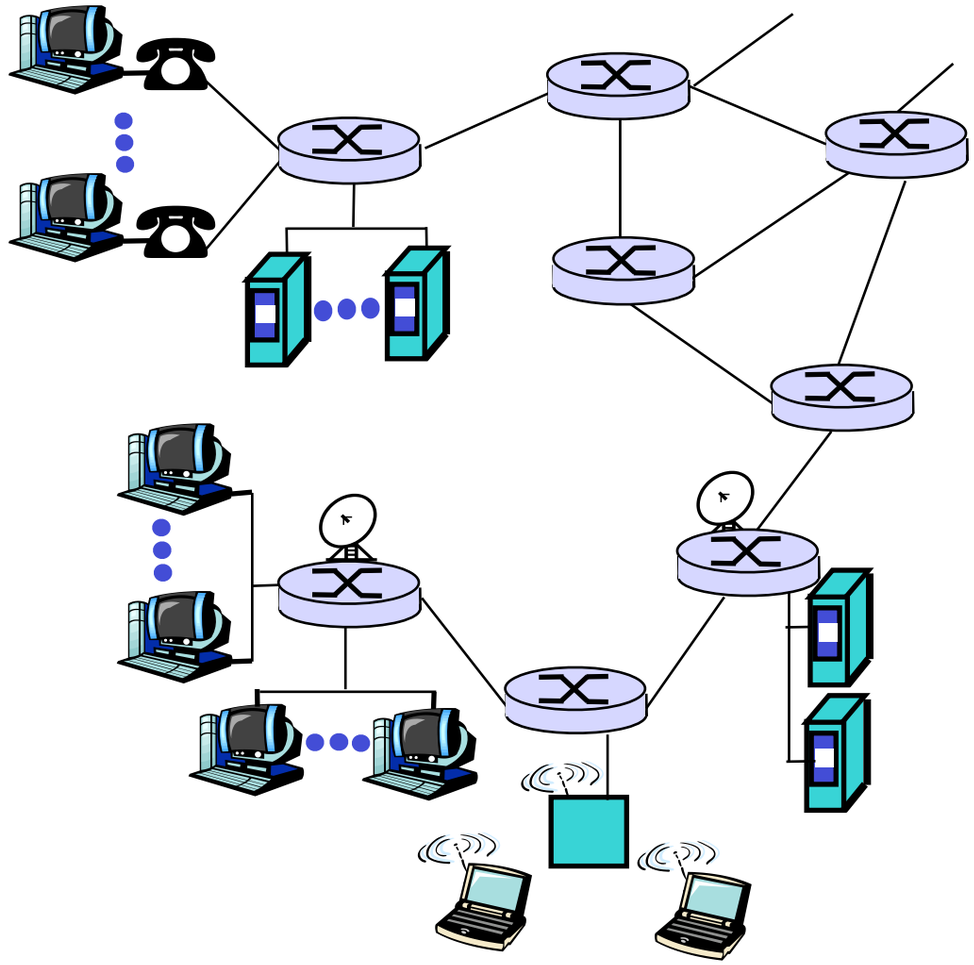
- access networks: the network the physically connects end system to the first router

A Closer Look at Network Structure:

- network edge: applications and hosts

- network core:
  - routers
  - network of networks

- physical media: twisted-pair copper wire, coaxial cable, multimode fiber-optic cable, terrestrial radio spectrum, satellite radio spectrum communication links



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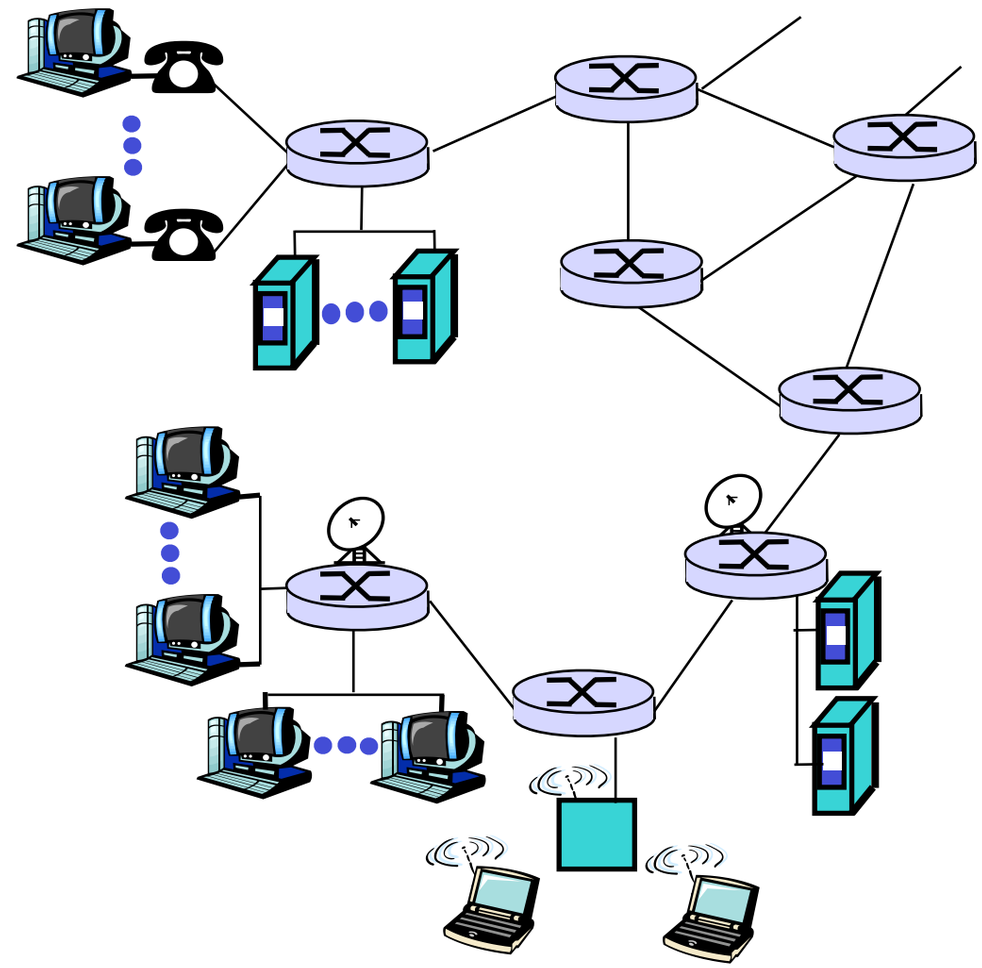
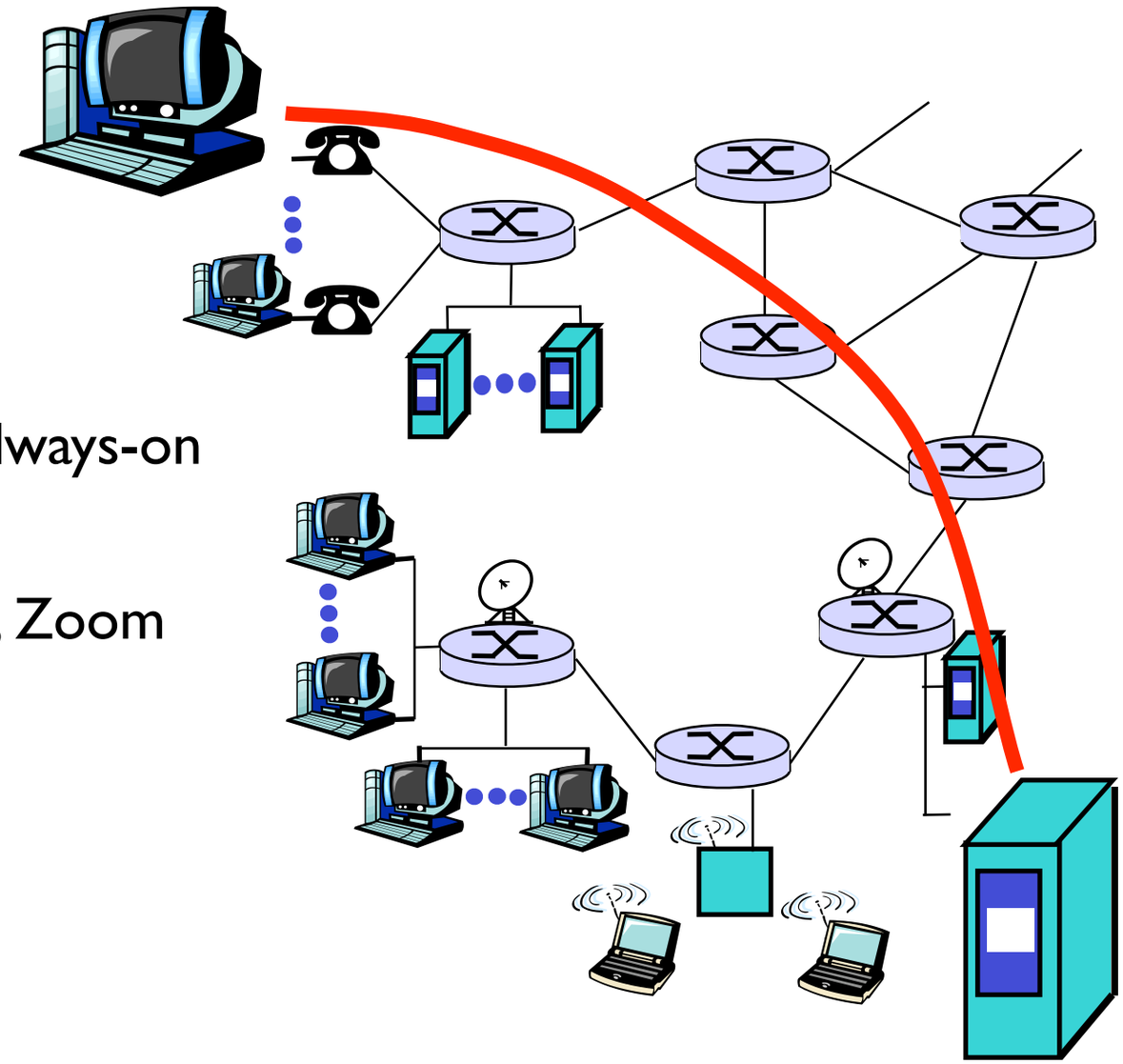


- Guided vs unguided

The Network Edge:

- end systems (hosts):
  - run application programs
  - e.g. Web, email, at "edge of network"
- client/server model
  - client host requests, receives service from always-on server
  - e.g. Web browser/server; email client/server, Zoom
- peer-peer model:
  - minimal (or no) use of dedicated servers
  - e.g. Skype, BitTorrent, KaZaA



Network Edge: Connection-Oriented Service

Goal: data transfer between end systems

- *handshaking*: setup (prepare for) data transfer ahead of time
  - Hello, hello back human protocol
  - set up "state" in two communicating hosts
- TCP - Transmission Control Protocol
  - Internet's connection-oriented service

TCP service [RFC 793]

- reliable, in-order byte-stream data transfer
  - loss: acknowledgements and retransmissions
- flow control:
  - sender won't overwhelm receiver
- congestion control:
  - senders "slow down sending rate" when network congested

Network Edge: Connectionless Service

- *Goal:* data transfer between end systems
  - same as before!

- UDP - User Datagram Protocol [RFC 768]:
  - connectionless
  - unreliable data transfer
  - no flow control
  - no congestion control

App's using TCP:

- HTTP (Web), FTP (file transfer), Telnet (remote login), SMTP (email)

App's using UDP:

- streaming media, teleconferencing, DNS, Internet telephony

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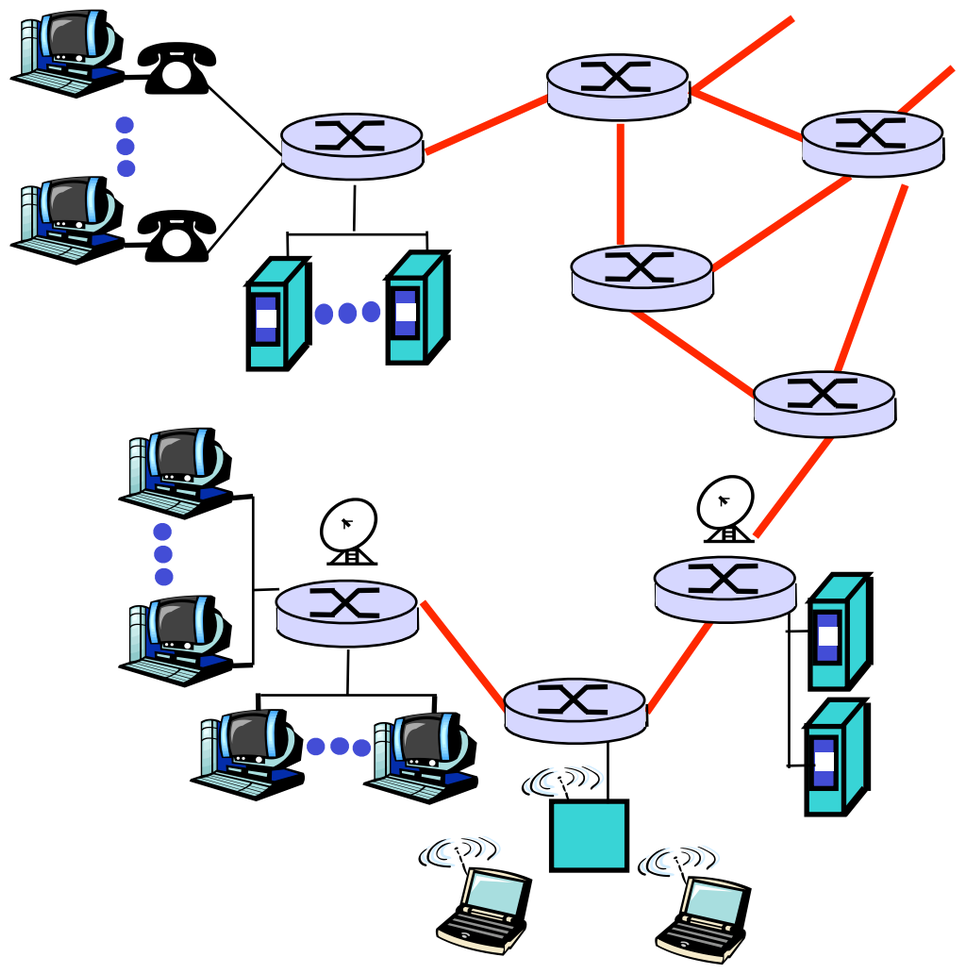
The Network Core

- mesh of interconnected routers

- *the* fundamental question: how is data transferred through net?

  - circuit switching: dedicated circuit per call: telephone net

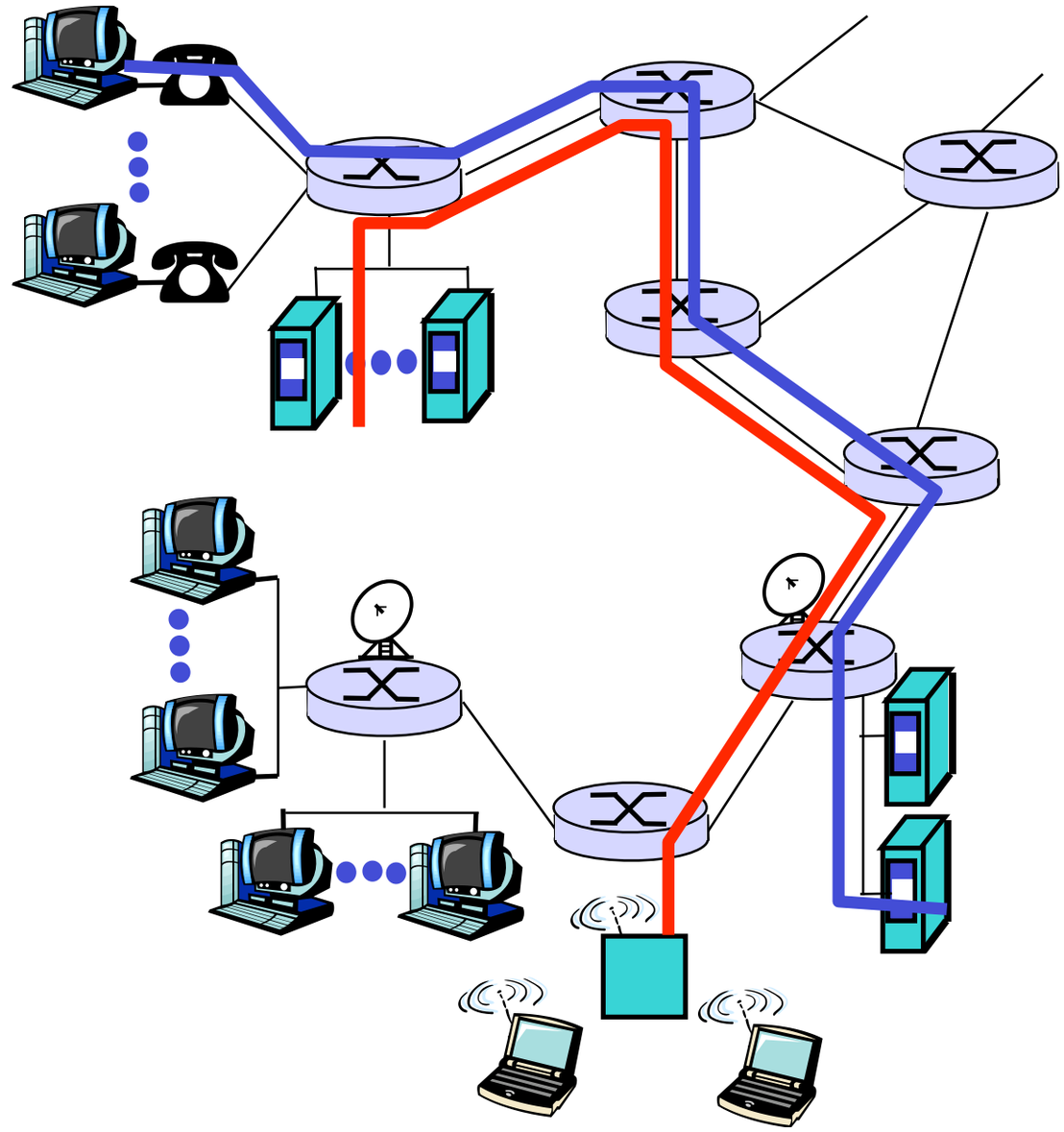
  - packet-switching: data sent thru net in discrete "chunks"



Network Core: Circuit Switching

End-end resources
reserved for "call"

- link bandwidth, switch capacity
- dedicated resources: no sharing
- circuit-like (guaranteed) performance
- call setup required



Network Core: Circuit Switching

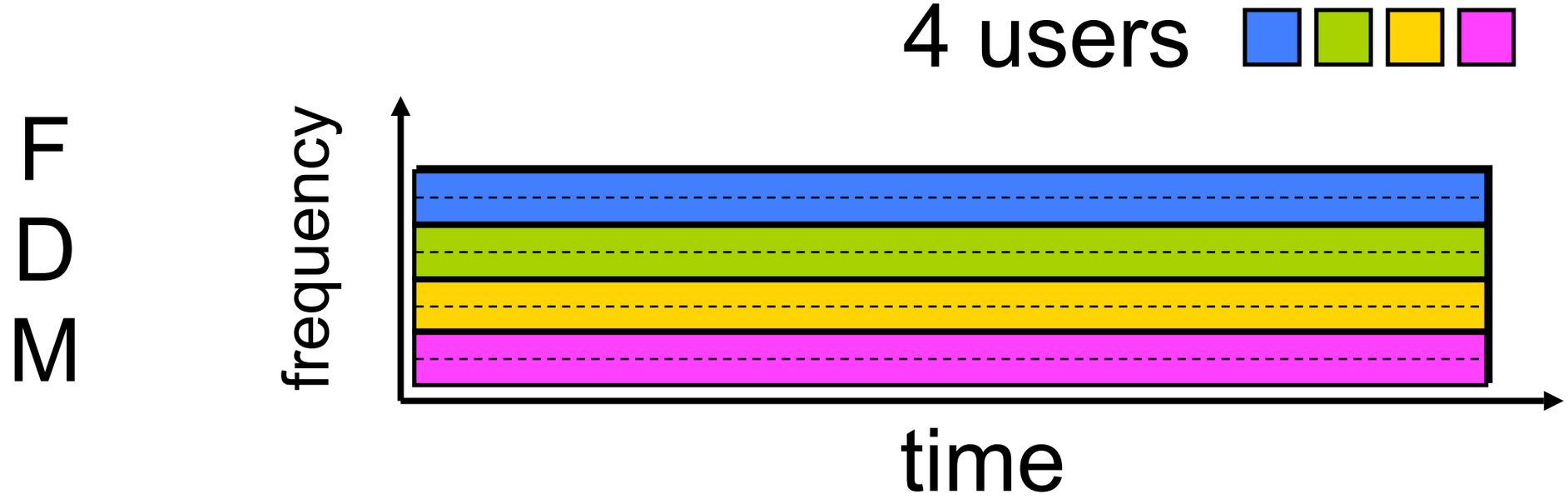
network resources
(e.g., bandwidth)
divided into "pieces"

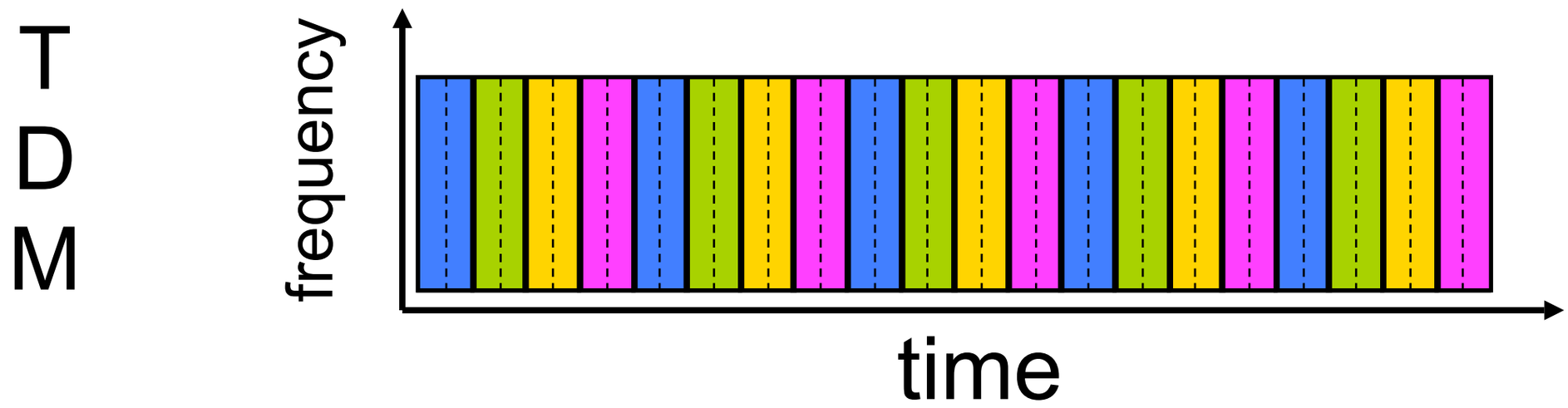
- pieces allocated to calls
- resource piece *idle* if not used by owning call *(no sharing)*

- dividing link bandwidth into "pieces"
  - frequency division
  - time division

Circuit Switching: FDM and TDM

Example:

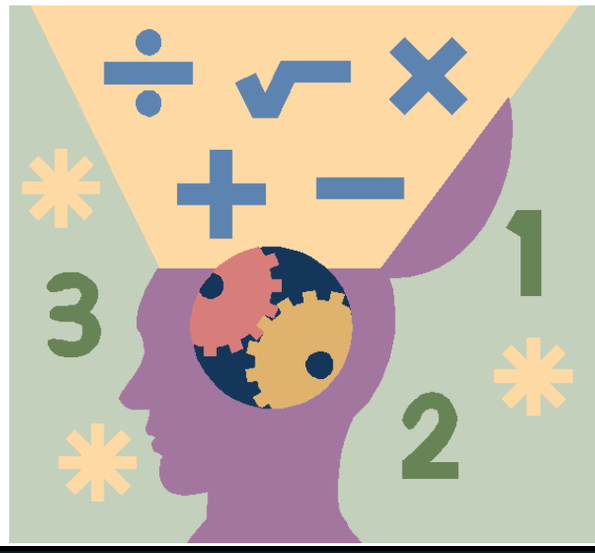




Numerical Example

- How long does it take to send a file of 640,000 bits from host A to host B over a circuit-switched network?
  - All links are 1.536 Mbps
  - Each link uses TDM with 24 slots/sec
  - 500 msec to establish end-to-end circuit

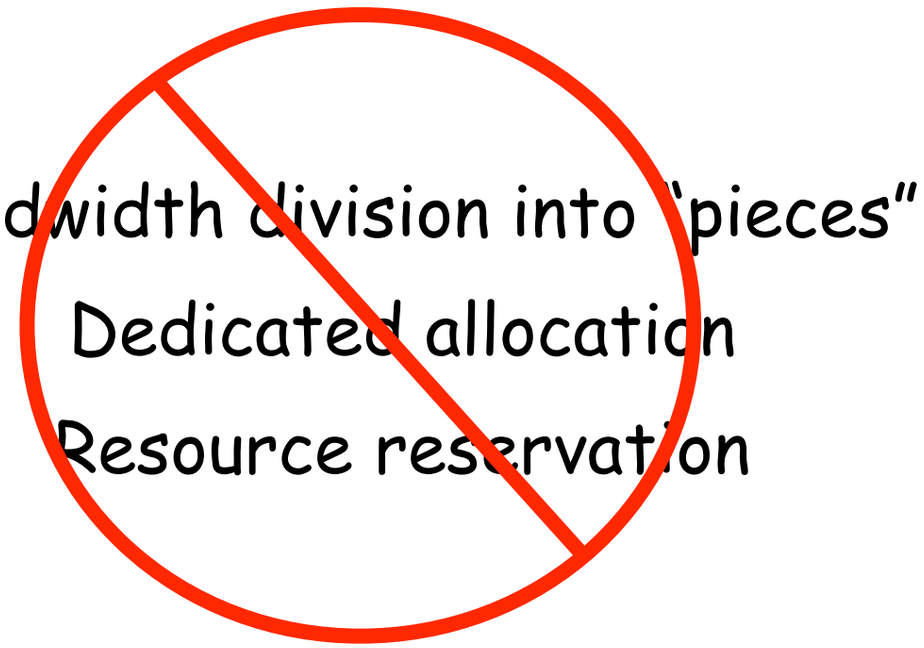
Let's work it out!



Network Core: Packet Switching

each end-end data stream
divided into *packets*

- user A, B packets *share* network resources
- each packet uses full link bandwidth
- resources used *as needed*



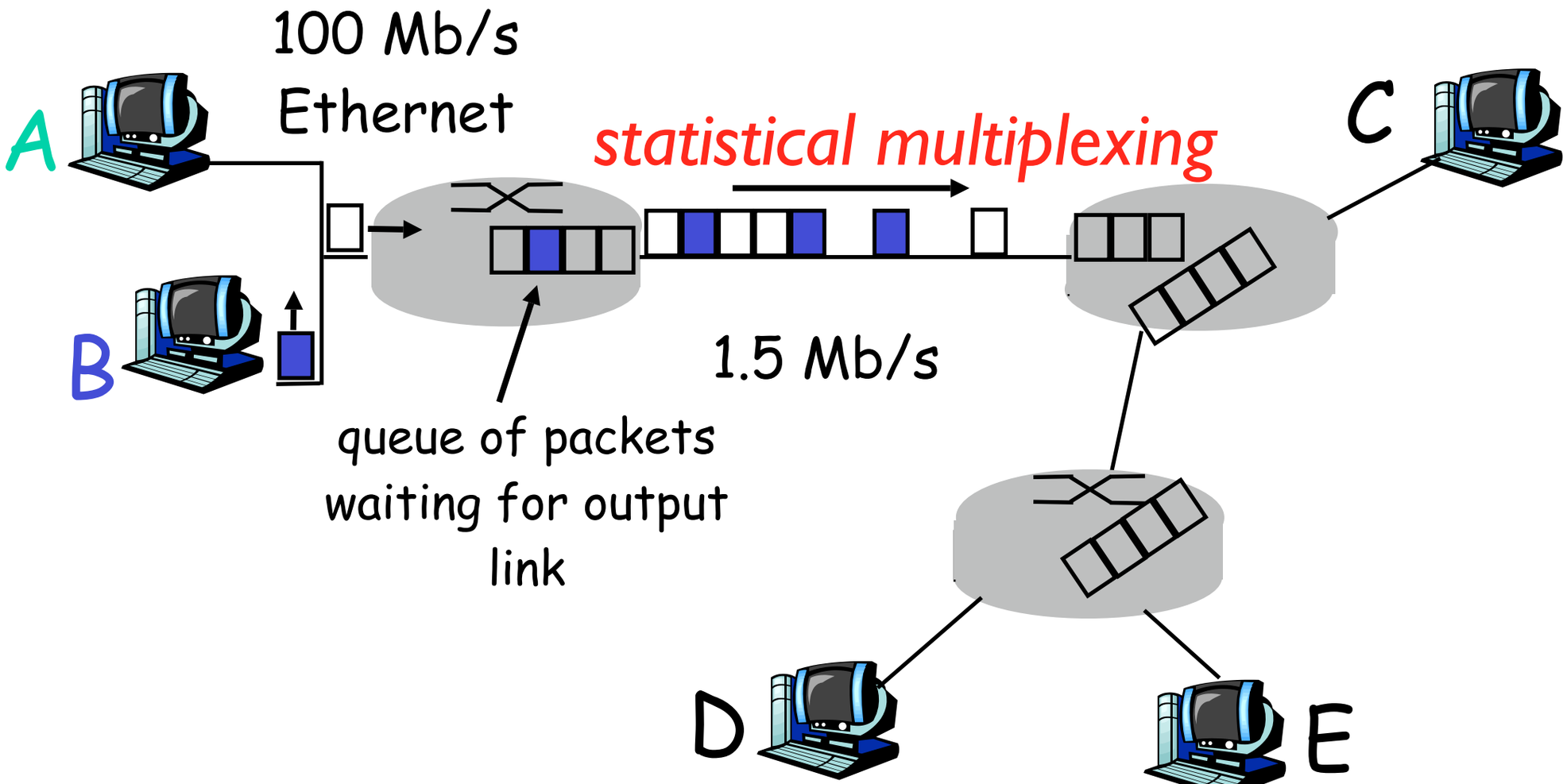
resource contention:

- aggregate resource demand can exceed amount available
- congestion: packets queue, wait for link use
- store and forward: packets move one hop at a time
  - Node receives complete packet before forwarding

Question:

- Which do you think would be better for the Internet and why?
  - Take 5 minutes to think about this. I want justification here!

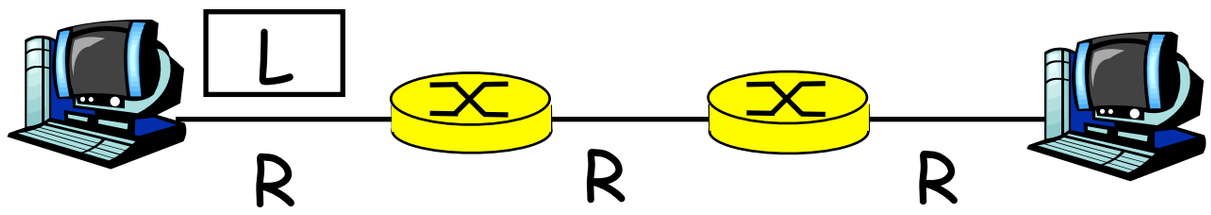
Packet Switching: Statistical Multiplexing



Sequence of A & B packets does not have fixed pattern, shared on demand : *statistical multiplexing* (slots allocated dynamically according to demand)

TDM: each host gets same slot in revolving TDM frame.

Packet-Switching: Store and Forward



- Takes L/R seconds to transmit (push out) packet of L bits on to link of R bps
- Entire packet must arrive at router before it can be transmitted on next link: *store and forward*
- delay = 3L/R (assuming zero propagation delay)

Example:

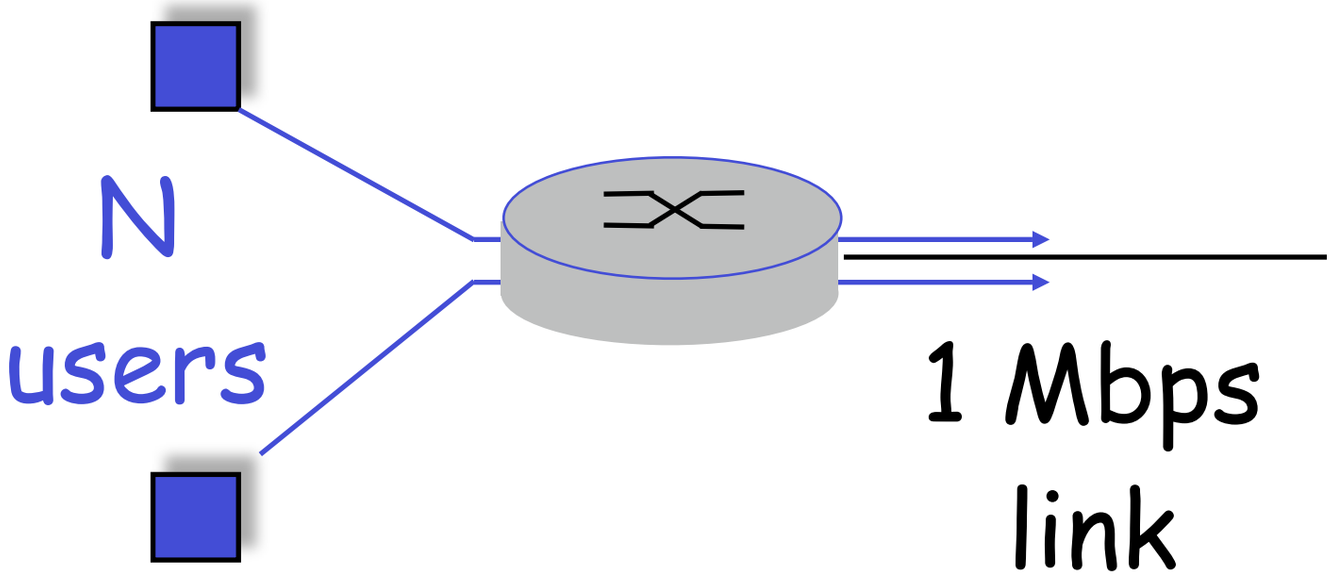
- L = 7.5 Mbits
- R = 1.5 Mbps
- delay = 15 sec

} more on delay shortly …

Packet Switching vs Circuit Switching

Packet switching allows more users to use network!

- 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 less than .0004



Q: how did we get value 0.0004?

Conclusion

- Is packet switching a "slam dunk" winner?
  - Great for bursty data
    - Resource sharing, simpler, no call setup
  - Excessive congestion: 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
- Q: Human analogies of reserved resources (circuit switching) vs on-demand allocation (packet switching)?

Conclusion

- Welcome to CMSC 332 - this will be a great class.
- Go get the books and start doing the reading (if you haven't already)!
- Regularly visit the webpage to figure out when homeworks and projects will be due.
- Questions?

"Okay, folks, that's a wrap!"