Spring 2003 CS118
Computer Network Fundamentals

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  - Office: 4531G Boelter Hall
  - Office hours:
    - Tuesdays: 4:00-5:00pm
    - Thursdays: 1:00-2:00pm
    - Other times: appointment by email
  - When email me: pls put cs118 in the subject line
- TAs:
  - Vasileios Pappas <vpappas@CS.UCLA.EDU>
  - Jon Canan <jdcanan@cs.ucla.edu>
- Course homepage: http://www.cs.ucla.edu/classes/spring03/cs118/

What this course is about

- **What are the underlying concepts and technologies that make the Internet run?**
- First/introductory course in computer networking
  - Learn basic networking technologies & principles
  - Develop network programming skills

Course Workload

- Reading assignment for every lecture
- Weekly homework assignment
  - Assigned every Thursday (except the 10th week)
  - Due 6:00pm the following Thursday to TA's mailbox; homework solutions posted Friday morning.
- Two programming projects
  - Check class website for details
- Midterm and final exams
- Last but not least: Classroom participation

Grading breakdown

- Homework: 20%
- Projects: 30%
- Midterm: 20%
  - Thursday, May 8th
- Final exam: 30%
  - 3:00-6:00PM, Saturday June 7th

Course Policies

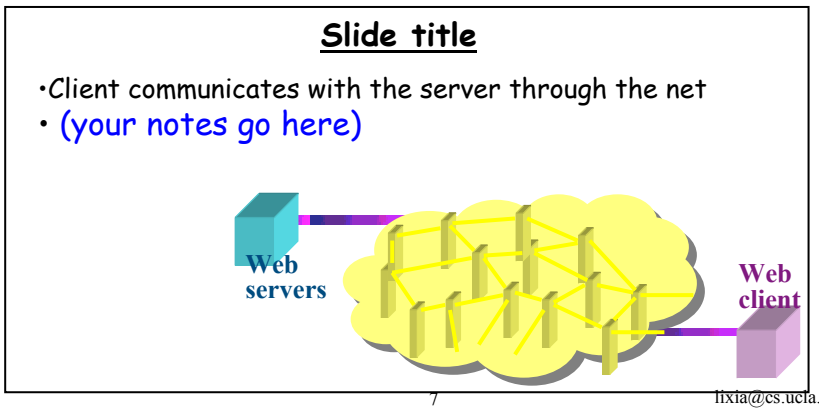
- no late turn-in is accepted for credit
- no make-up exams
- no misconduct

Lets have a shared understanding

- Why are you here?
- The goal in next 10 weeks
- What I can help
- Whose fault would it be, if you:
  - failed to understand the lecture material
  - failed to turn in an assignment on time
  - fell to sleep in class
  - Missed one of the exams

Lecture Teaching

- "Taking notes in class helps me understand better"
- So posted lecture notes will be like this



Part I: Introduction

Assignment: Read chapter 1

Today's goal:

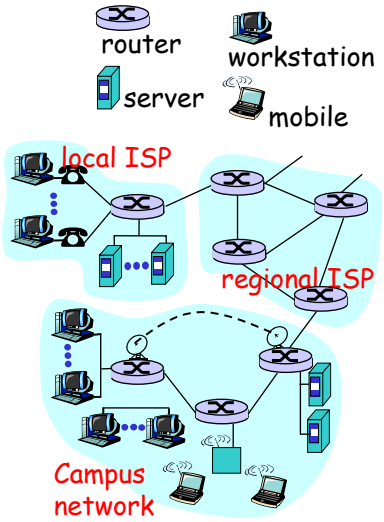
- get context, overview, "feel" of networking
  - more depth, detail *later* in course

Overview:

- what's the Internet
  - network edge, network core, access net, physical media
- Circuit switching vs. packet switching
- Protocols, protocol layers
- Performance measure: data loss, delay

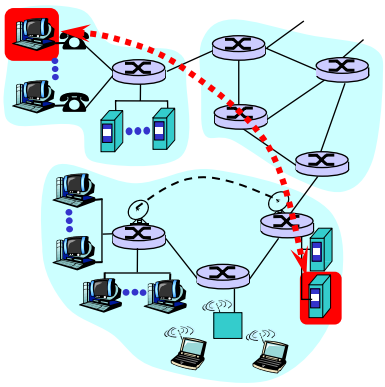
What's the Internet: "nuts and bolts" view

- *hosts (end-systems):*
  - pc's workstations, servers, PDA's phones, toasters..
  - Send/receive data, but do not forward
- Connected to *networks* made of
  - *communication links*
    - fiber, copper, radio, satellite
  - *routers:* forward chunks of data (*packets*) through a network
- running *network applications*
  - WWW, email, games, e-commerce, file sharing (MP3)



A closer look at network structure:

- network edge: end systems (hosts)
  - run application programs at "edge of network"
  - client/server model



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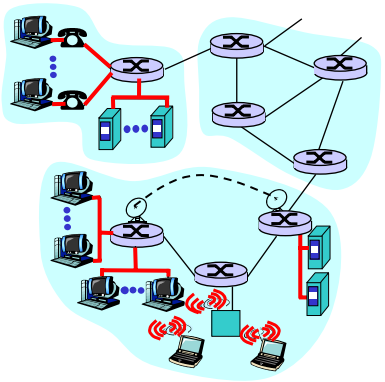
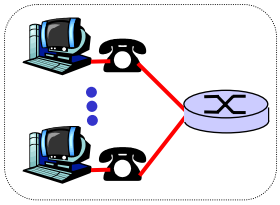
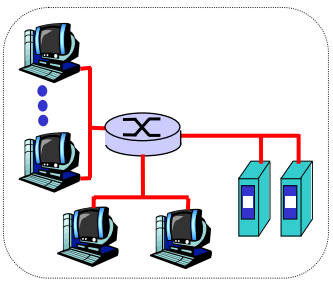
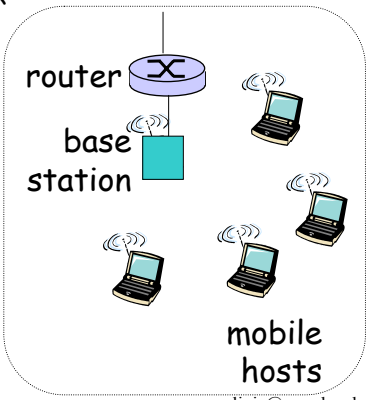


Access Networks

- Compus: local area network (LAN)
  - Ethernet:10 Mbps, 100Mbps, Gigabit Ethernet
- wireless LANs:
  - radio spectrum replaces wire
  - wider-area wireless access: CDPD—wireless access to Internet via cellular network
- Dialup via modem, ADSL (asymmetric digital subscriber line)

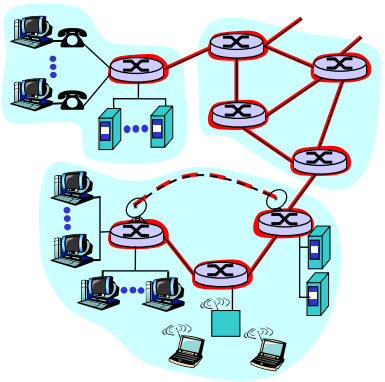






A closer look at network structure:

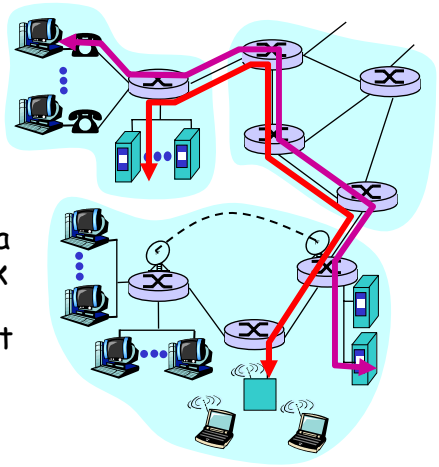
- network edge: end systems (hosts)
  - run application programs at "edge of network"
  - client/server model
- access networks
  - Physical media, communication links
- network core:
  - mesh of interconnected routers
  - network of networks
  - *the* fundamental question: how is data transferred through the net?
    - Circuit switching
    - Packet switching



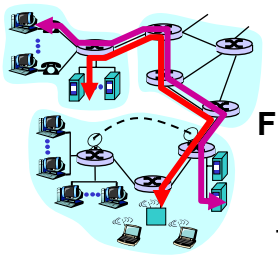
How multiple data transfers share the same network

Circuit Switching vs. Packet Switching

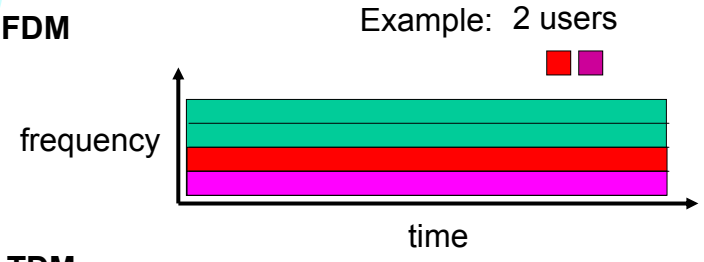
- Circuit switching
  - dedicate link bandwidth & switch capacity to each "call"
  - Requires call setup
  - Guaranteed performance
- Packet switching
  - Packet: small chunks of data
  - Send packets as soon as link available
  - switch receives a full packet then forwards it towards the destination



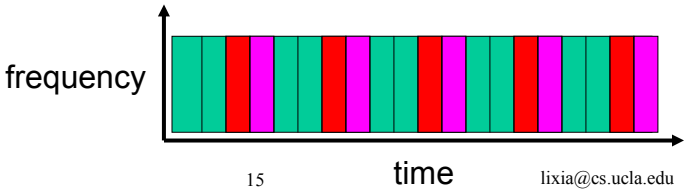
Circuit Switching: FDM and TDM



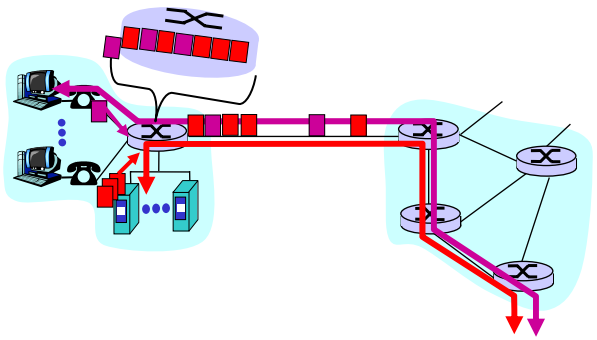
FDM



TDM



Packet Switching: Statistical Multiplexing

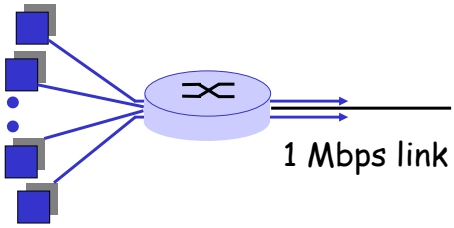


- Store-and-forward
- Packet switch can temporarily buffer up packets
  - Introduce *queueing delay*
  - Packets get *dropped* when the queue is full

Packet switching versus circuit switching

Example: how many users can share a 1 megabits/sec (1 Mbps) link?

- each user:
  - 100,000 bits/sec when "active"
  - active 10% of time
- circuit-switching:
  - 10 users
- packet switching:
  - 35 users: Prob.(n > 10) < 0.0004



A number of issues related to packet switching:

- How does a router figure out where to forward packets?
- What if packets get lost? Or get garbled along the way?

Tentative Course Schedule:

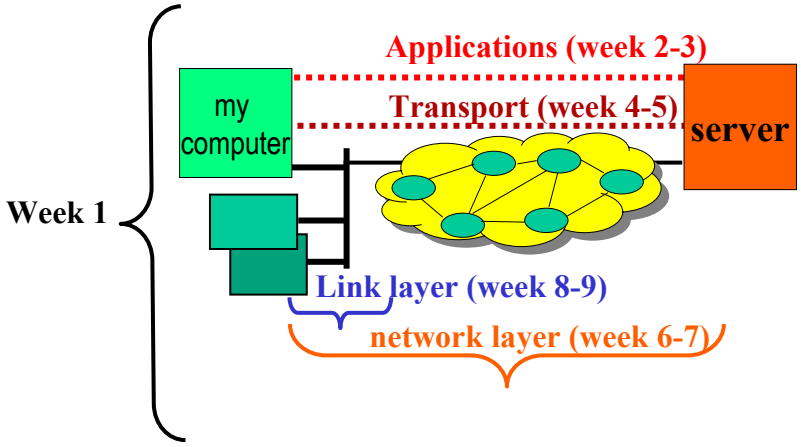
- Introduction (2 lectures, textbook: Chapter 1)
- Network applications (3 lectures, Chapter 2)
  - Socket programming (1 lecture)
- Transport protocols (3~4 lectures, Chapter 3)

Midterm exam (in class)

- Network protocols (4 lectures, Chapter 4)
- Link Layer: LANs (3 lectures, Chapter 5)
- Network Security (1 lecture, Chapter 7)

Review for final exam

Or more intuitively

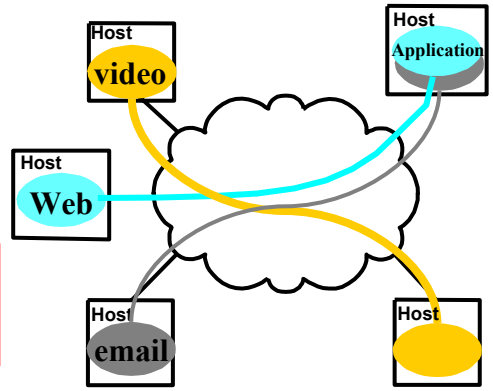


What to do after this class

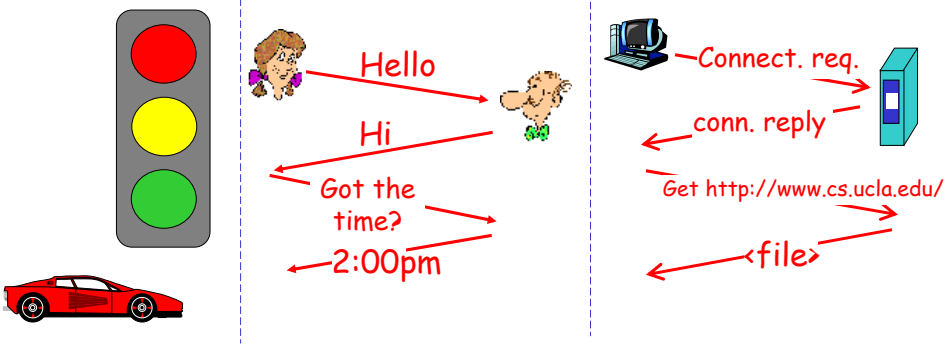
- Take a look at the course homepage
- Finish reading assignment before next lecture
- Food for thought:
  - What makes the Internet so popular these days?
  - What's lay ahead?
- Interesting articles on Internet histories
  - "**Some Perspectives on Networks—Past, Present and Future**" by Paul Baran, http://irl.cs.ucla.edu/papers/ifip.ps
  - http://www.isoc.org/internet-history

Packet Switched Networks

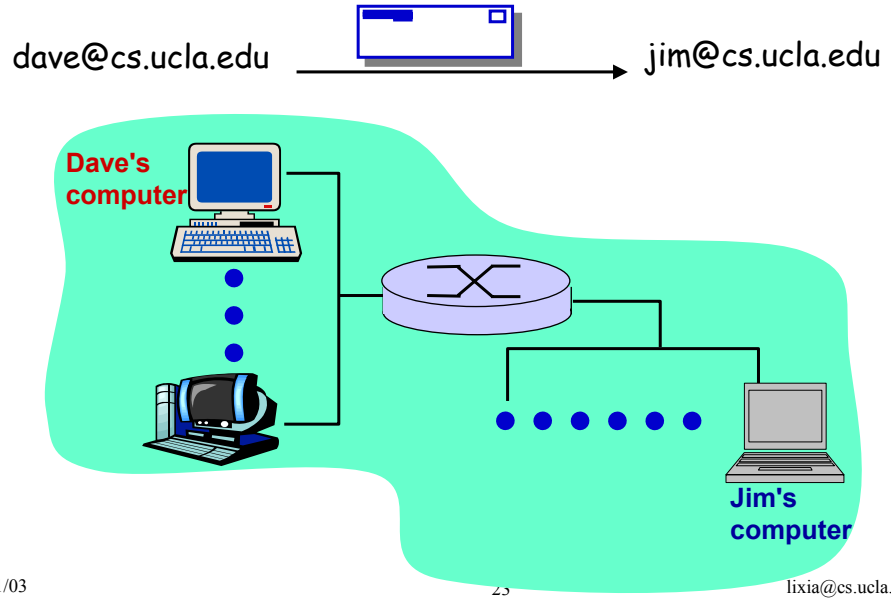
Network protocols govern all communication activities in a network



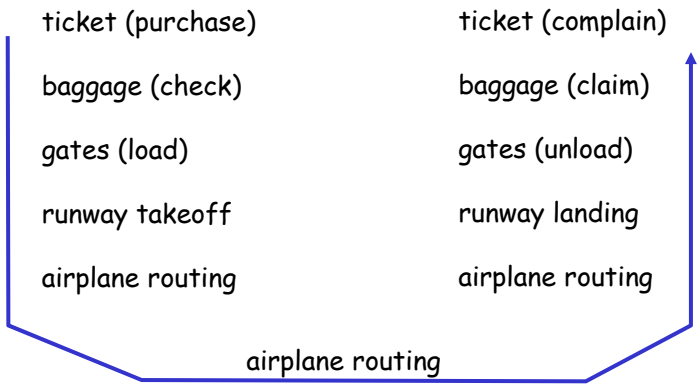
What's a protocol?



One example: send email

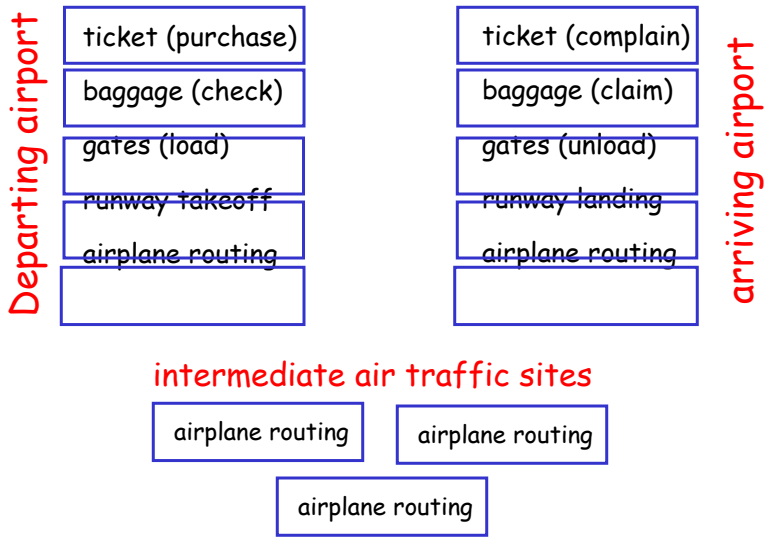


Organization of air travel

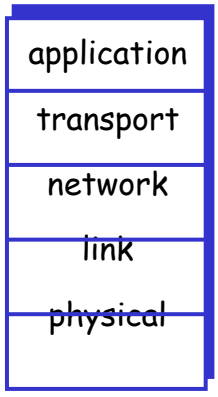


- a series of steps

Distributed implementation of layer functionality



Internet protocol stack



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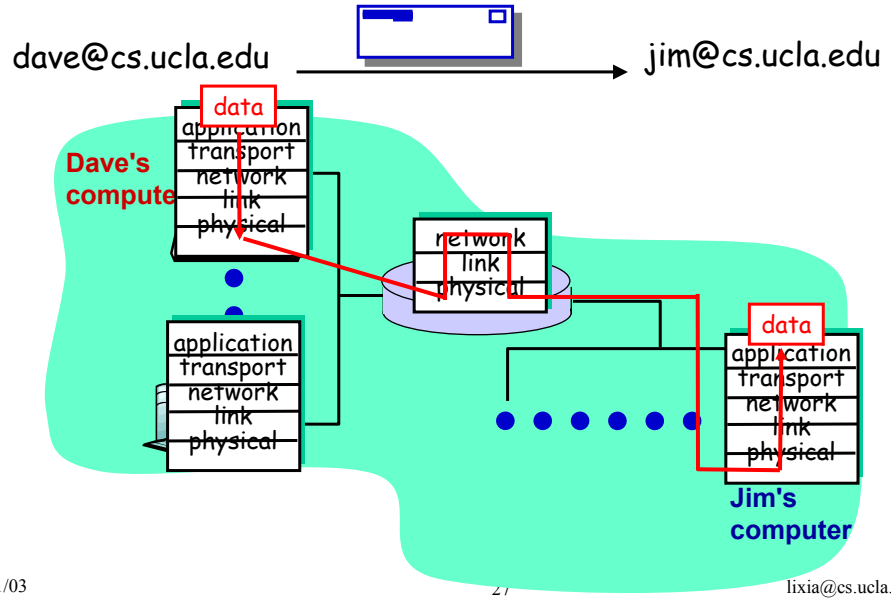
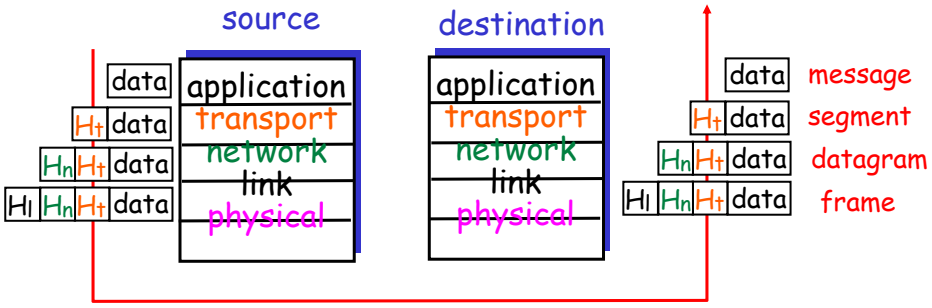
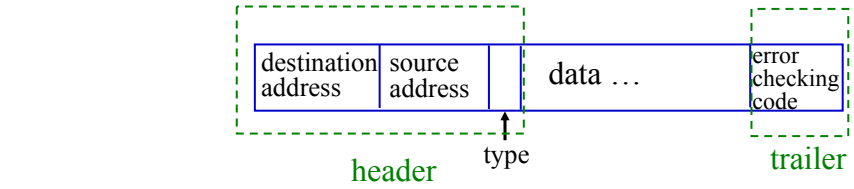


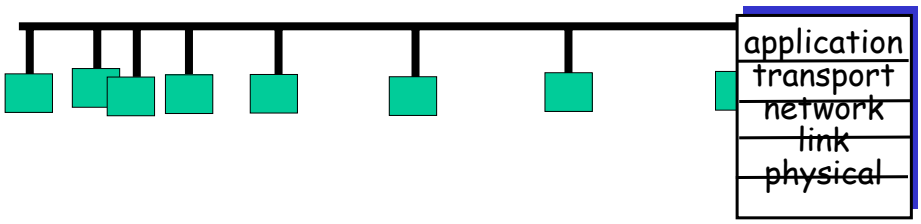
Protocol layering and data



Protocol header: one examples

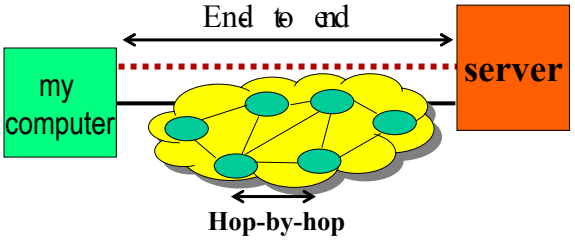
Link layer: Ethernet frame format





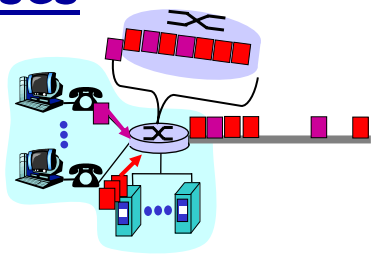
Data Delivery Performance

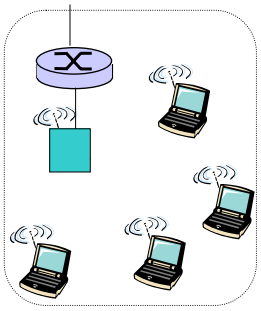
- 3 basic measuremetns



Packet Losses

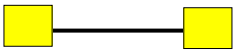
- Loss due to congestion
- Loss due to transmission errors
- wireless links



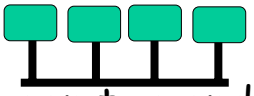


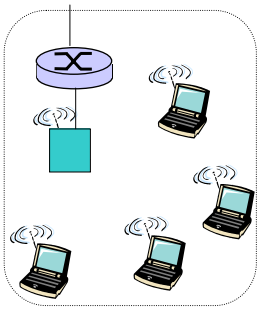
Throughput

- Throughput over a single link
  - Point-to-point

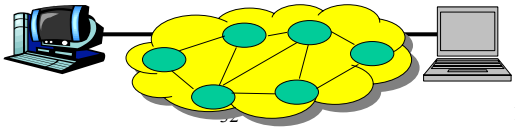


  - Multi-access





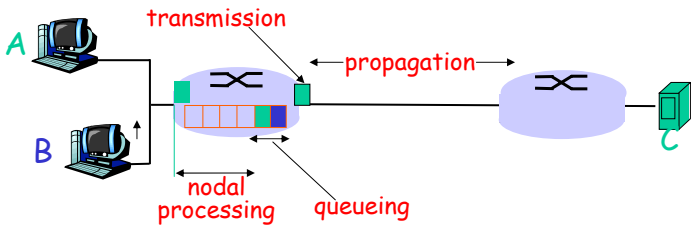
- Throughput between two end hosts



Delay in packet-switched networks

4 sources of delay at each hop

- nodal processing:
- Transmission = L / R
- Queueing
- Propagation = d/s

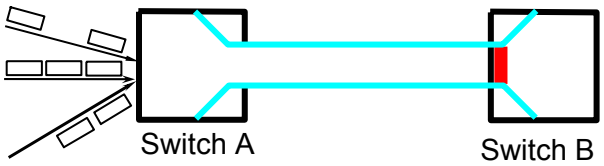


Example: one hop delay

total delay (A→B) = $1ms \times 2 + 1ms + 0.5ms = 3.5ms$

- Queuing delay =
- transmission delay =
- Propagation delay =

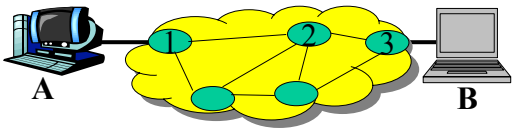
link length = 100 km
Bandwidth= 1 Mbps
packet size= 1000 bits
(all pkts equal length)



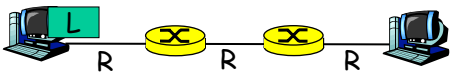
(2.0x10^8 meters/sec in a fiber)

Network latency

- Time to send a packet from point *A* to point *B*
  - sum of delays across each hop along the path
- RTT: round-trip-time

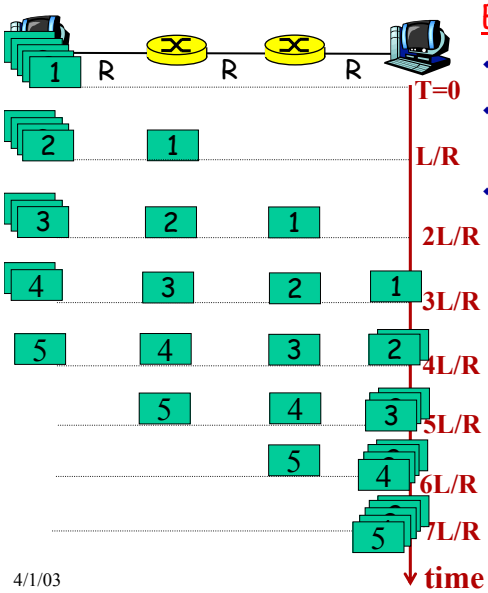


Packet-switching: store-and-forward



- 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*
- *Ignore propagation delay*

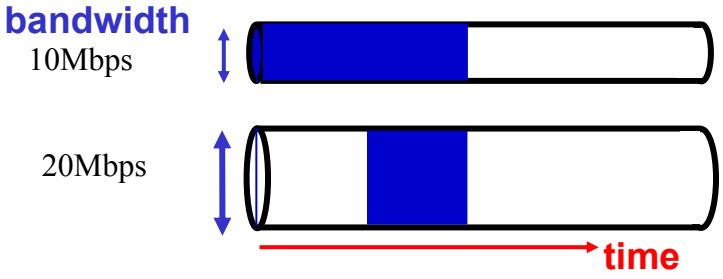
Packet-switching: store-and-forward



Example 2:

- A sends 5 packets to B
- L = 8000 bits, R = 2 Mbps
  - Ignore propagation delay
- How long does it take starting from A sending the first bit of first packet till B receives the last bit of the last packet?

Bandwidth, transmission delay, and propagation delay



(bandwidth × delay) product: amount of data "in-the-pipe"