

CMSC 332: Computer Networks Intro (cont.)

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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?

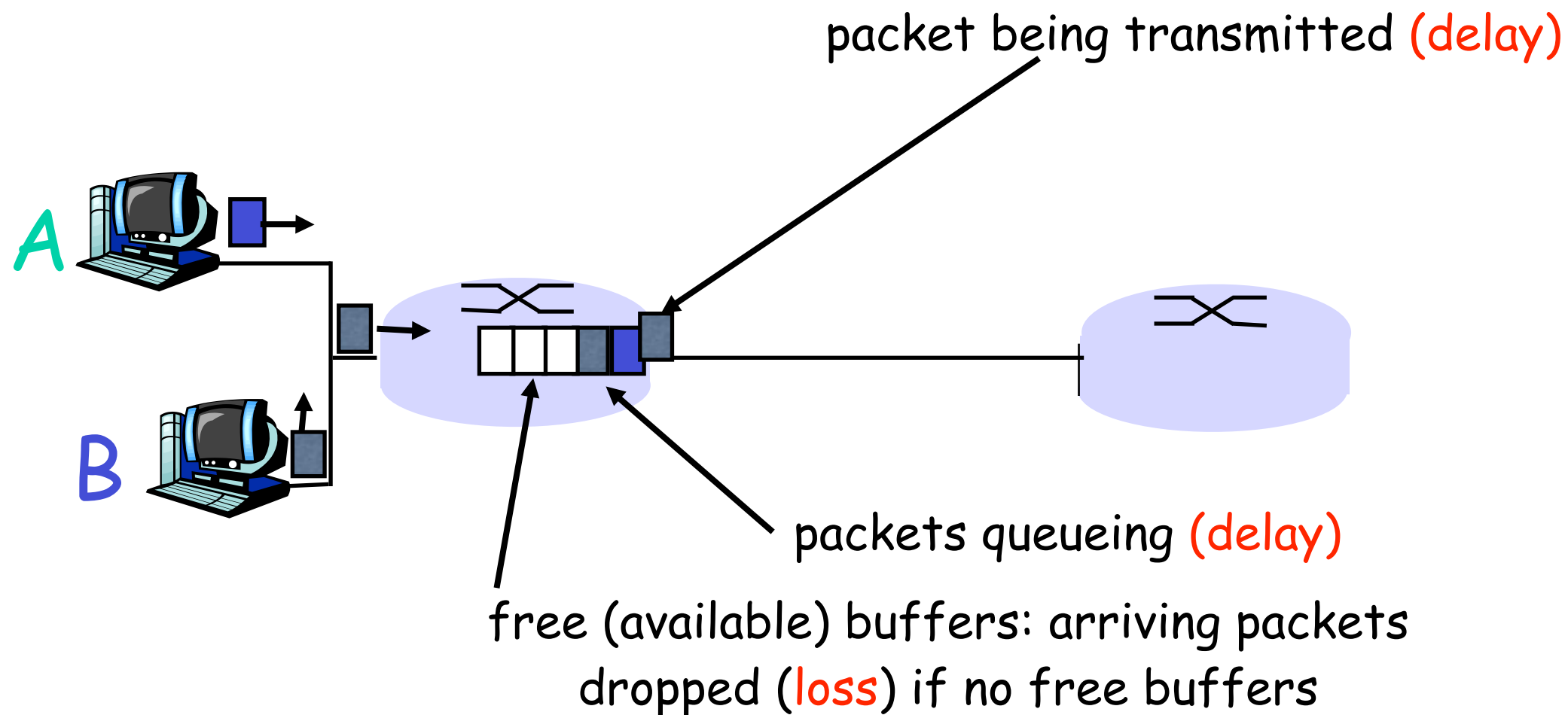
- The time it takes you to get to class depends on a lot of different factors.
 - How congested were the sidewalks? Any construction?
 - Was there a line outside the building? The classroom?
 - Were you carrying more things than usual?
- Network traffic is similarly influenced.
 - After all, traffic 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



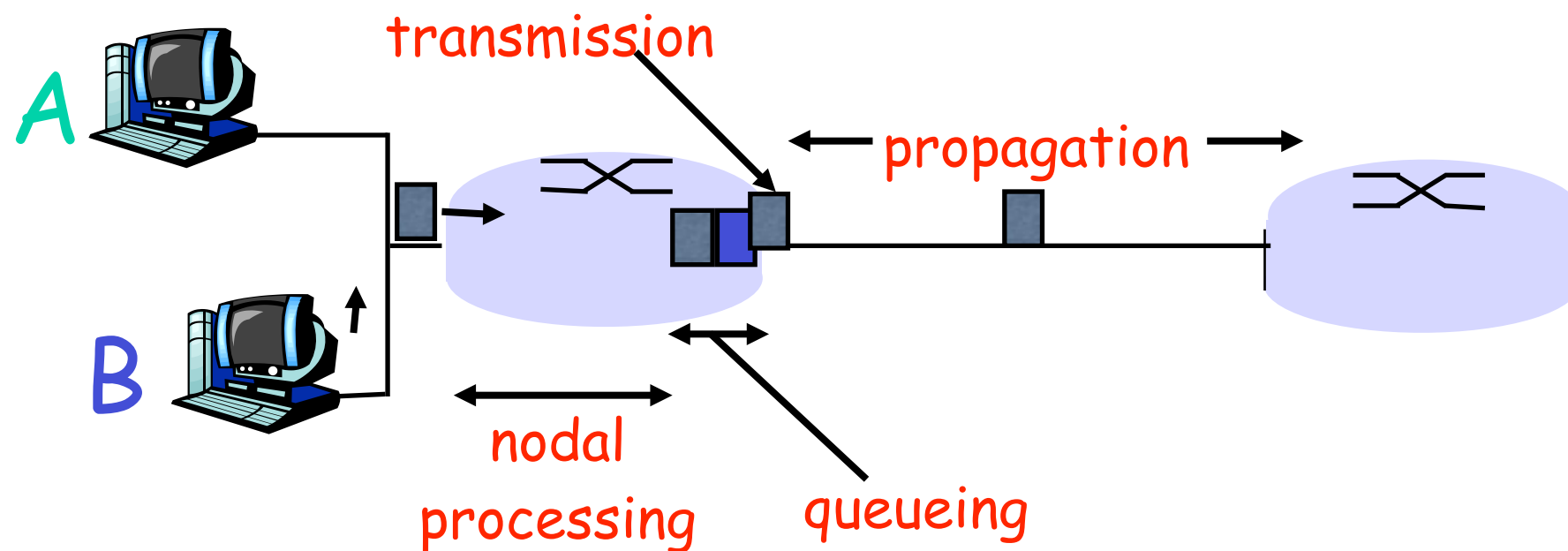
Four sources of packet delay

- **1. nodal processing:**

- check bit errors
- determine output link

- **2. queueing:**

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



Delay in packet-switched networks

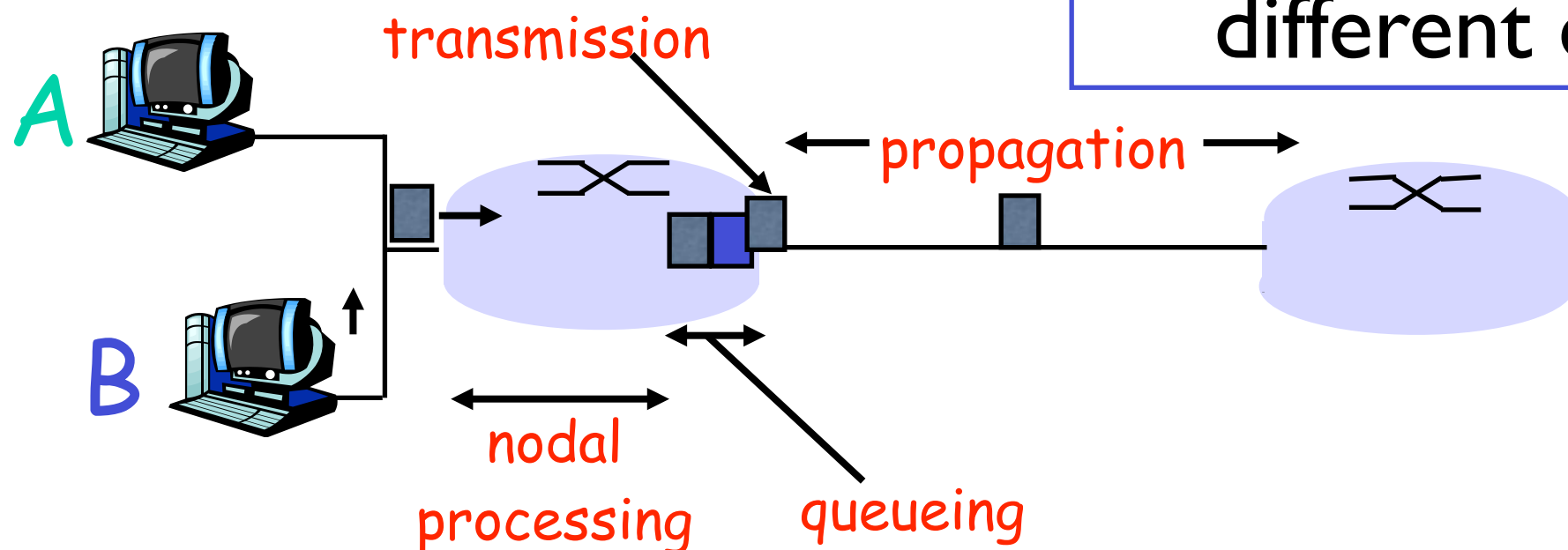
3. Transmission delay:

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

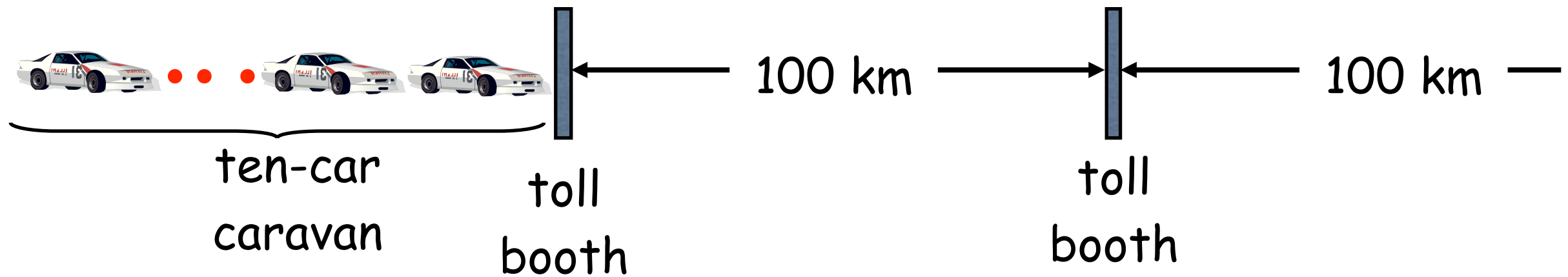
4. Propagation delay:

- d = length of physical link
- s = propagation speed in medium ($\sim 2 \times 10^8$ m/sec)
- propagation delay = d/s

Note: s and R are very different quantities!



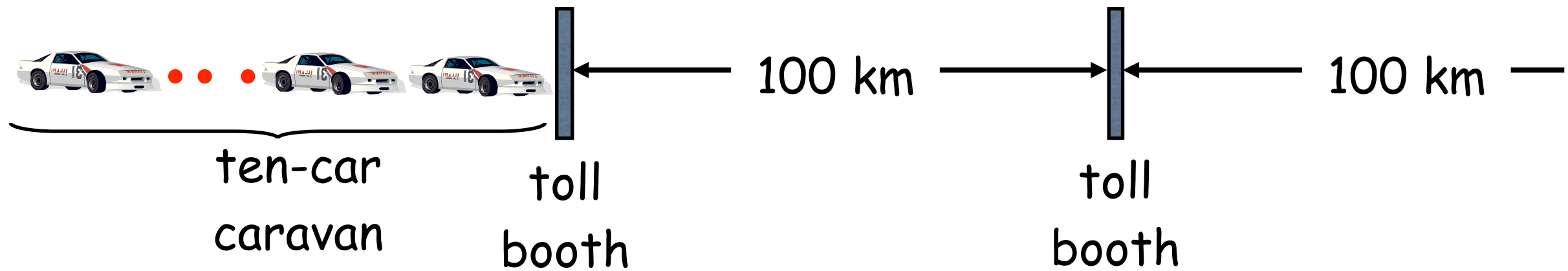
Caravan analogy



- 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?**

- Time to “push” entire caravan through toll booth onto highway = $12 \times 10 = 120$ sec
 - Time for last car to propagate from 1st to 2nd toll booth: $100\text{km} / (100\text{km/hr}) = 1$ hr
 - **A: 62 minutes**
- transmission delay
- 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

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

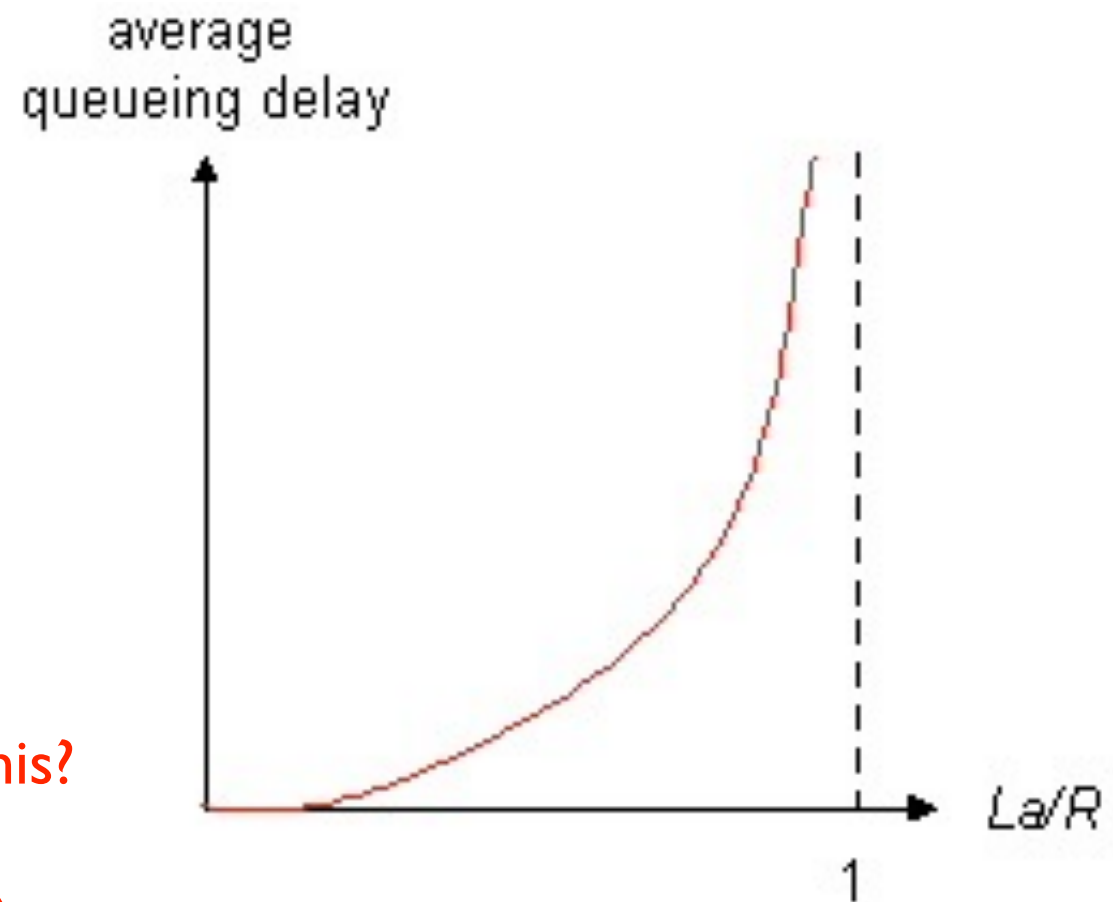
- d_{proc} = processing delay
 - typically a few microsecs or less
- d_{queue} = queuing delay
 - depends on congestion
- d_{trans} = transmission delay
 - $= L/R$, significant for low-speed links
- d_{prop} = propagation delay
 - a few microsecs to hundreds of msecs



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

- $La/R \sim 0$: average queueing delay small
- $La/R \rightarrow 1$: delays become large
- $La/R > 1$: more “work” arriving than can be serviced, average delay infinite!

Packet loss

- queue (aka buffer) preceding link 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

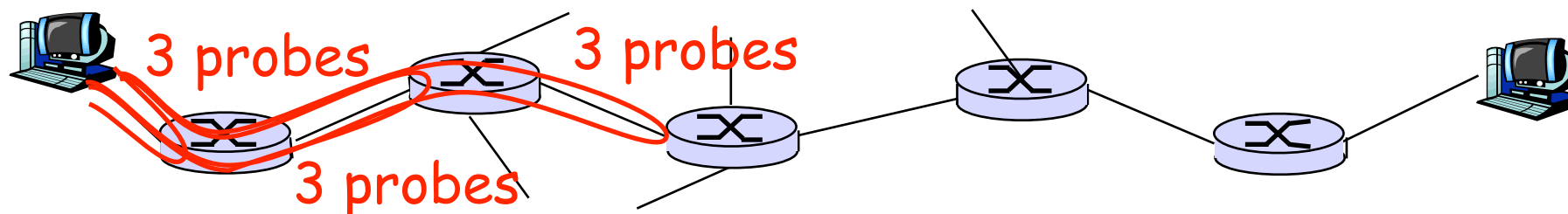


FAILURE

WHEN YOUR BEST JUST ISN'T GOOD ENOUGH.

“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.



“Real” Internet delays and routes

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

Three 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 (how do we
know this?)

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

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Protocol “Layers”

Networks are complex!

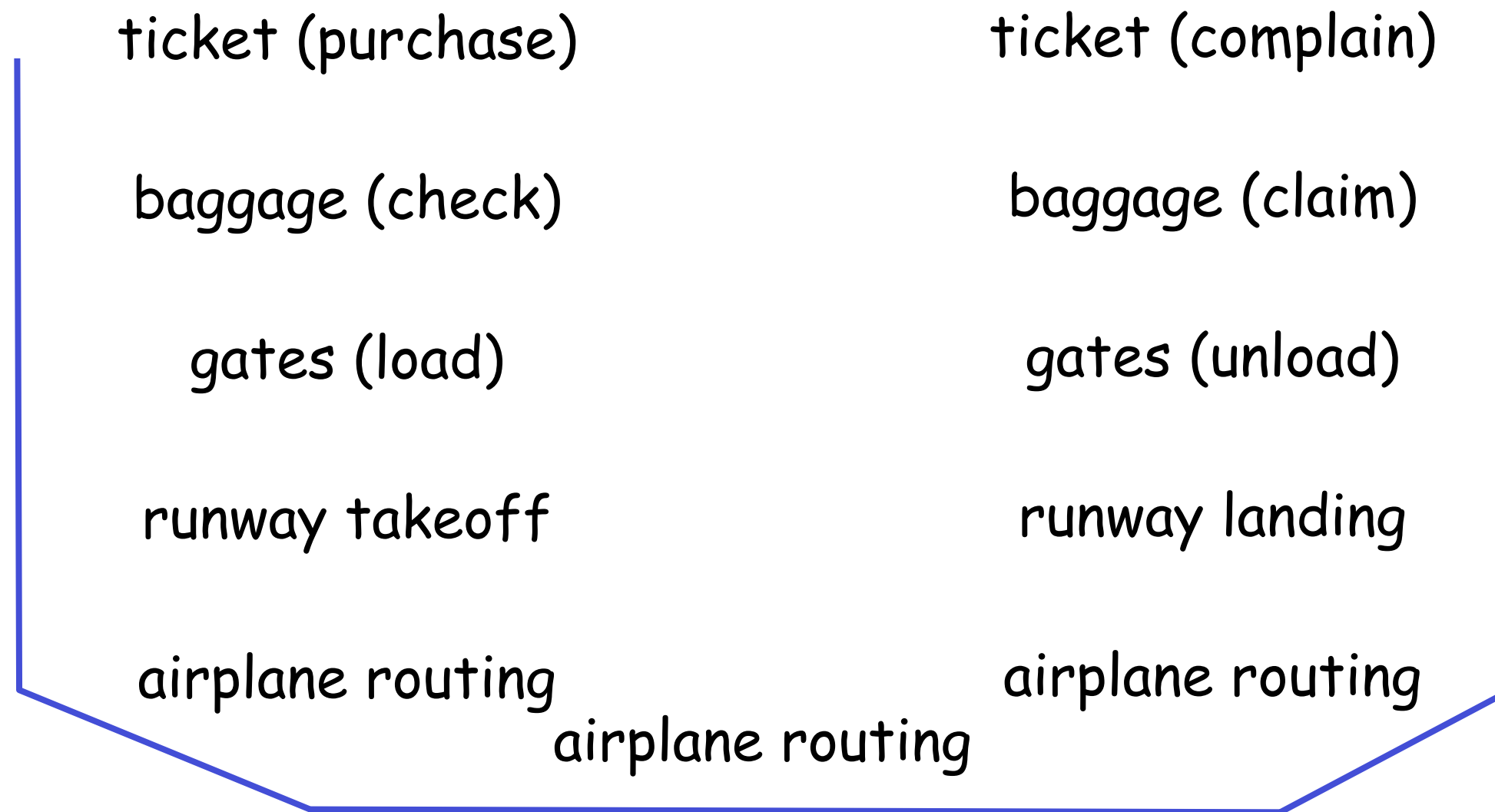
- many “pieces”:
 - hosts
 - routers
 - links of various media
 - applications
 - protocols
 - hardware, software

Question:

Is there any hope of
organizing structure of
network?

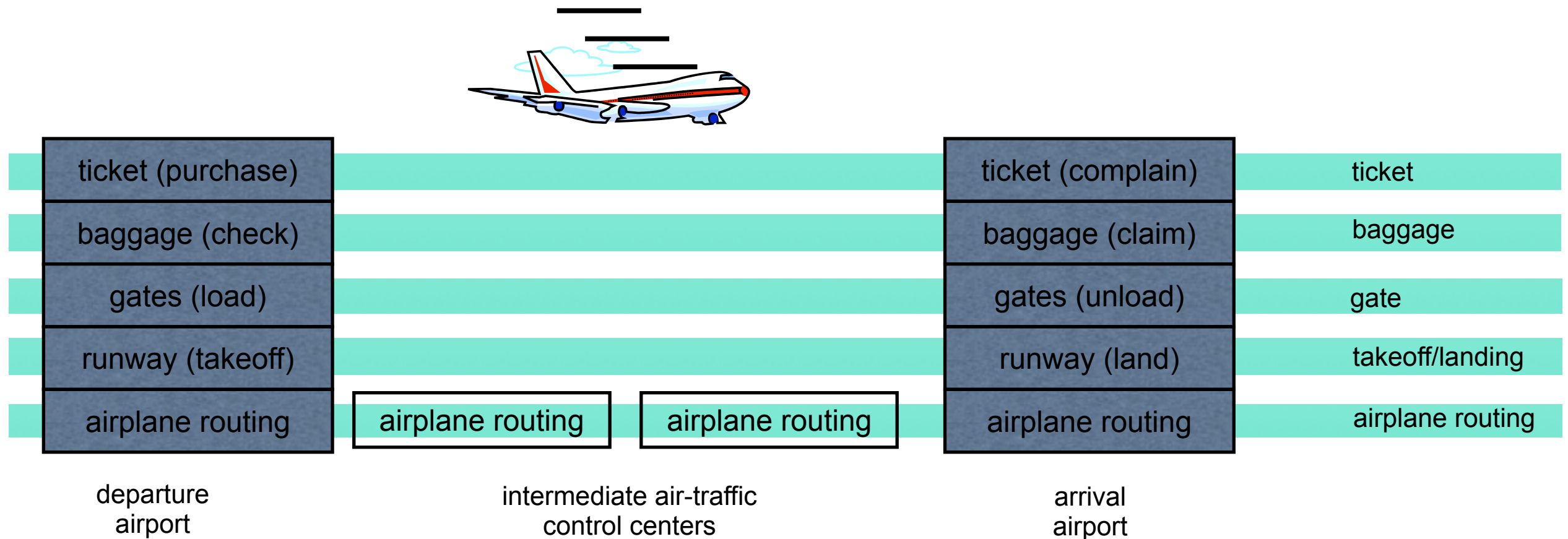
Or at least our discussion
of networks?

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

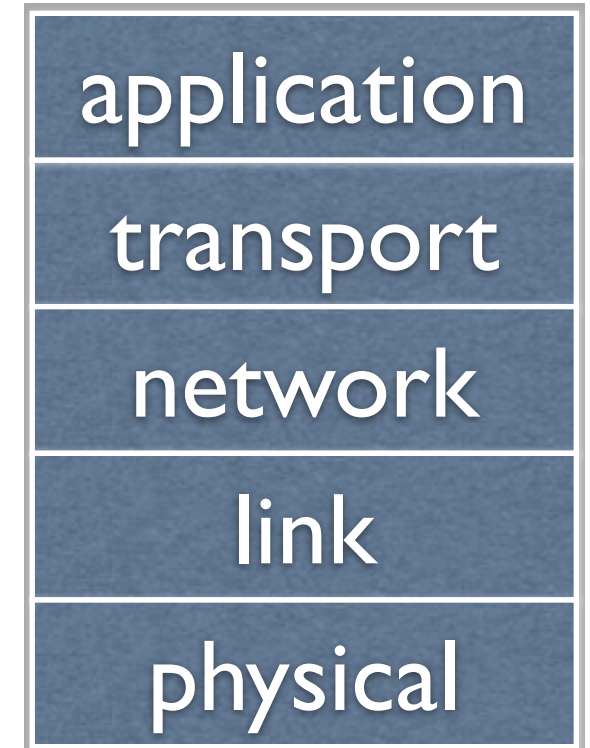
Why layering?

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”

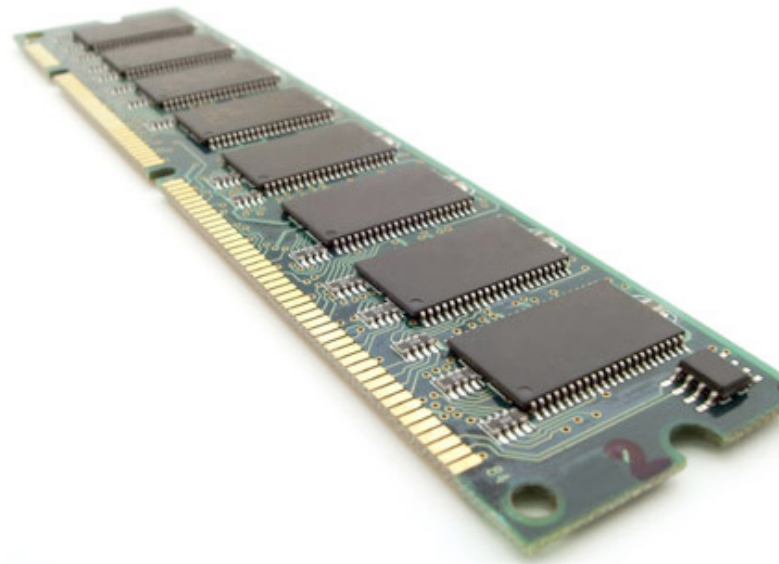


OSI Reference Model

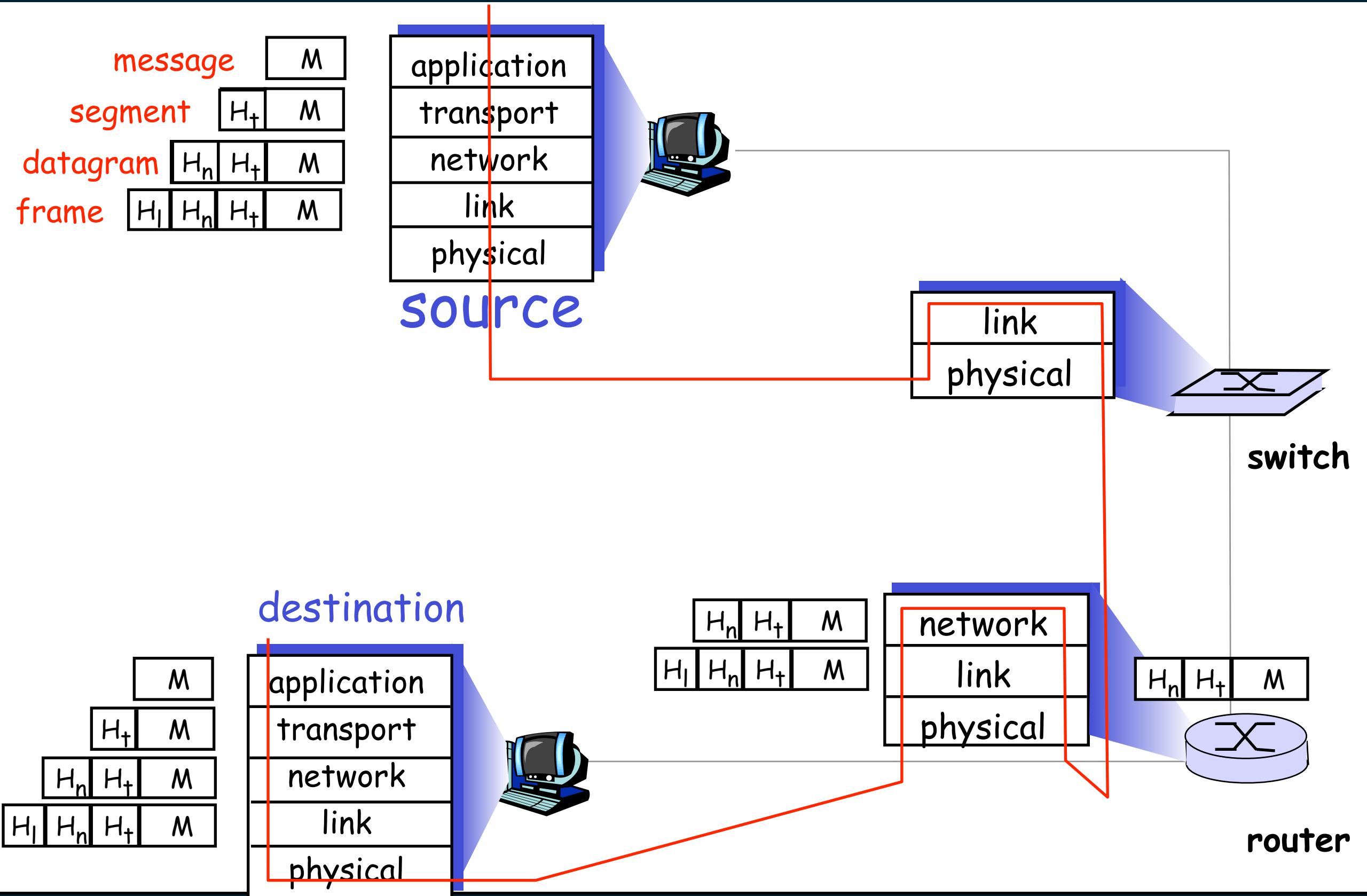
- The Open Systems Interconnection (OSI) model has two additional layers: Session and Presentation.
- Session Layer: Manages sessions between applications
 - (e.g., SSH, RTCP, RPC, NFS)
- Presentation Layer: Delivery and formatting of messages.
 - (e.g., RDP, ASCII)

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

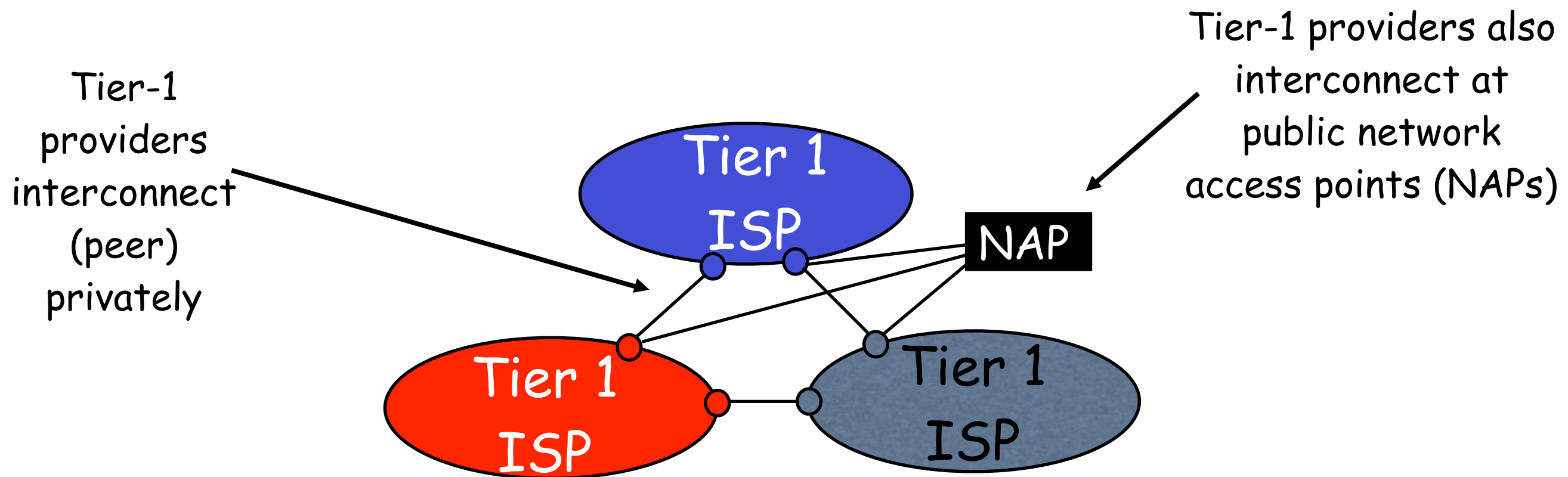


Encapsulation



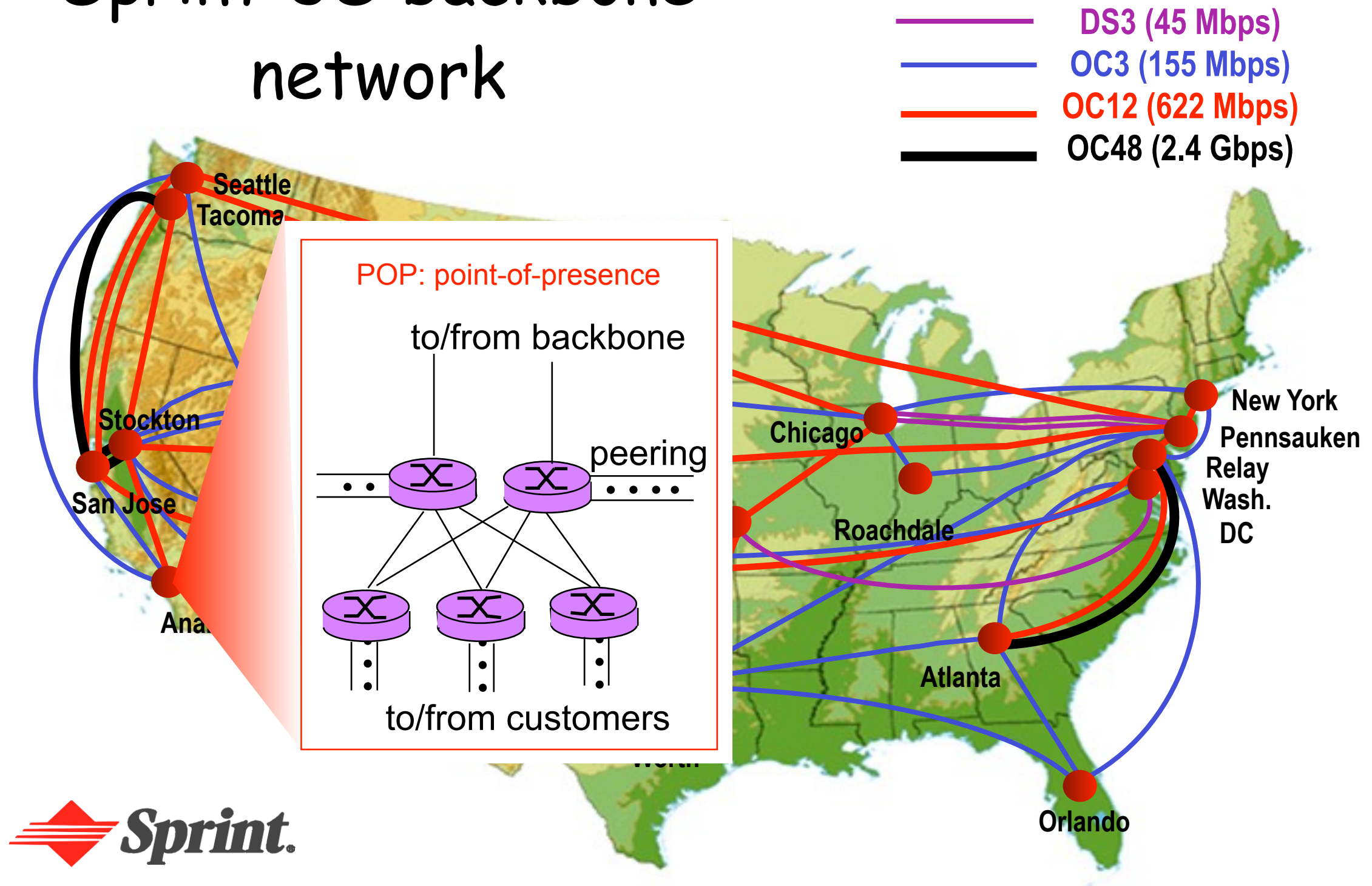
Internet structure: network of networks

- roughly hierarchical
- **at center: “tier-1” ISPs** (e.g., MCI, Sprint, AT&T, Cable and Wireless), national/international coverage
 - treat each other as equals



Tier-I ISP: e.g., Sprint

Sprint US backbone network



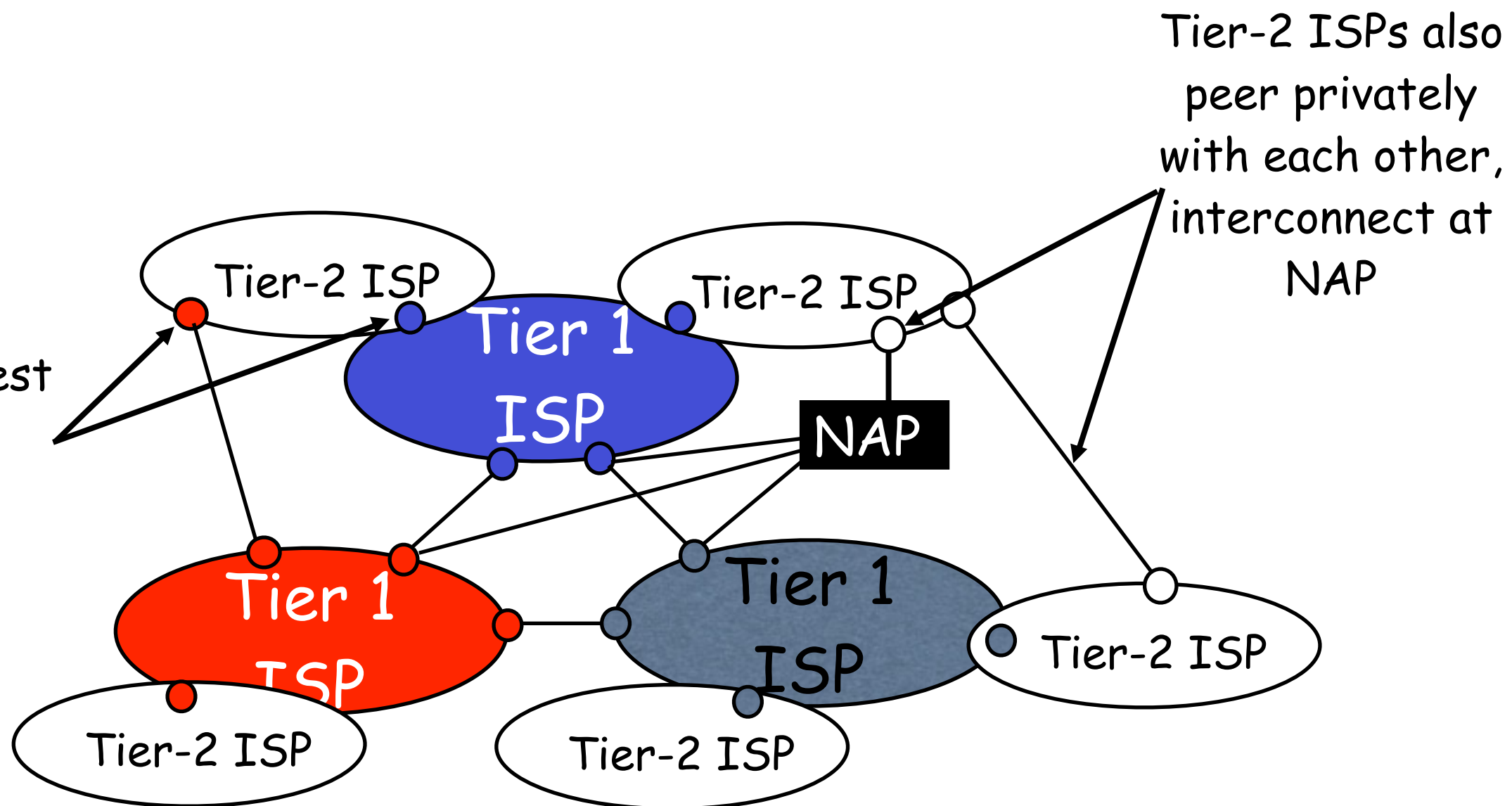
Internet structure: network of networks

- “Tier-2” ISPs: smaller (often regional) ISPs

- Connect to one or more tier-1 ISPs, possibly other tier-2 ISPs

Tier-2 ISP pays tier-1 ISP for connectivity to rest of Internet

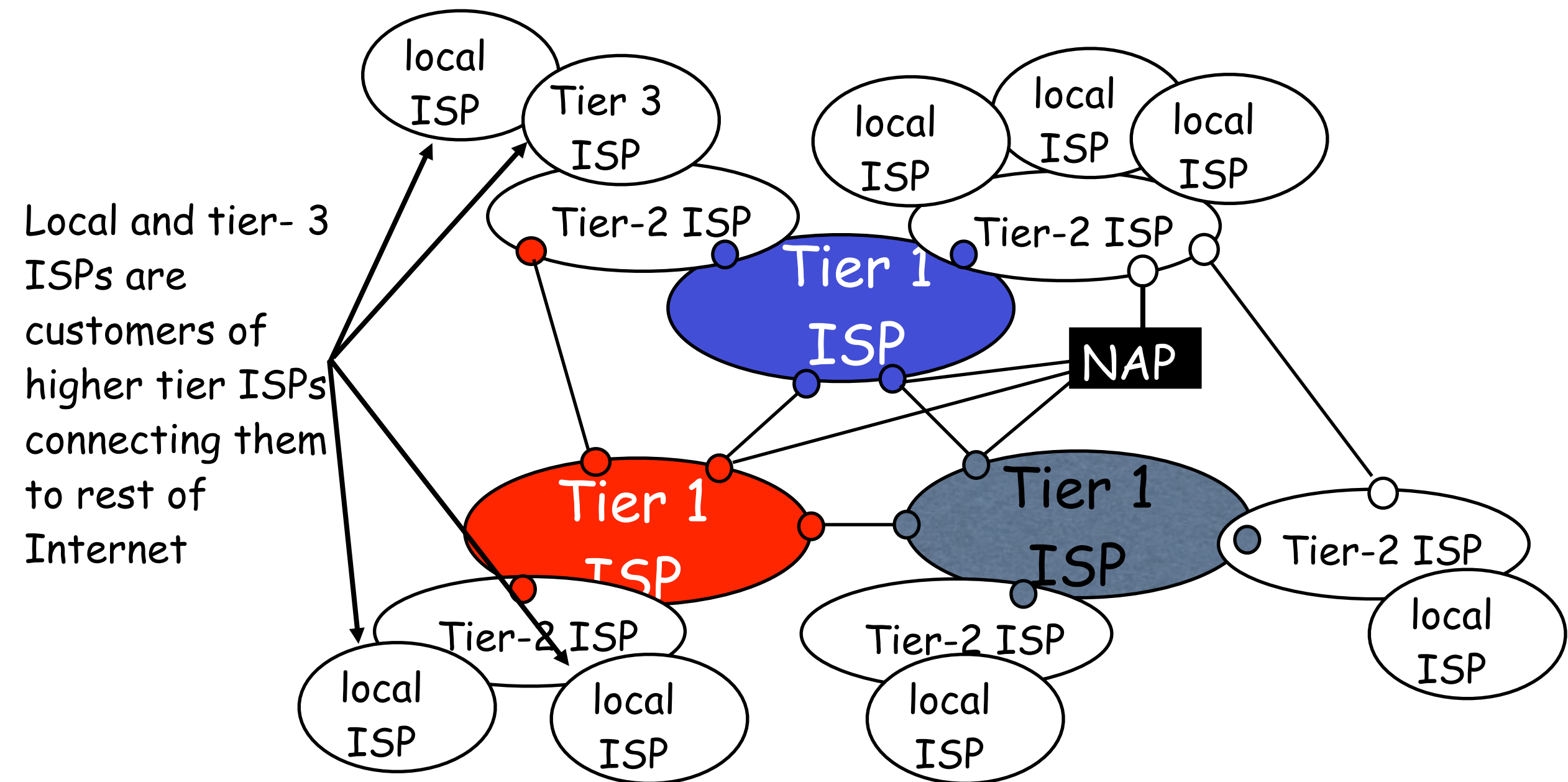
- tier-2 ISP is customer of tier-1 provider



Internet structure: network of networks

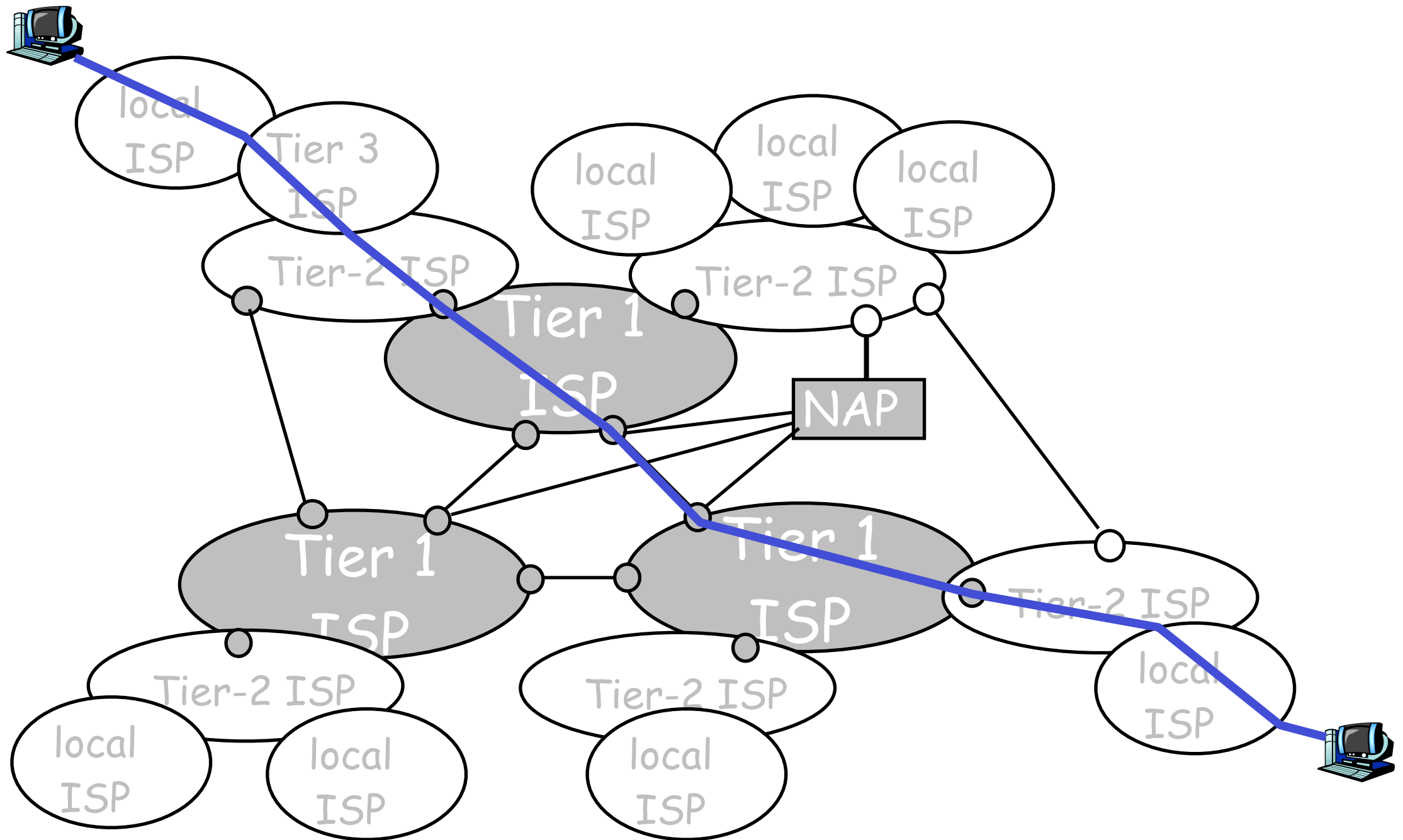
- “Tier-3” ISPs and local ISPs

- last hop (“access”) network (closest to end systems)



Internet structure: network of networks

- a packet passes through many networks!



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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?



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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1.4 Network access and physical media

1.5 Internet structure and ISPs

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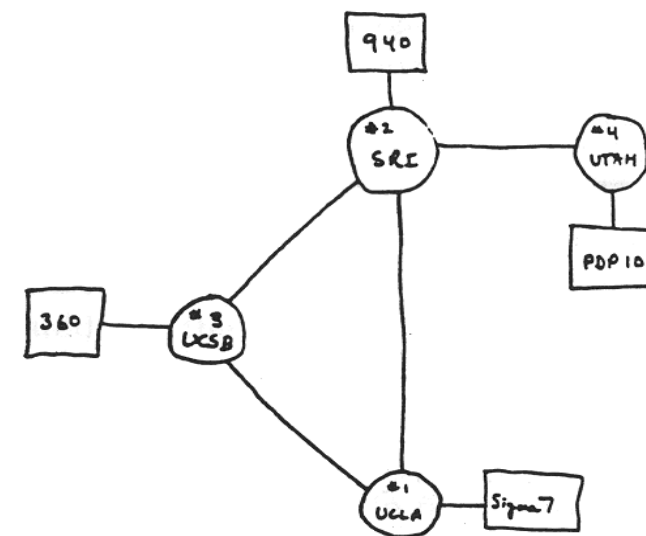
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1.8 History

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:

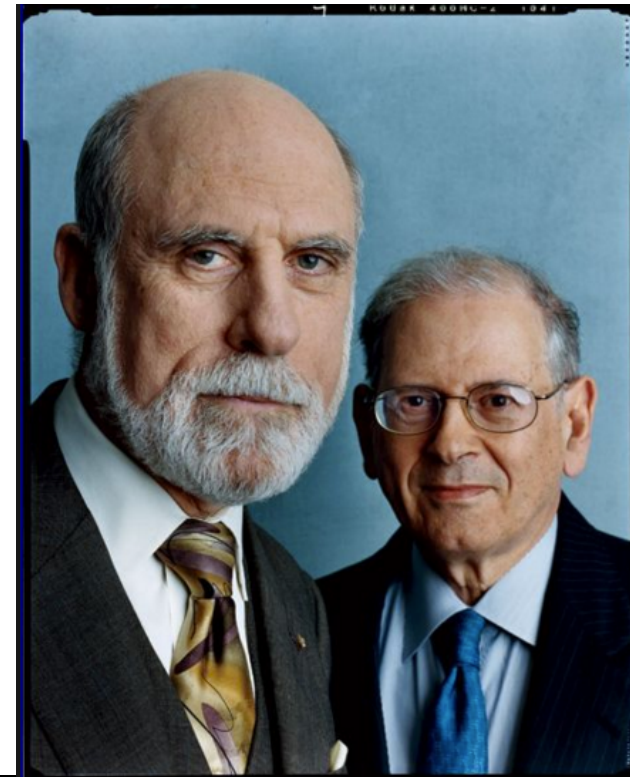
- ▶ minimalism, autonomy - no internal changes required to interconnect networks
- ▶ best effort service model
- ▶ stateless routers
- ▶ decentralized control

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, KaZaA
- network security to forefront
- est. 50 million host, 100 million+ users
- backbone links running at Gbps

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 will be assigned shortly

