CS 3251- Computer Networks I: Intro (contd)

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Lecture 02

8/22/2013

Announcements

- Homework 1 posted
  - Due Tuesday, September 3rd
  - Get started early - there is a good deal to be done.
- Office hours: Tuesday 11-12
- Reminder: Prepend [CS 3251] to all email!

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

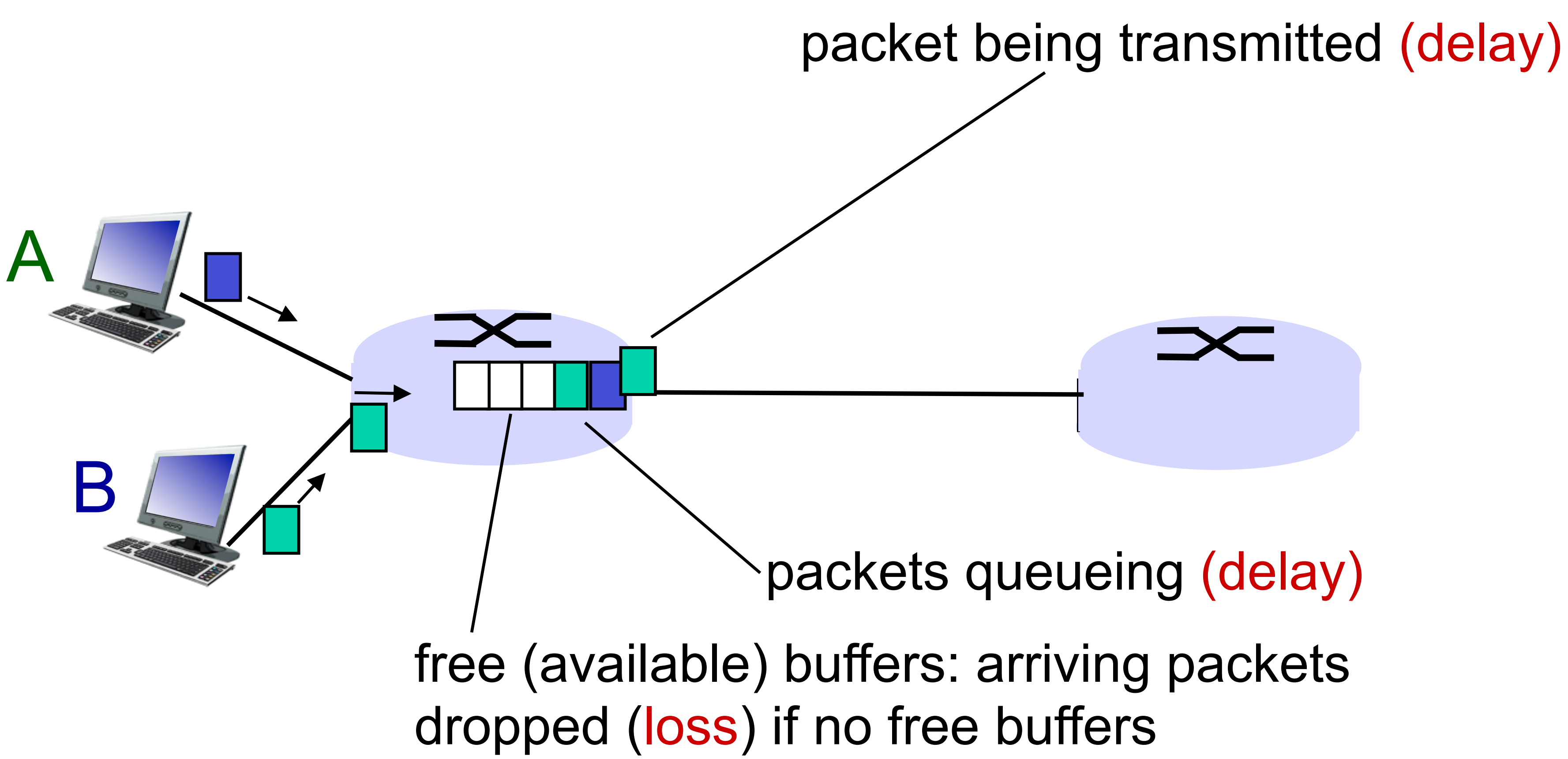
What Took You So Long?

- The time it takes you to get to class depends on a lot of different factors.
  - How congested were the sidewalks? Any construction?
  - Was there a line outside the building? The classroom?
  - Were you carrying more things than usual?
- Network traffic is similarly influenced.
  - After all, traffic is not transmitted instantaneously.
  - Why?

How do loss and delay occur?

packets *queue* in router buffers

- packet arrival rate to link exceeds output link capacity
- packets queue, wait for turn



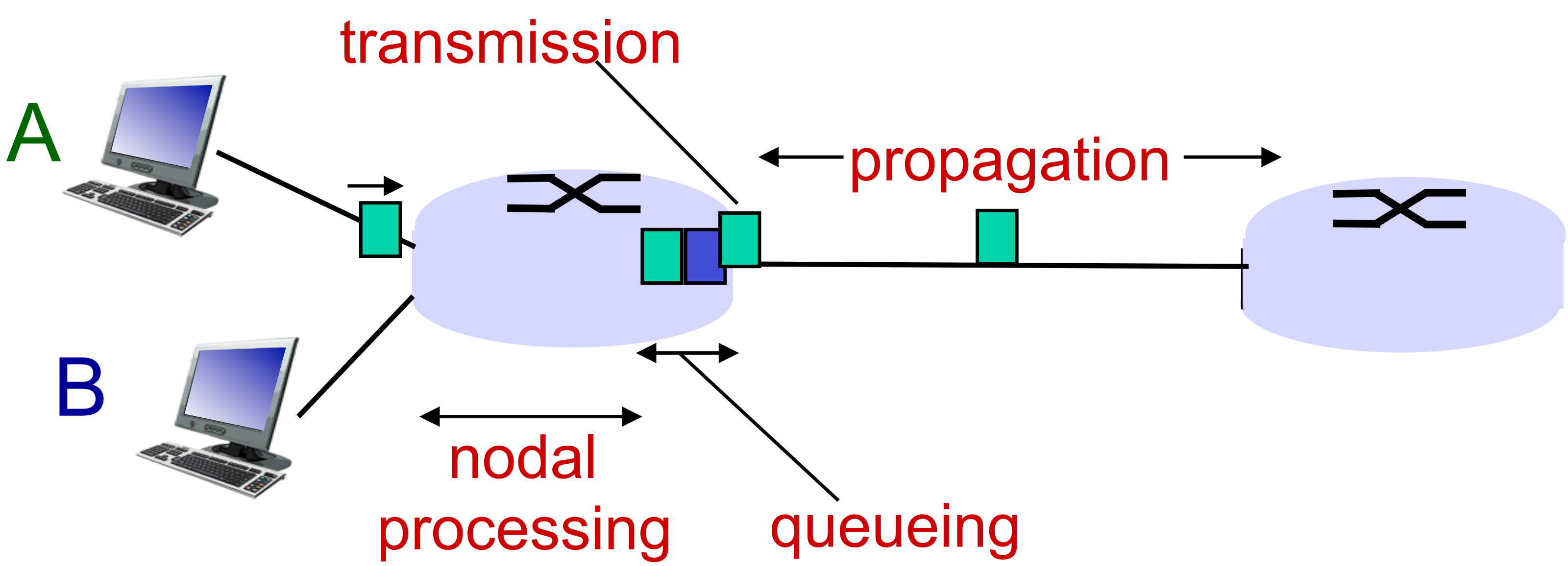
Four sources of packet delay

1. nodal processing:

- check bit errors
- determine output link
- typically < msec

2. queueing:

- time waiting at output link for transmission
- depends on congestion level of router



$$d_{\text{nodal}} = d_{\text{proc}} + d_{\text{queue}} + d_{\text{trans}} + d_{\text{prop}}$$

Delay in packet-switched networks

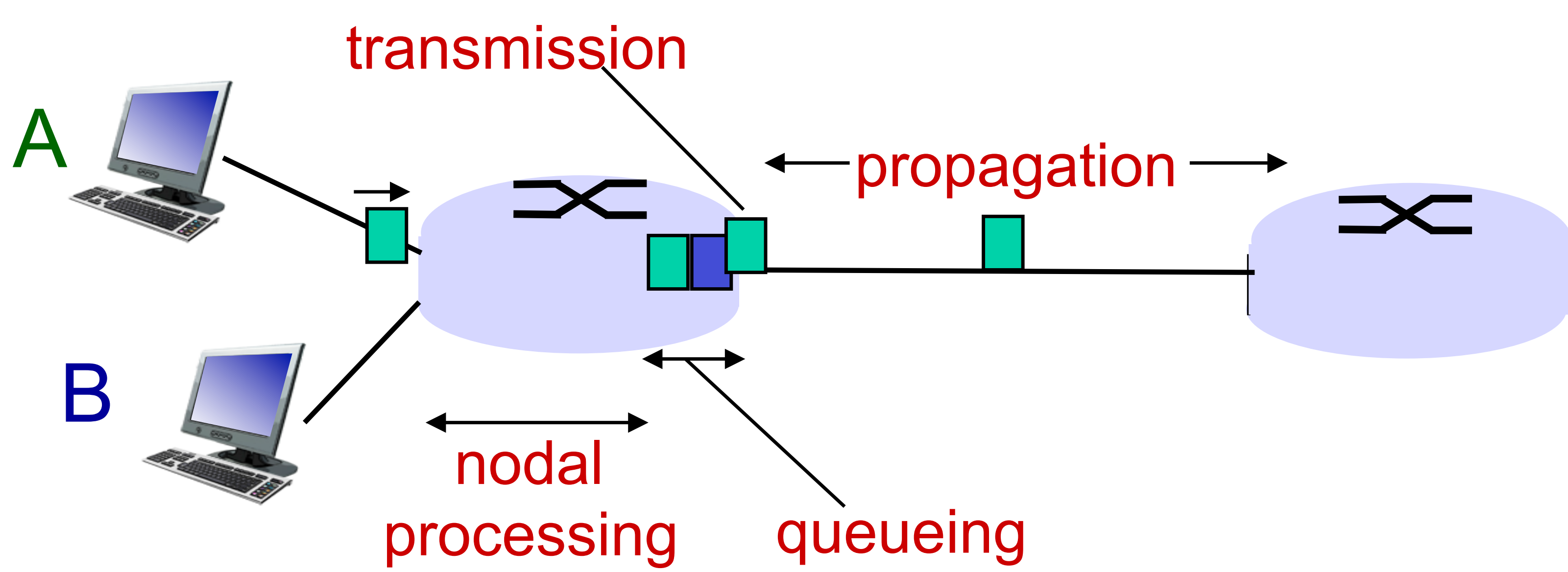
3. Transmission delay:

- R=link bandwidth (bps)
- L=packet length (bits)
- time to send bits into link = L/R

d_{trans} and d_{prop} *very* different

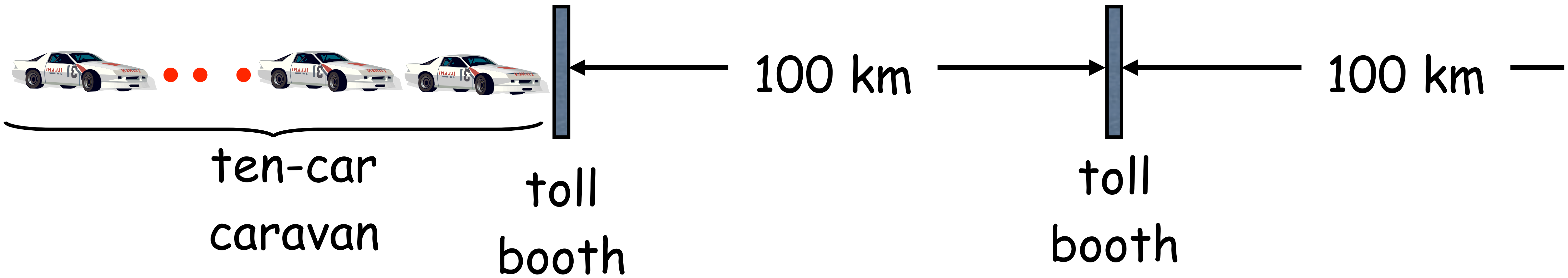
4. Propagation delay:

- d = length of physical link
- s = propagation speed in medium (~2x10^8 m/sec)
- propagation delay = d/s



$$\boxed{d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}}$$

Caravan analogy



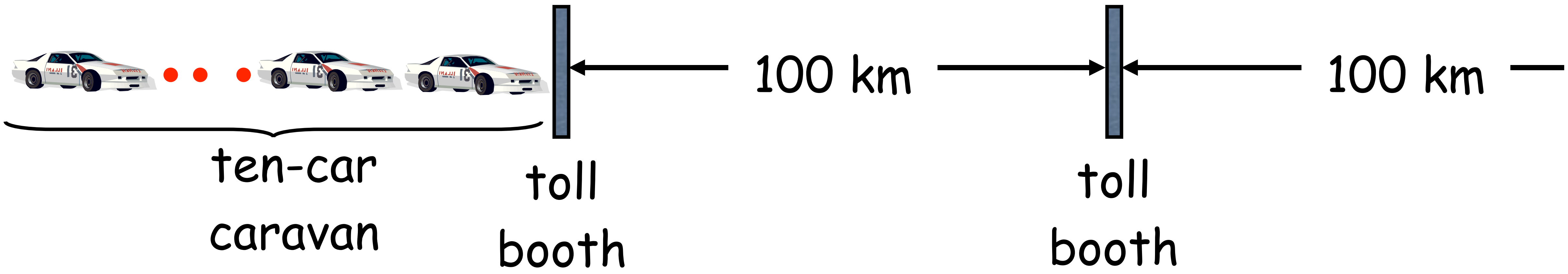
- Cars "propagate" at 100 km/hr
- Toll booth takes 12 sec to service a car (transmission time)
- car~bit; caravan ~ packet
- Q: How long until caravan is lined up before 2nd toll booth?

transmission delay

- Time to "push" entire caravan through toll booth onto highway = 12*10 = 120 sec
- Time for last car to propagate from 1st to 2nd toll both: 100km/(100km/hr)= 1 hr
- A: 62 minutes

propagation delay

Caravan analogy (more)



- Cars now "propagate" at 1000 km/hr
- Toll booth now takes 1 min to service a car
- Q: Will cars arrive to 2nd booth before all cars serviced at 1st booth?

- Yes! After 7 min, 1st car at 2nd booth and 3 cars still at 1st booth.
- 1st bit of packet can arrive at 2nd router before packet is fully transmitted at 1st router!
  - See Ethernet applet at the text book's Web site (K&R)

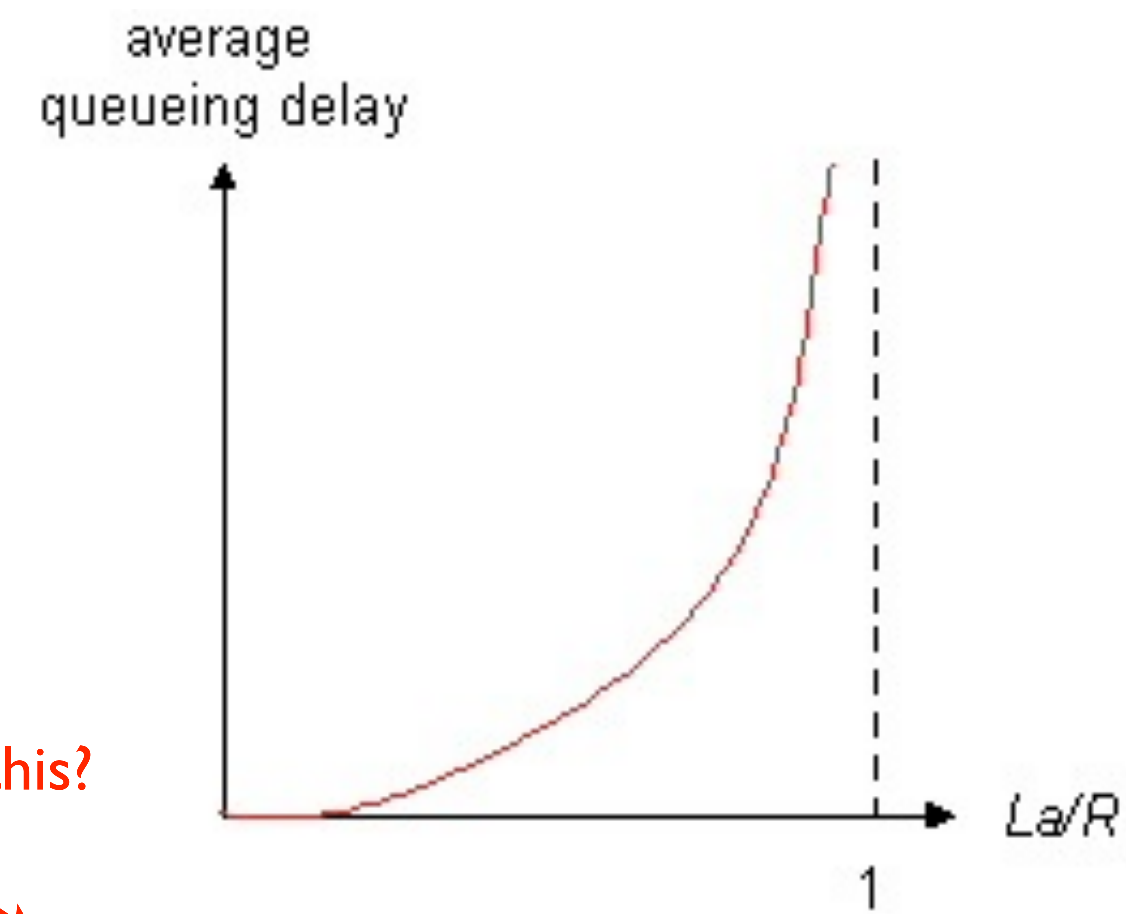
Nodal delay

$$\boxed{d_{\text{nodal}} = d_{\text{proc}} + d_{\text{queue}} + d_{\text{trans}} + d_{\text{prop}}}$$

- d_{proc} = processing delay
  - typically a few microsecs or less
- d_{queue} = queuing delay
  - depends on congestion
- d_{trans} = transmission delay
  - = L/R, significant for low-speed links
- d_{prop} = propagation delay
  - a few microsecs to hundreds of msecs

Queueing delay (revisited)

- R=link bandwidth (bps)
- L=packet length (bits)
- a=average packet arrival rate



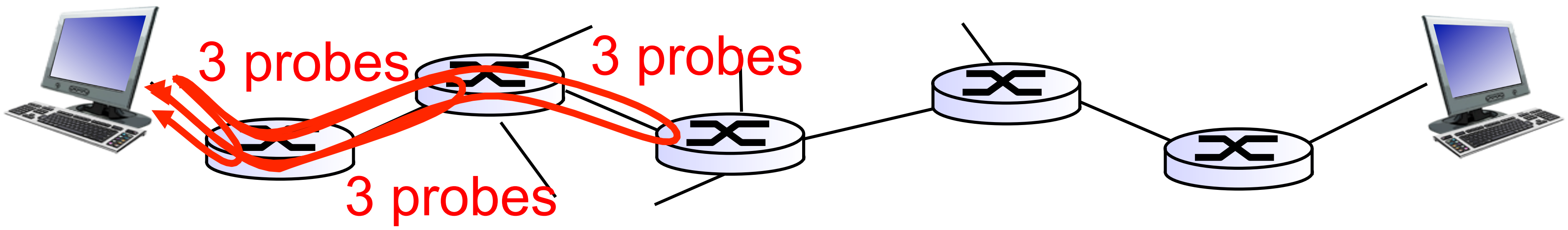
how do we get this?

traffic intensity = La/R

- La/R ~ 0: average queueing delay small
- La/R -> 1: delays become large
- La/R > 1: more "work" arriving than can be serviced, average delay infinite!

“Real” Internet delays and routes

- What do “real” Internet delay & loss look like?
- Traceroute program: provides delay measurement from source to router along end-end Internet path towards destination. For all *i*:
  - sends three packets that will reach router *i* on path towards destination
  - router *i* will return packets to sender
  - sender times interval between transmission and reply.

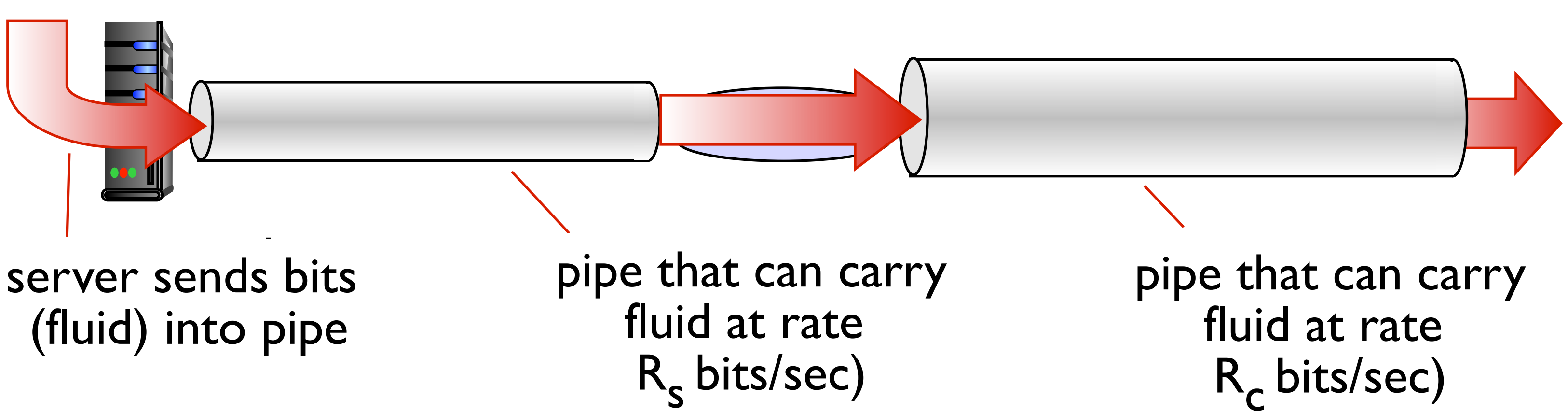


Packet loss

- queue (aka buffer) preceding link in buffer has finite capacity
- when packet arrives to full queue, packet is dropped (aka lost)
- lost packet may be retransmitted by previous node, by source end system, or not retransmitted at all

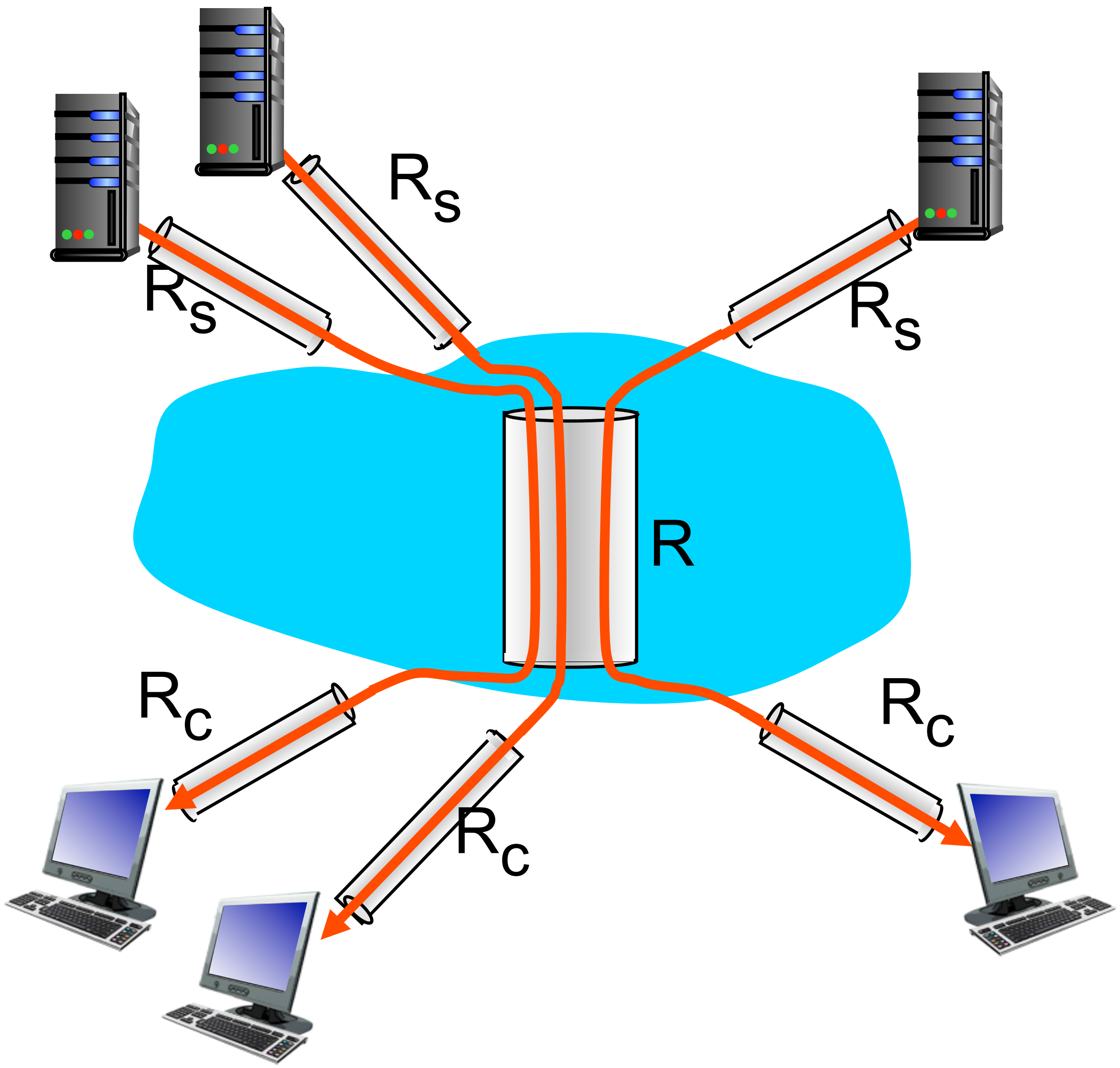
Throughput

- *Throughput*: rate (bits/time unit) at which bits transferred between sender/receiver
  - *instantaneous*: rate at given point in time
  - *average*: rate over longer period of time



Throughput: Internet Scenario

- Per-connection end-end throughput: $\min(R_c, R_s, R/10)$
- In practice: R_c or R_s is often bottleneck



10 connections (fairly) share backbone bottleneck link R bits/sec

“Real” Internet delays and routes

traceroute: gaia.cs.umass.edu to www.eurecom.fr

3 delay measurements from gaia.cs.umass.edu to cs-gw.cs.umass.edu

1 cs-gw (128.119.240.254) 1 ms 1 ms 2 ms
2 border1-rt-fa5-1-0.gw.umass.edu (128.119.3.145) 1 ms 1 ms 2 ms
3 cht-vbns.gw.umass.edu (128.119.3.130) 6 ms 5 ms 5 ms
4 jn1-at1-0-0-19.wor.vbns.net (204.147.132.129) 16 ms 11 ms 13 ms
5 jn1-so7-0-0-0.wae.vbns.net (204.147.136.136) 21 ms 18 ms 18 ms
6 abilene-vbns.abilene.ucaid.edu (198.32.11.9) 22 ms 18 ms 22 ms
7 nycm-wash.abilene.ucaid.edu (198.32.8.46) 22 ms 22 ms 22 ms
8 62.40.103.253 (62.40.103.253) 104 ms 109 ms 106 ms
9 de2-1.de1.de.geant.net (62.40.96.129) 109 ms 102 ms 104 ms
10 de.fr1.fr.geant.net (62.40.96.50) 113 ms 121 ms 114 ms
11 renater-gw.fr1.fr.geant.net (62.40.103.54) 112 ms 114 ms 112 ms
12 nio-n2.cssi.renater.fr (193.51.206.13) 111 ms 114 ms 116 ms
13 nice.cssi.renater.fr (195.220.98.102) 123 ms 125 ms 124 ms
14 r3t2-nice.cssi.renater.fr (195.220.98.110) 126 ms 126 ms 124 ms
15 eurecom-valbonne.r3t2.ft.net (193.48.50.54) 135 ms 128 ms 133 ms
16 194.214.211.25 (194.214.211.25) 126 ms 128 ms 126 ms
17 * * *
18 * * *
19 fantasia.eurecom.fr (193.55.113.142) 132 ms 128 ms 136 ms

trans-oceanic link

* means no response (probe lost, router not replying)

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1.8 Summary

Protocol "Layers"

Networks are complex!

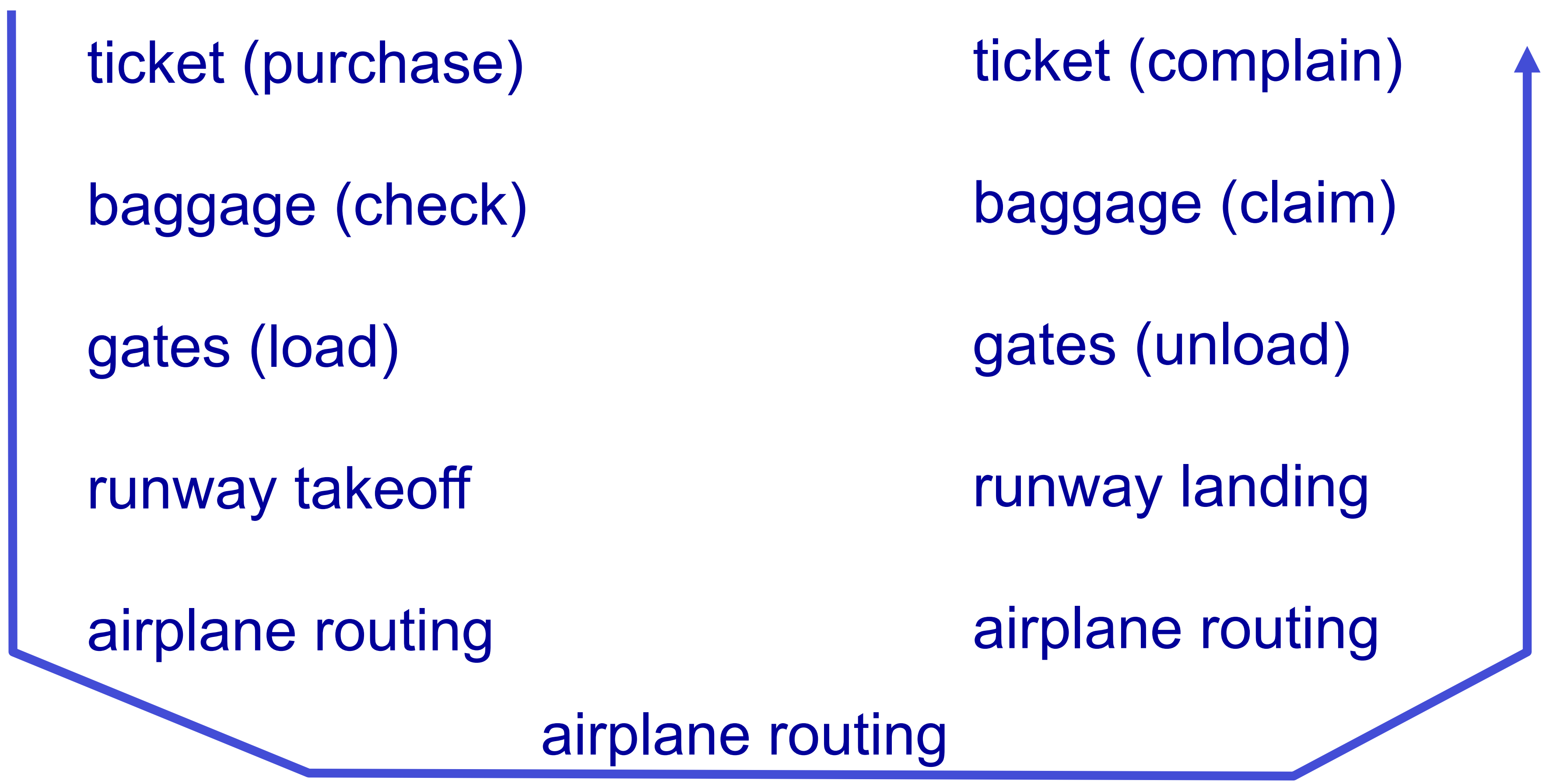
- many "pieces":
  - hosts
  - routers
  - links of various media
  - applications
  - protocols
  - hardware, software

Question:

Is there any hope of organizing structure of network?

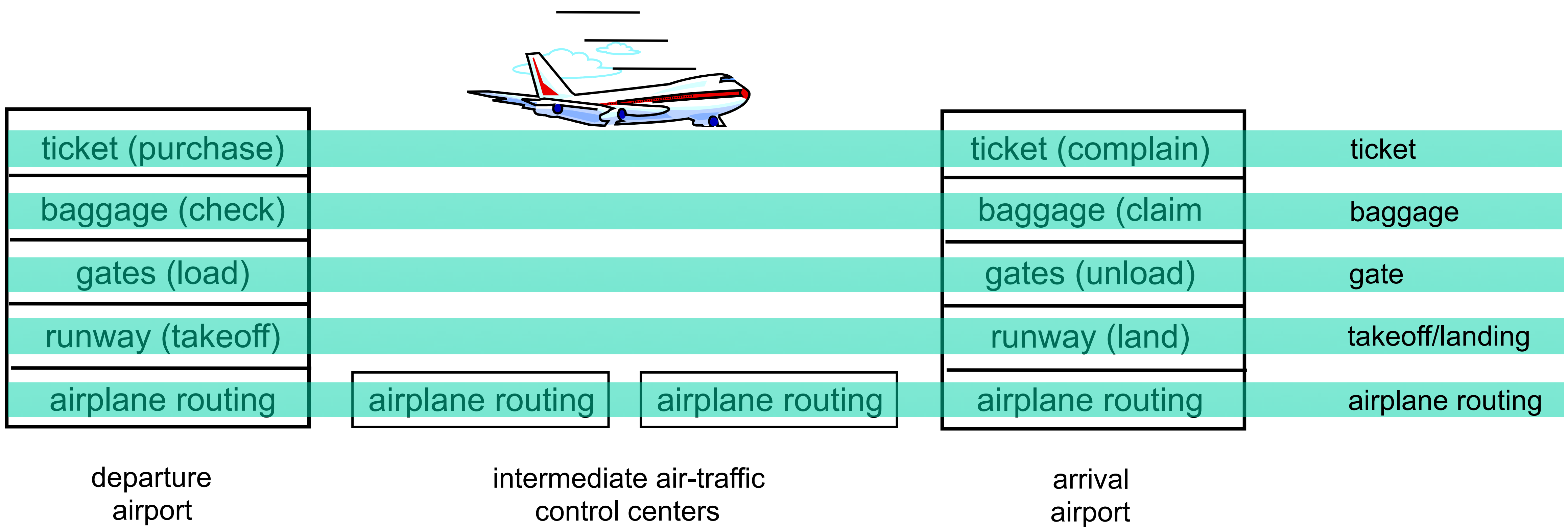
Or at least our discussion of networks?

Organization of air travel



- a series of steps

Layering of airline functionality



Layers: each layer implements a service

- via its own internal-layer actions
- relying on services provided by layer below

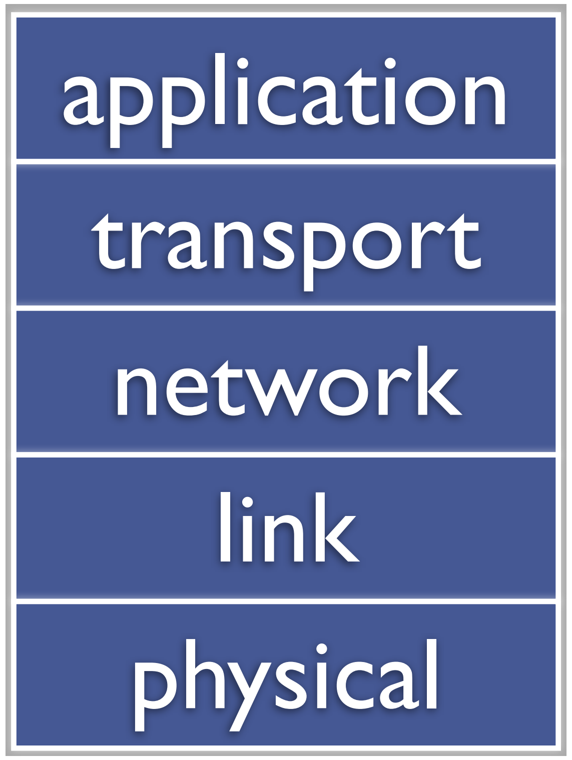
Why layering?

Dealing with complex systems:

- explicit structure allows identification, relationship of complex system's pieces
  - layered reference model for discussion
- modularization eases maintenance, updating of system
  - change of implementation of layer's service transparent to rest of system
  - e.g., change in gate procedure doesn't affect rest of system
- layering considered harmful?

Internet protocol stack

- application: supporting network applications
    - FTP, SMTP, HTTP
- transport: process-process data transfer
    - TCP, UDP
- network: routing of datagrams from source to destination
    - IP, routing protocols
- link: data transfer between neighboring network elements
    - PPP, Ethernet
- physical: bits “on the wire”

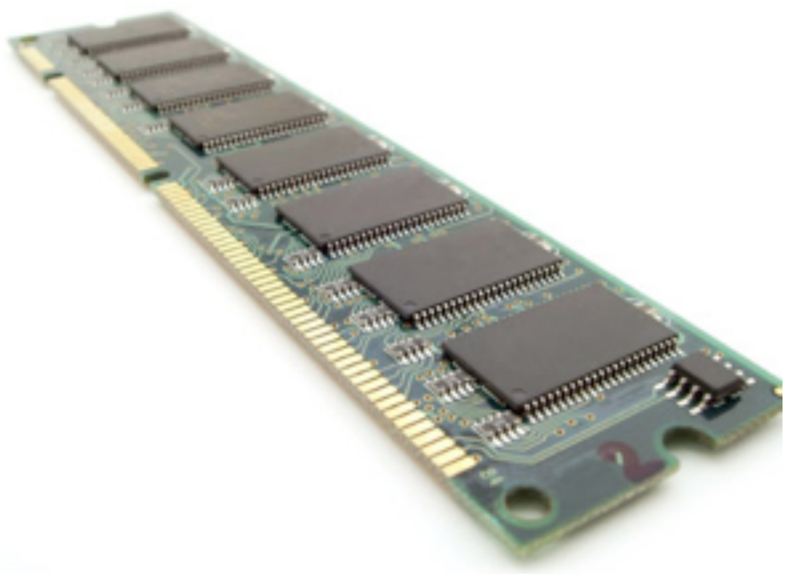


OSI Reference Model

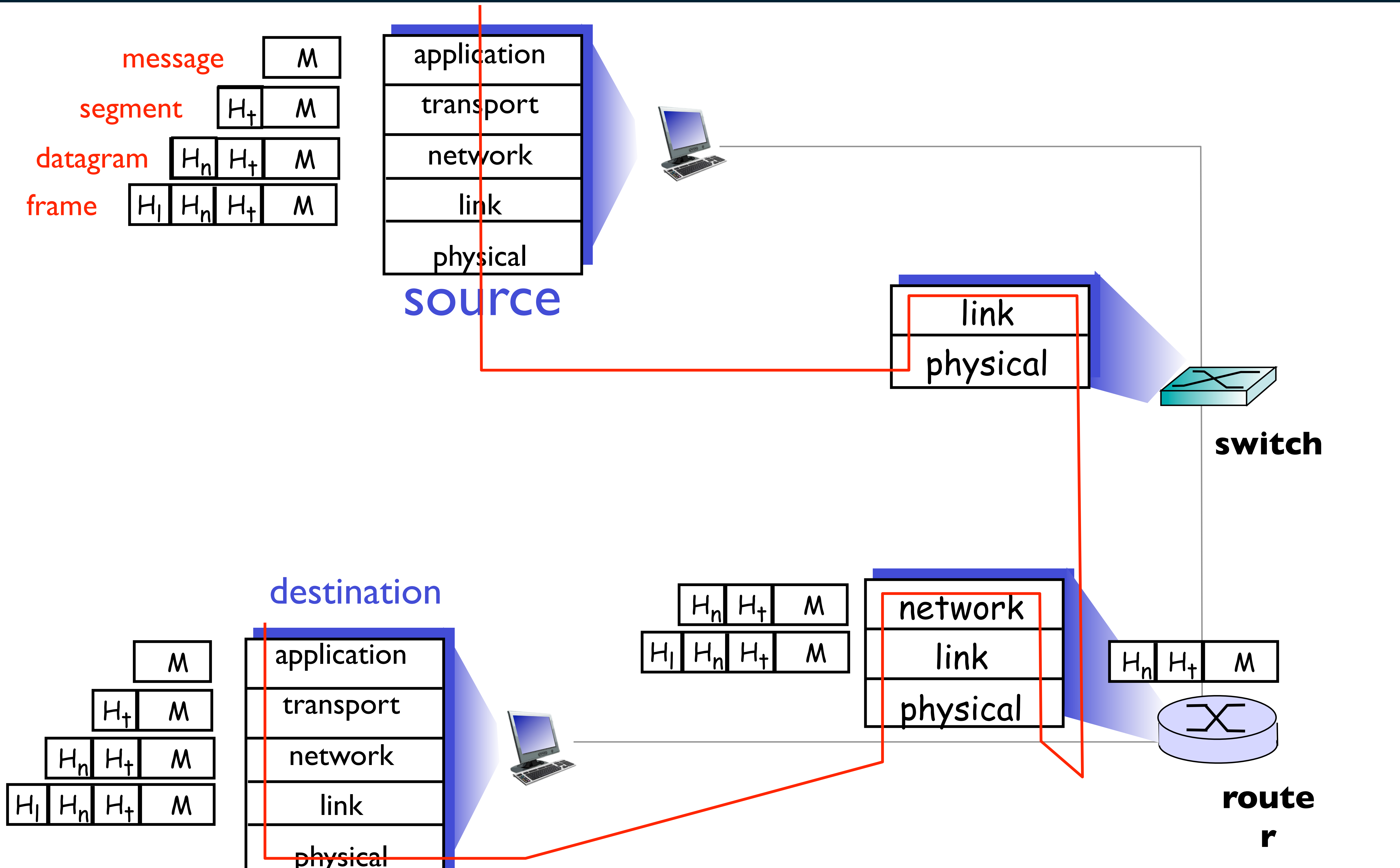
- The Open Systems Interconnection (OSI) model has two additional layers: Session and Presentation.
- Session Layer: Manages sessions between applications
  - (e.g., SSH, RTCP, RPC, NFS)
- Presentation Layer: Delivery and formatting of messages.
  - (e.g., RDP, ASCII)

How Can I Remember This?

- There are a few simple mnemonics:
  - Please Do Not Tell Sales People Anything
  - All People Seem To Need Data Processing
  - Please Don't Nuke The South Pacific Again



Encapsulation



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Back to the Silk Road

- When the Mongol Empire collapsed around 1400, most of the trade routes became too dangerous.
  - Columbus tried to avoid all of that.

- Any system in which huge amounts of money and information are exchanged will always be of interest to criminals.
  - The Internet is no different.

- What sorts of threats are out there?

Malware

- Malicious software is generically known as *malware*.
  - (e.g., Virus, worm, botnet, trojan horse)
- The distinction between these is often due to:
  - ...how they propagate...
  - ...what they control...
  - ...their usefulness to you...
- Anyone here every been infected?
- Anyone think they haven't?

Attacking Availability

- An adversary may try to shut you down with a *Denial of Service* (DoS) attack.
- The book considers three categorizations, but the community has generally settled on two:
  - Flooding: Simply overwhelming your servers with more traffic than they can handle.
  - Logical: Exploiting a limited resource or known vulnerability.

Packet Manipulation

- If the Internet is a network of networks, who says that someone in the middle can't mess with your packets?
- Assume that everything sent over the Internet is read or *sniffed* by someone/thing.
- Anyone with control of the wire can also arbitrarily drop or modify your packets.
  - When might this be a problem?
  - Does it happen?

Authenticity

- How do you know who you are talking to?
  - In real life? On the web?
- Pretending to be someone else is easier than you think.
- An adversary can *spoof* identity in any number of ways...
  - Has this ever happened to you?

"On the Internet, nobody knows you're a dog."

Security

- Security is, in general, a hard problem.
  - Even picking a good definition is difficult.

- As we move through this semester, ask yourself a few questions about the topics we study:
  - Did the designer consider malicious behavior?
  - How would I break this?
  - How would I fix this?

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1.1 What *is* the Internet?

1.2 Network edge

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1.4 Network access and physical media

1.5 Internet structure and ISPs

1.6 Networks Under Attack

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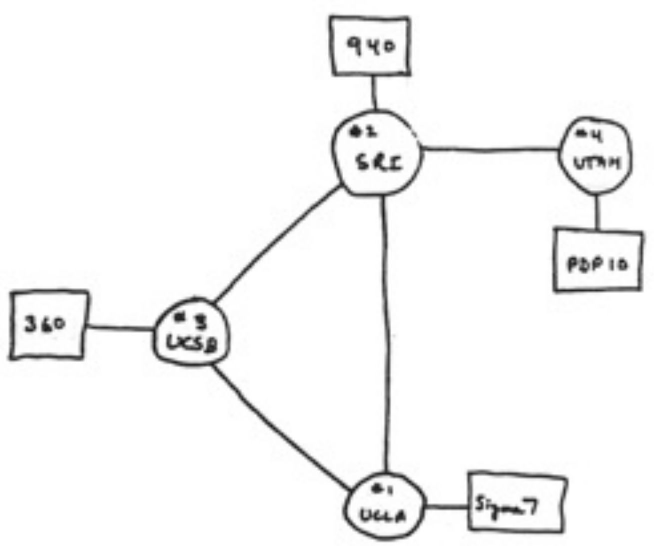
Internet History

1961-1972: Early packet-switching principles

- 1961: Kleinrock - queueing theory shows effectiveness of packet-switching
- 1964: Baran - packet-switching in military nets
- 1967: ARPAnet conceived by Advanced Research Projects Agency
- 1969: first ARPAnet node operational

- 1972:
  - ARPAnet public demonstration
  - NCP (Network Control Protocol) first host-host protocol
  - first e-mail program
  - ARPAnet has 15 nodes



THE ARPA NETWORK

Internet History

1972-1980: Internetworking, new and proprietary nets

- 1970: ALOHAnet satellite network in Hawaii
- 1974: Cerf and Kahn - architecture for interconnecting networks
- 1976: Ethernet at Xerox PARC
- late 70's: proprietary architectures: DECnet, SNA, XNA
- late 70's: switching fixed length packets (ATM precursor)
- 1979: ARPAnet has 200 nodes

Cerf and Kahn's internetworking principles:

- minimalism, autonomy - no internal changes required to interconnect networks
- best effort service model
- stateless routers
- decentralized control

define today's Internet architecture

Internet History

1980-1990: new protocols, a proliferation of networks

- 1983: deployment of TCP/IP
- 1982: smtp e-mail protocol defined
- 1983: DNS defined for name-to-IP-address translation
- 1985: ftp protocol defined
- 1988: TCP congestion control

- new national networks: Csnet, BITnet, NSFnet, Minitel
- 100,000 hosts connected to confederation of networks

Internet History

1990, 2000's: commercialization, the Web, new apps

- Early 1990's: ARPAnet decommissioned
- 1991: NSF lifts restrictions on commercial use of NSFnet (decommissioned, 1995)
- early 1990s: Web
  - hypertext [Bush 1945, Nelson 1960's]
  - HTML, HTTP: Berners-Lee
  - 1994: Mosaic, later Netscape
  - late 1990's: commercialization of the Web

Late 1990's – 2000's:

- more killer apps: instant messaging, P2P file sharing
- network security to forefront
- est. 50 million host, 100 million+ users
- backbone links running at Gbps

Internet History

2005 - Present

- ~750 million hosts
  - Smartphones and tablets
- Aggressive deployment of broadband access
- Increasing ubiquity of high-speed wireless access
- Emergence of online social networks:
  - Facebook: over one billion users
- Service providers (Google, Microsoft) create their own networks
  - Bypass Internet, providing "instantaneous" access to search, email, etc.
- E-commerce, universities, enterprises running their services in "cloud" (eg, Amazon EC2)

Introduction: Summary

Covered a "ton" of material!

- Internet overview
- what's a protocol?
- network edge, core, access network
  - packet-switching versus circuit-switching
- Internet/ISP structure
- performance: loss, delay
- layering and service models
- history

You now have:

- context, overview, "feel" of networking
- more depth, detail to follow!

Next Time

- Next Class
  - Read the "End-to-End argument" (link on website)
  - Read through Section 2.1
- Homework 1 is due Tuesday, September 3rd