CS 332: Computer Networks

Introduction

Professor Doug Szajda

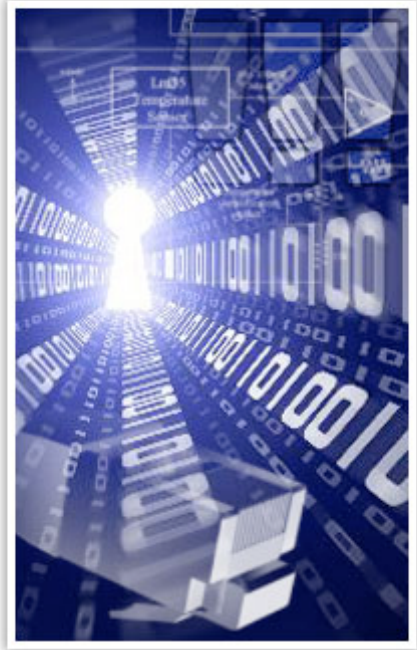
Thanks!

- I've taught this course many times, the most recent being Spring 2014. 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, many assignments, almost all of the slides, etc, are taken word for word.
- 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!)

What's this all about?

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.
- It even impacts you where you least expect it.
  - E.g. Shipping/Supply Chain Management

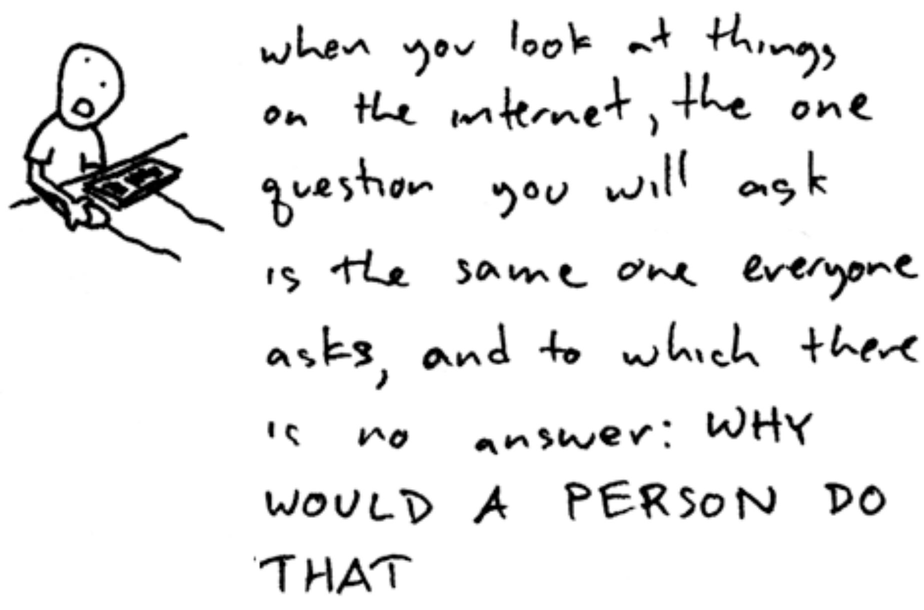


Why Do I Need This Course?

- 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 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.

What Topics Will We Cover?

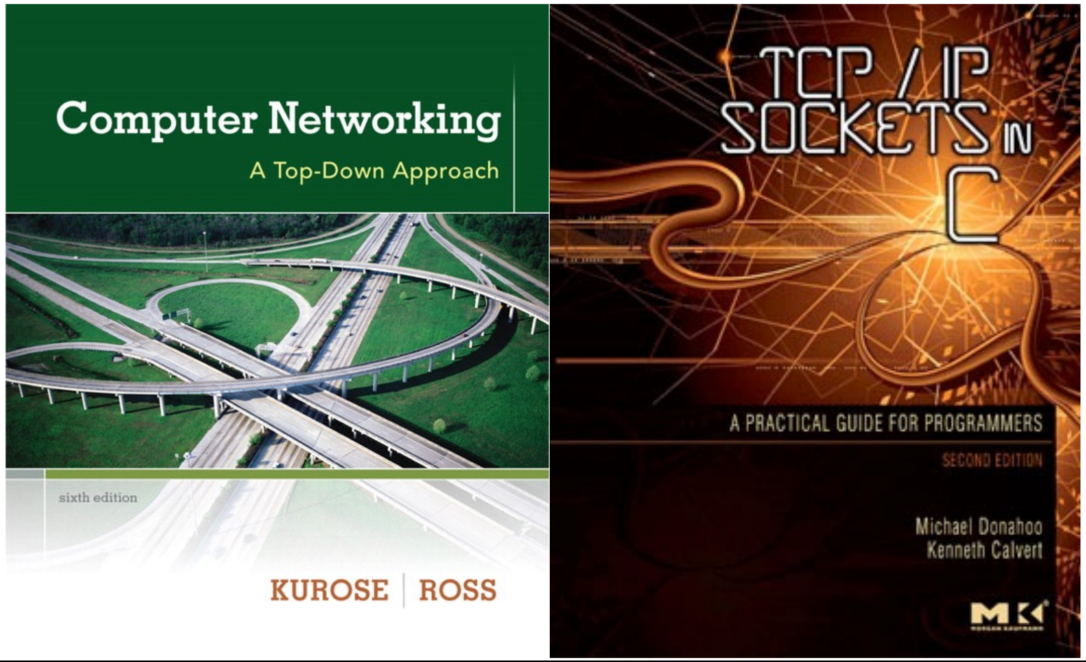
- This is an introductory course, so you will get a bit of everything:
    - TCP, IP, UDP, DNS, BGP, Email, P2P, Routing Algorithms, Congestion Control, Queuing Fundamentals, Network Management, Wireless, Cellular, Security, Ethics and lots more...

- I will be maintaining the course at: http://www.richmond.edu/~dszajda/classes/cs332/Spring_2016/index.html

- Assignments, slides and other information will be made available here.

Textbooks

- There are two *required* books for this class:
  - Computer Networking: A Top-Down Approach
  - 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 *three* 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 the specified language - no exceptions.
    - Generally C - check each assignment.
  - Check the website.

Course Calendar

- The course calendar contains a listing of readings, assignments and deadlines.
- 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*).

COURSE CALENDAR

Below is the calendar for this semester course. This is the preliminary schedule, which may need to be altered as the semester progresses. It is the *responsibility of the students* to frequently check this web-page for schedule, readings, and assignment changes. As the professor, I will attempt to announce any change to the class, but this web-page should be viewed as authoritative. If you have any questions, please contact me (contact information is available at the course homepage).

Date	Topic	Assignments Due	Readings/Discussions (do readings before class)	Slides
01/11/11	Introduction		Syllabus (link)	
01/13/11	Introduction		Chapter 1 Homework 1 Assigned	
01/18/11	Introduction/Application Layer		End-To-End Arguments in System Design (link) Chapter 2.1	
01/20/11	Web and FTP		Chapter 2.2, 2.3 Project 1 Assigned	
01/25/11	Email and DNS		Chapter 2.4, 2.5	
01/27/11	P2P and Sockets (1)	Homework 1	Chapter 2.6	
02/01/11	Sockets (2)			
02/03/11	Transport Layer	Project 1	Chapter 3.1 - 3.3	
02/08/11	Reliable Data Transfer		Chapter 3.4	
02/10/11	TCP (1)		Chapter 3.5, 3.6 Project 2 Assigned	
02/15/11	TCP (2)		Chapter 3.6, 3.7	
02/17/11	Network Layer		Chapter 4.1 - 4.3	
02/22/11	IP		Chapter 4.4	
02/24/11	Routing Algorithms		Chapter 4.5	
03/01/11	Internet Routing/Multicast		Chapter 4.6, 4.7 Homework 2 Assigned	
03/03/11	Link Layer (1)	Project 2	Chapter 5.1 - 5.3	
03/08/11	Link Layer (2)		Chapter 5.4 - 5.6	
03/10/11	Midterm Review	Homework 2		
03/15/11	**Midterm Exam**			
03/17/11	Link Layer (3)		Chapter 5.7 - 5.10 Project 3 Assigned	
03/22/11	**Spring Break**			
03/24/11	**Spring Break**			
03/29/11	Physical Layer	Project 3	Homework 3 Assigned	
03/31/11	Android Overview		TBA Project 4 Assigned	
04/05/11	Wireless		Chapter 6.1 - 6.4	
04/07/11	Mobility		Chapter 6.5 - 6.9	
04/12/11	Security		Chapter 8.1, 8.2	
04/14/11	Authentication		Chapter 8.3 - 8.4	
04/19/11	Security Protocols (1)	Homework 3	Chapter 8.5 - 8.6 S. Bellovin, Security Problems in the TCP/IP Protocol Suite. Computer Communications Review 2:19, pp. 32-48, April 1989. (link)	
04/21/11	Security Protocols (2)/Operational Security	Project 4	Chapter 8.7 - 8.9	
04/26/11	Multimedia Networking		Chapter 7.1 - 7.4	
04/28/11	Final Exam Review		TBA	
05/05/11	**Final Exam - TBA**			

Expectations

- This is going to be *a hard course*. The key to success is sustained effort. Failure to keep up with readings and assignments will result in poor grades and more critically, little understanding of the material.

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

Grading

- Grading in this class will be distributed as follows:
  10% Homework
  30% Projects
  25% Midterm
  30% Final
  5% Class Participation
- I reserve the right to give "Unannounced Learning Experiences".
- *You get the grade that you earn, so be sure that you earn a grade you like.*

Lateness

- All homework is due at the beginning of class.
- Projects must be submitted as an attachment to an email sent to a special Box email.
- Late assignments are assessed a 15% 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.
  - Unless the problem is apocalyptic, don't give me excuses.

Academic Integrity

- As scientists and engineers, we must trust each other to make progress.

- Numerous examples exist to show the consequences of this breakdown.
  - Jan Hendrik Schon…

- 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.

Course Outline

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

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

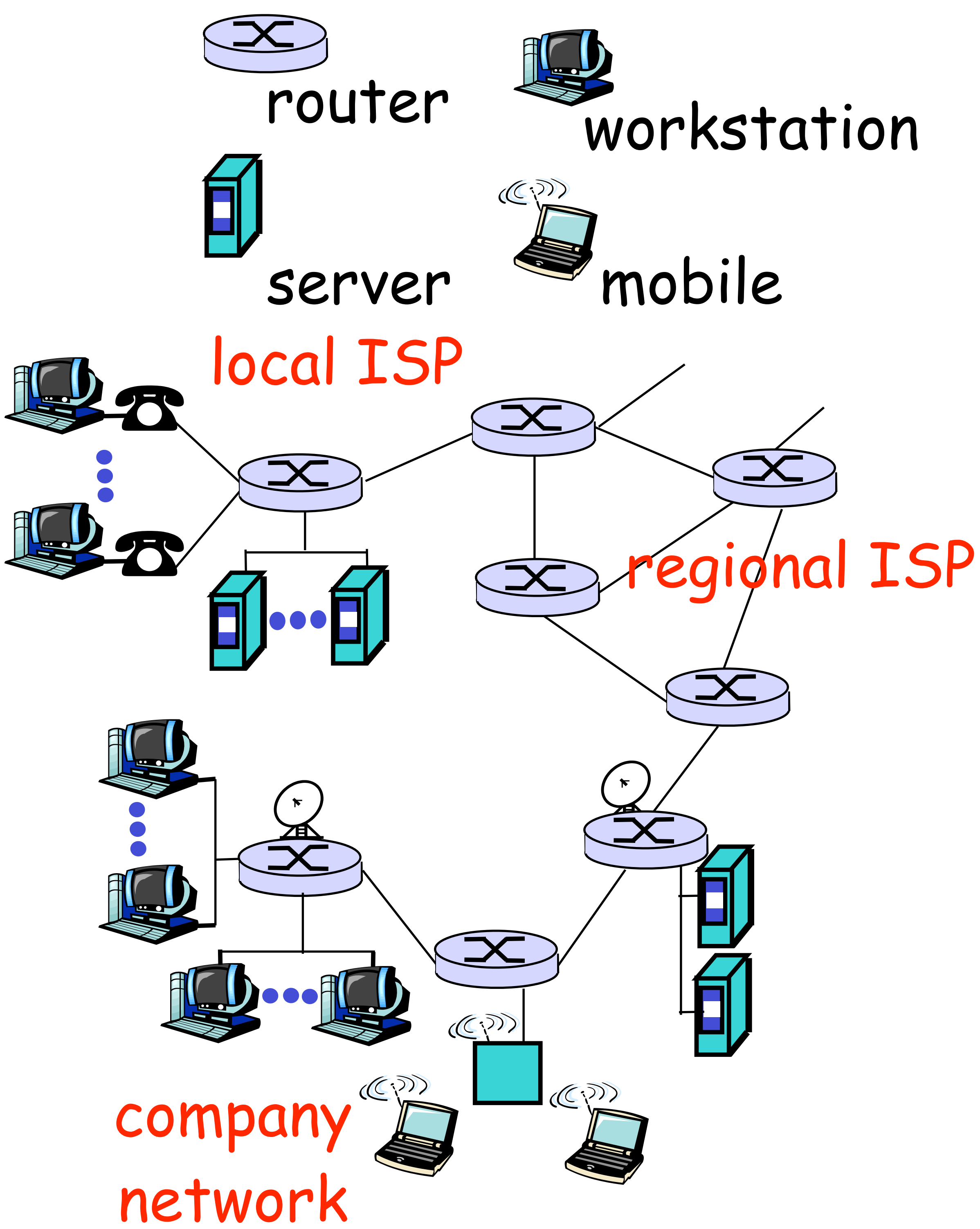
running network apps

communication links

fiber, copper, radio, satellite

transmission rate = bandwidth

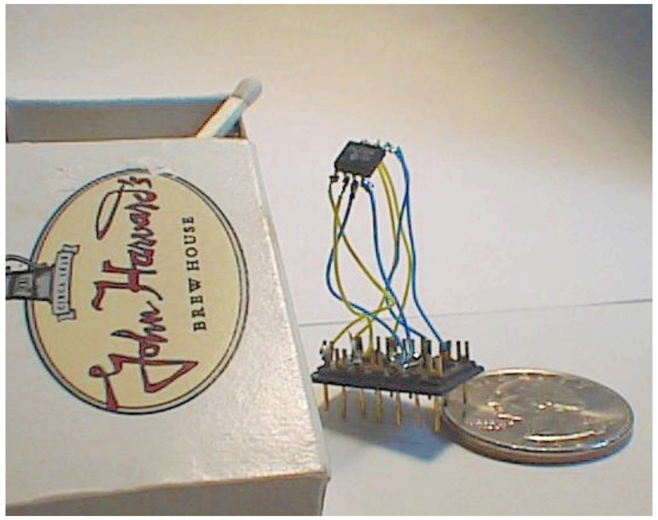
routers: forward packets (chunks of data)



Cool Internet Appliances

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

Web-enabled toaster +
weather forecaster



World’s smallest web server
http://www-ccs.cs.umass.edu/~shri/iPic.html

Internet phones

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"

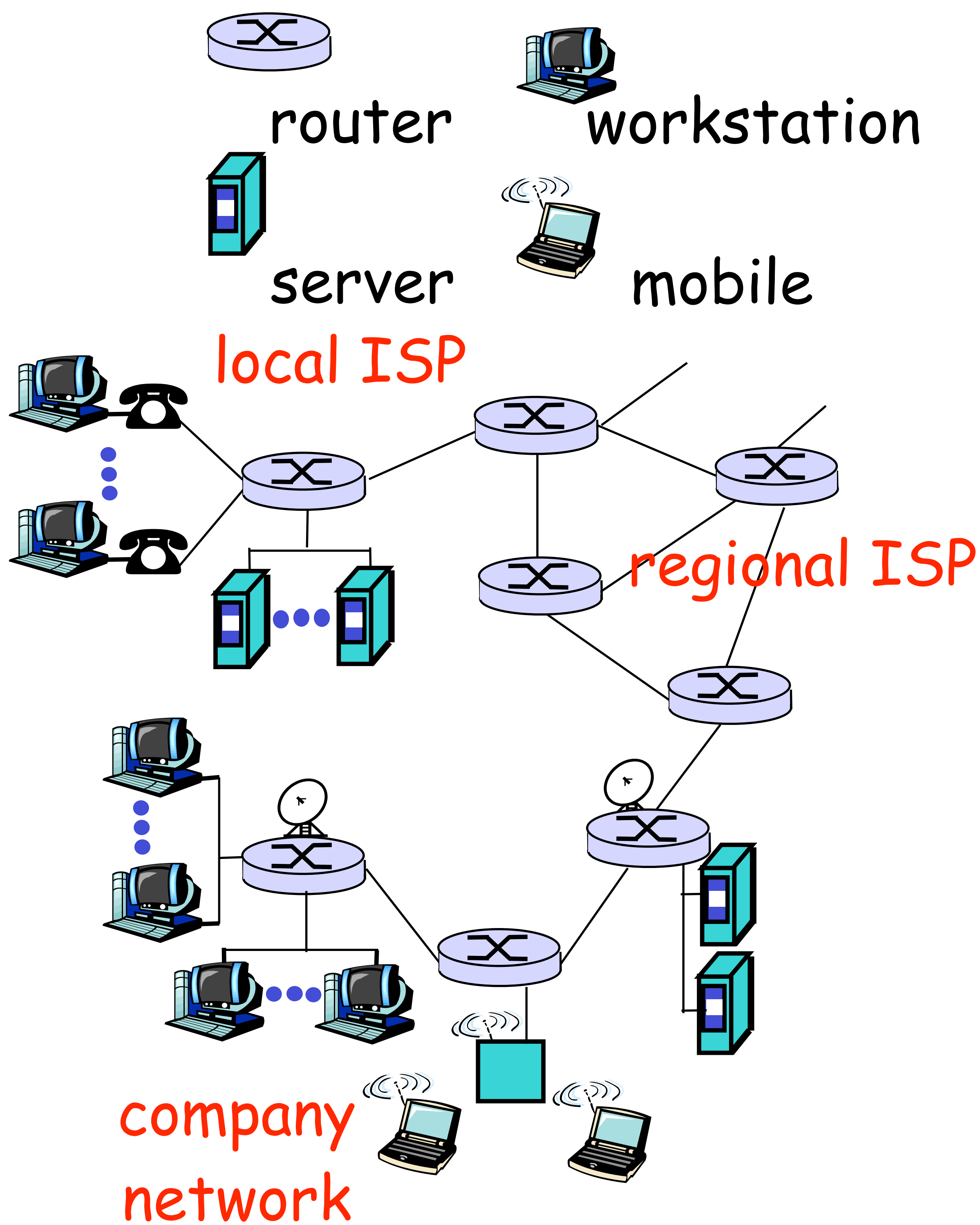
loosely hierarchical

public Internet versus private intranet

Internet standards

RFC: Request for comments

IETF: Internet Engineering Task Force



What's the Internet: A Service View

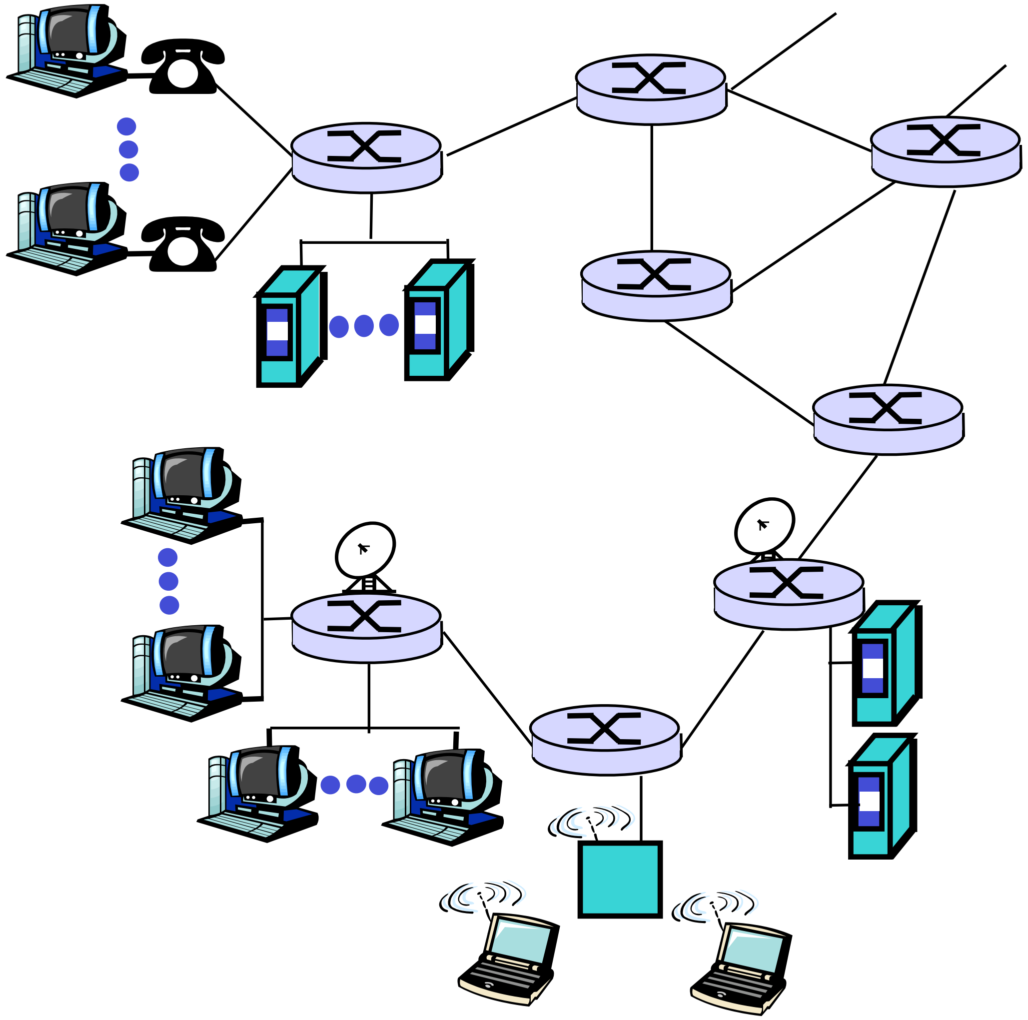
communications infrastructure enables distributed applications:

Web, email, games, e-commerce, file sharing

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

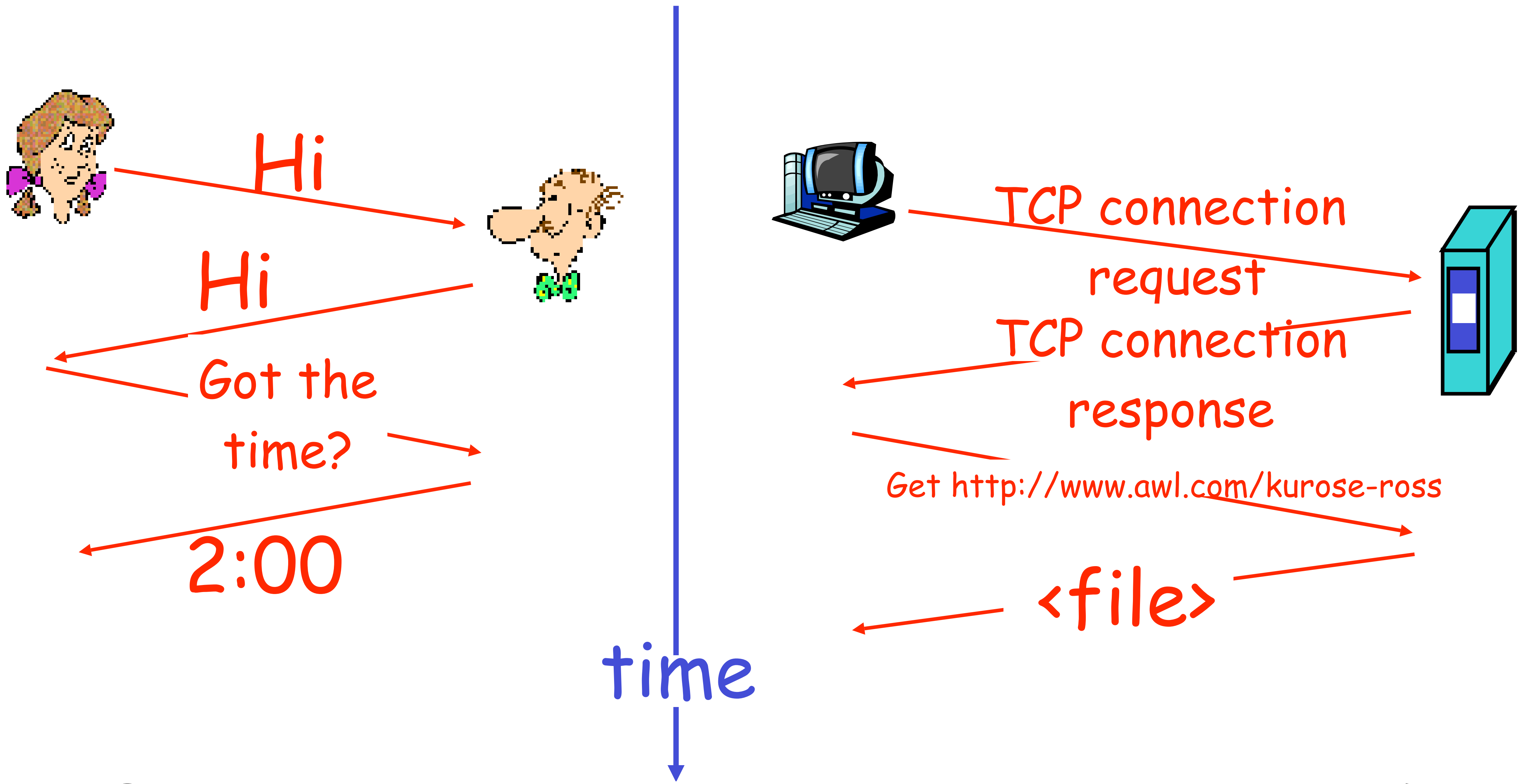
network protocols:

- 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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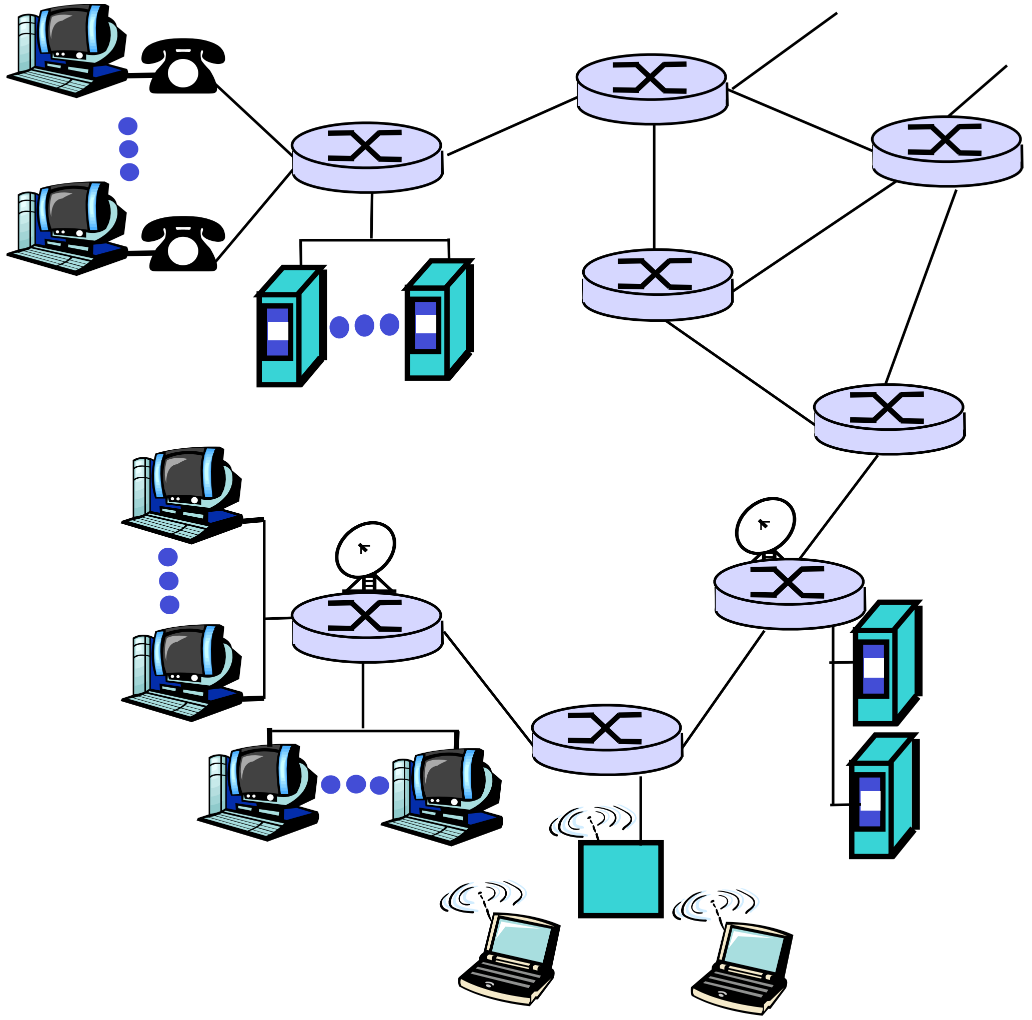
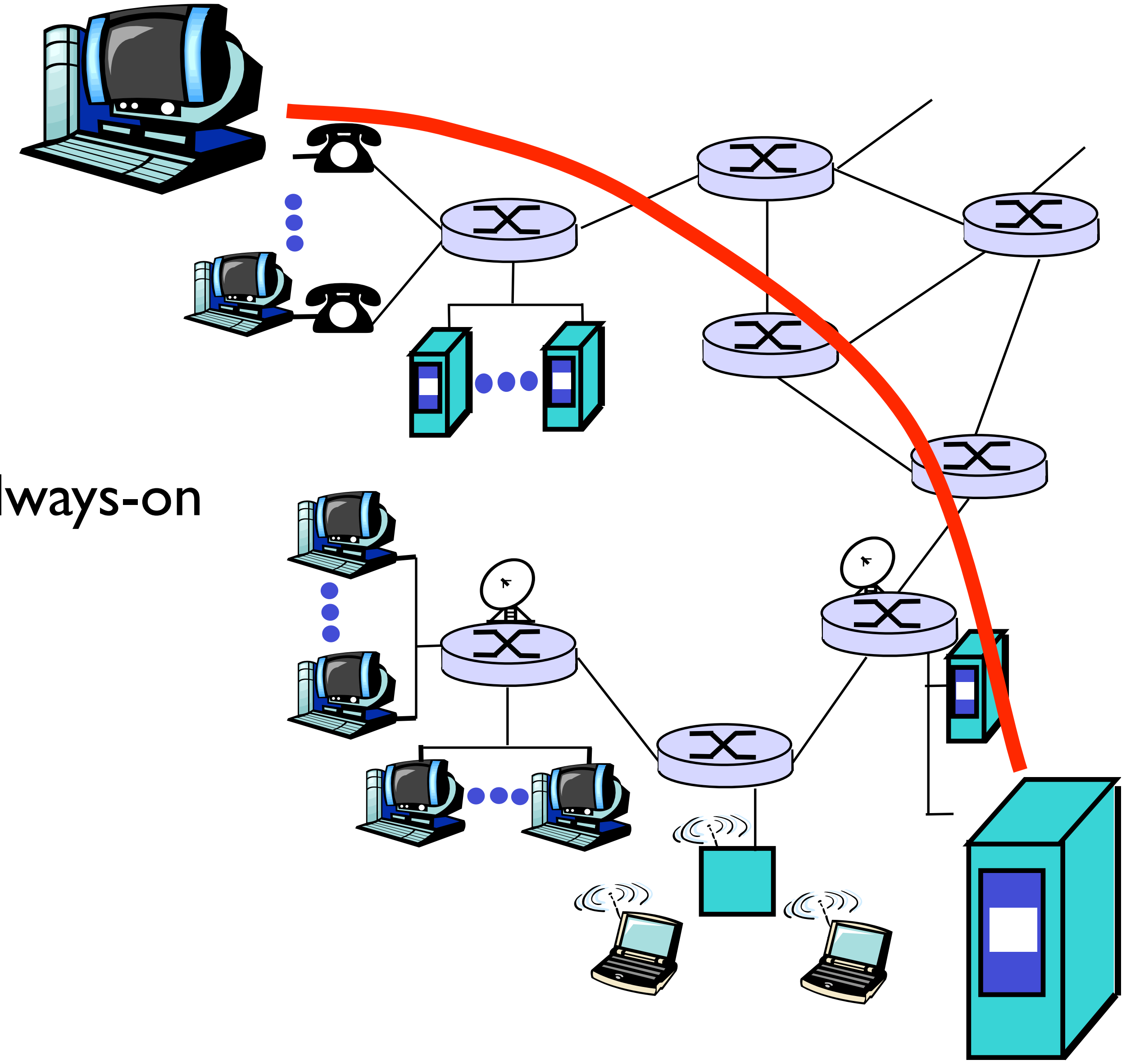
A Closer Look at Network Structure:

- network edge: applications and hosts
- network core:
  - routers
  - network of networks
- access networks, physical media: communication links



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
- 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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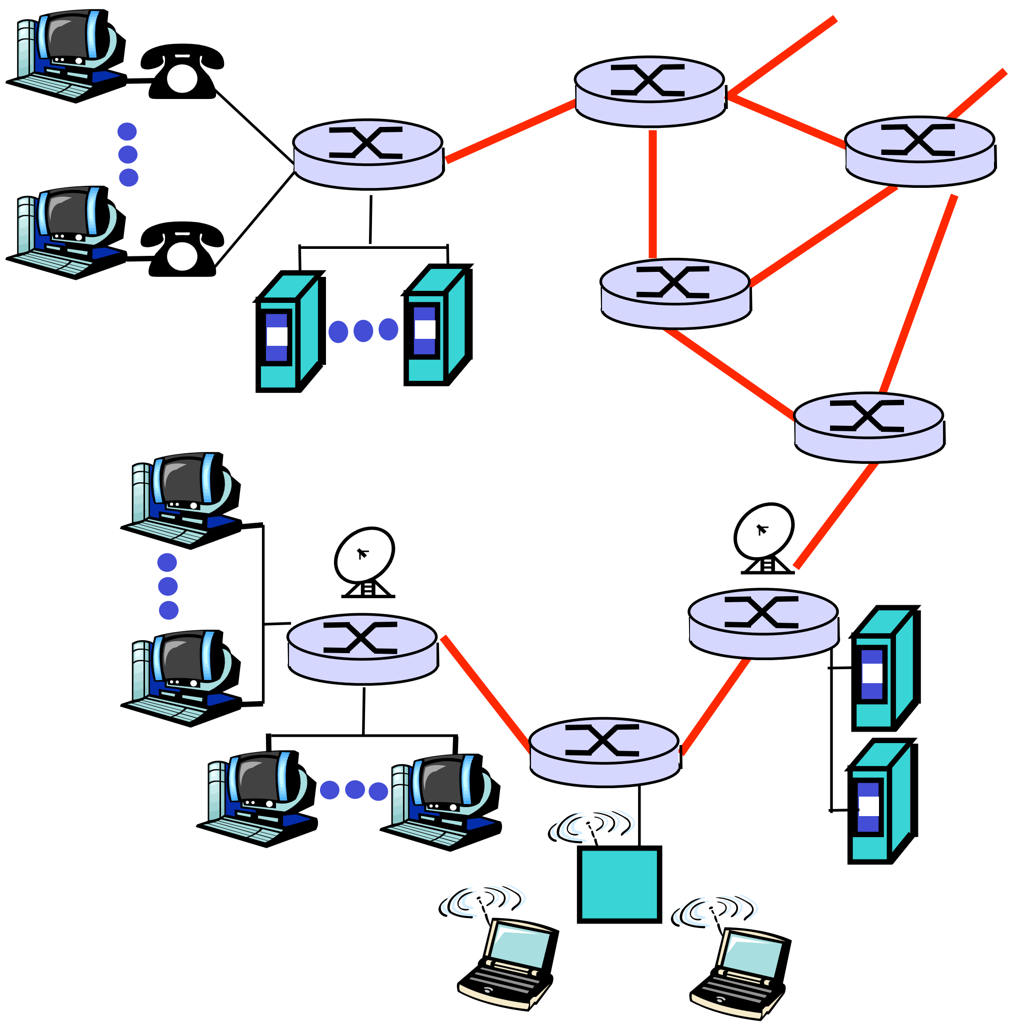
The Network Core

- mesh of interconnected routers

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

  - circuit switching: dedicated circuit per call: telephone net

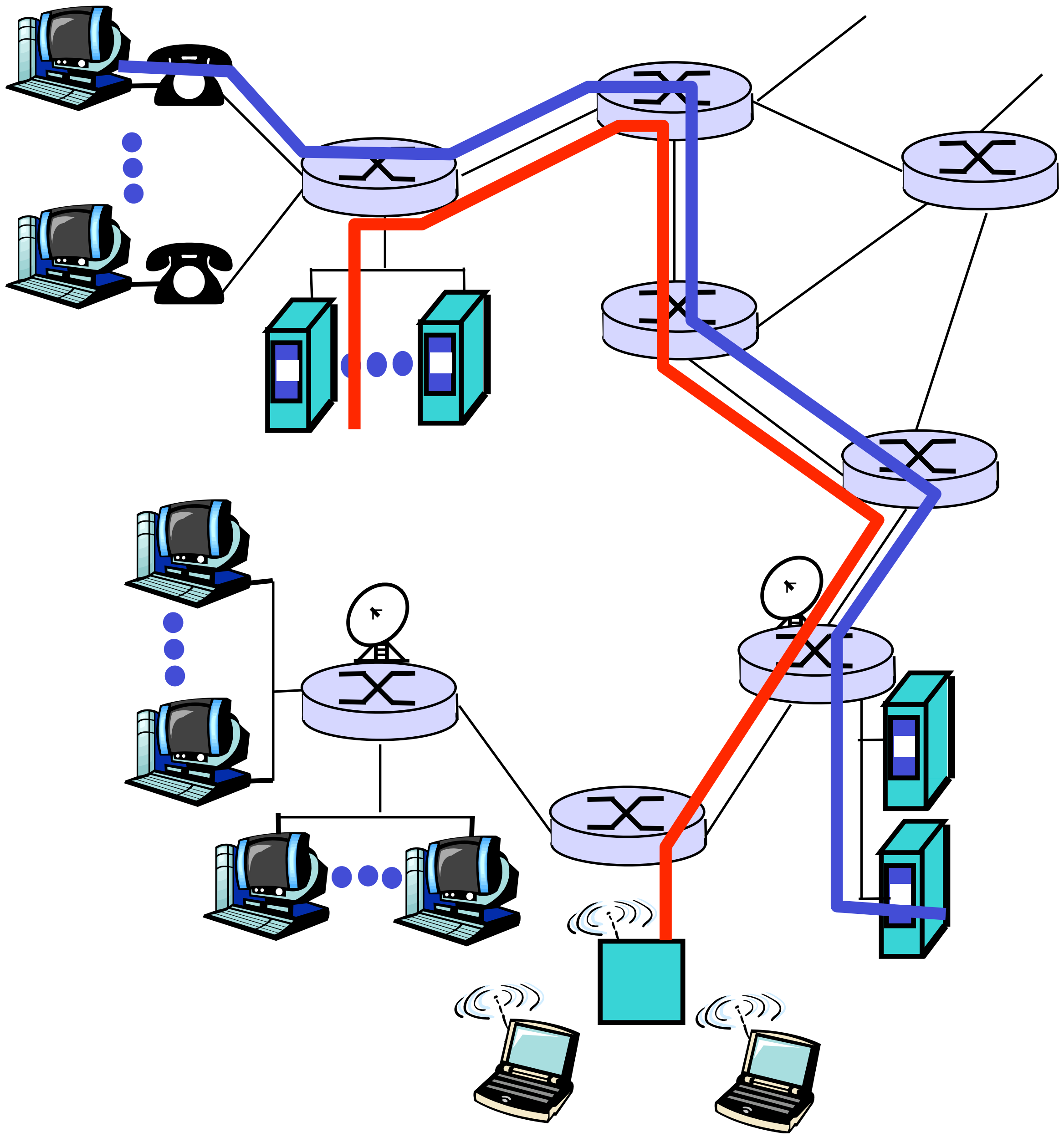
  - packet-switching: data sent thru net in discrete "chunks"



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

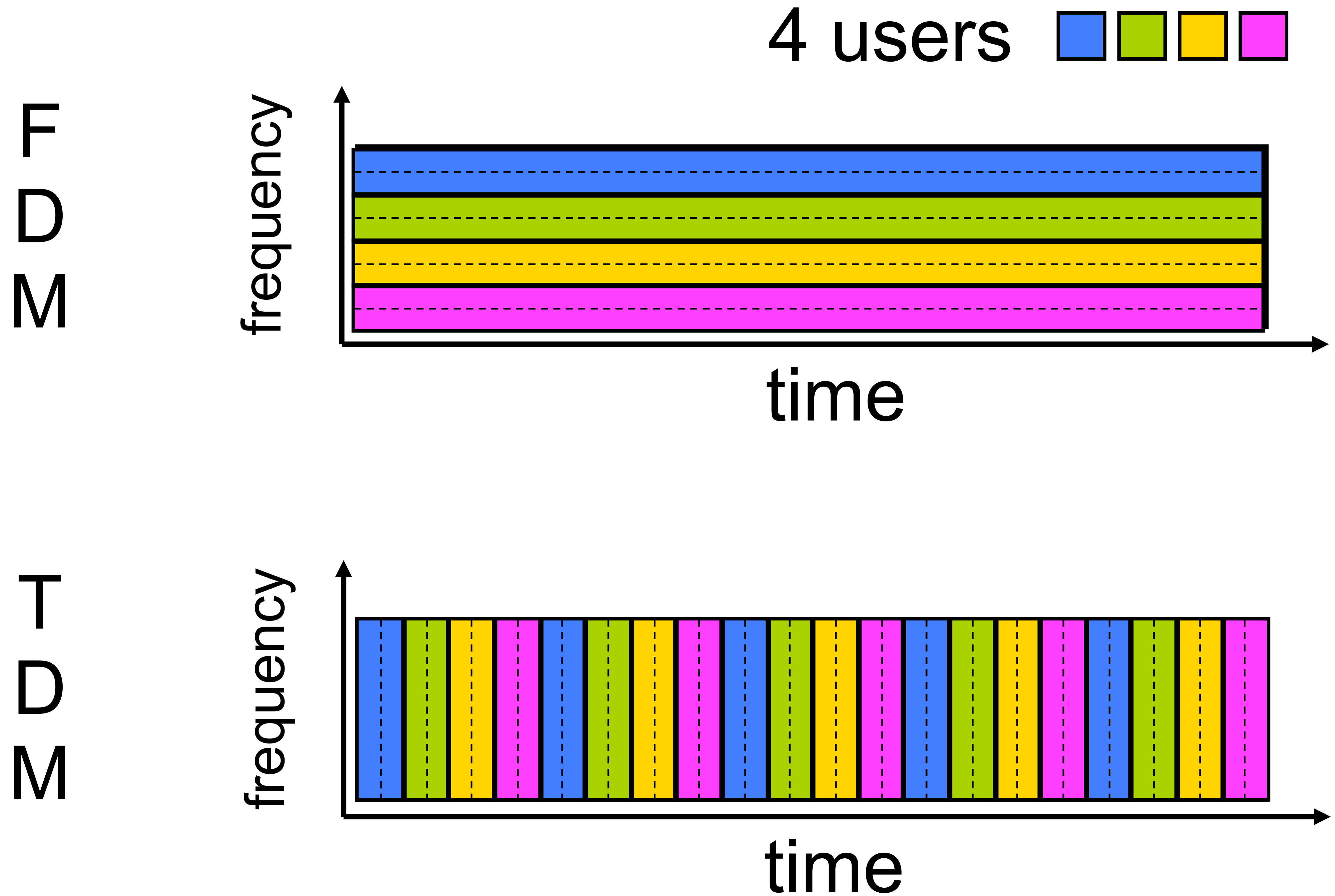
network resources (e.g., bandwidth) divided into "pieces"

- 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

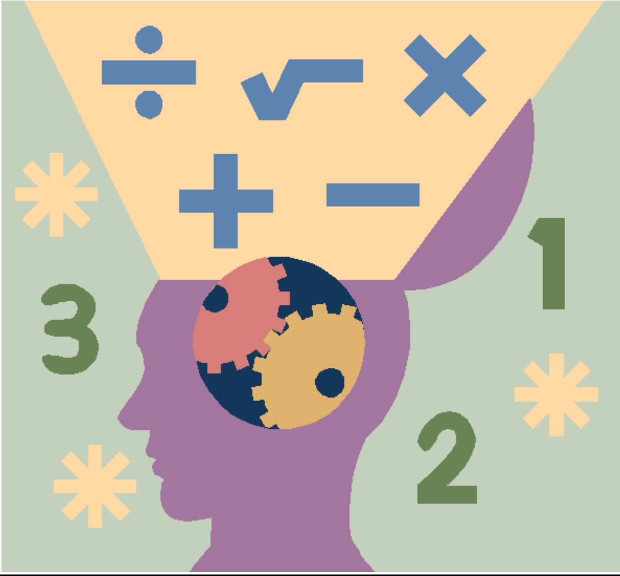
Example:



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*

Bandwidth division into "pieces"

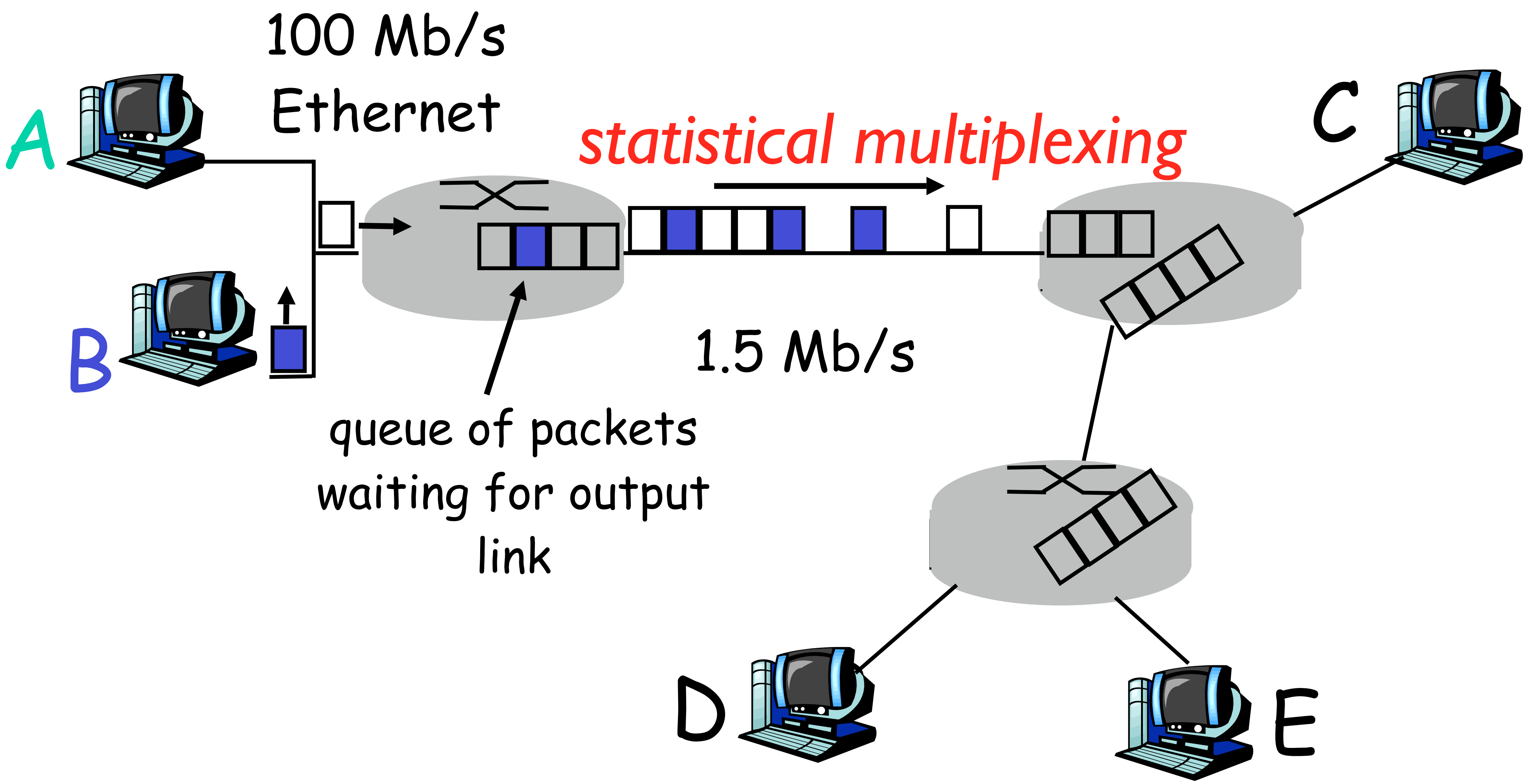
Dedicated allocation

Resource reservation

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

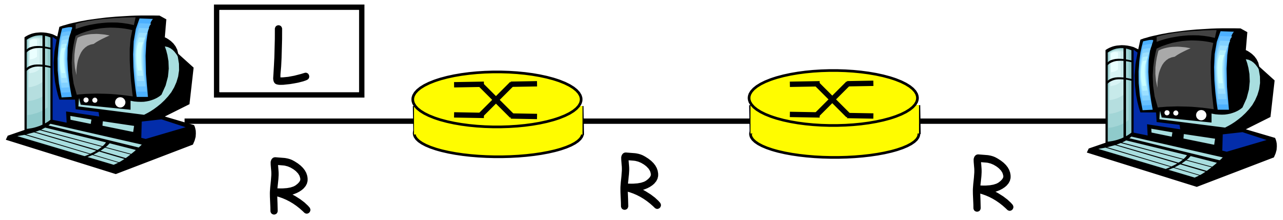
Packet Switching: Statistical Multiplexing



Sequence of A & B packets does not have fixed pattern, shared on demand : *statistical multiplexing*.

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:

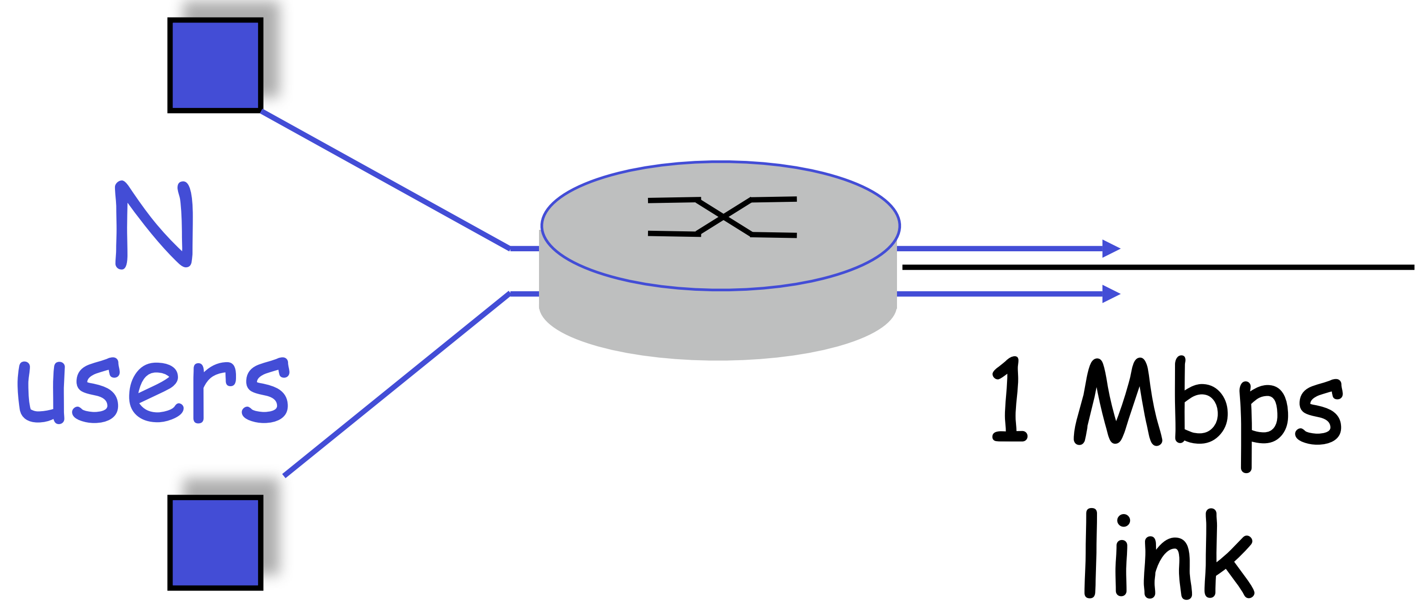
- L = 7.5 Mbits
- R = 1.5 Mbps
- delay = 15 sec

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?

Packet Switching vs Circuit Switching

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 (chapter 7)

Q: human analogies of reserved resources (circuit switching) versus 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)!
- Go to the webpage and figure out when homeworks and projects will be due.
- Questions?

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