



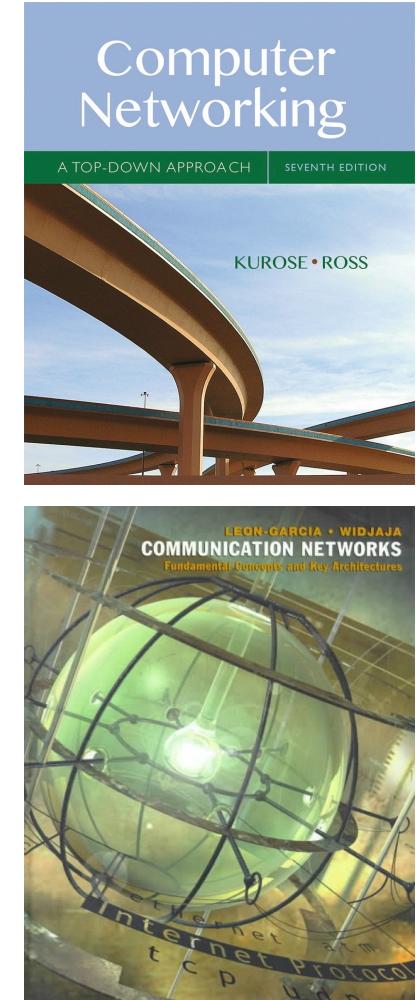
COEN 366-
Communication Networks and Protocols

Concordia University

Chadi Assi
CIISE department
EV9.179

Text books

- “Computer Networking: A Top-Down Approach”, 7th (or 8th) Edition by James Kurose and Keith Ross
- “Communication Networks: Fundamental Concepts and Key Architectures” by Alberto Leon-Garcia and Indra Widjaja



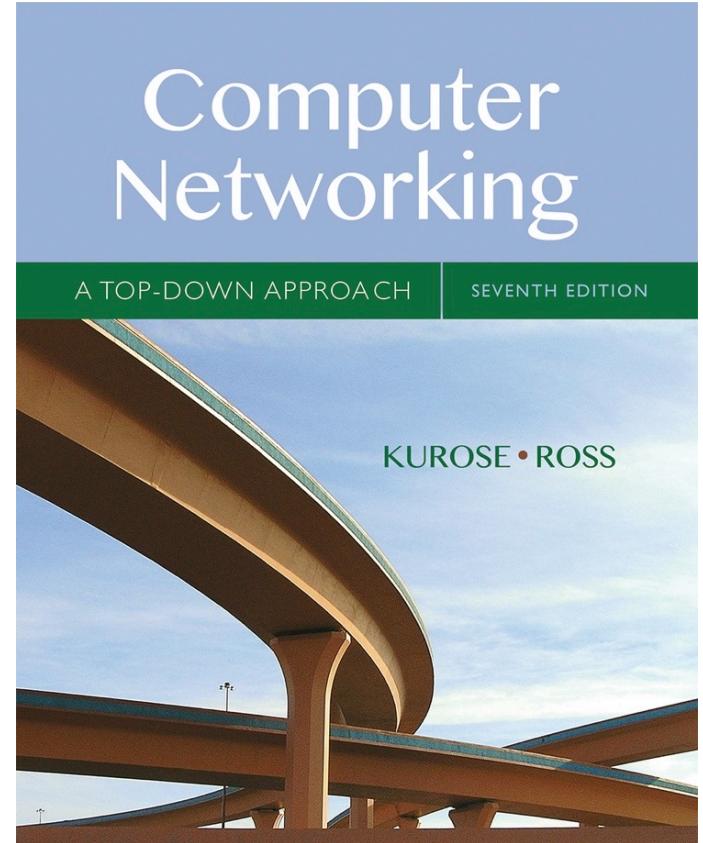
Course outline

- Introduction to Computer networks
- Application Layer (principles, some apps, socket programming)
- Transport Layer (Principles of error detection and control , principles of Flow and congestion control, TCP)
- Network Layer (forwarding, switching, routing, addressing and internetworking, SDN, etc.)
- (if time permits) Link Layer (Error detection and control, Access methods: deterministic and random, Aloha and S-Aloha, CSMA/CD, Ethernet, STP protocol)
- Learning Wireshark, Mininet, socket programming

Course outline

- Chadi Assi, chadi.assi@concordia.ca
 - Office : E 9.179
 - Office Phone: 5799
 - Office Hours : W/F 11:30pm – 12:30pm
- Marking Scheme:
 - Midterm 20%
 - Final 50%
 - Lab assignments + Proj. 30%
 - Mohamad Adraa and Shreya Khisa (Lab instructors)
- More info: ENCS Moodle

Chapter I Introduction



*Computer
Networking: A Top
Down Approach*

7th edition
Jim Kurose, Keith Ross
Pearson/Addison Wesley
April 2016

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J.F Kurose and K.W. Ross, All Rights Reserved

Chapter I: introduction

overview:

- what's the Internet?
- what's a protocol?
- network edge; hosts, access net, physical media
- network core: packet/circuit switching, Internet structure
- performance: loss, delay, throughput
- security
- protocol layers, service models
- history

Chapter I: roadmap

I.1 what *is* the Internet?

I.2 network edge

- end systems, access networks, links

I.3 network core

- packet switching, circuit switching, network structure

I.4 delay, loss, throughput in networks

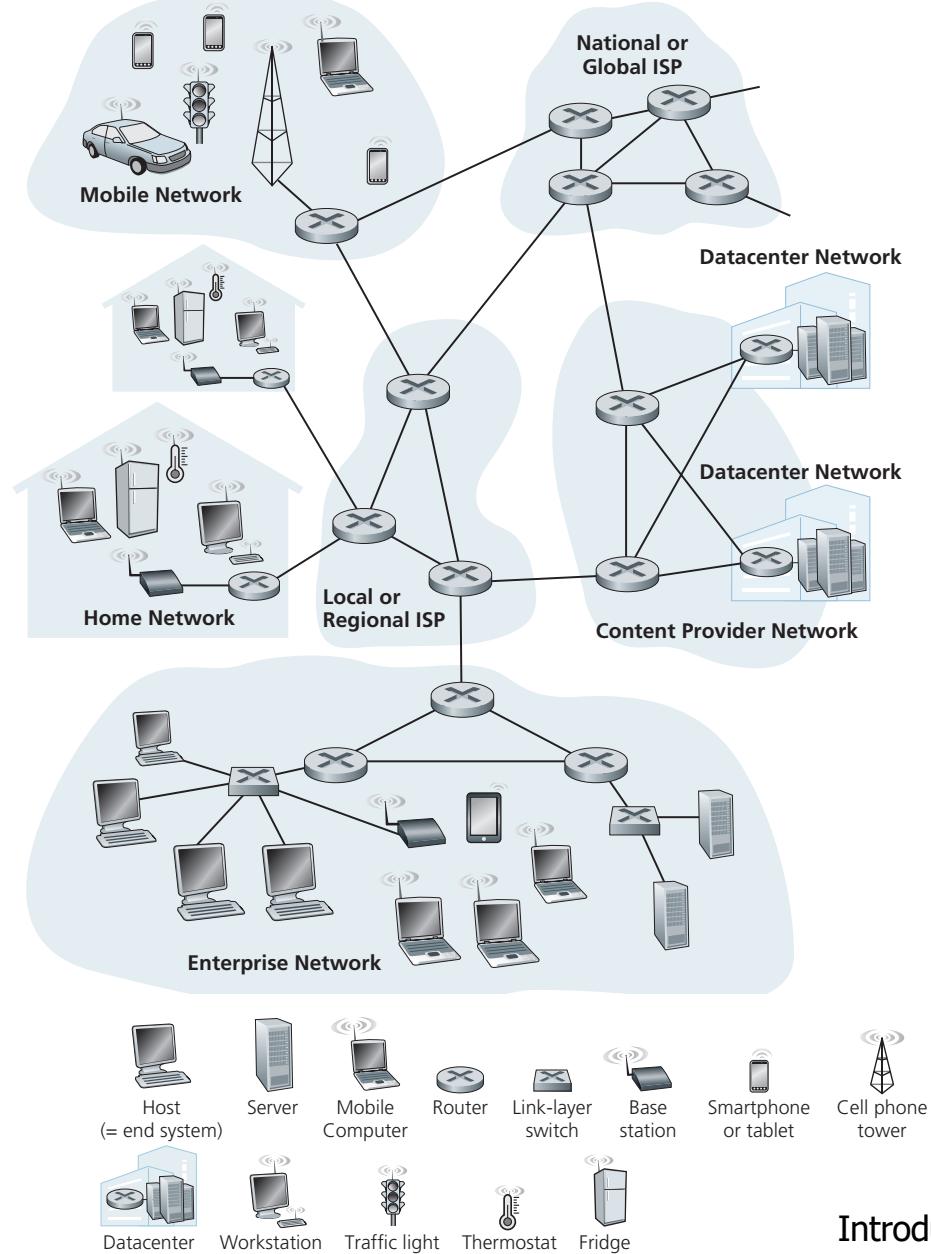
I.5 protocol layers, service models

I.6 networks under attack: security

I.7 history

What's the Internet: “nuts and bolts” view

- billions of connected computing devices:
 - *hosts = end systems*
 - running *network apps*
- *communication links*
 - fiber, copper, radio, satellite
 - transmission rate: *bandwidth*
- *packet switches*: forward packets (chunks of data)
 - *routers* and *switches*



What's the Internet: “nuts and bolts” view



Layer 2 Switches



Hub



Multi Layer Switches



Firewalls



Modems



Routers



Bridges



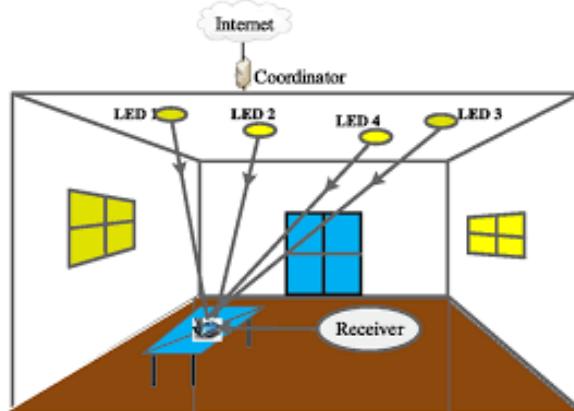
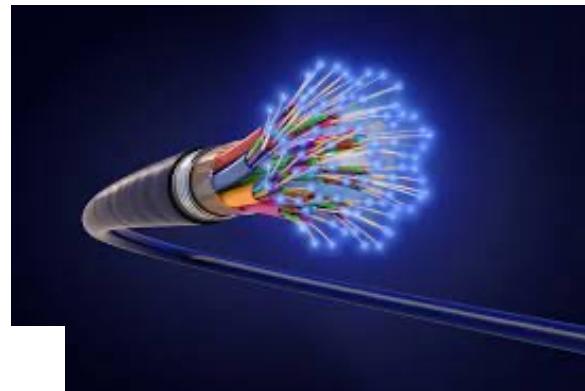
Repeater

What's the Internet: “nuts and bolts” view



The Middlebox World

What's the Internet: “nuts and bolts” view



“Fun” Internet-connected devices



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



Web-enabled toaster +
weather forecaster



Tweet-a-watt:
monitor energy us



Internet
refrigerator



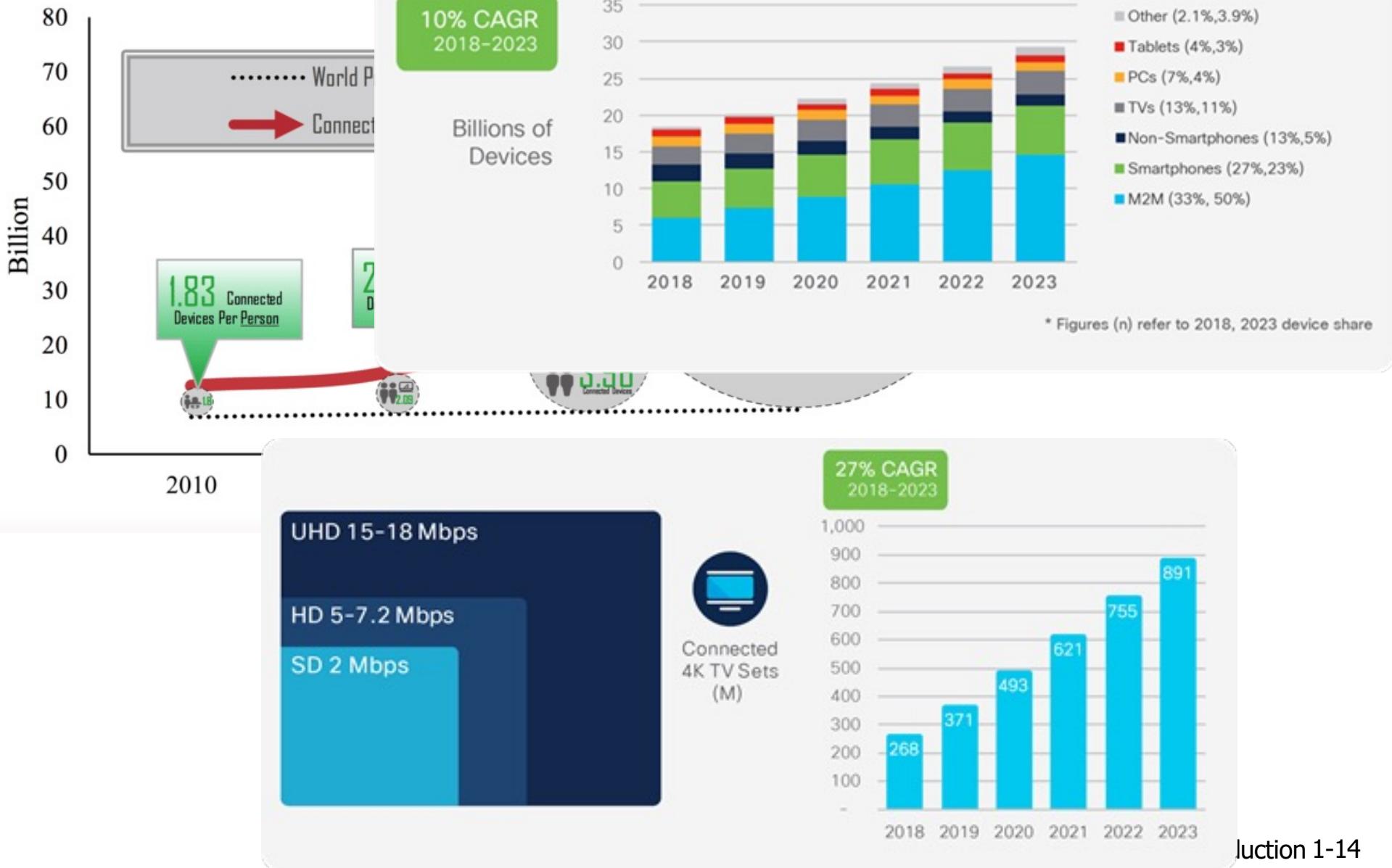
Slingbox: watch,
control cable TV remotely



WIRELESS IMPLANTABLE MEDICAL DEVICES

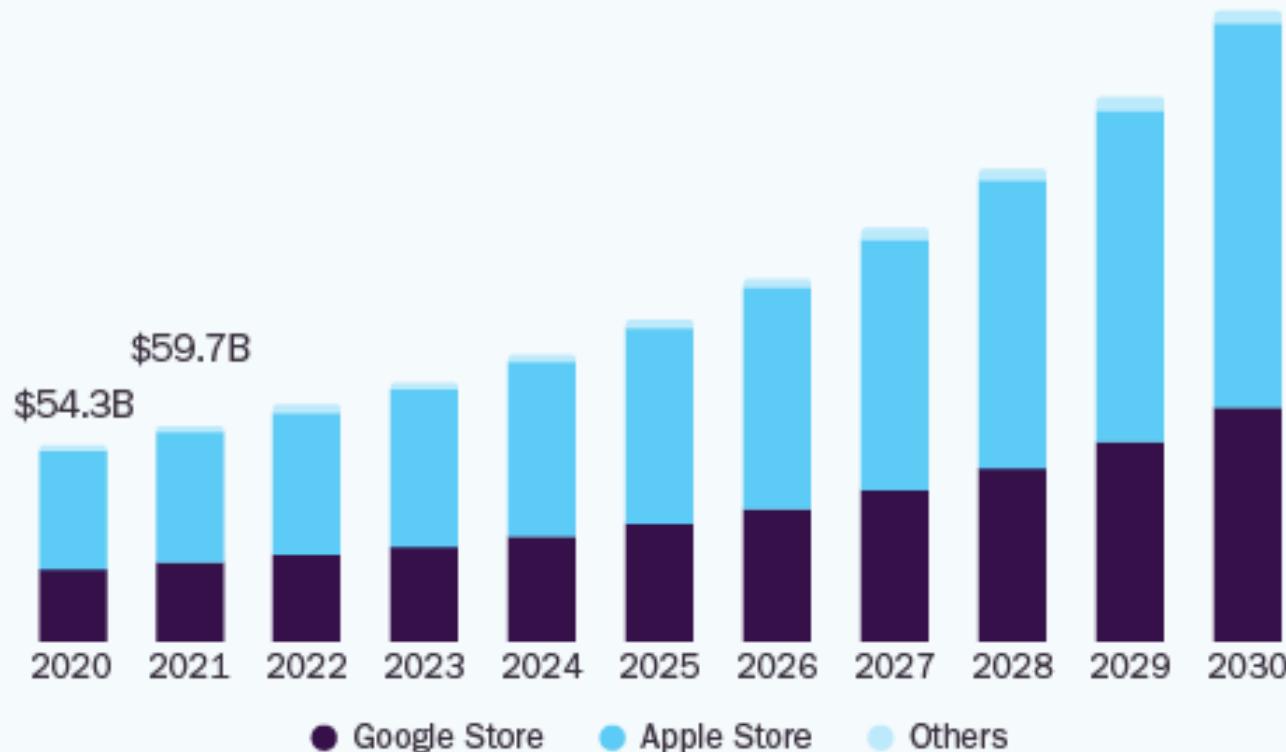


Statistics



Internet services

North America Mobile Application Market size, by store type, 2020 - 2030 (USD Billion)



13.4%

N. America Market CAGR,
2022 - 2030

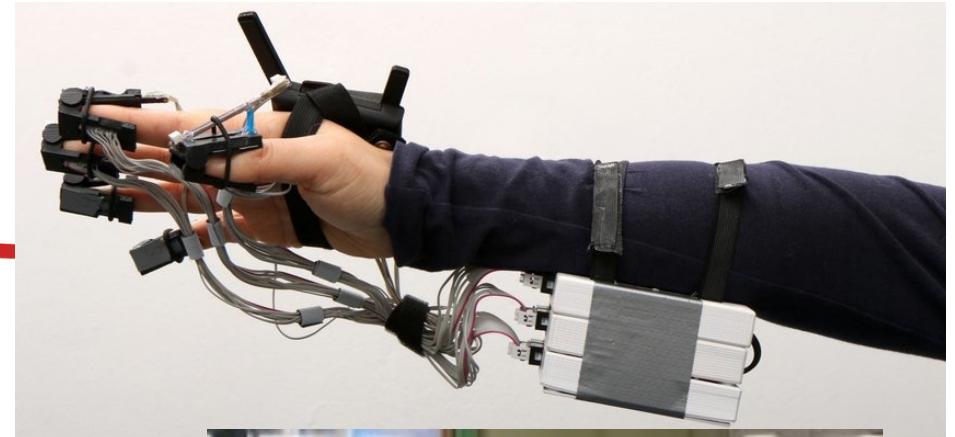
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www.grandviewresearch.com

Internet services



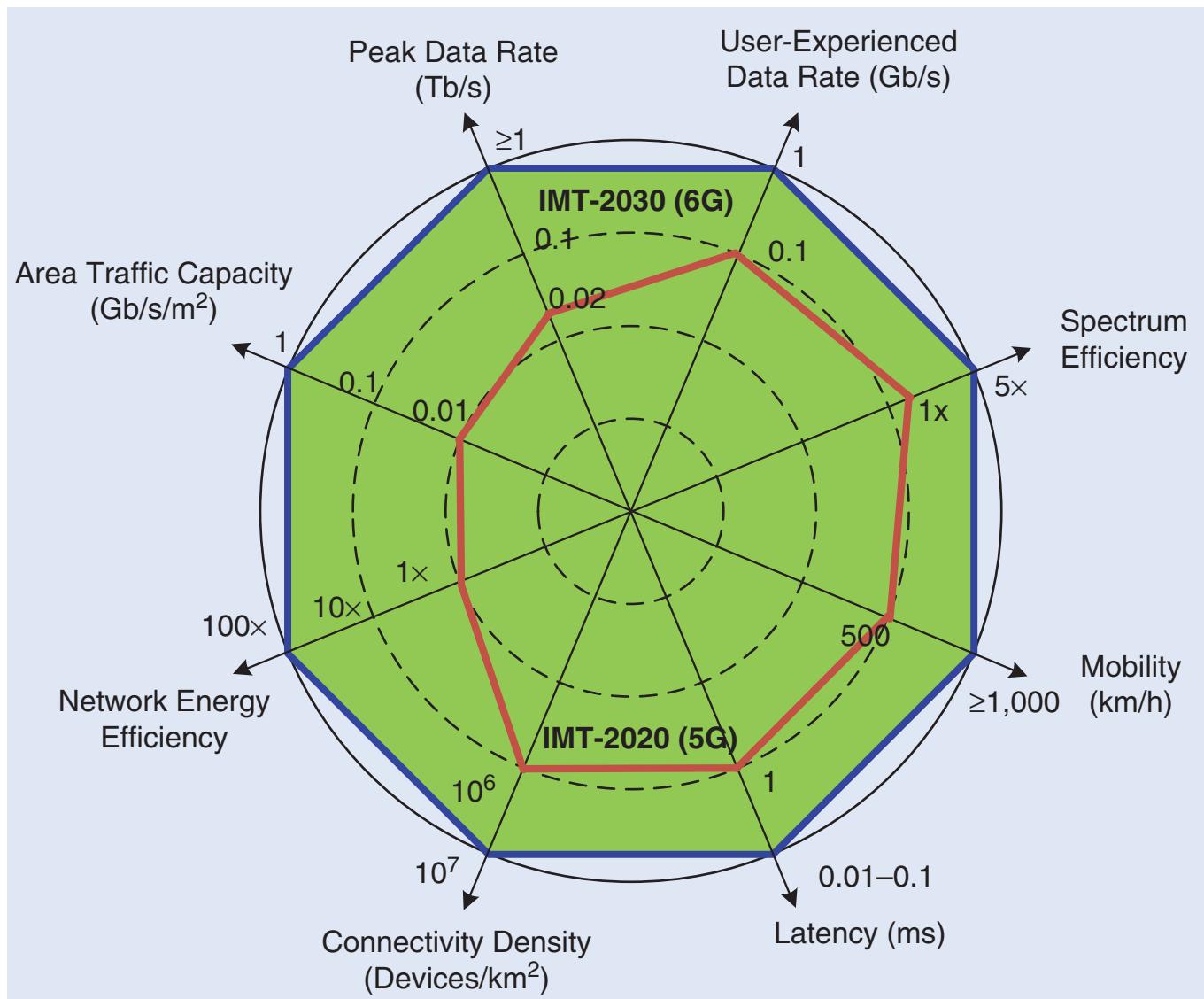
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Internet services



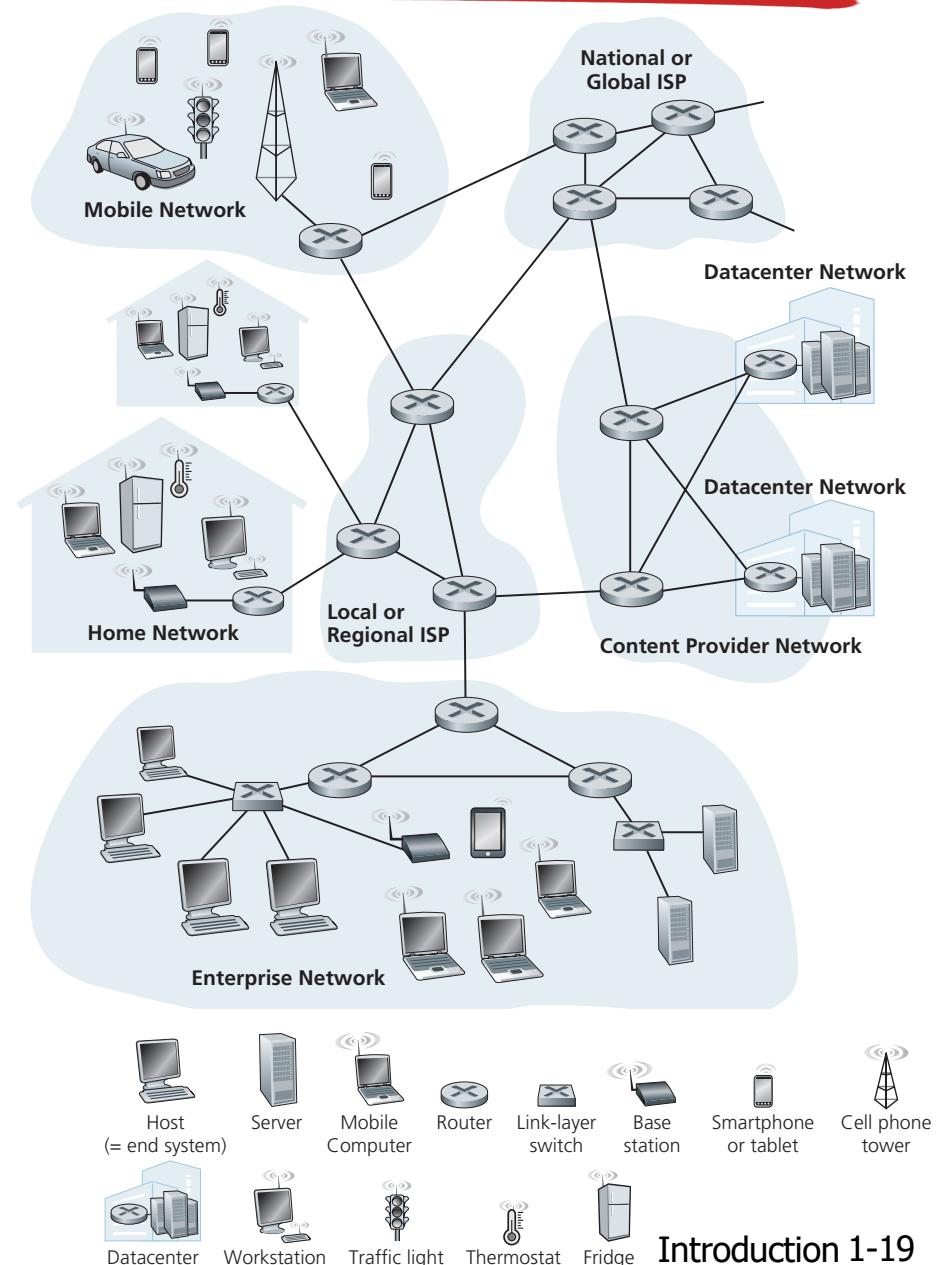
The Tactile Internet

Where are we heading



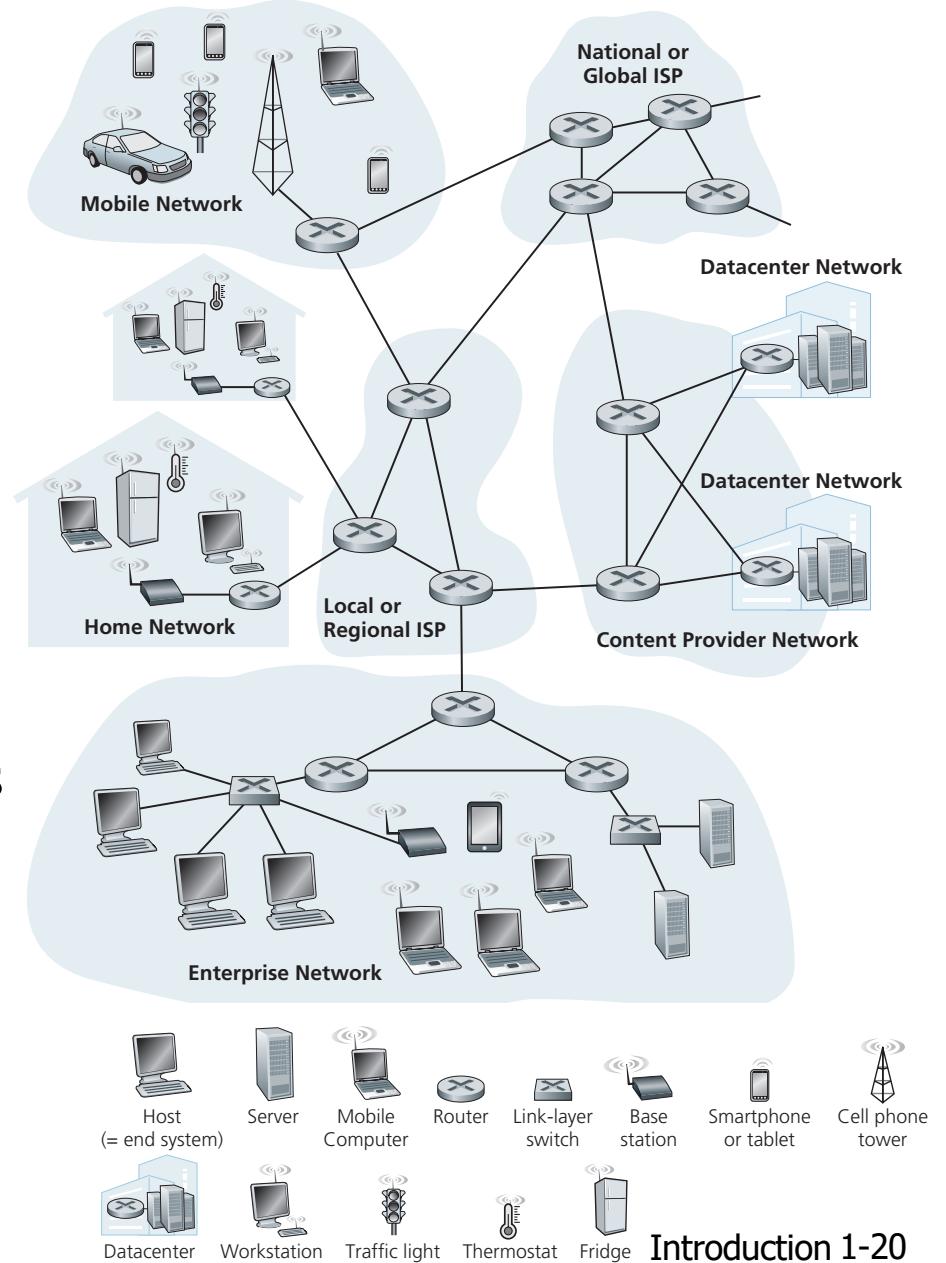
What's the Internet: “nuts and bolts” view

- *Internet: “network of networks”*
 - Interconnected ISPs
- *protocols control sending, receiving of messages*
 - e.g., TCP, IP, HTTP, Skype, 802.11
- *Internet standards*
 - RFC: Request for comments
 - IETF: Internet Engineering Task Force



What's the Internet: a service view

- *infrastructure that provides services to applications:*
 - Web, VoIP, email, games, e-commerce, social nets, ...
- *provides programming interface to apps*
 - hooks that allow sending and receiving app programs to “connect” to Internet
 - provides service options, analogous to postal service



What's a protocol?

human protocols:

- “what’s the time?”
- “I have a question”
- introductions

... specific messages sent

... specific actions taken
when messages
received, or other
events

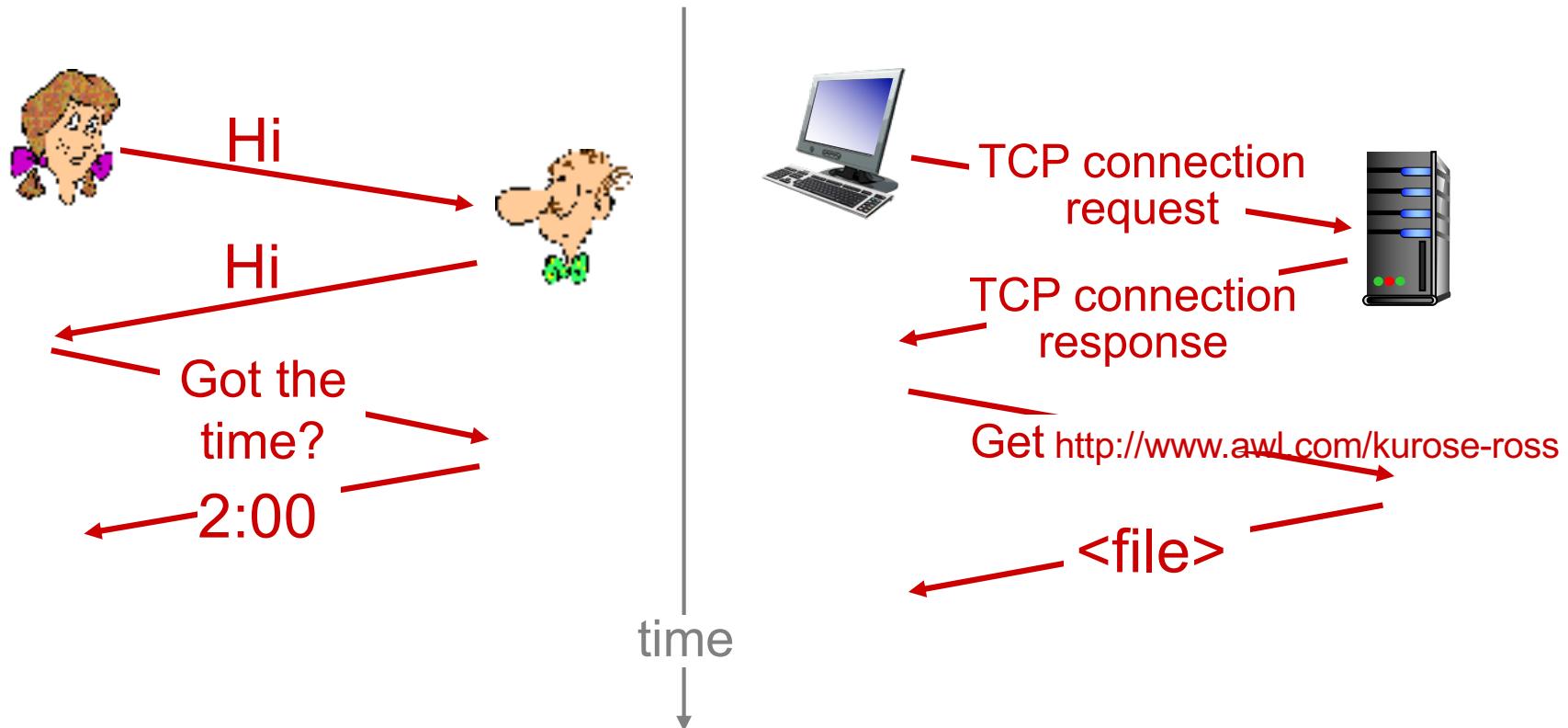
network protocols:

- machines rather than humans
- all communication activity in Internet governed by protocols

*protocols define format, order of
messages sent and received
among network entities, and
actions taken on message
transmission, receipt*

What's a protocol?

a human protocol and a computer network protocol:



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- packet switching, circuit switching, network structure

I.4 delay, loss, throughput in networks

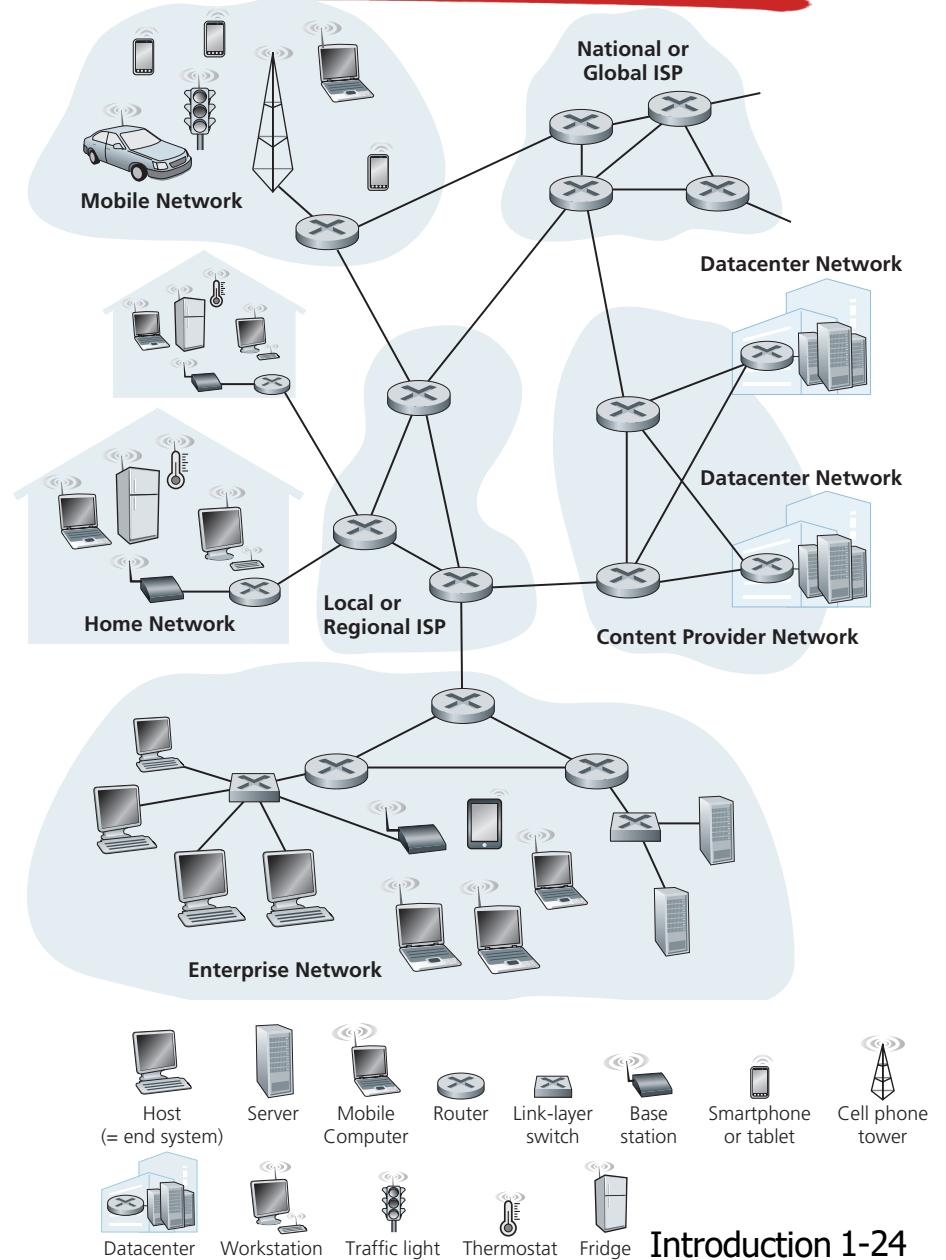
I.5 protocol layers, service models

I.6 networks under attack: security

I.7 history

A closer look at network structure:

- **network edge:**
 - hosts: clients and servers
 - servers often in data centers
- **access networks, physical media:** wired, wireless communication links
- **network core:**
 - interconnected routers
 - network of networks



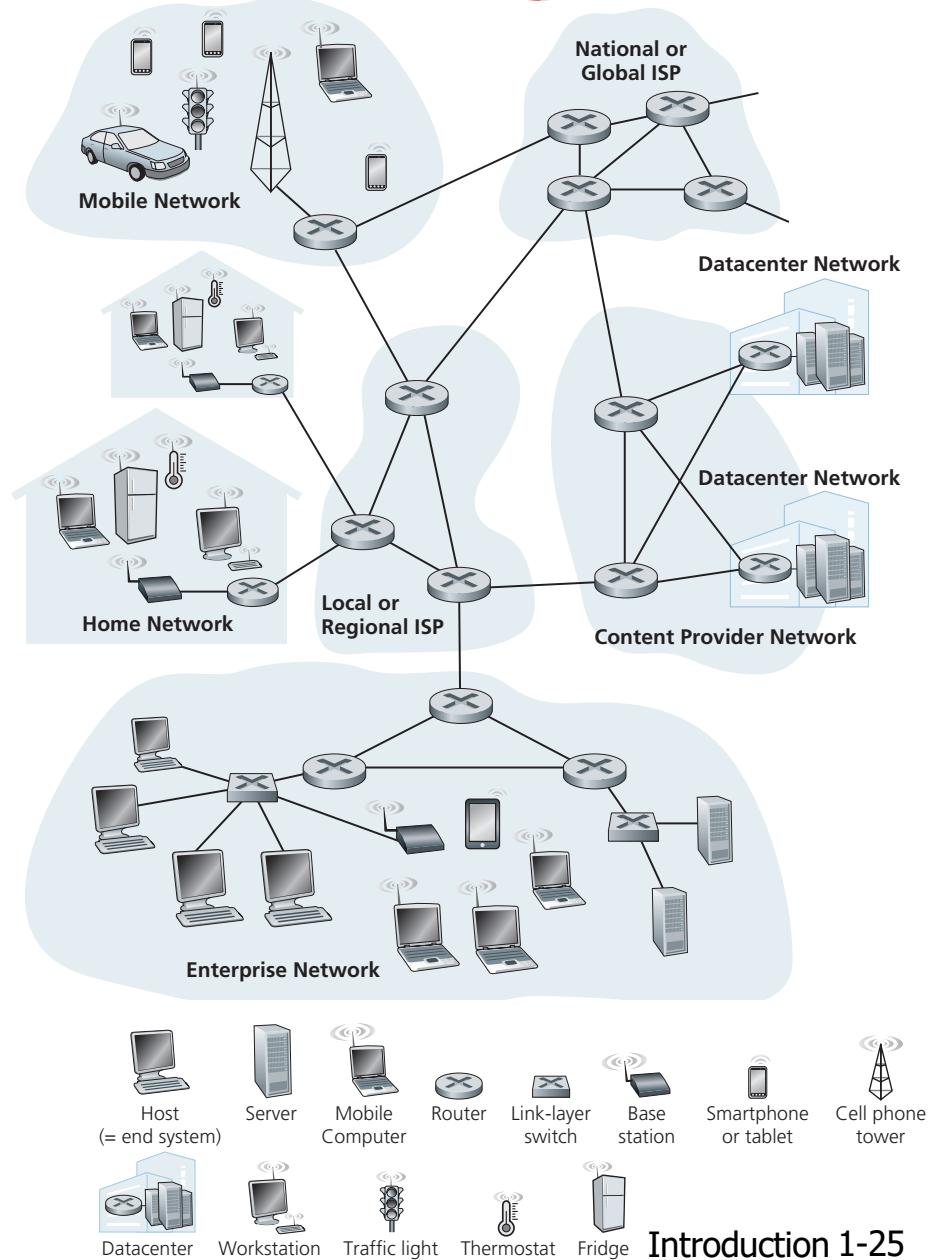
Access networks and physical media

Q: How to connect end systems to edge router?

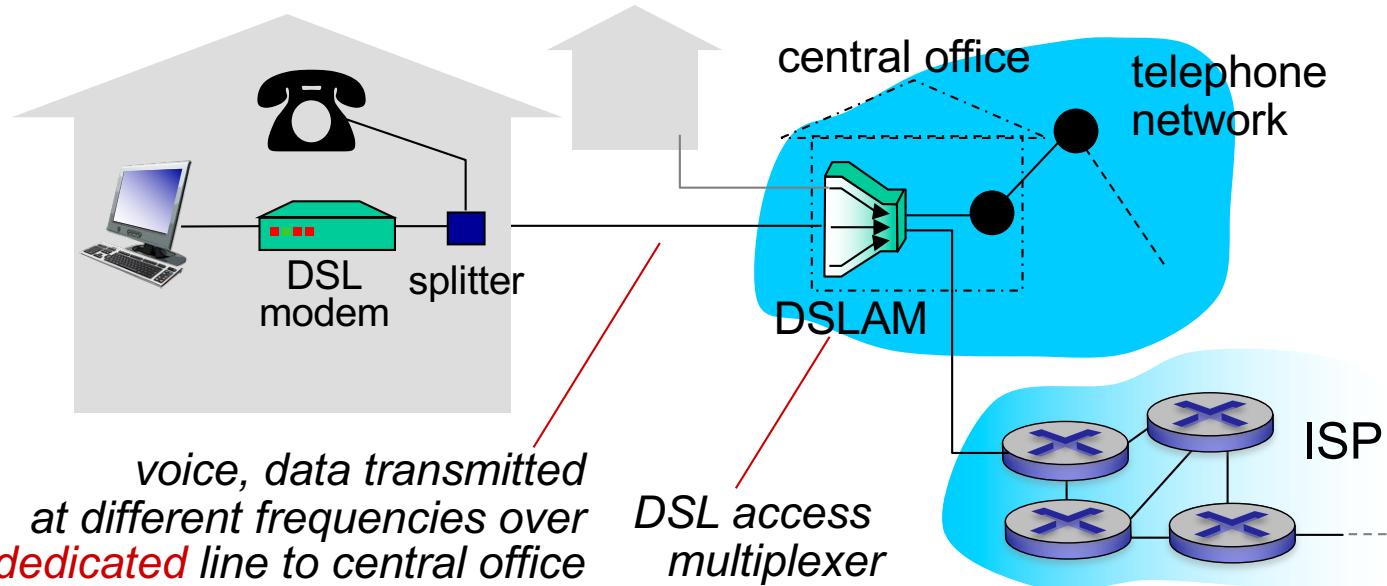
- residential access nets
- institutional access networks (school, company)
- mobile access networks

keep in mind:

- bandwidth (bits per second) of access network?
- shared or dedicated?

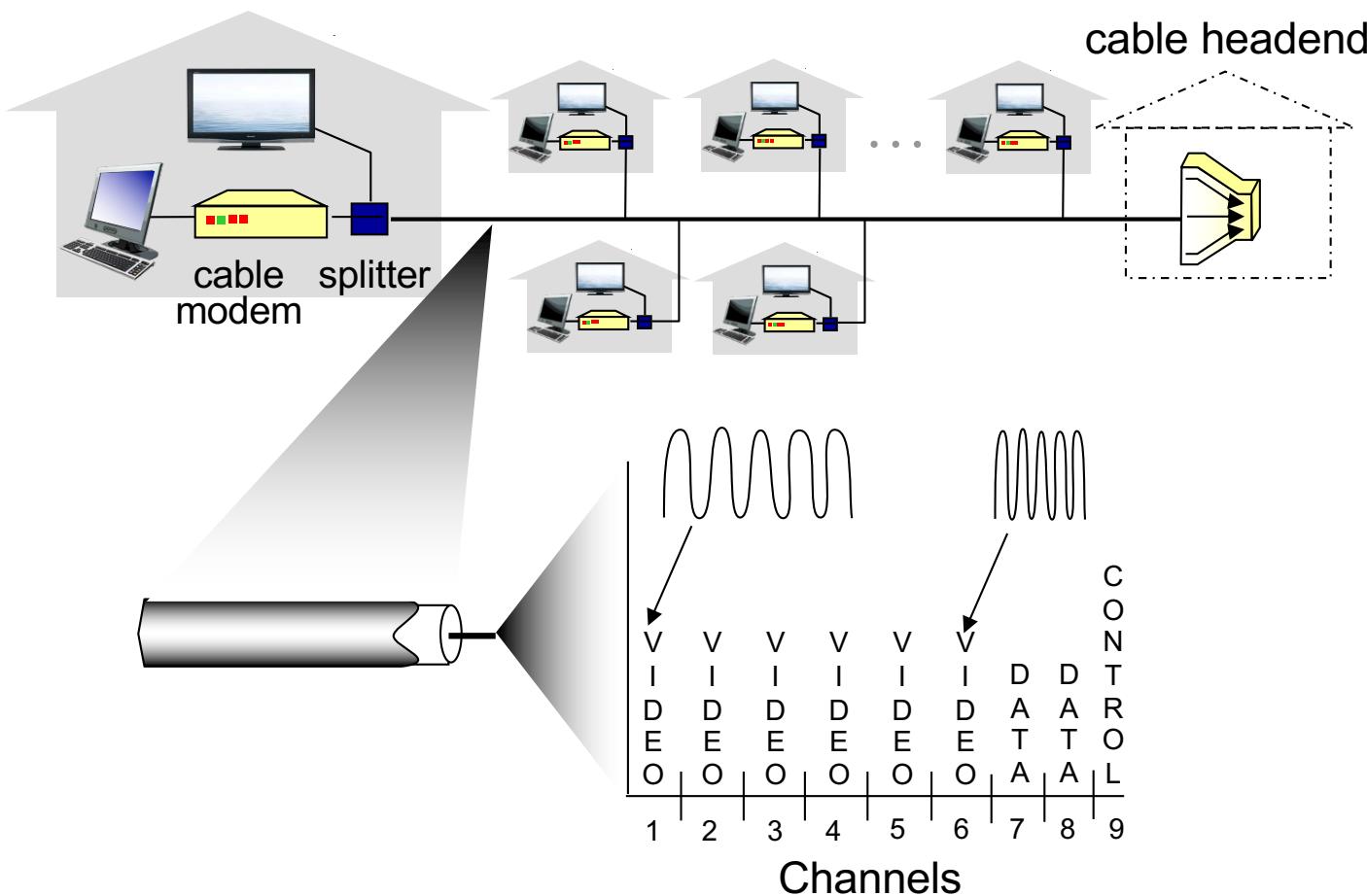


Access network: digital subscriber line (DSL)



- use **existing** telephone line to central office DSLAM
 - data over DSL phone line goes to Internet
 - voice over DSL phone line goes to telephone net
- < 2.5 Mbps upstream transmission rate (typically < 1 Mbps)
- < 24 Mbps downstream transmission rate (typically < 10 Mbps)
- Rates may vary with the standard used.
- Rates vary with distance (~5-10 Miles)

Access network: cable network



frequency division multiplexing: different channels transmitted in different frequency bands

Access network: cable network

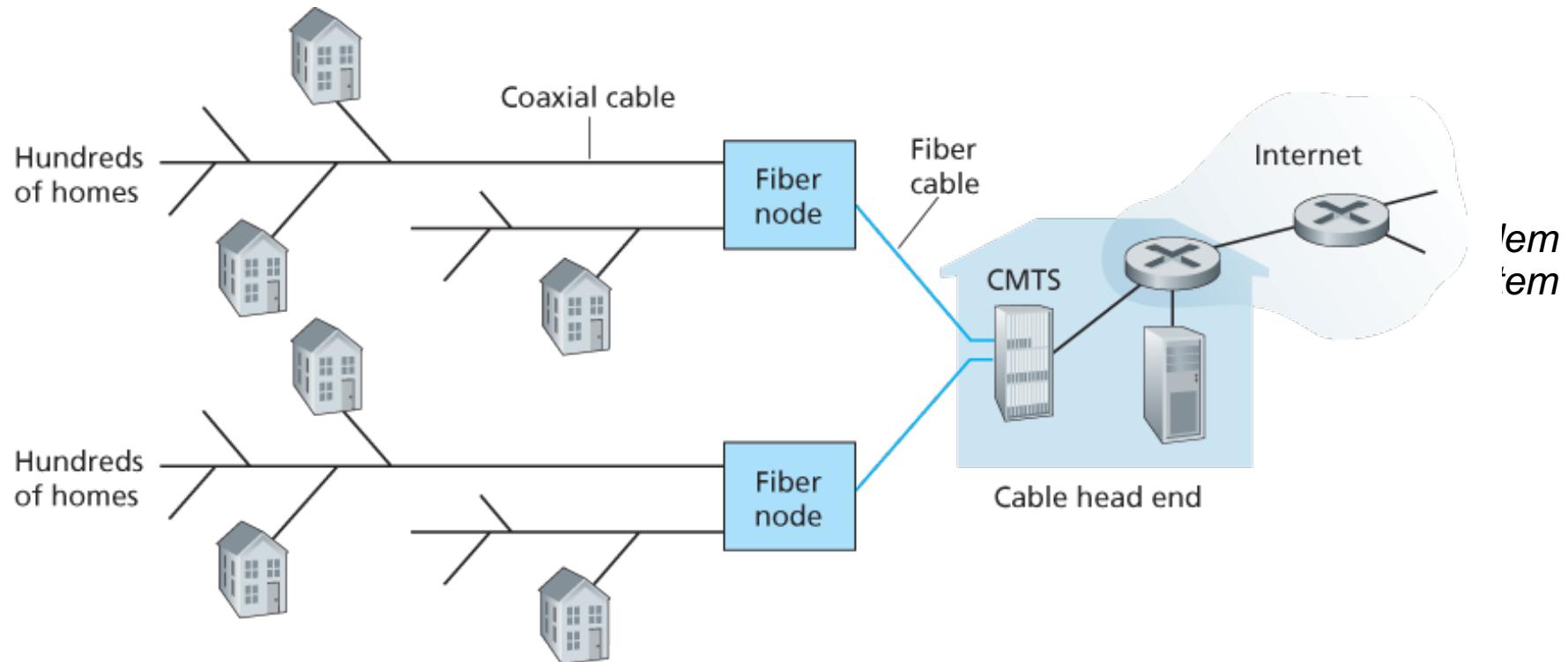


Figure 1.6 A hybrid fiber-coaxial access network

2

- **network of cable, fiber attaches homes to ISP router**
 - homes *share access network* to cable headend
 - unlike DSL, which has dedicated access to central office

Access network: FTTH

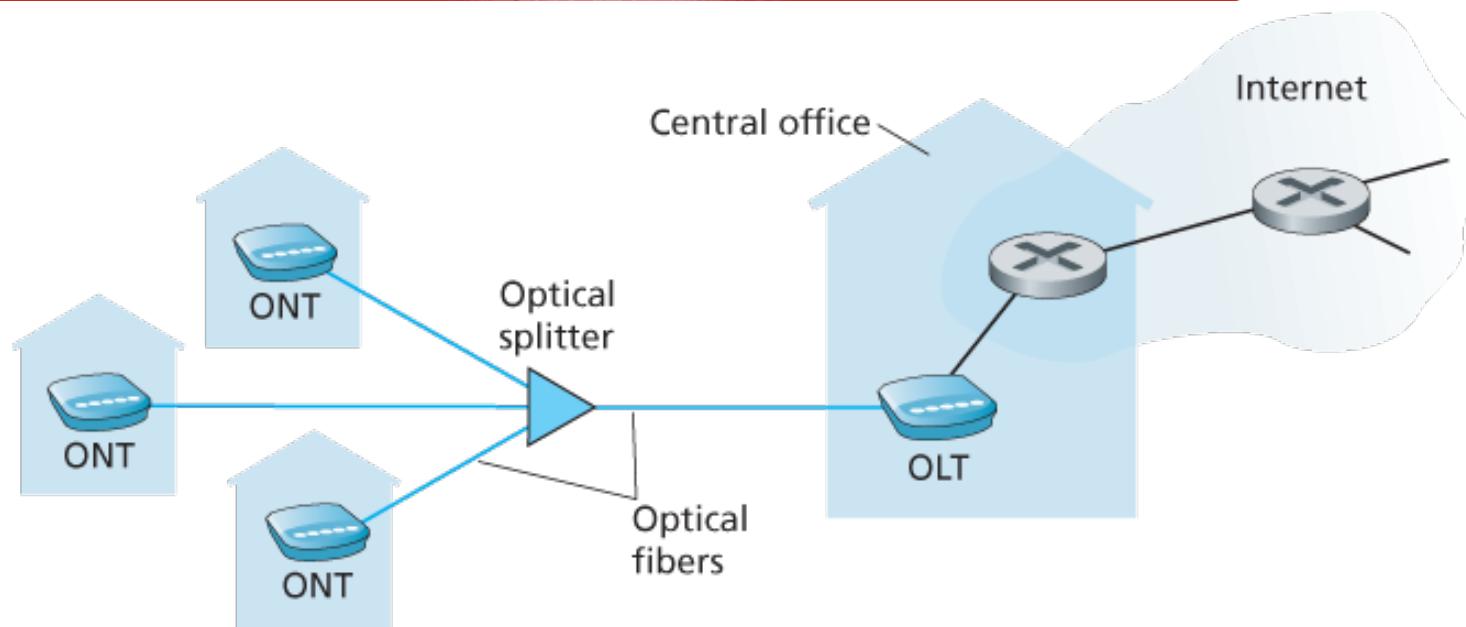
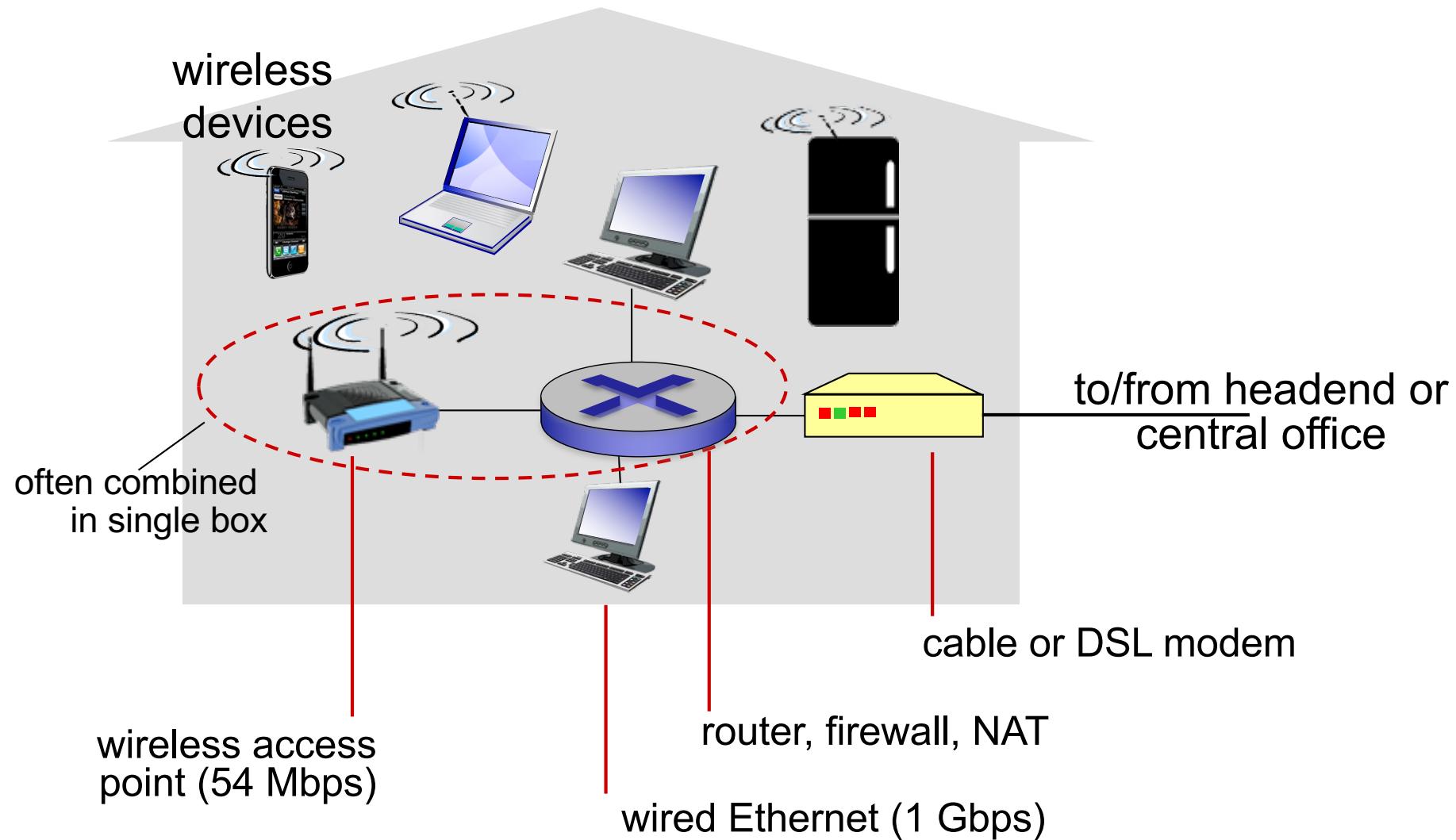


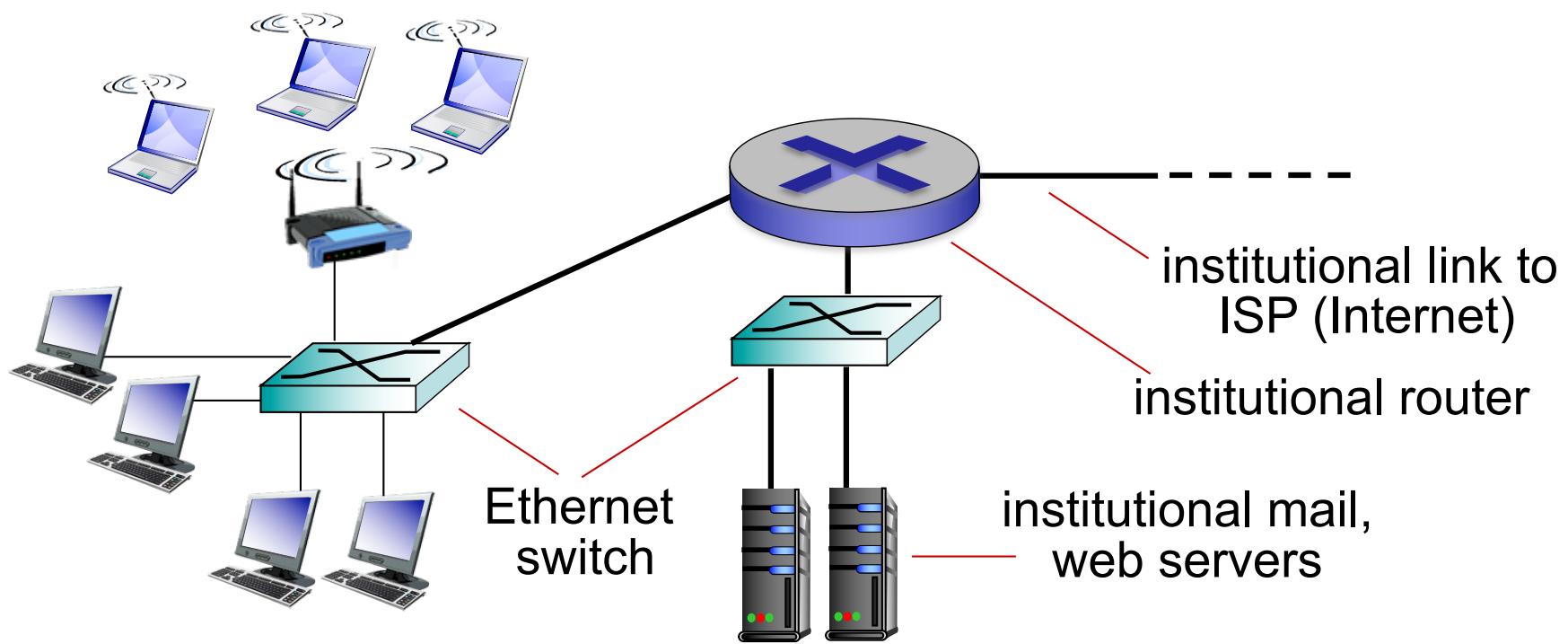
Figure 1.7 FTTH Internet access

- **FTTH Internet Access**
 - Up to Gbps rates (with typical average rates of 20Mbps or more)
- **PON, EPON, GPON, LR-PON, etc.**

Access network: typical home network



Enterprise access networks (Ethernet)



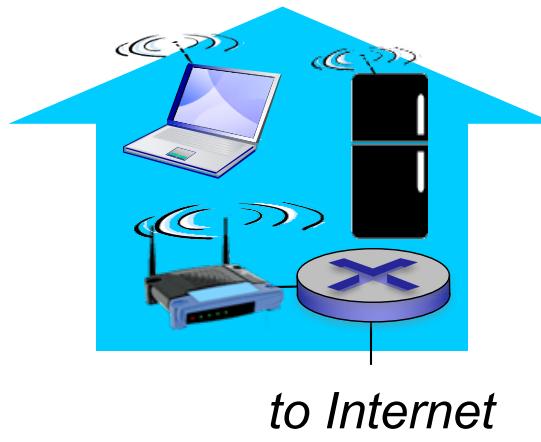
- typically used in companies, universities, etc.
- 10 Mbps, 100Mbps, 1 Gbps, 10Gbps transmission rates
- today, end systems typically connect into Ethernet switch

Wireless access networks

- shared wireless access network connects end system to router
 - via base station aka “access point”

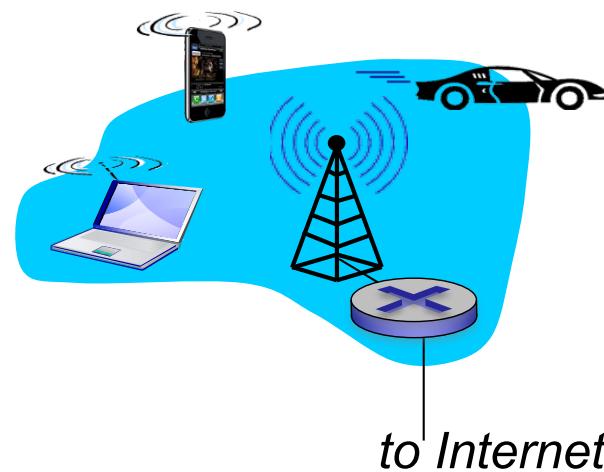
wireless LANs:

- within building (100 ft.)
- 802.11b/g/n (WiFi): 11, 54, 450 Mbps transmission rate



wide-area wireless access

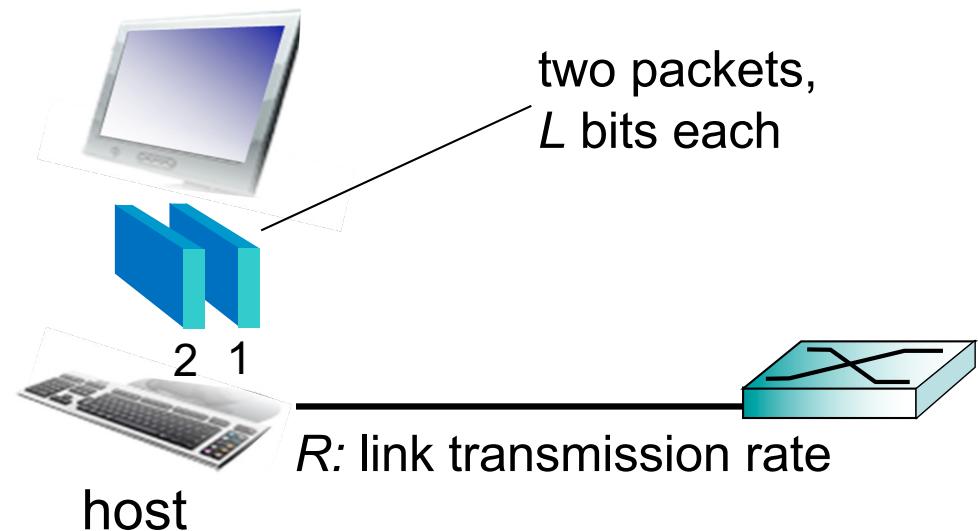
- provided by telco (cellular) operator, 10's km
- between 1 and 10 Mbps
- 3G, 4G: LTE



Host: sends packets of data

host sending function:

- takes application message
- breaks into smaller chunks, known as *packets*, of length L bits
- transmits packet into access network at *transmission rate R*
 - link transmission rate, aka link *capacity*, aka *link bandwidth*



$$\text{packet transmission delay} = \frac{\text{time needed to transmit } L\text{-bit packet into link}}{R \text{ (bits/sec)}}$$

Physical media

- **bit:** propagates between transmitter/receiver pairs
- **physical link:** what lies between transmitter & receiver
- **guided media:**
 - signals propagate in solid media: copper, fiber, coax
- **unguided media:**
 - signals propagate freely, e.g., radio

twisted pair (TP)

- two insulated copper wires
 - Category 5: 100 Mbps, 1 Gbps Ethernet
 - Category 6: 10Gbps



Physical media: coax, fiber

coaxial cable:

- two concentric copper conductors
- Bidirectional
- Common in cable TV
- broadband:
 - multiple channels on cable



fiber optic cable:

- glass fiber carrying light pulses, each pulse a bit
- high-speed operation:
 - high-speed point-to-point transmission (e.g., 10's-100's Gbps transmission rate)
- low error rate:
 - repeaters spaced far apart
 - immune to electromagnetic noise



Physical media: radio

- signal carried in electromagnetic spectrum
- no physical “wire”
- bidirectional
- propagation environment effects:
 - reflection
 - obstruction by objects
 - interference

radio link types:

- terrestrial microwave
 - e.g. up to 45 Mbps channels
- LAN (e.g., WiFi)
 - 54 Mbps
- wide-area (e.g., cellular)
 - 4G cellular: ~ 10 Mbps
- satellite
 - Kbps to 45Mbps channel (or multiple smaller channels)
 - 270 msec end-end delay
 - geosynchronous versus low altitude

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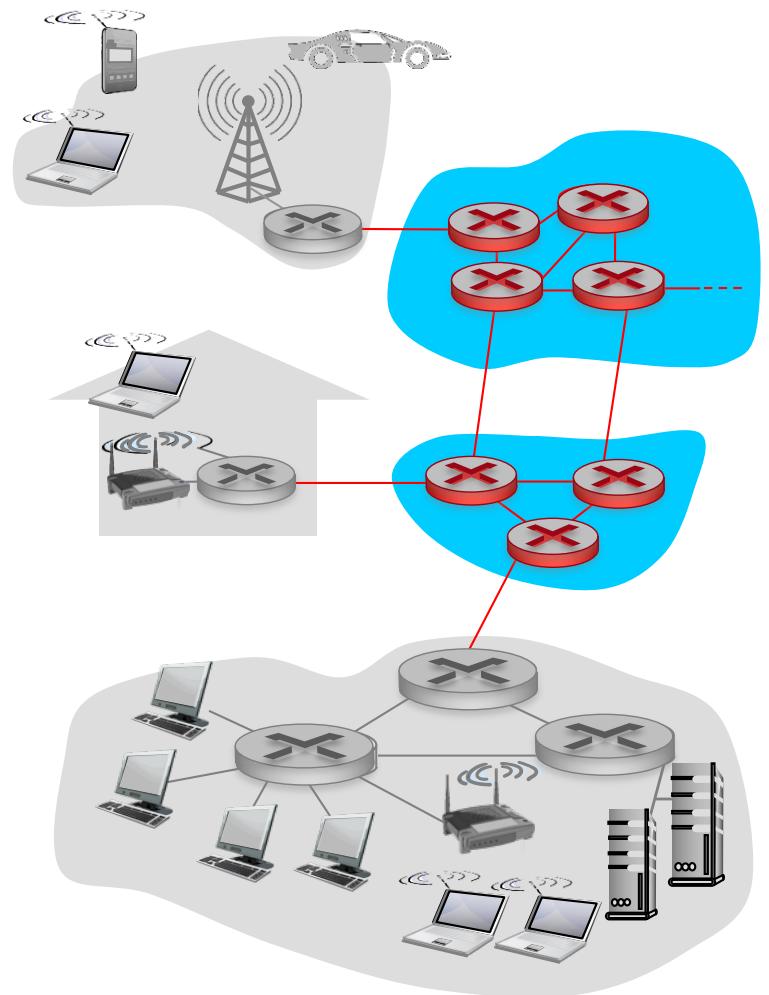
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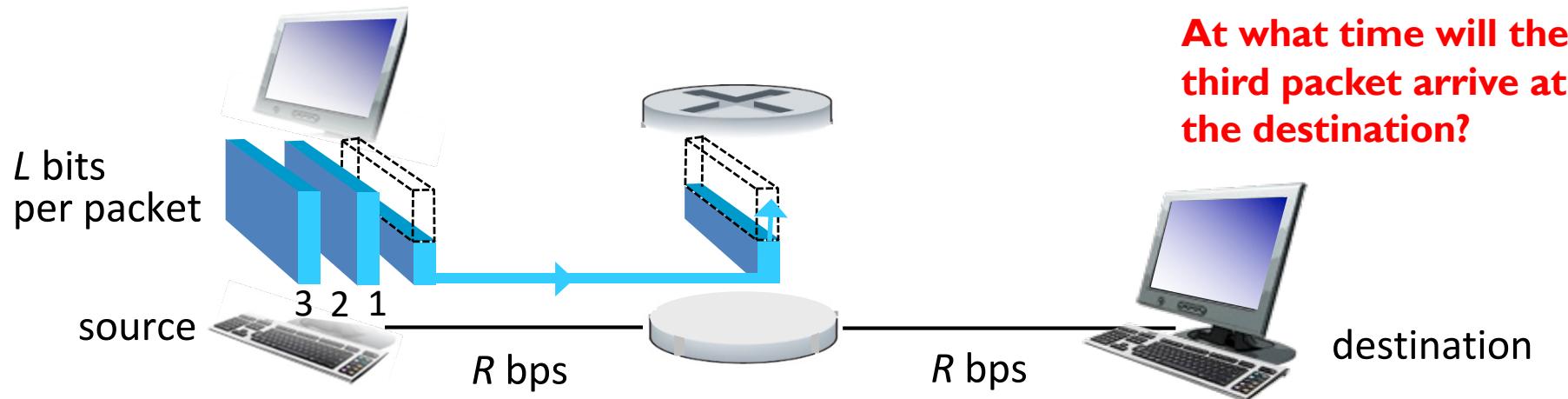
I.7 history

The network core

- mesh of interconnected routers
- **packet-switching:** hosts break application-layer messages into packets
 - forward packets from one router to the next, across links on path from source to destination
 - each packet transmitted at full link capacity



Packet-switching: store-and-forward



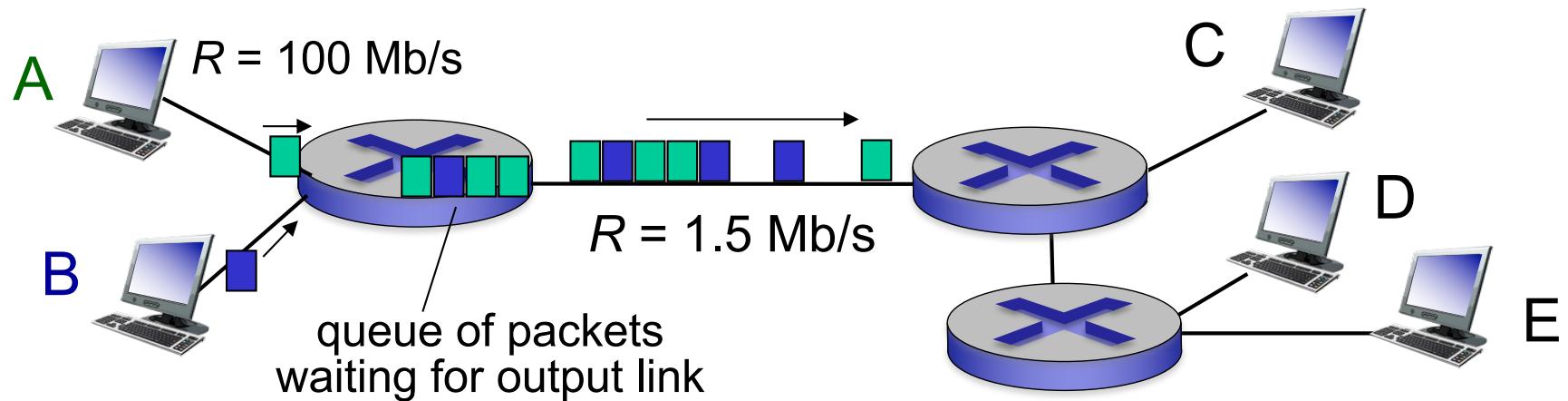
- takes L/R seconds to transmit (push out) L -bit packet into link at R bps
- **store and forward:** entire packet must arrive at router before it can be transmitted on next link
- end-end delay = $2L/R$ (assuming zero propagation delay)

one-hop numerical example:

- $L = 7.5 \text{ Mbits}$
- $R = 1.5 \text{ Mbps}$
- one-hop transmission delay = 5 sec

} more on delay shortly ...

Packet Switching: queueing delay, loss



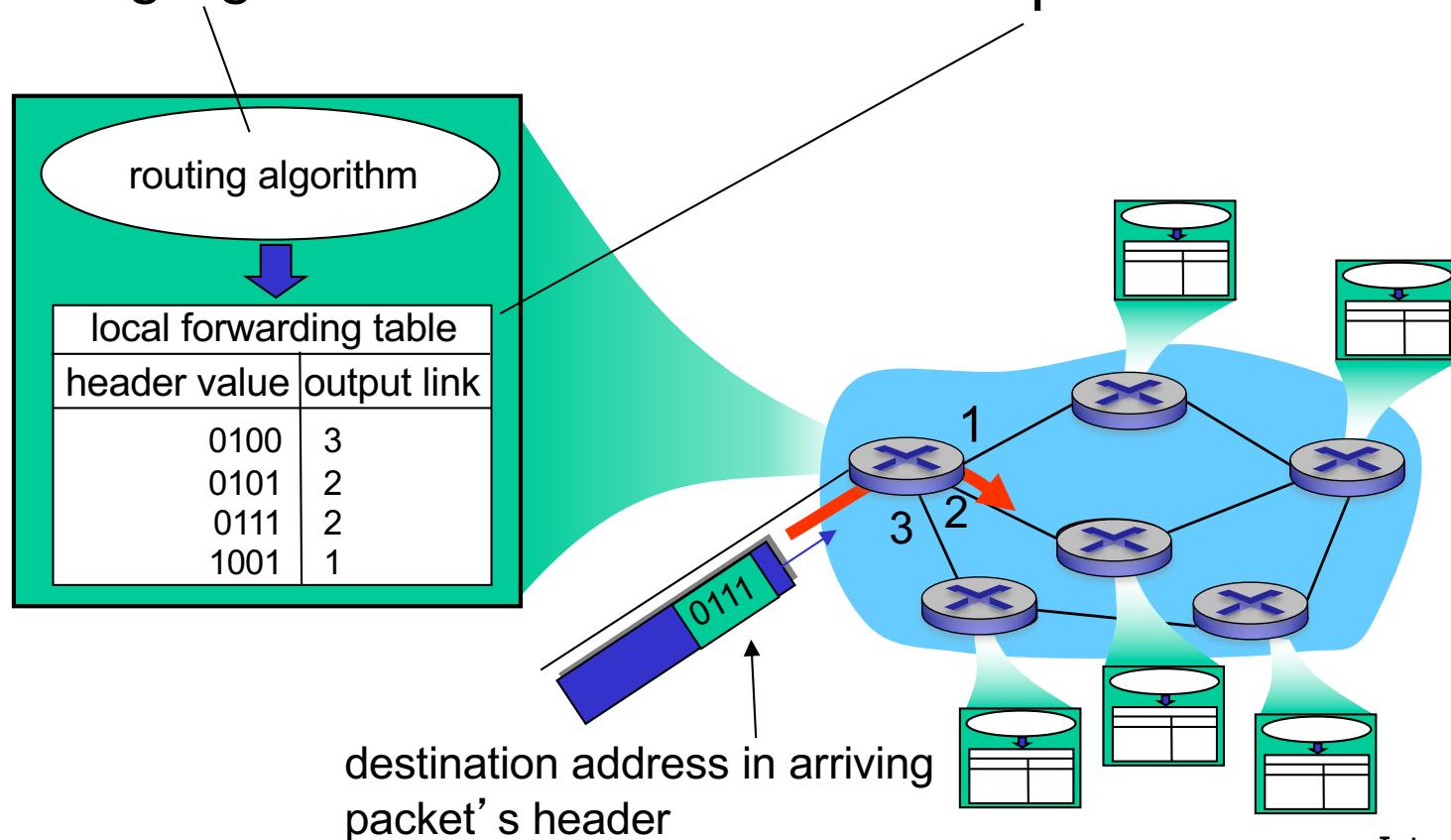
queuing and loss:

- if arrival rate (in bits) to link exceeds transmission rate of link for a period of time:
 - packets will queue, wait to be transmitted on link
 - packets can be dropped (lost) if memory (buffer) fills up

Two key network-core functions

routing: determines source-destination route taken by packets

- *routing algorithms*

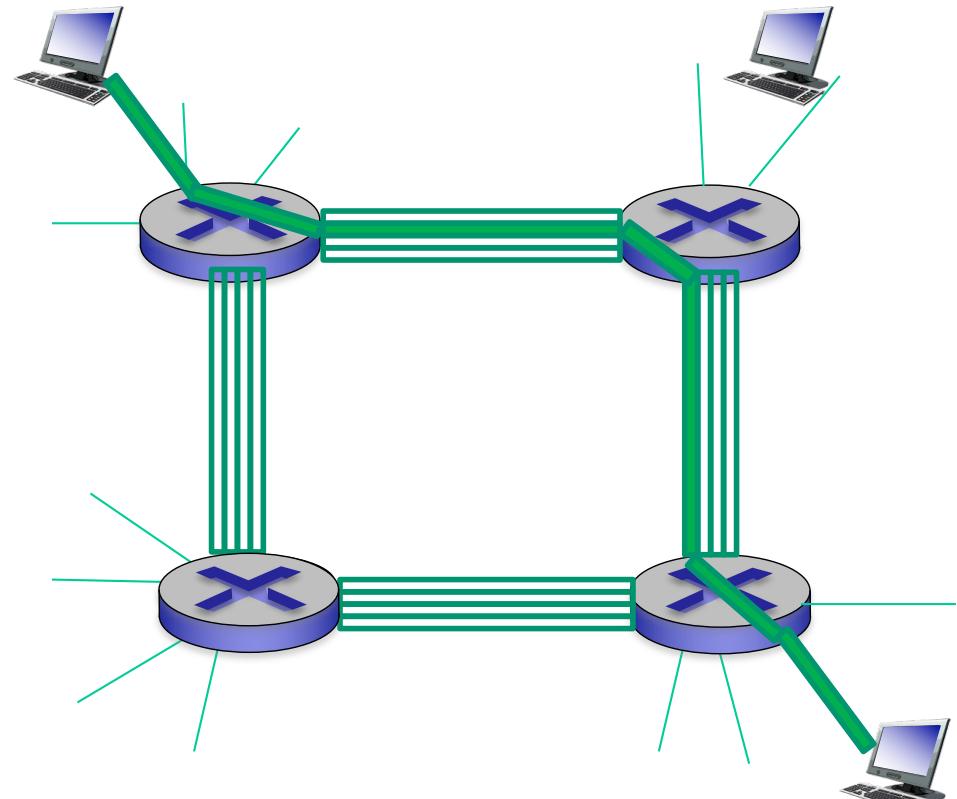


forwarding: move packets from router's input to appropriate router output

Alternative core: circuit switching

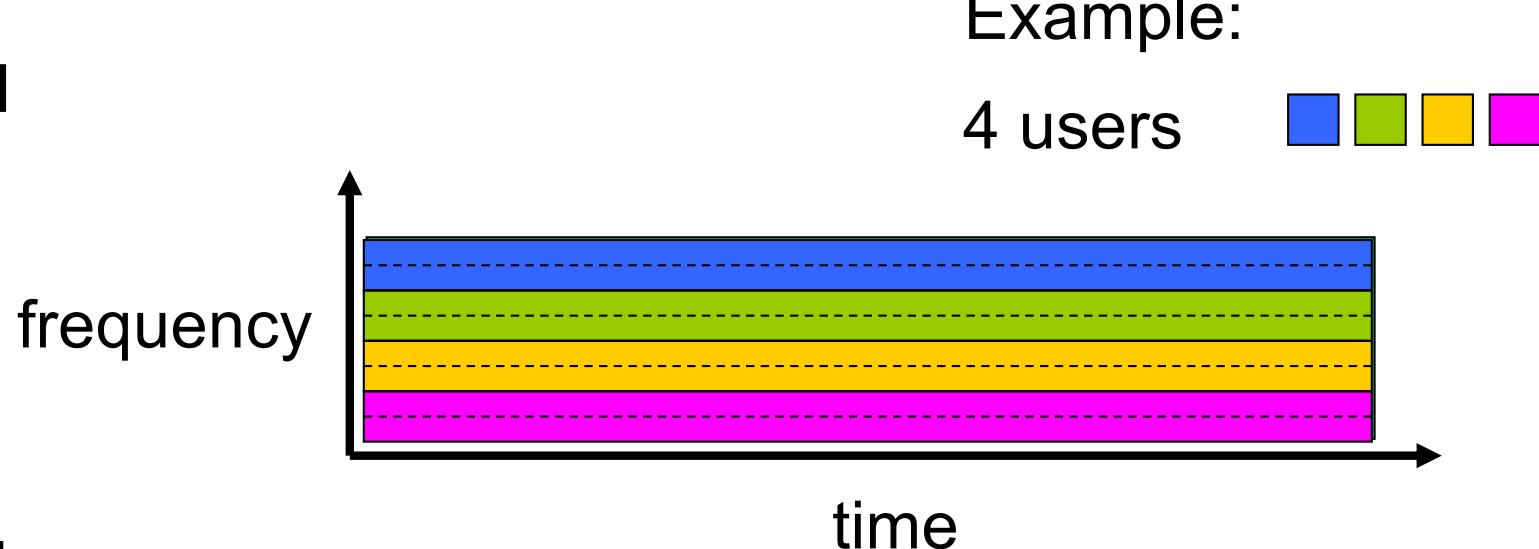
end-end resources allocated
to, reserved for “call”
between source & dest:

- in diagram, each link has four circuits.
 - call gets 2nd circuit in top link and 1st circuit in right link.
- dedicated resources: no sharing
 - circuit-like (guaranteed) performance
- circuit segment idle if not used by call (*no sharing*)
- commonly used in traditional telephone networks

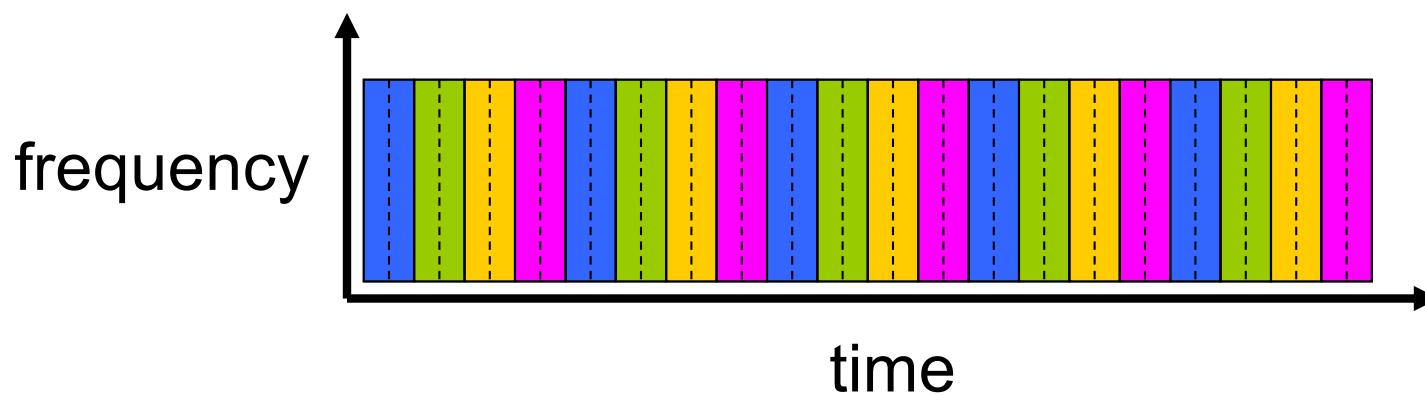


Circuit switching: FDM versus TDM

FDM



TDM

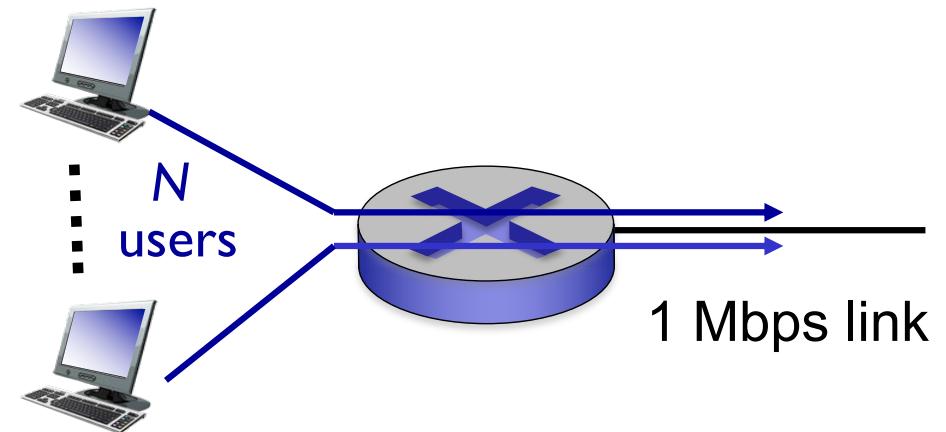


Packet switching versus circuit switching

packet switching allows more users to use network!

example:

- 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 at same time is less than .0004 *



Q: how did we get value 0.0004?

Q: what happens if > 35 users ?

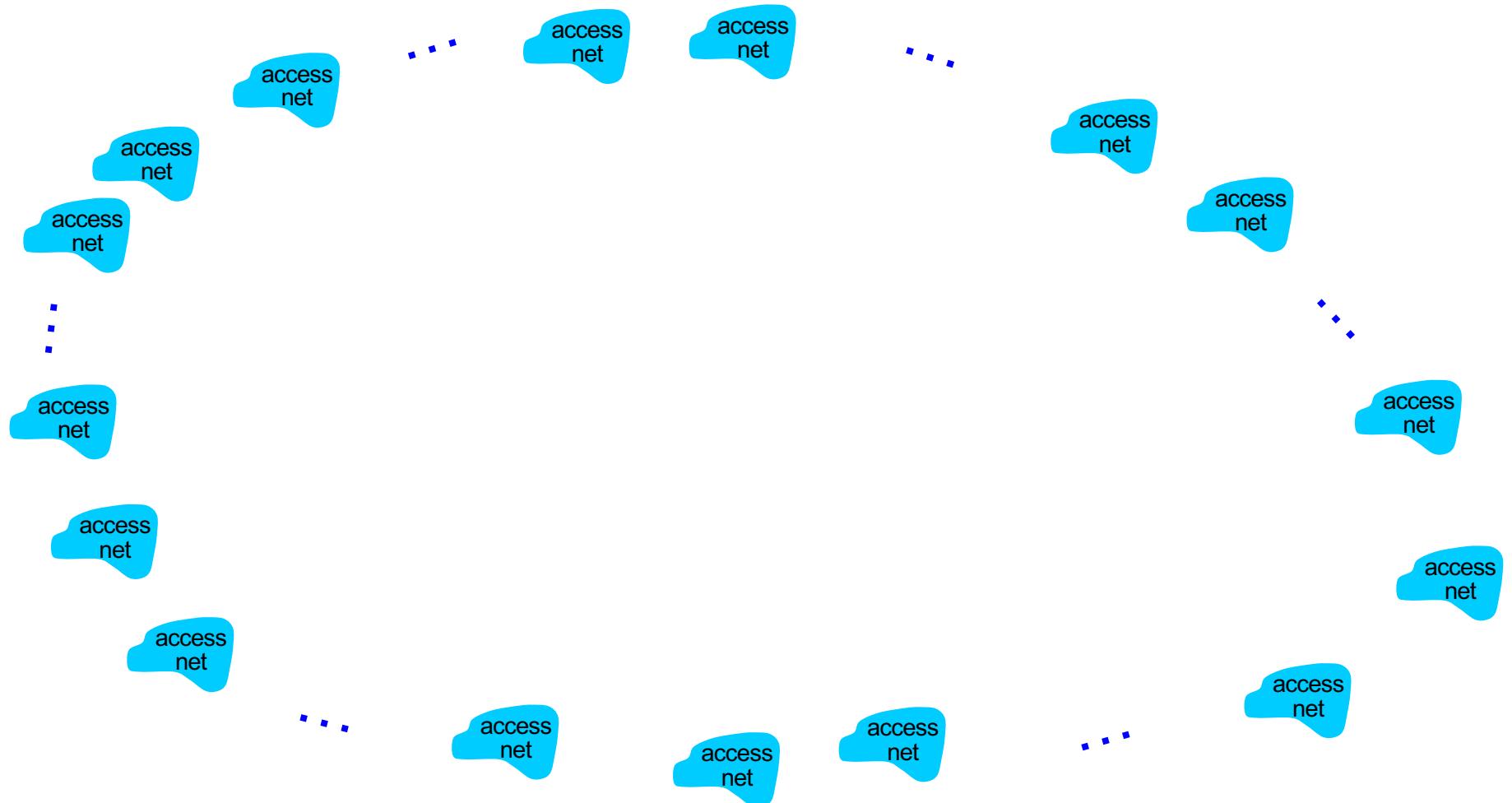
* Check out the online interactive exercises for more examples: http://gaia.cs.umass.edu/kurose_ross/interactive/

Internet structure: network of networks

- End systems connect to Internet via **access ISPs** (Internet Service Providers)
 - residential, company and university ISPs
- Access ISPs in turn must be interconnected.
 - so that any two hosts can send packets to each other
- Resulting network of networks is very complex
 - evolution was driven by **economics** and **national policies**
- Let's take a stepwise approach to describe current Internet structure

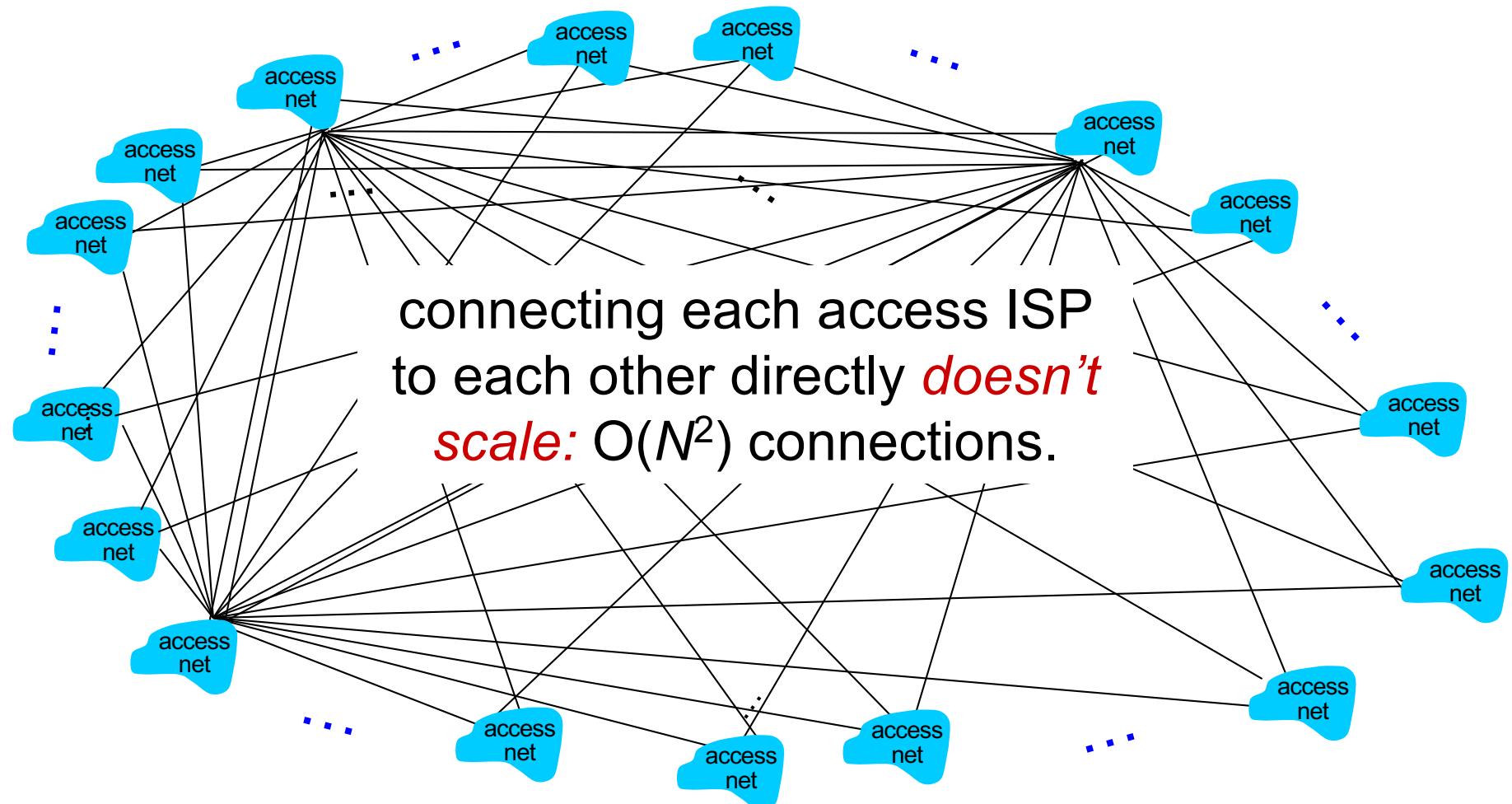
Internet structure: network of networks

Question: given *millions* of access ISPs, how to connect them together?



Internet structure: network of networks

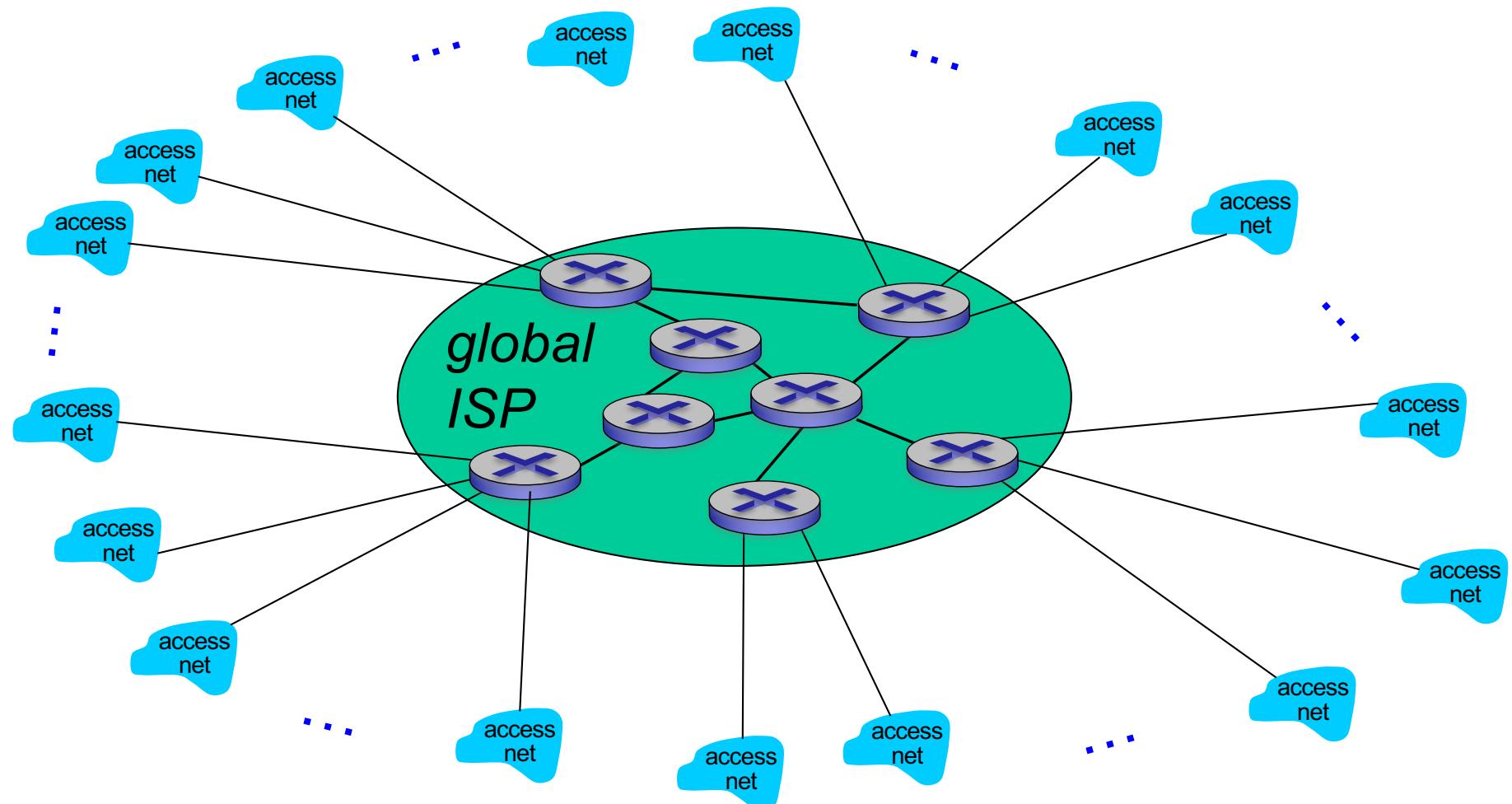
Option: connect each access ISP to every other access ISP?



Internet structure: network of networks

Option: connect each access ISP to one global transit ISP?

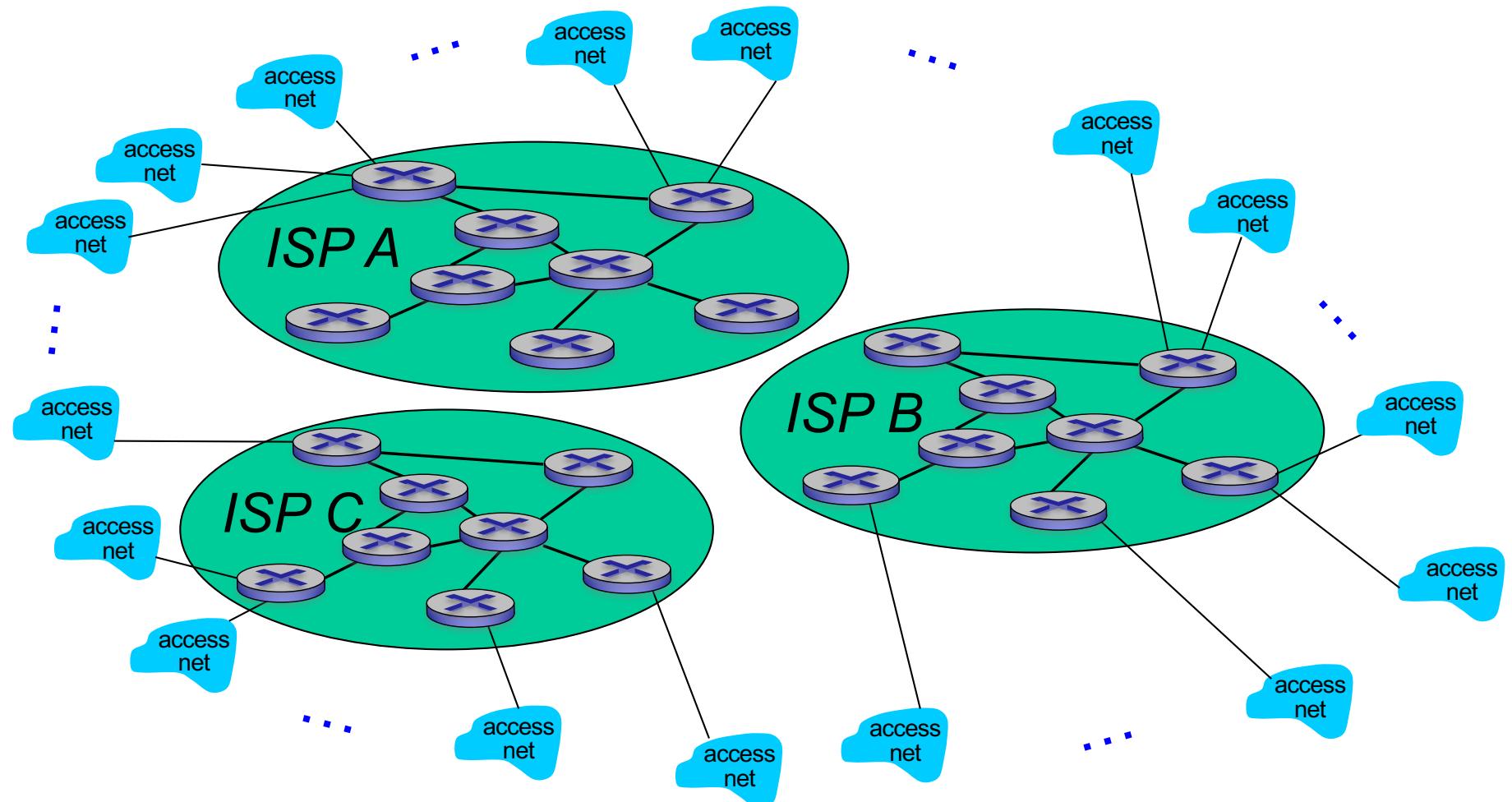
Customer and provider ISPs have economic agreement.



Internet structure: network of networks

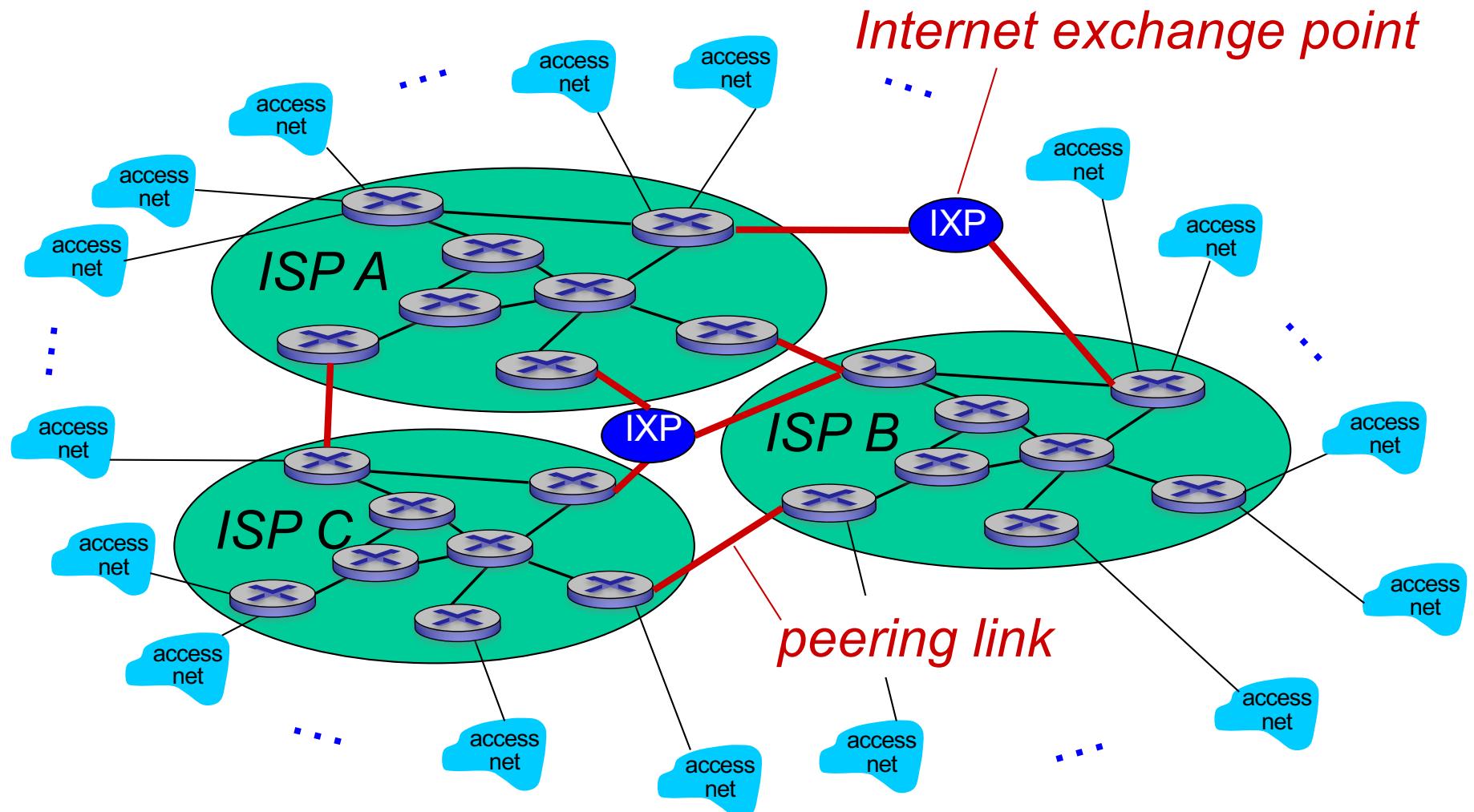
But if one global ISP is viable business, there will be competitors

....



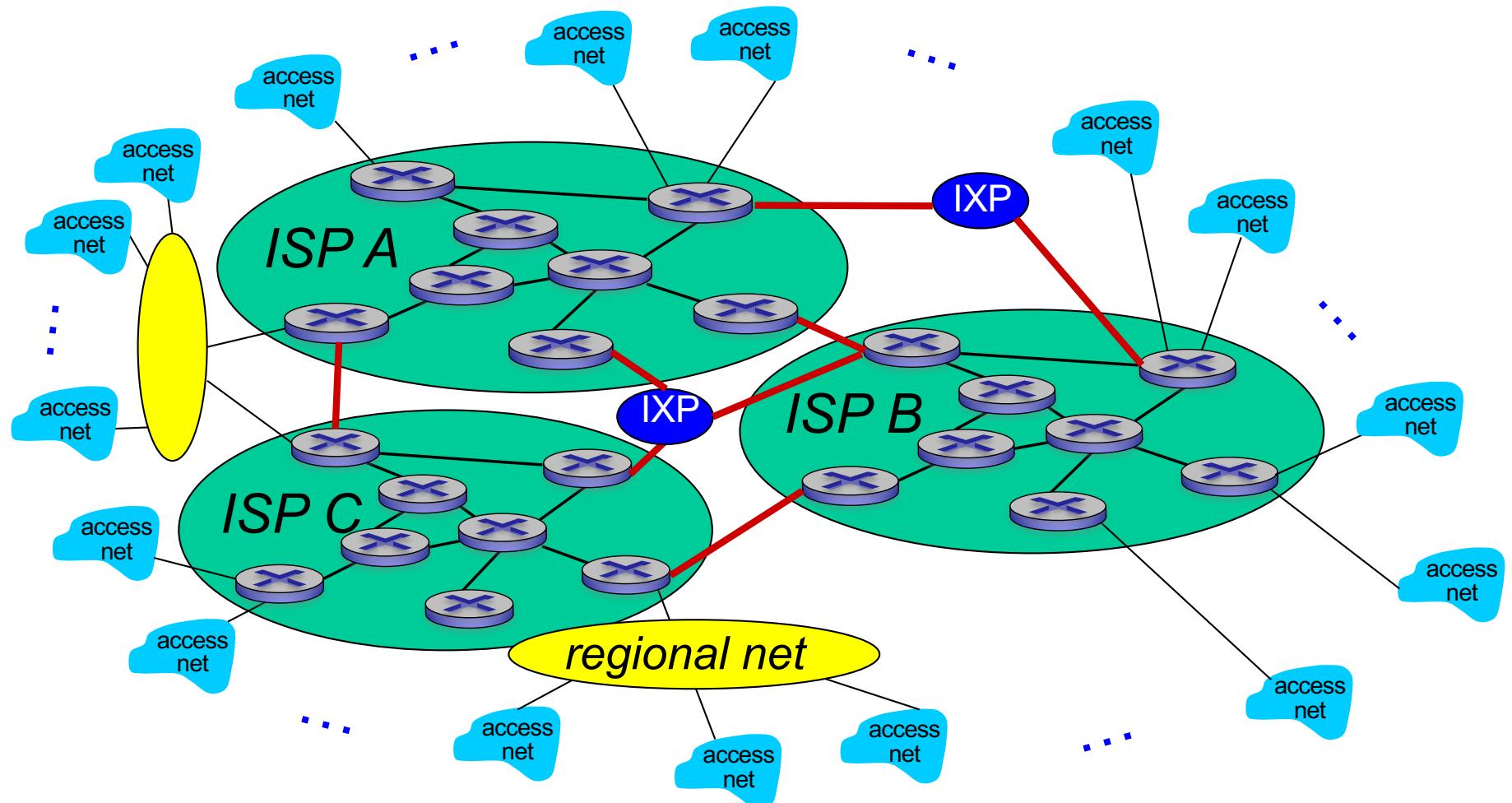
Internet structure: network of networks

But if one global ISP is viable business, there will be competitors
.... which must be interconnected



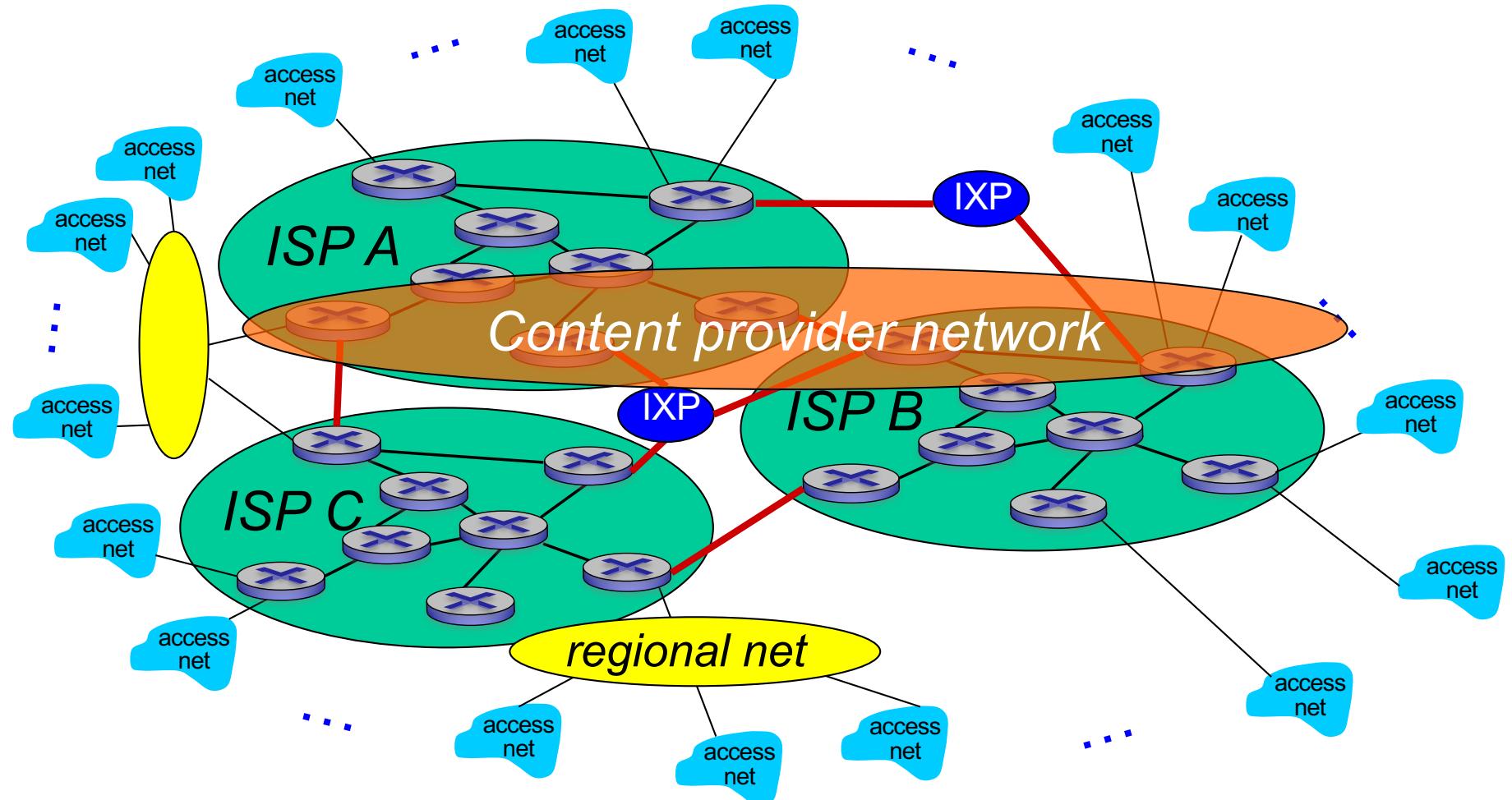
Internet structure: network of networks

... and regional networks may arise to connect access nets to ISPs

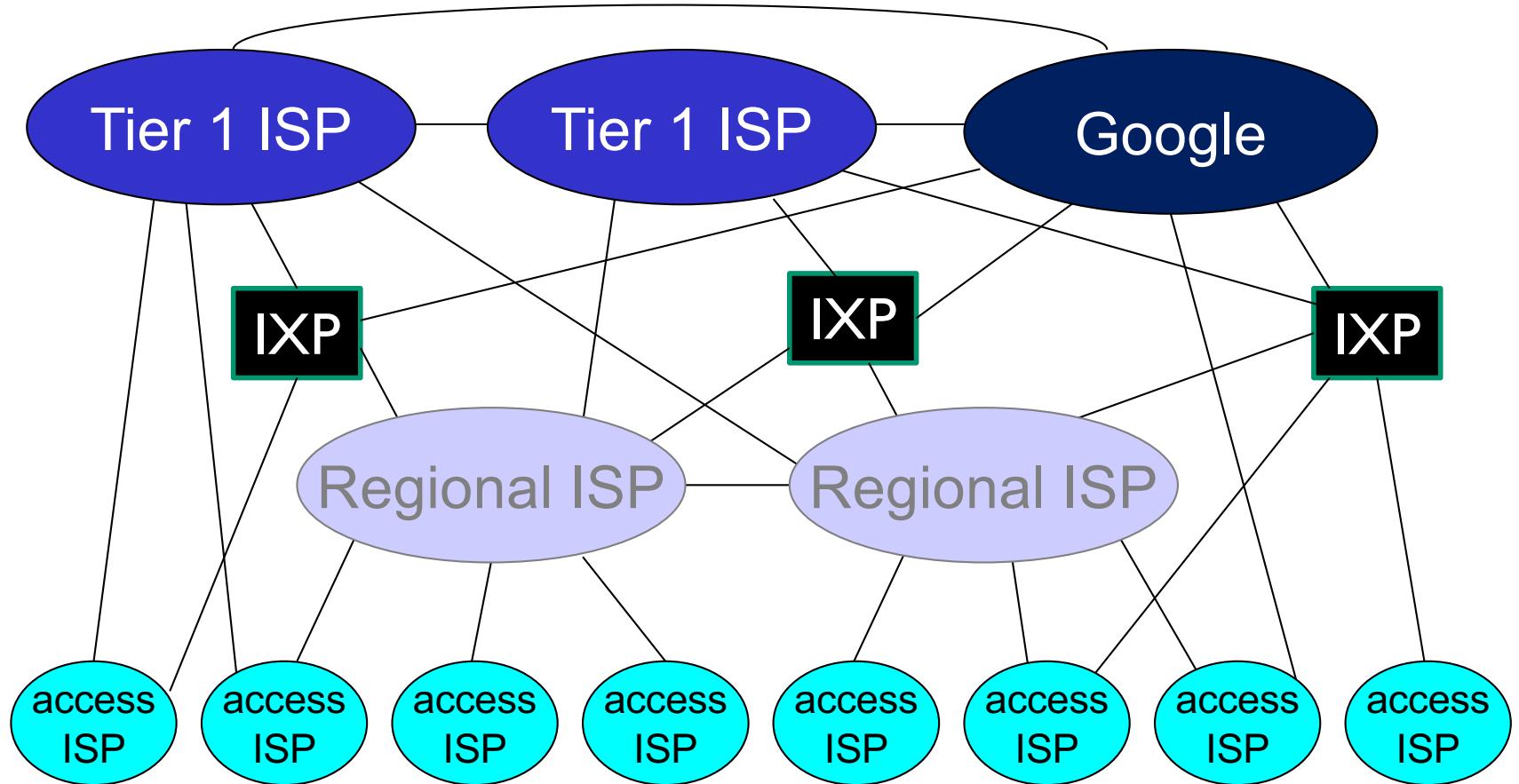


Internet structure: network of networks

... and content provider networks (e.g., Google, Microsoft, Akamai) may run their own network, to bring services, content close to end users

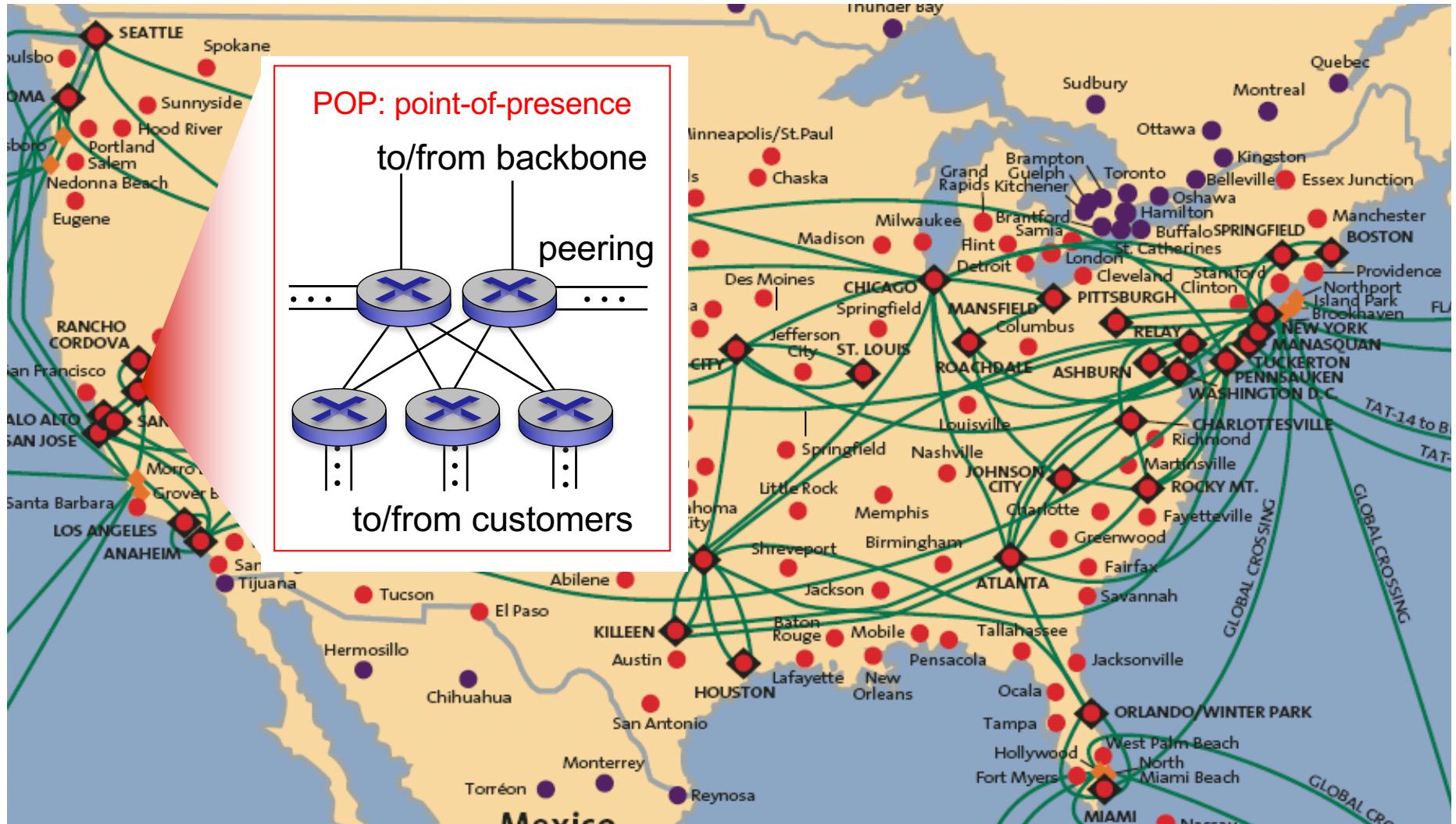


Internet structure: network of networks



- at center: small # of well-connected large networks
 - “tier-1” commercial ISPs (e.g., Level 3, Sprint, AT&T, NTT), national & international coverage
 - **content provider network** (e.g., Google): private network that connects its data centers to Internet, often bypassing tier-1, regional ISPs

Tier-1 ISP: e.g., Sprint



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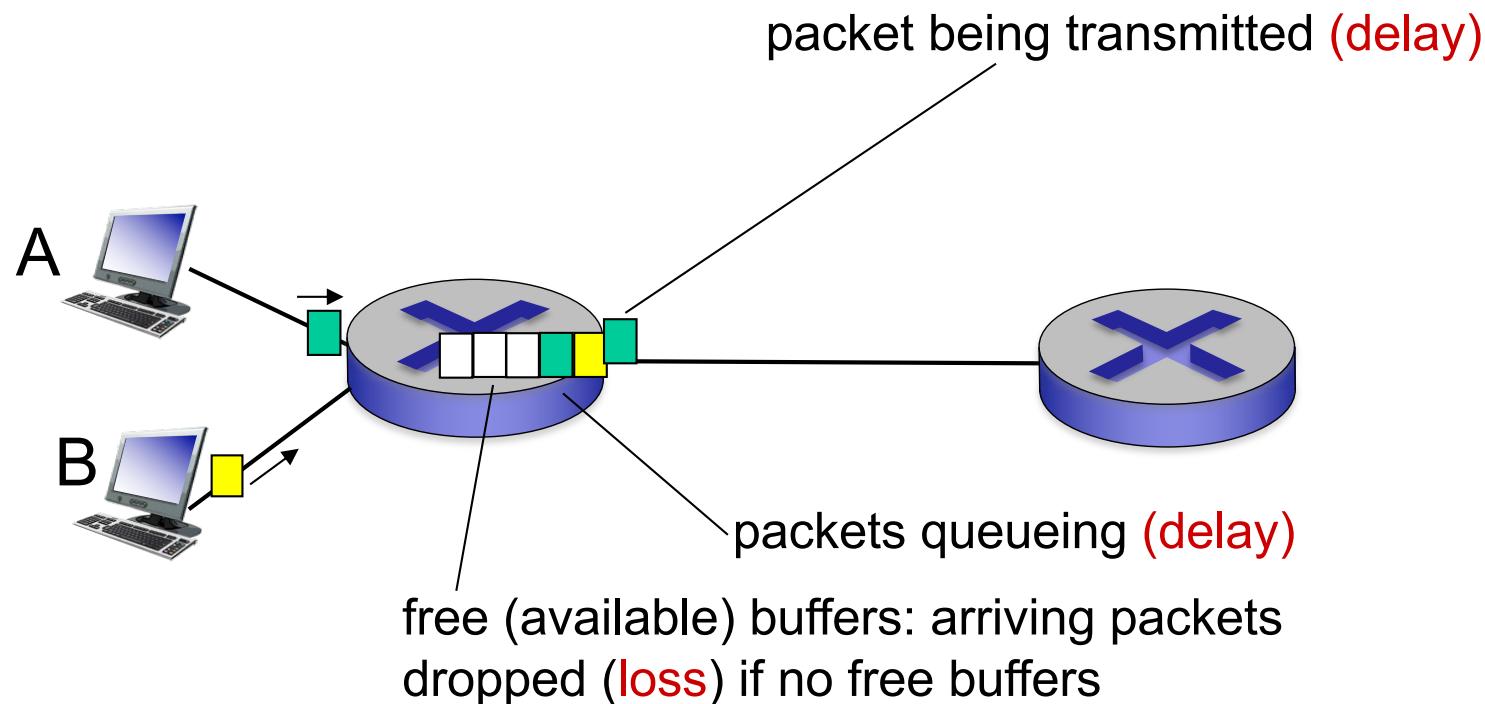
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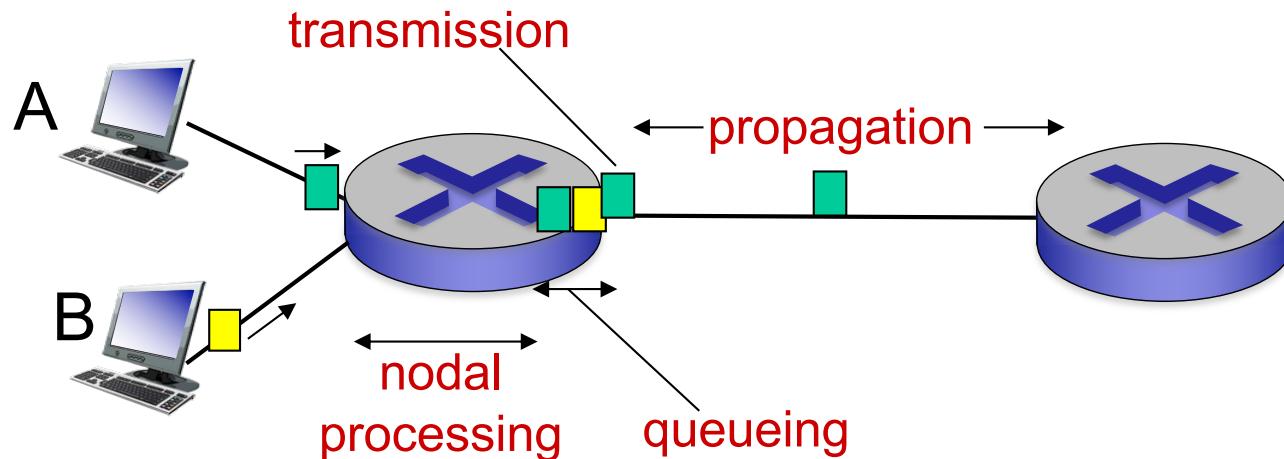
How do loss and delay occur?

packets queue in router buffers

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



Four sources of packet delay



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

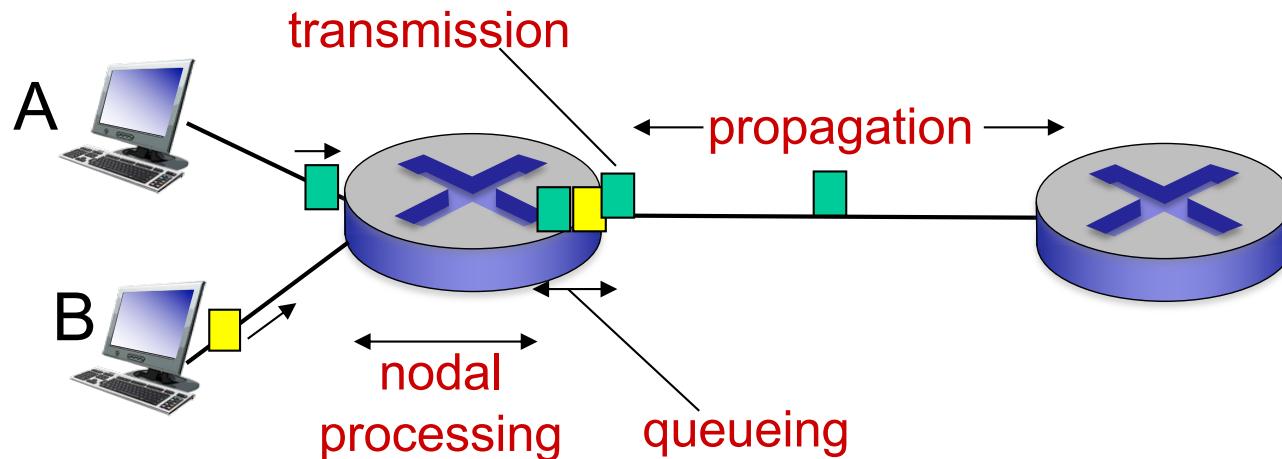
d_{proc} : nodal processing

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

d_{queue} : queueing delay

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

Four sources of packet delay



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

d_{trans} : transmission delay:

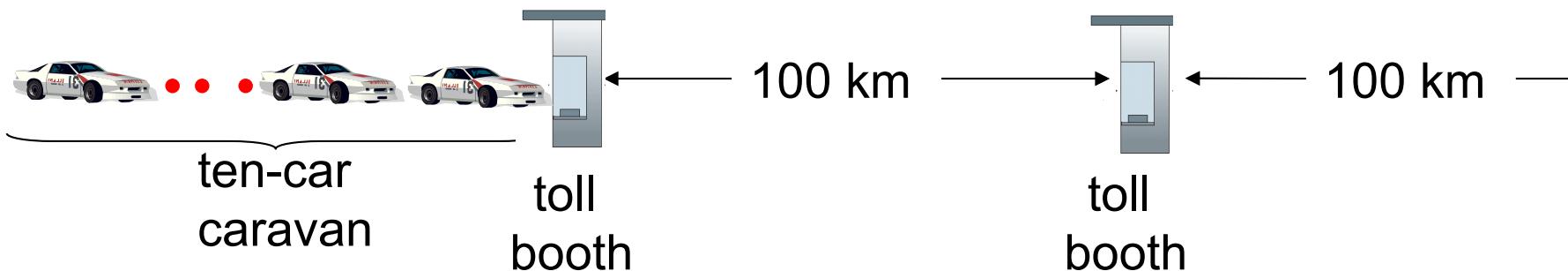
- L : packet length (bits)
- R : link bandwidth (bps)
- $d_{\text{trans}} = L/R$ ← d_{trans} and d_{prop} →
very different

d_{prop} : propagation delay:

- d : length of physical link
- s : propagation speed ($\sim 2 \times 10^8$ m/sec)
- $d_{\text{prop}} = d/s$

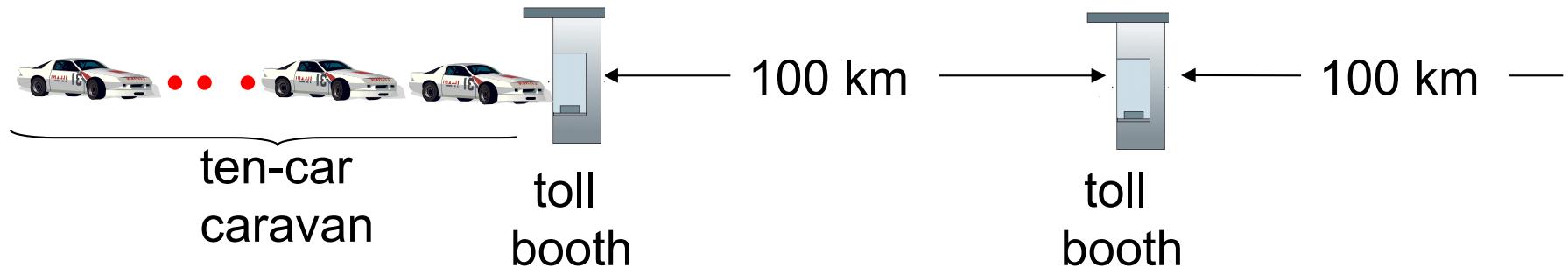
- * Check out the online interactive exercises for more examples: http://gaia.cs.umass.edu/kurose_ross/interactive/
- * Check out the Java applet for an interactive animation on trans vs. prop delay

Caravan analogy



- cars “propagate” at 100 km/hr
- toll booth takes 12 sec to service car (bit 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 = $12*10 = 120$ sec
 - time for last car to propagate from 1st to 2nd toll both:
 $100\text{km}/(100\text{km/hr})= 1\text{ hr}$
 - A: 62 minutes

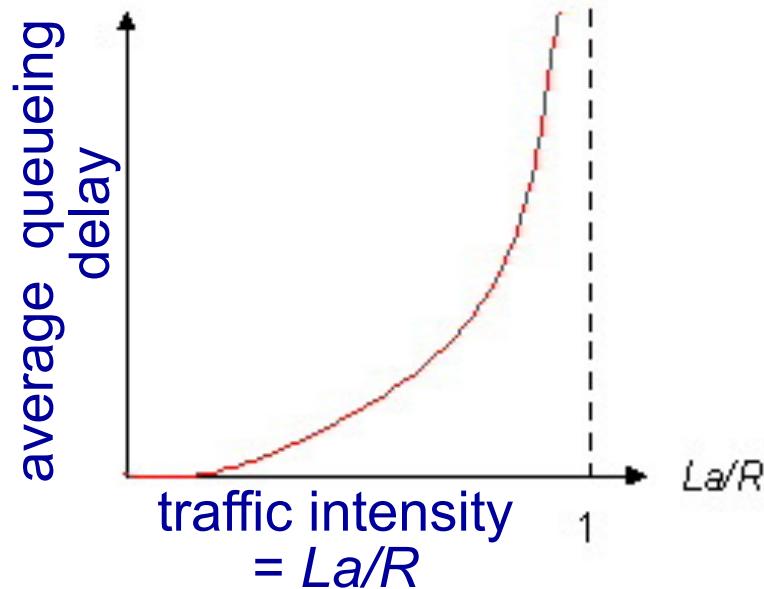
Caravan analogy (more)



- suppose cars now “propagate” at 1000 km/hr
- and suppose toll booth now takes one min to service a car
- **Q: Will cars arrive to 2nd booth before all cars serviced at first booth?**
 - **A: Yes!** after 7 min, first car arrives at second booth; three cars still at first booth

Queueing delay (revisited)

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



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



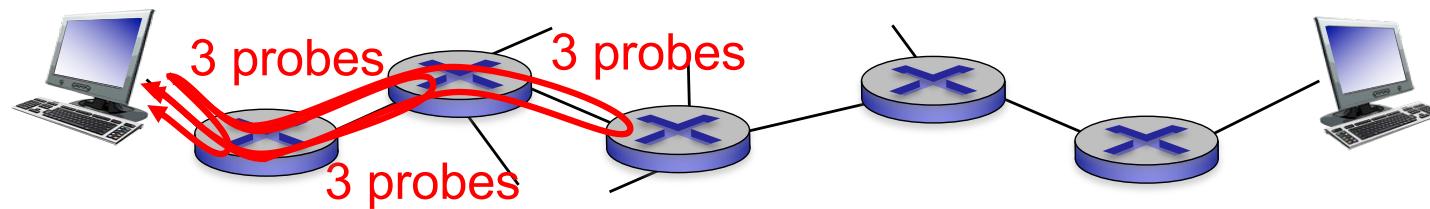
* Check online interactive animation on queuing and loss

Example

- Consider sending a large file of F bits from Host A to Host B. There are three links (and two switches) between A and B, and the links are uncongested (that is, no queuing delays). Host A segments the file into segments of S bits each and adds 80 bits of header to each segment, forming packets of $L=80 + S$ bits. Each link has a transmission rate of R bps. Find the value of S that minimizes the delay of moving the file from Host A to Host B. Disregard propagation delay.

“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, routes

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

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

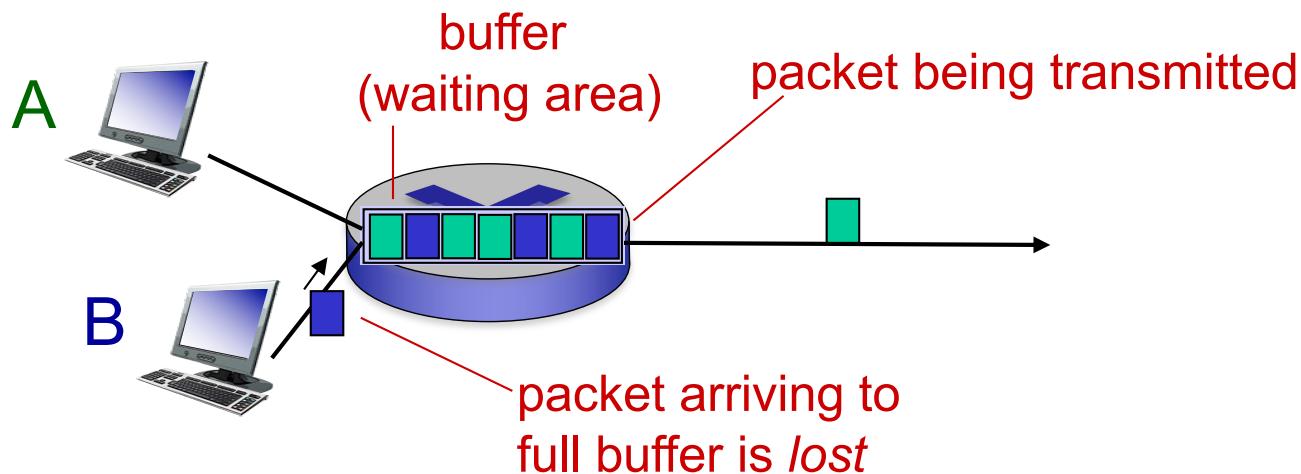
1	cs-gw (128.119.240.254)	1 ms	1 ms	2 ms
2	border1-rt-fa5-1-0.gw.umass.edu (128.119.3.145)	1 ms	1 ms	2 ms
3	cht-vbns.gw.umass.edu (128.119.3.130)	6 ms	5 ms	5 ms
4	jn1-at1-0-0-19.wor.vbns.net (204.147.132.129)	16 ms	11 ms	13 ms
5	jn1-so7-0-0-0.wae.vbns.net (204.147.136.136)	21 ms	18 ms	18 ms
6	abilene-vbns.abilene.ucaid.edu (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	***	* means no response (probe lost, router not replying)		
18	***			
19	fantasia.eurecom.fr (193.55.113.142)	132 ms	128 ms	136 ms

trans-oceanic
link

* Do some traceroutes from exotic countries at www.traceroute.org

Packet loss

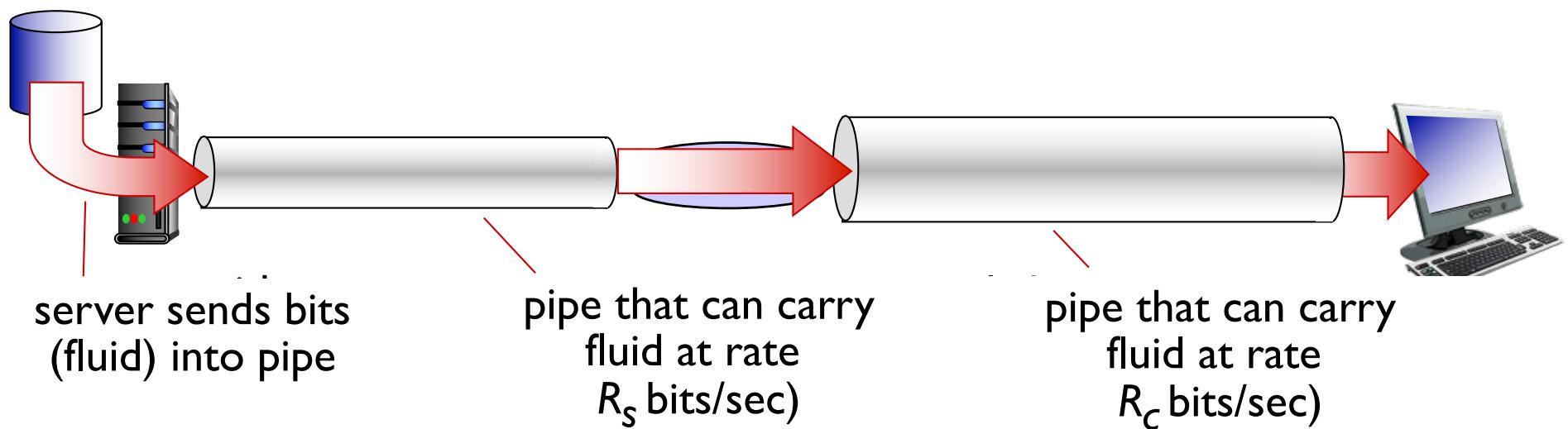
- queue (aka buffer) preceding link in buffer has finite capacity
- packet arriving to full queue dropped (aka lost)
- lost packet may be retransmitted by previous node, by source end system, or not at all



* Check out the Java applet for an interactive animation on queuing and loss

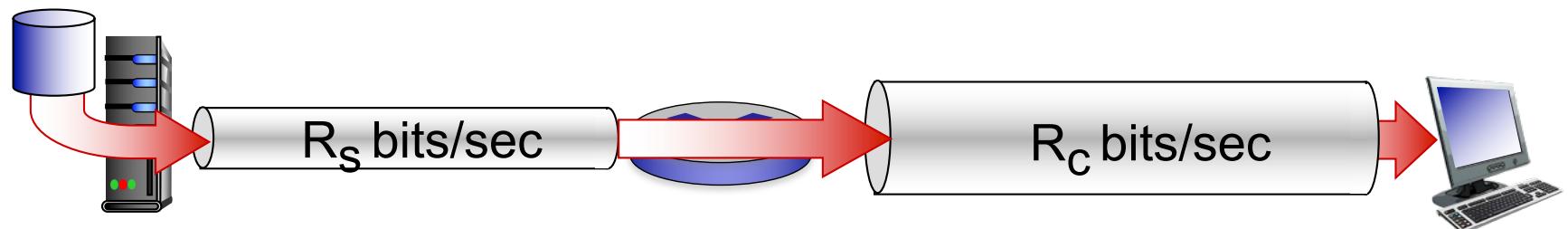
Throughput

- *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

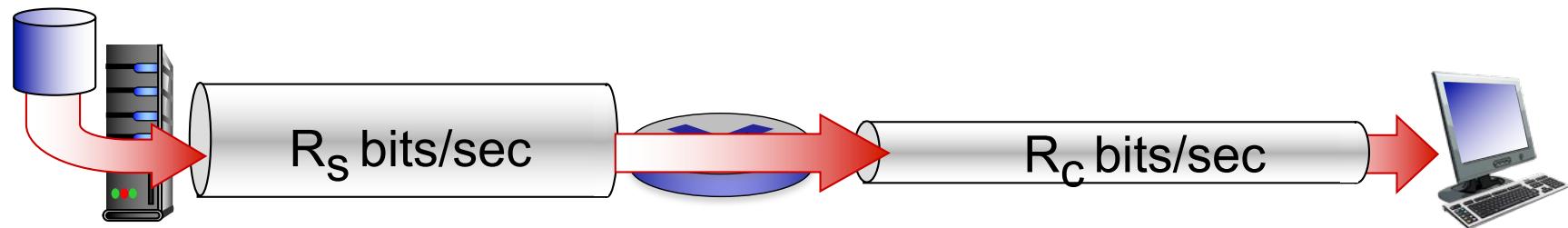


Throughput (more)

- $R_s < R_c$ What is average end-end throughput?



- $R_s > R_c$ What is average end-end throughput?

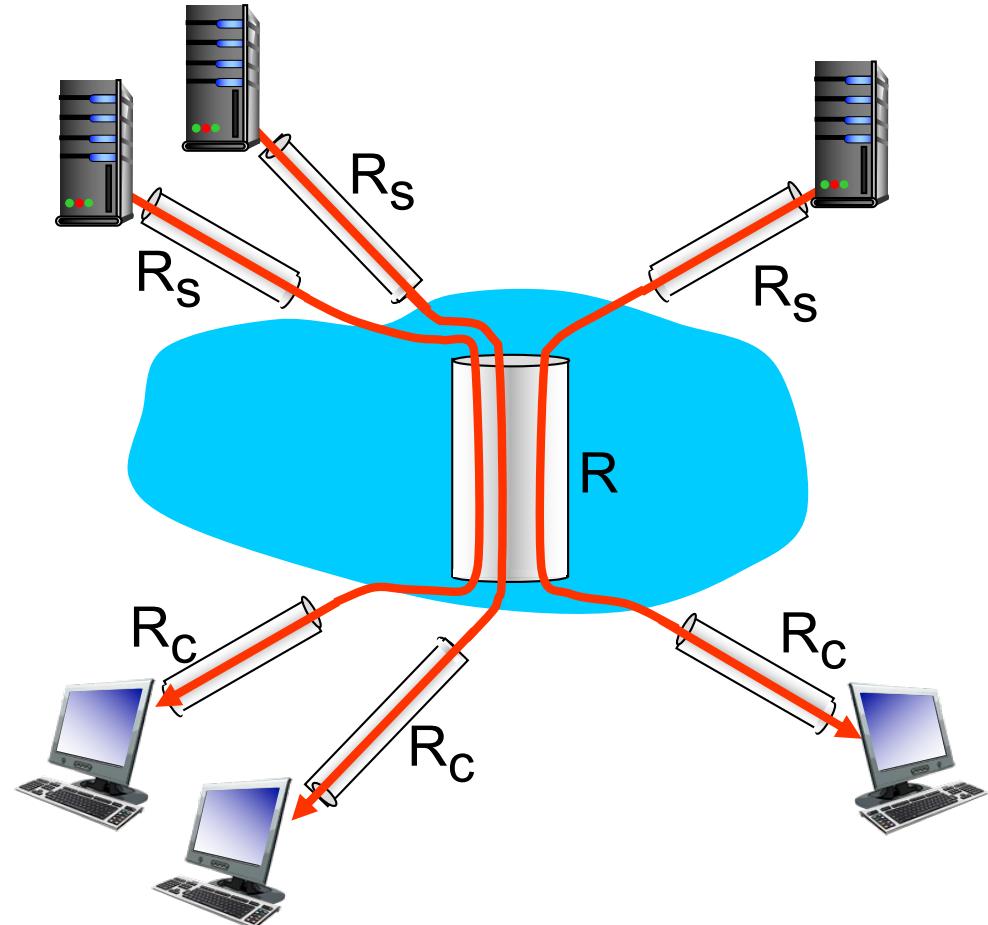


bottleneck link

link on end-end path that constrains end-end throughput

Throughput: Internet scenario

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



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

* Check out the online interactive exercises for more examples: http://gaia.cs.umass.edu/kurose_ross/interactive/

Chapter I: roadmap

I.1 what *is* the Internet?

I.2 network edge

- end systems, access networks, links

I.3 network core

- packet switching, circuit switching, network structure

I.4 delay, loss, throughput in networks

I.5 protocol layers, service models

I.6 networks under attack: security

I.7 history

Protocol “layers”

*Networks are complex,
with many “pieces”:*

- hosts
- routers
- links of various media
- applications
- protocols
- hardware, software

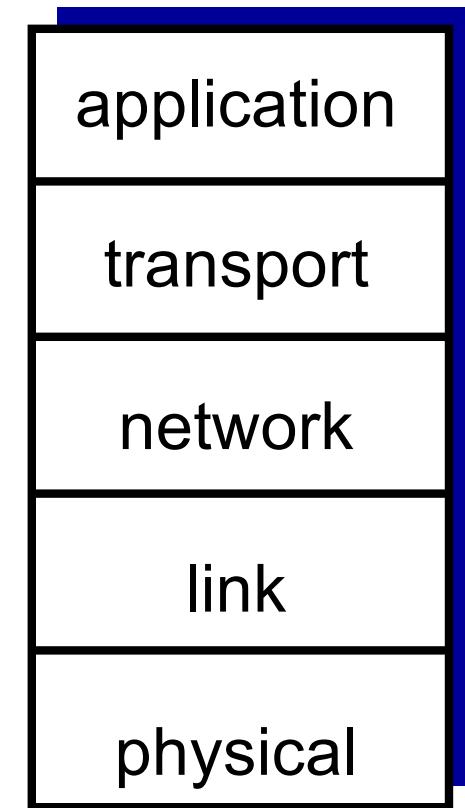
Question:

is there any hope of
*organizing structure of
network?*

.... or at least our
discussion of networks?

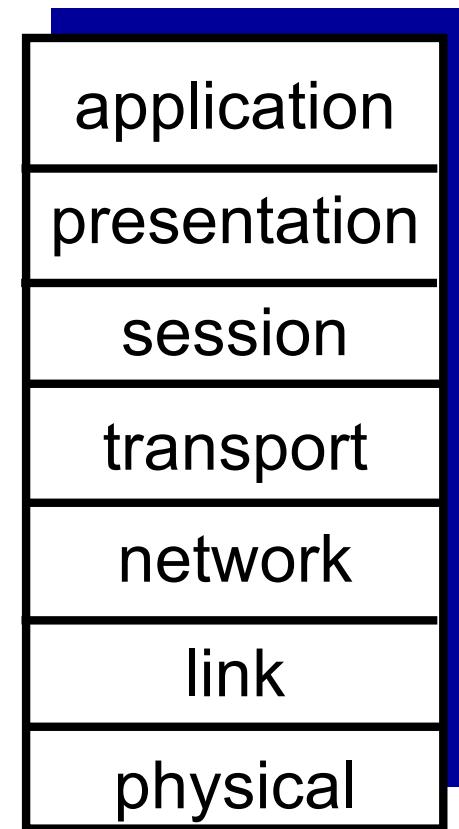
Internet protocol stack

- *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
 - Ethernet, 802.111 (WiFi), PPP
- *physical*: bits “on the wire”

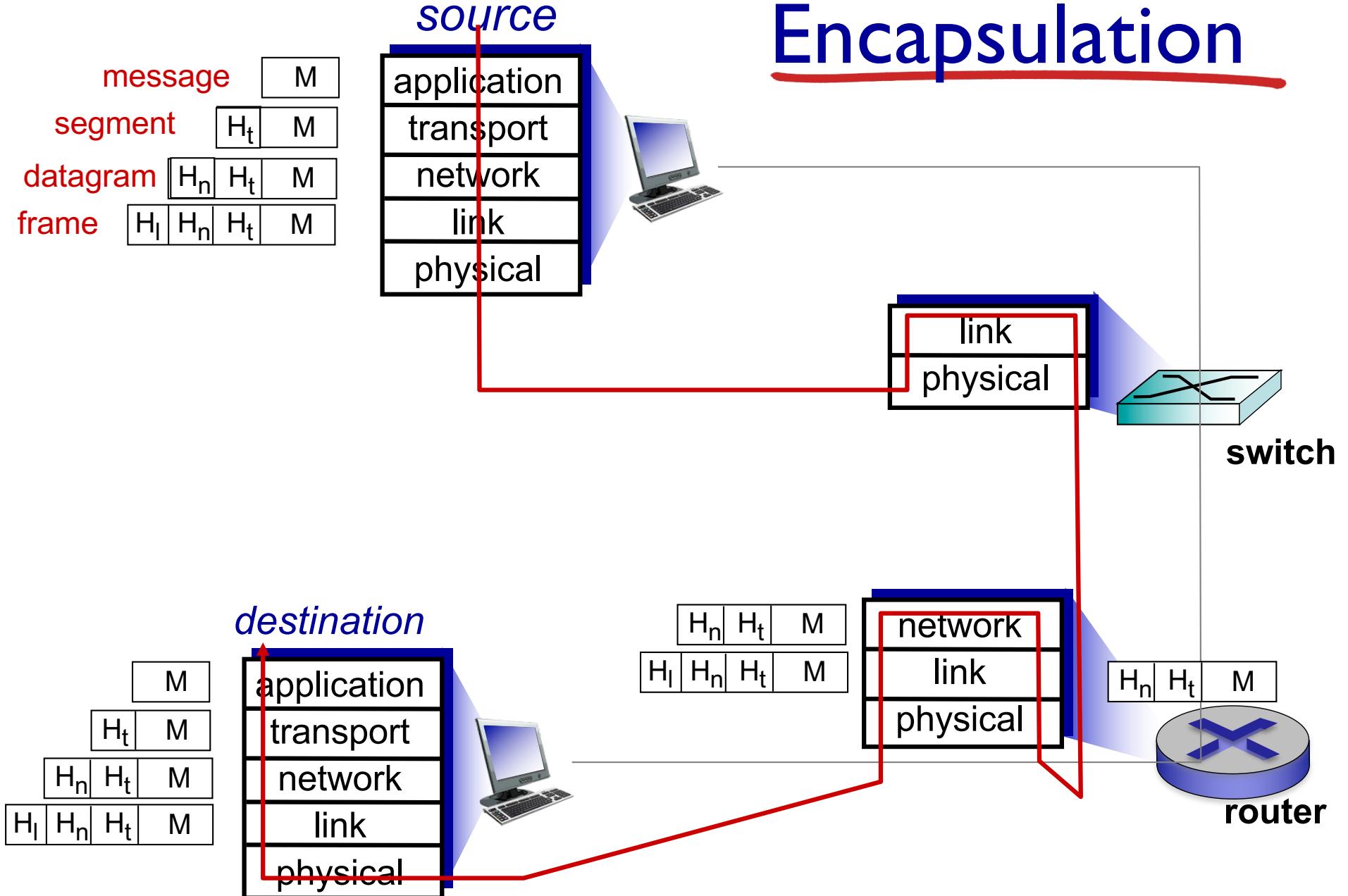


ISO/OSI reference model

- *presentation*: allow applications to interpret meaning of data, e.g., encryption, compression, machine-specific conventions
- *session*: synchronization, checkpointing, recovery of data exchange
- Internet stack “missing” these layers!
 - these services, *if needed*, must be implemented in application
 - needed?



Encapsulation



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Network security

- field of network security:
 - how bad guys can attack computer networks
 - how we can defend networks against attacks
 - how to design architectures that are immune to attacks
- Internet not originally designed with (much) security in mind
 - *original vision:* “a group of mutually trusting users attached to a transparent network” ☺
 - Internet protocol designers playing “catch-up”
 - security considerations in all layers!

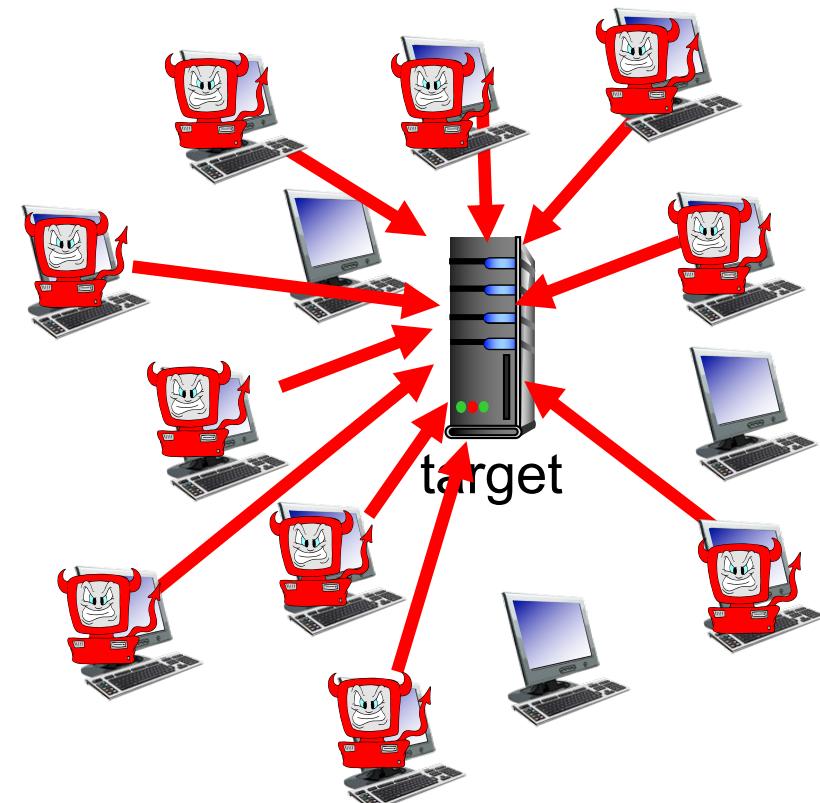
Bad guys: put malware into hosts via Internet

- malware can get in host from:
 - **virus**: self-replicating infection by receiving/executing object (e.g., e-mail attachment)
 - **worm**: self-replicating infection by passively receiving object that gets itself executed
- **spyware malware** can record keystrokes, web sites visited, upload info to collection site
- infected host can be enrolled in **botnet**, used for spam. DDoS attacks

Bad guys: attack server, network infrastructure

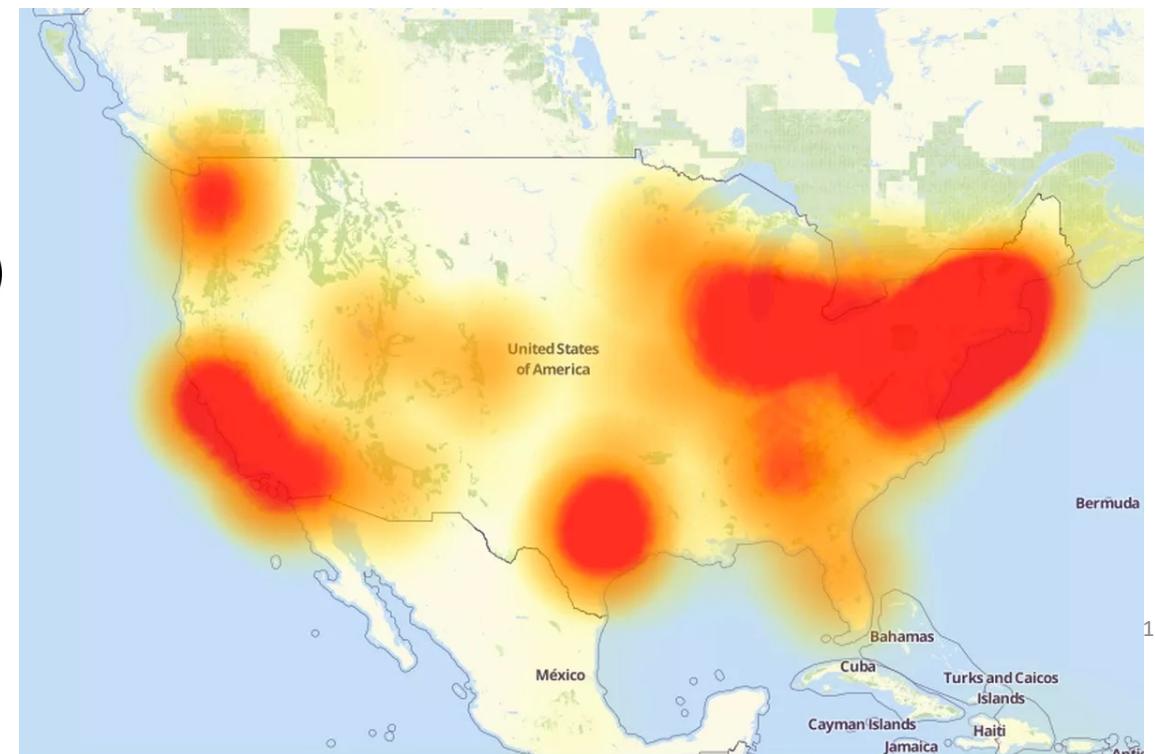
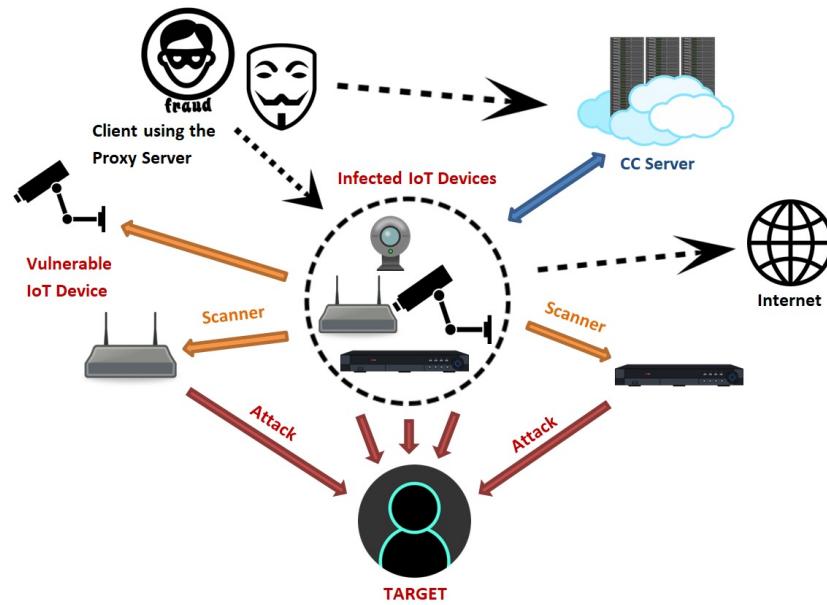
Denial of Service (DoS): attackers make resources (server, bandwidth) unavailable to legitimate traffic by overwhelming resource with bogus traffic

1. select target
2. break into hosts around the network (see botnet)
3. send packets to target from compromised hosts



The Mirai Botnet (2016)

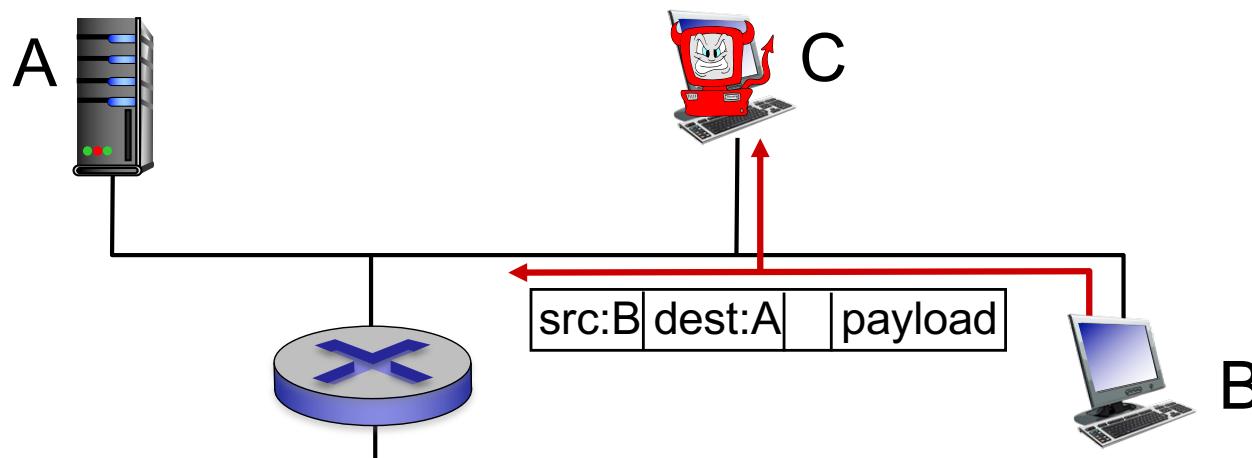
- Malware scans and infects IoT devices (with default factory credentials) and turn them into bots
- Large scale attacks (SYN Flood) → inaccessibility of several high-profile websites such as [GitHub](#), [Twitter](#), [Reddit](#), [Netflix](#), [Airbnb](#) and many others



Bad guys can sniff packets

packet “sniffing”:

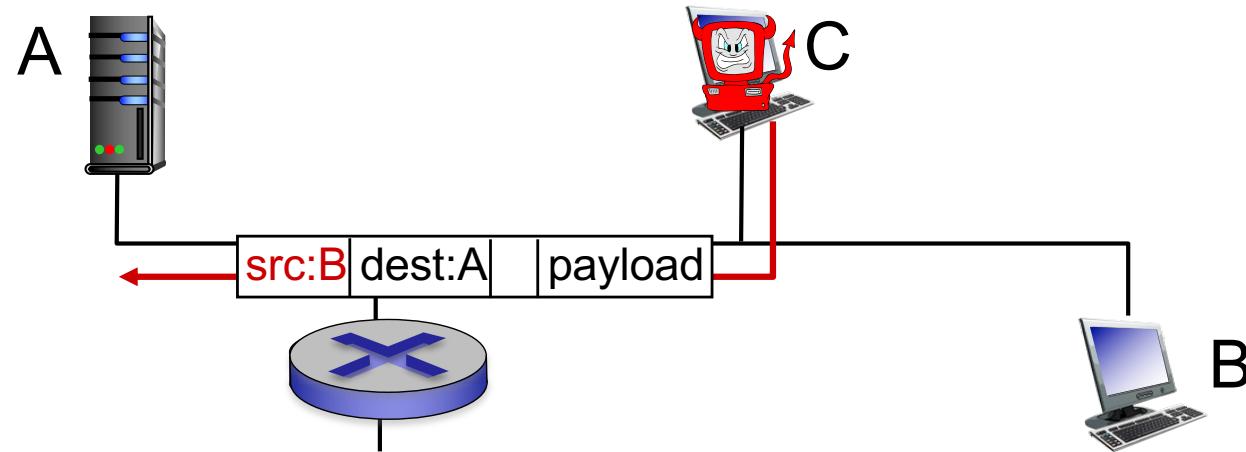
- broadcast media (shared Ethernet, wireless)
- promiscuous network interface reads/records all packets (e.g., including passwords!) passing by



- wireshark software used for end-of-chapter labs is a (free) packet-sniffer

Bad guys can use fake addresses

IP spoofing: send packet with false source address



... lots more on security (throughout, Chapter 8)

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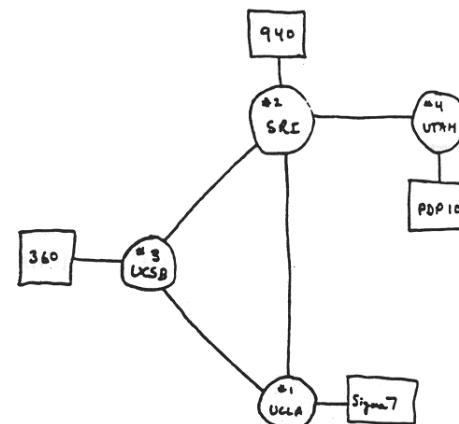
I.6 networks under attack: security

I.7 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 demo
 - NCP (Network Control Protocol) first host-host protocol
 - first e-mail program
 - ARPAnet has 15 nodes



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

- ~5B devices attached to Internet (2016)
 - smartphones and tablets
- aggressive deployment of broadband access
- increasing ubiquity of high-speed wireless access
- emergence of online social networks:
 - Facebook: ~ one billion users
- service providers (Google, Microsoft) create their own networks
 - bypass Internet, providing “instantaneous” access to search, video content, email, etc.
- e-commerce, universities, enterprises running their services in “cloud” (e.g., 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 structure
- performance: loss, delay, throughput
- layering, service models
- security
- history

you now have:

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

Chapter I

Additional Slides

