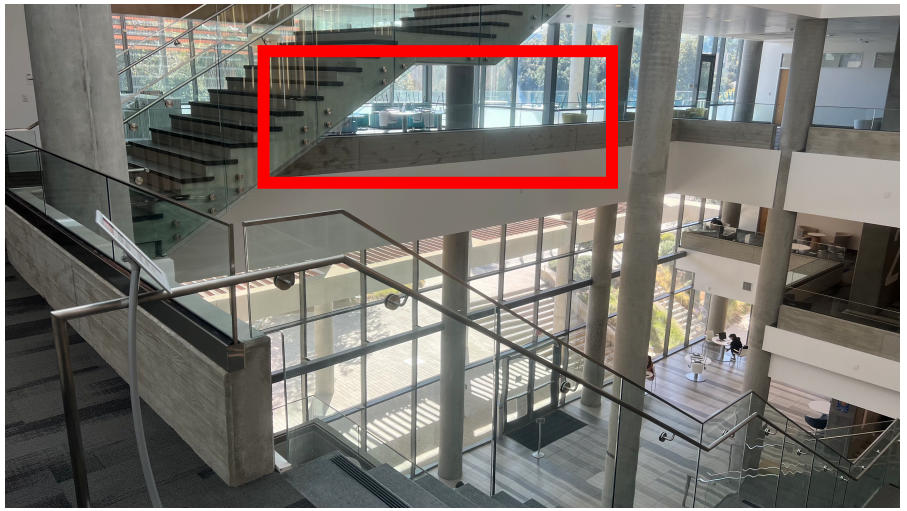
Course Overview

CS204: Advanced Computer Networks

Oct. 2, 2023

Logistics

- Lectures: MW 6:30-7:50PM, Winston Chung Hall 138
- Instructor: Zhaowei Tan
  - Email: ztan@ucr.edu
  - Office hours: Tuesdays 9-11AM; Winston Chung Hall 357
- TA: Yunshu Wang
  - Email: yunshu.wang@email.ucr.edu
  - Office hours: Fridays 11AM-1PM
    - Multidisciplinary Research Building, 3rd Floor

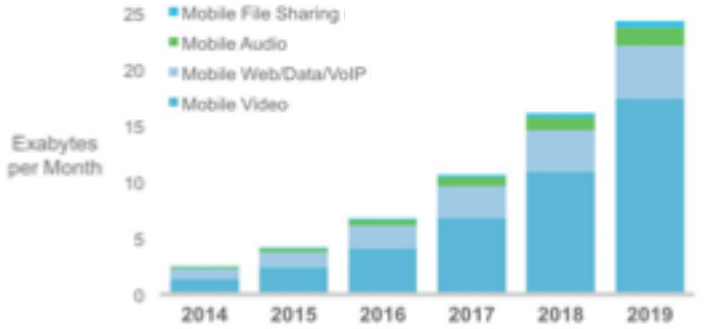


Why Networks?

More Users

- 97% of Americans between 18-29
- 40% of the world population → scope for more users

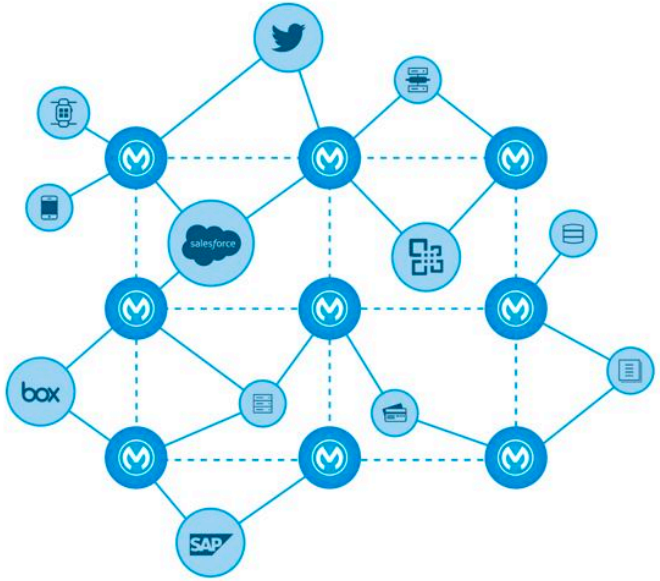
Higher Traffic



YouTube

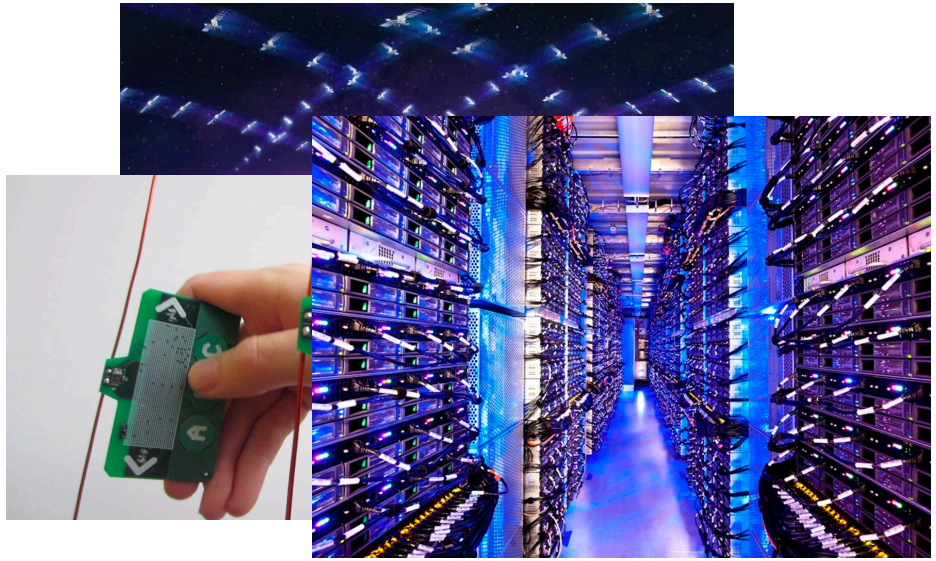
NETFLIX

Diverse Applications



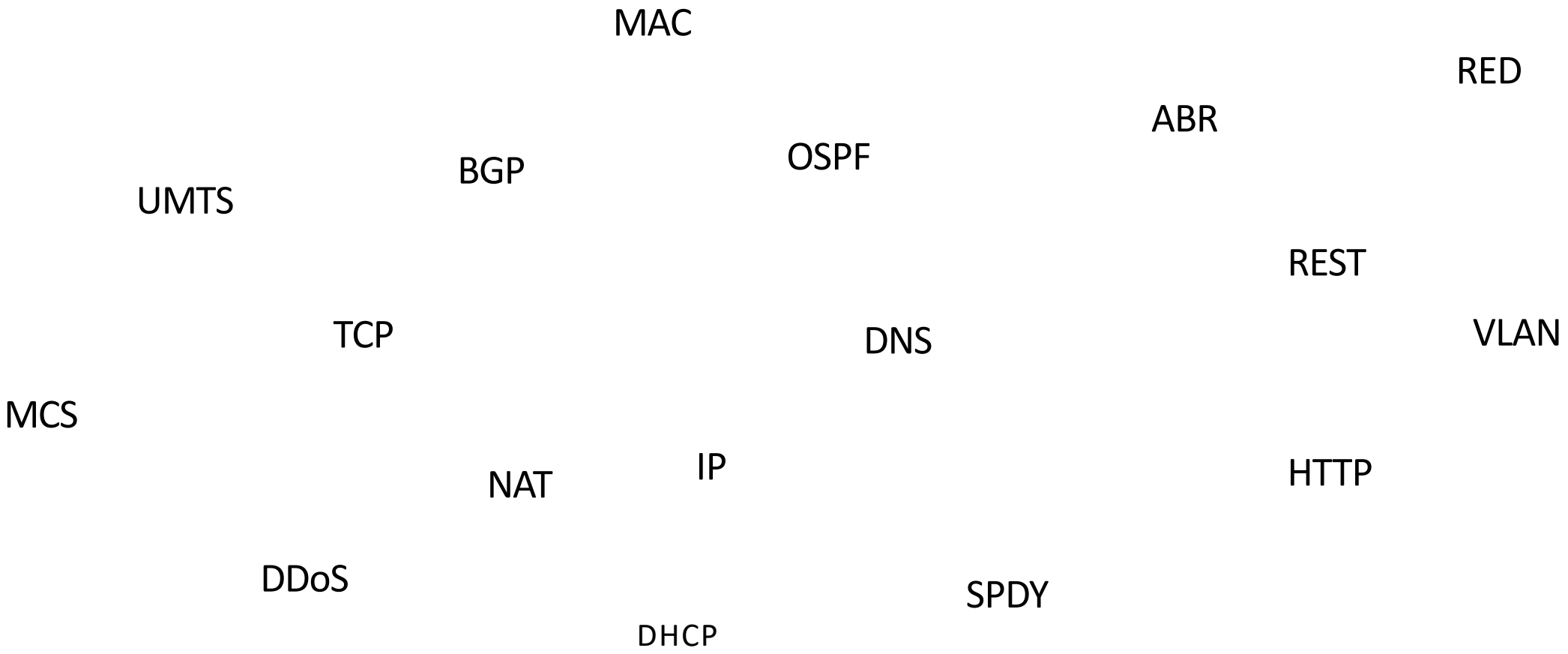
New Challenges

Emerging Technologies



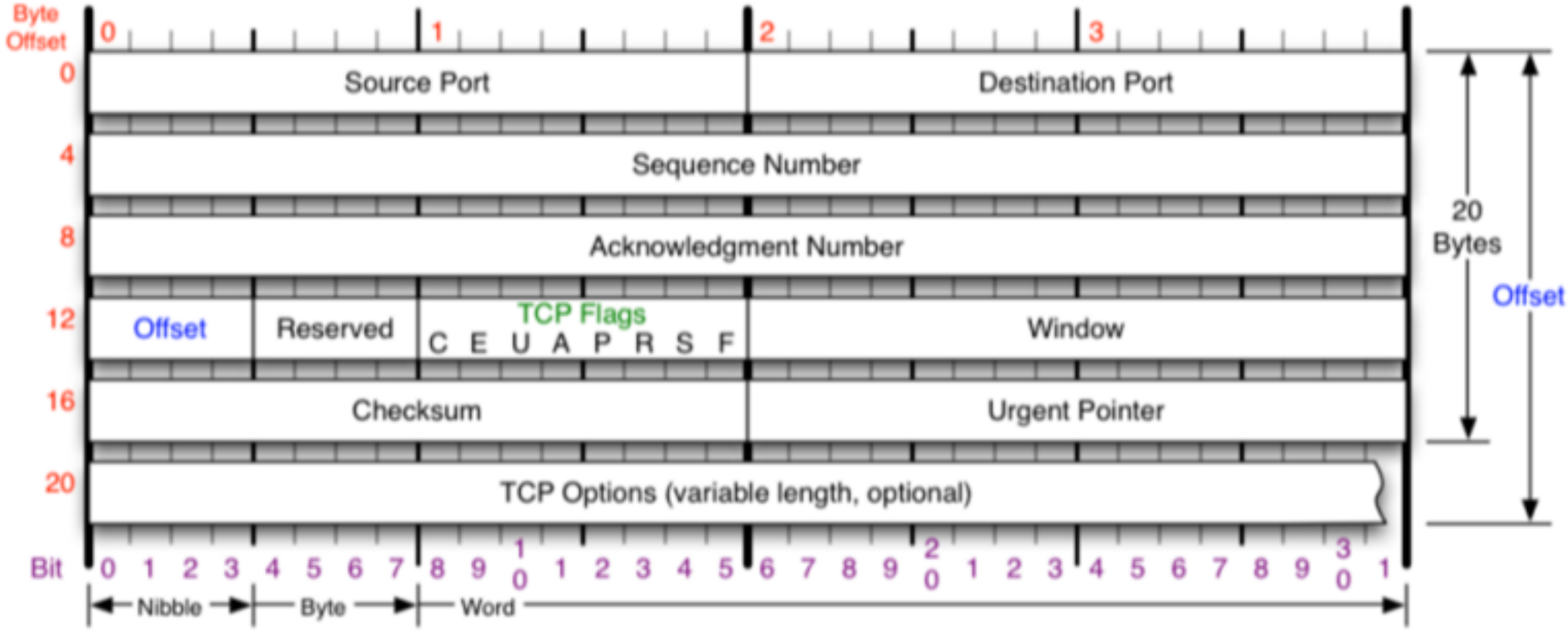
Mentioning “Networking”, you think about…

- Bunch of acronyms



Mentioning “Networking”, you think about…

- Bunch of protocols and headers



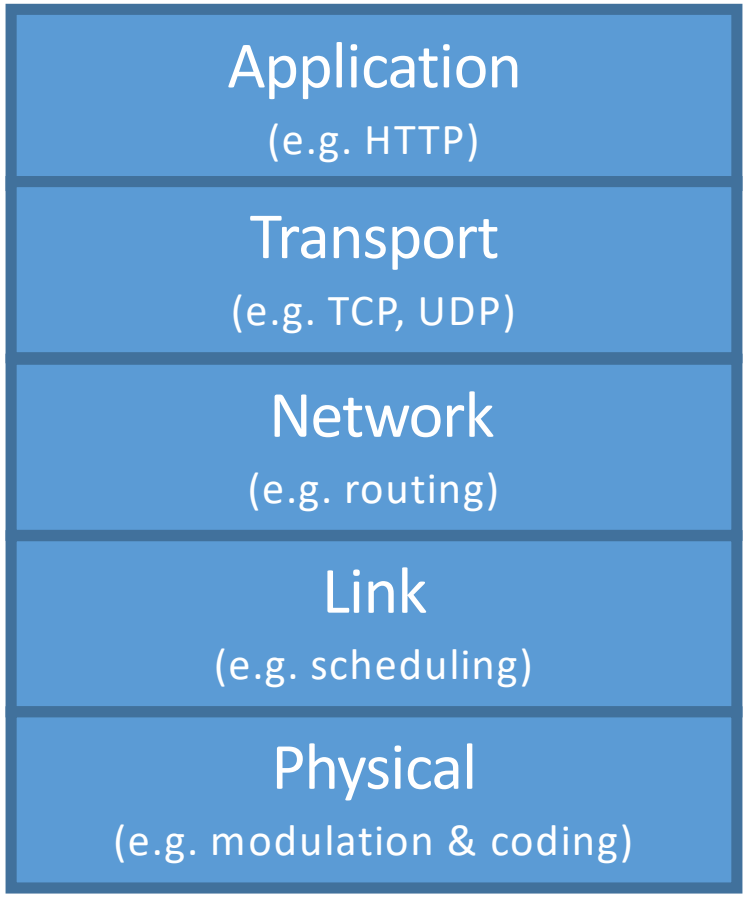
Source: https://nmap.org/book/tcpip-ref.html

Networking is…

The search for general principles to guide communication

Sample Topics in Networking

- Layering
  - What functionality to place within each layer?
  - How many layers should there be?
- Protocols
  - How to communicate within each layer, and offer nice features as intended?
- Wireless
  - How to avoid collision for one-on-one communication in an inherently broadcast environment?
- Resource allocation
  - How to share limited resources between competing users?



What You Will Learn in this Course

- Knowledge
  - 50%: Link layer through application layer (undergrad networking ++)
    - We expect you already have taken an undergrad level networking course
  - 50%: Emerging topics in networking (wireless, multimedia, data centers, etc.)
  - Breadth and depth!
- Skills
  - How to read papers
  - How to present a work
  - How to build networking systems

Course Structure

- Final exam (30%)
  - Week 11 Monday, 7-10PM, This classroom
  - Multiple choice + short answers
  - 1 cheat sheet allowed, US letter, both sides
- Paper Reading (30%)
  - Choose one paper from the list and present to the class (20%)
  - Write a summary report (10%)
- Course Project (40%)
  - System or networking implementation
  - Proposal (5%), Progress Report (10%), Presentation (15%), Final Report (10%)
- Rest assured; You'll be fine if you try your best!
  - "Negative" result is a good result

Course Project

- We will offer topics related to course materials
  - Feel free to come up with you own project, as long as it's networking related
    - Discuss with me on your project selection
    - Implementation-centric; cannot focus on paper reaching or algorithm design

Milestone	**Deadline^**	**Description**	**%**
Project List Released	Week 2 Wed	List of available project	
Project Selection	Week 2 Sun	Form your team and submit your project preference	
Project Assignment	Week 3 Wed	Finalize and notify each team on project assignment	
Proposal*	Week 4 Fri	Describe the motivation, goal, methodology, and steps	5
Mid-Term Report*	Week 7 Fri	Describe the progress, obstacles, and remaining tasks	10
Final Presentation*	Week 10	Show us what you've done!	15
Final Report*	Week 11 Wed	Submit a well-formatted report on your project	10

Paper Reading

Milestone	Deadline^	Description	Grade (%)
List Released	Week 1 Sunday	[Instructor's Task] provide you with the list of available papers	
Selection	Week 2 Wednesday	Submit your presentation preference	
Paper Assignment	Week 2 Friday	Finalize and notify each person on final paper assignment	
Presentation	Your choice	Present the work you studied	20
Summary*	Week 10 Friday	Submit the written report	10

* Template will be provided.

^ The due time is 11:55 PM on each deadline day.

Calendar

Week	Day	Date	Topic
1	Mon	10/2	Logistics + Overview
	Wed	10/4	Principles for Networking Design
2	Mon	10/9	Application Layer - HTTP
	Wed	10/11	Application Layer - P2P
3	Mon	10/16	Transport Layer - MPTCP
	Wed	10/18	Transport Layer - TCP Cubic
4	Mon	10/23	Paper Presentation -
	Wed	10/25	Video Streaming, More MPTCP, etc.
5	Mon	10/30	Network Layer - IPv6
	Wed	11/1	Network Layer - BGP
6	Mon	11/6	Link Layer - WiFi
	Wed	11/8	Link Layer - 5G
7	Mon	11/13	Paper Presentation -
	Wed	11/15	SDN, BGP, Bluetooth, etc.
8	Mon	11/20	Emerging Topics: Datacenter Networking
	Wed	11/22	Emerging Topics: Edge Computing
9	Mon	11/27	Paper Presentation -
	Wed	11/29	Satellite, NFV, Backscatter, etc.
10	Mon	12/4	Project Presentation
	Wed	12/6	
11	Monday	12/11	7-10PM, this classroom One (1) cheatsheet (US letter, both sides) allowed

Academic Integrity

- Cite your sources!
  - Never copy any text verbatim from any source without properly citing
  - If verbatim, then needs to be in quotes and with a citation next to the quote
- You can discuss with me or others on the project, but make sure you implement it on your own and understand what you wrote
- Plagiarism is very serious
  - If you cheat, you will receive 0 on the project/exam
    - The incidents will be reported
  - If you try your best, I will try my best to give you partial credit
    - This course might not be easy, and I understand

Useful Links

- https://elearn.ucr.edu/
  - Announcements, course materials, project submission, discussion board…
- https://cs.ucr.edu/~ztan/courses/CS204/f23/
  - Syllabus and quick reference without UCR login
- https://forms.gle/F1bjhNHcwZEihHc9A
  - Form for any anonymous feedback
  - Alternatively, feel free to send me an email, or talk to me during office hour
  - I'll make sure that you learn both knowledge and skills from CS204!

Review

1.1 what *is* the Internet?

1.2 network edge

- end systems, access networks, links

1.3 network core

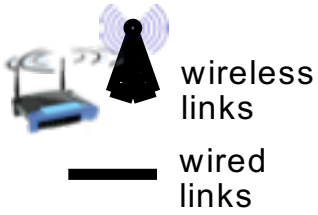
- packet switching, circuit switching, network structure

1.4 protocol layers, service models

Adapted from *Computer Networking: A Top-Down Approach*, Kurose & Ross

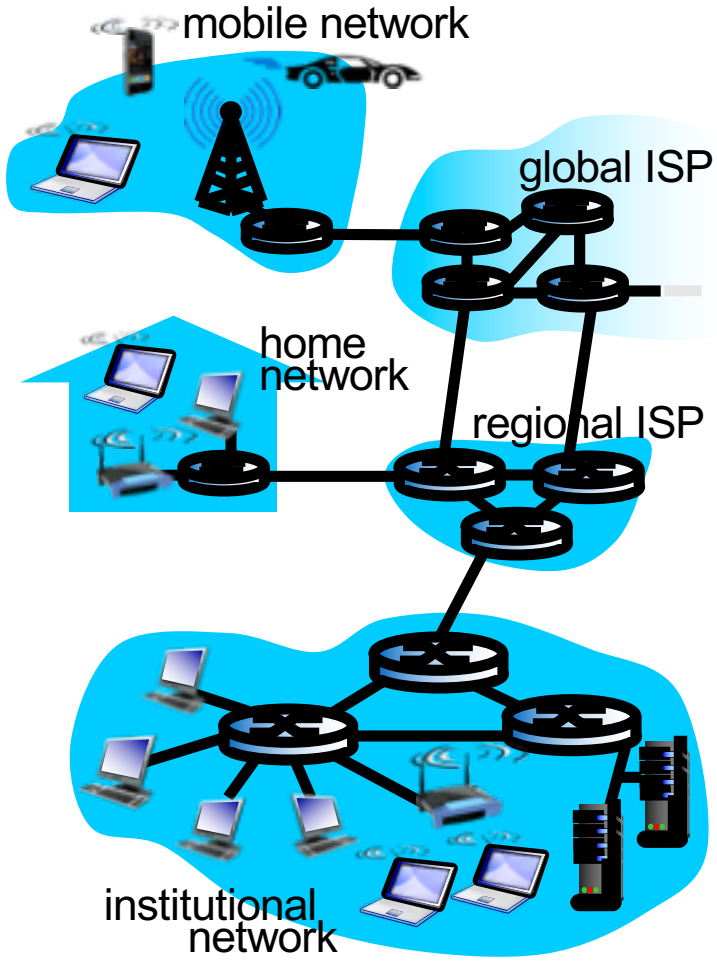
What's the Internet: "nuts and bolts" view

- Millions of connected computing devices:
  - *hosts = end systems*
  - running *network apps*



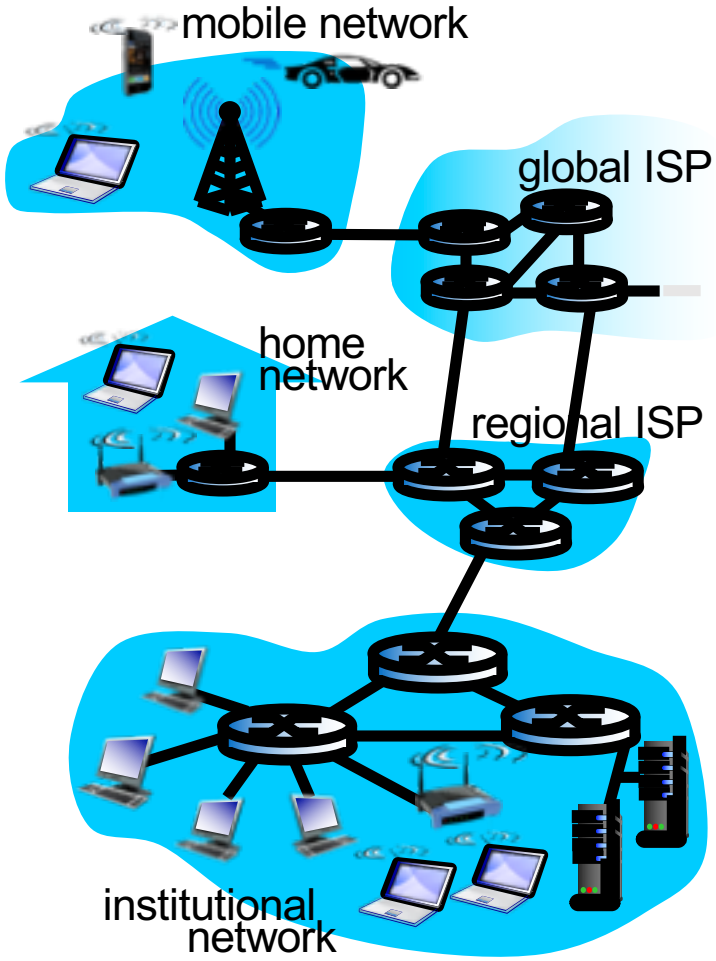
❖ *Communication links*
- fiber, copper, radio, satellite
- transmission rate: *bandwidth*

❖ *Packet switches:* forward packets (chunks of data)
- *routers* and *switches*



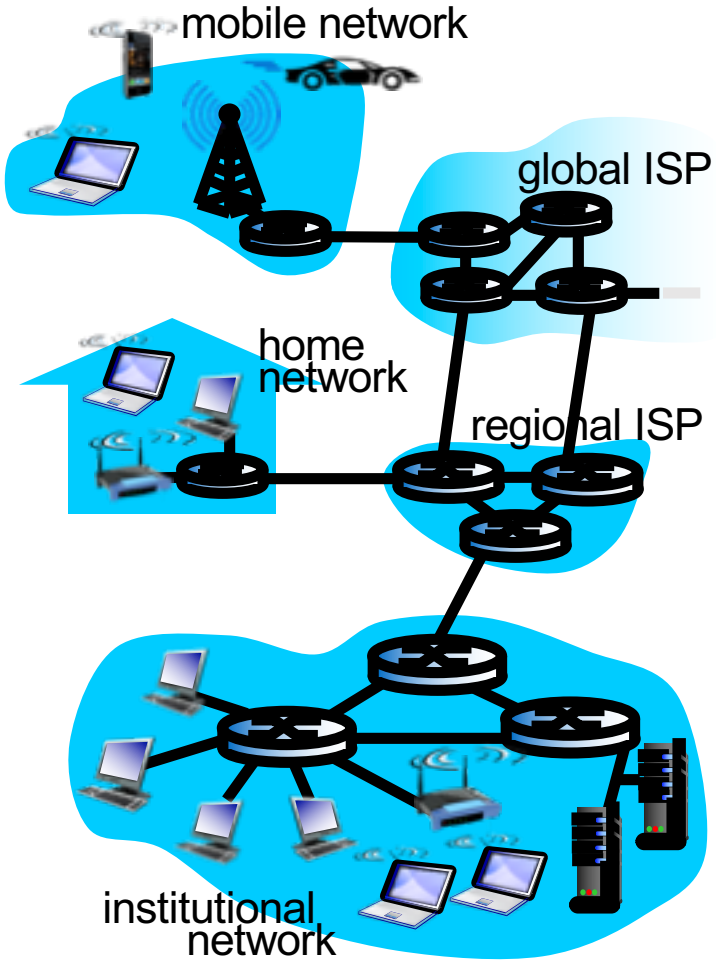
What's the Internet: "nuts and bolts" view

- *Internet:* "network of networks"
  - Interconnected ISPs
- *Protocols* control sending, receiving of msgs
  - e.g., TCP, IP, HTTP, Skype, 802.11
- *Internet standards*
  - 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 msgs sent

… specific actions taken when msgs received, or other events

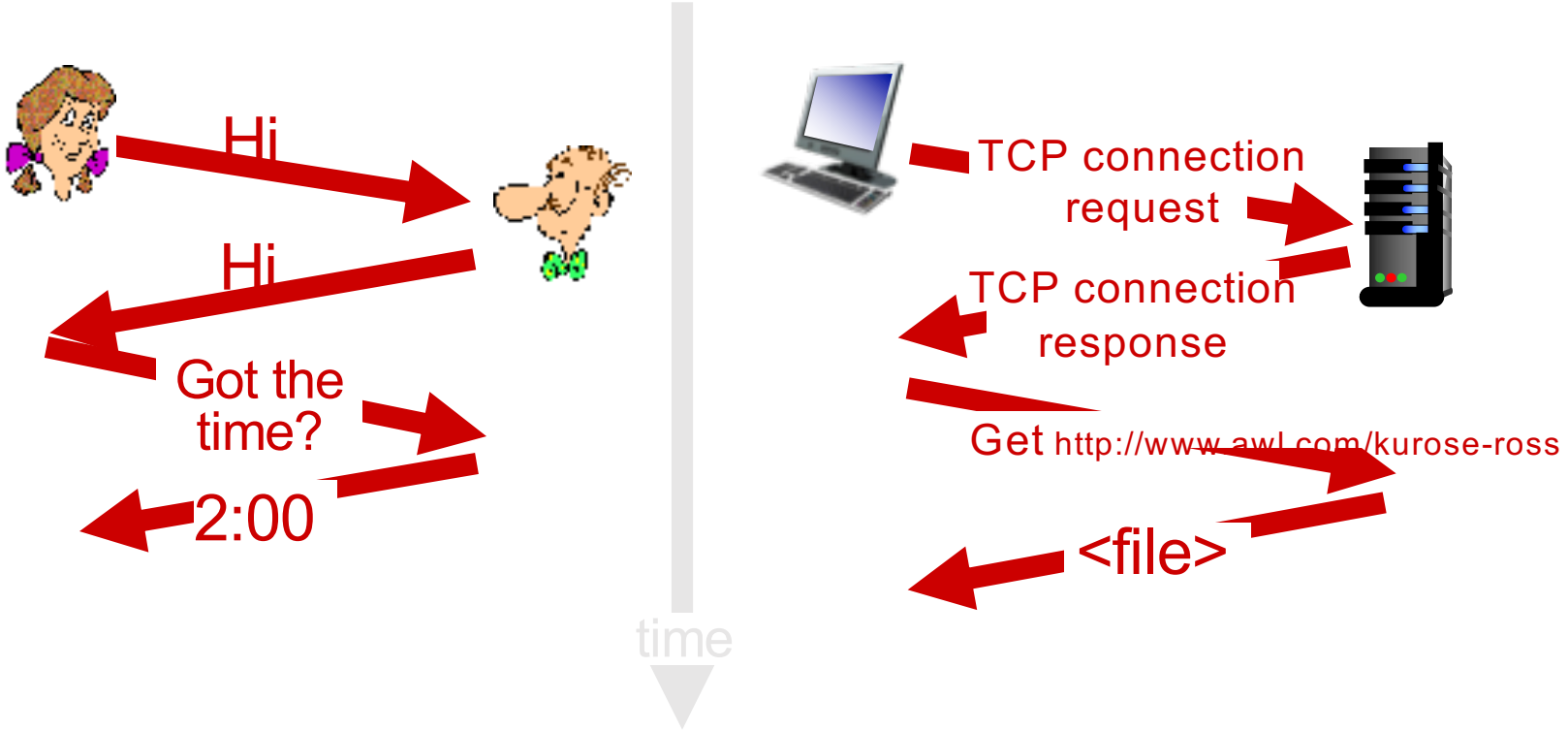
network protocols:

- 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?

a human protocol and a computer network protocol:



Roadmap

1.1 what *is* the Internet?

1.2 network edge

- end systems, access networks, links

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- packet switching, circuit switching, network structure

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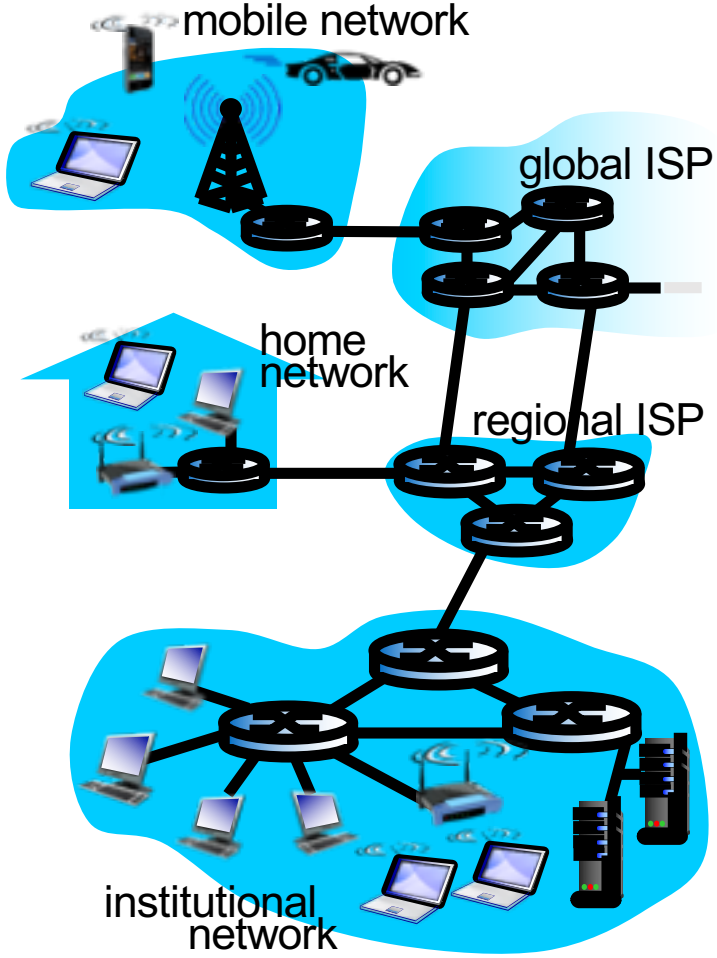
A closer look at network structure:

- *network edge:*
  - hosts: clients and servers
  - servers often in data centers

- *access networks, physical media:* wired, wireless communication links

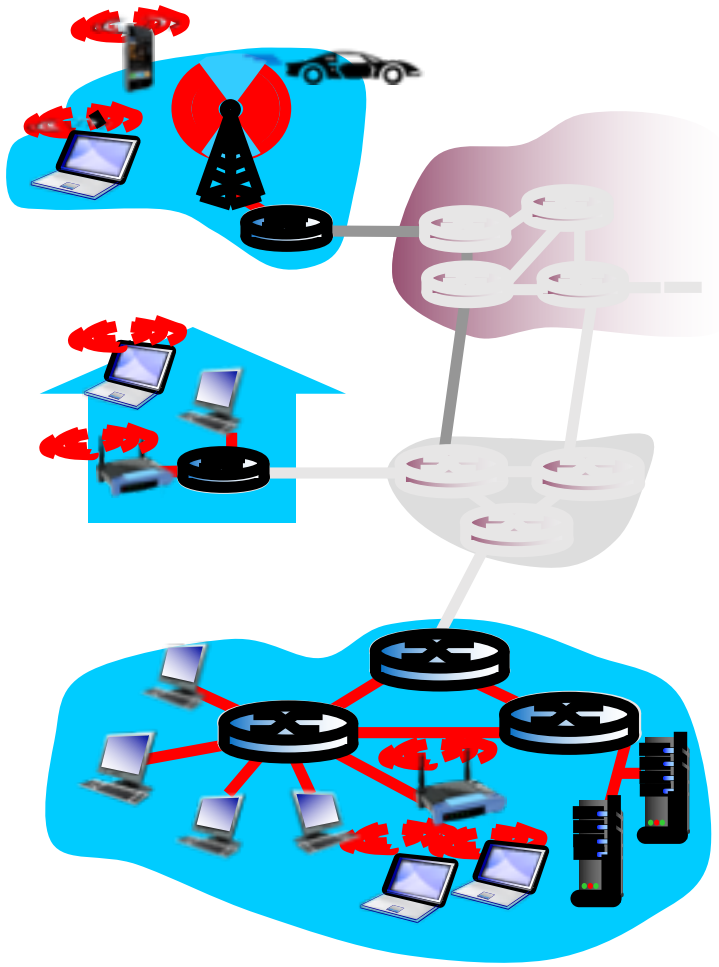
- *network core:*
  - interconnected routers
  - network of networks



Access networks and physical media

Q: How to connect end systems to edge router?

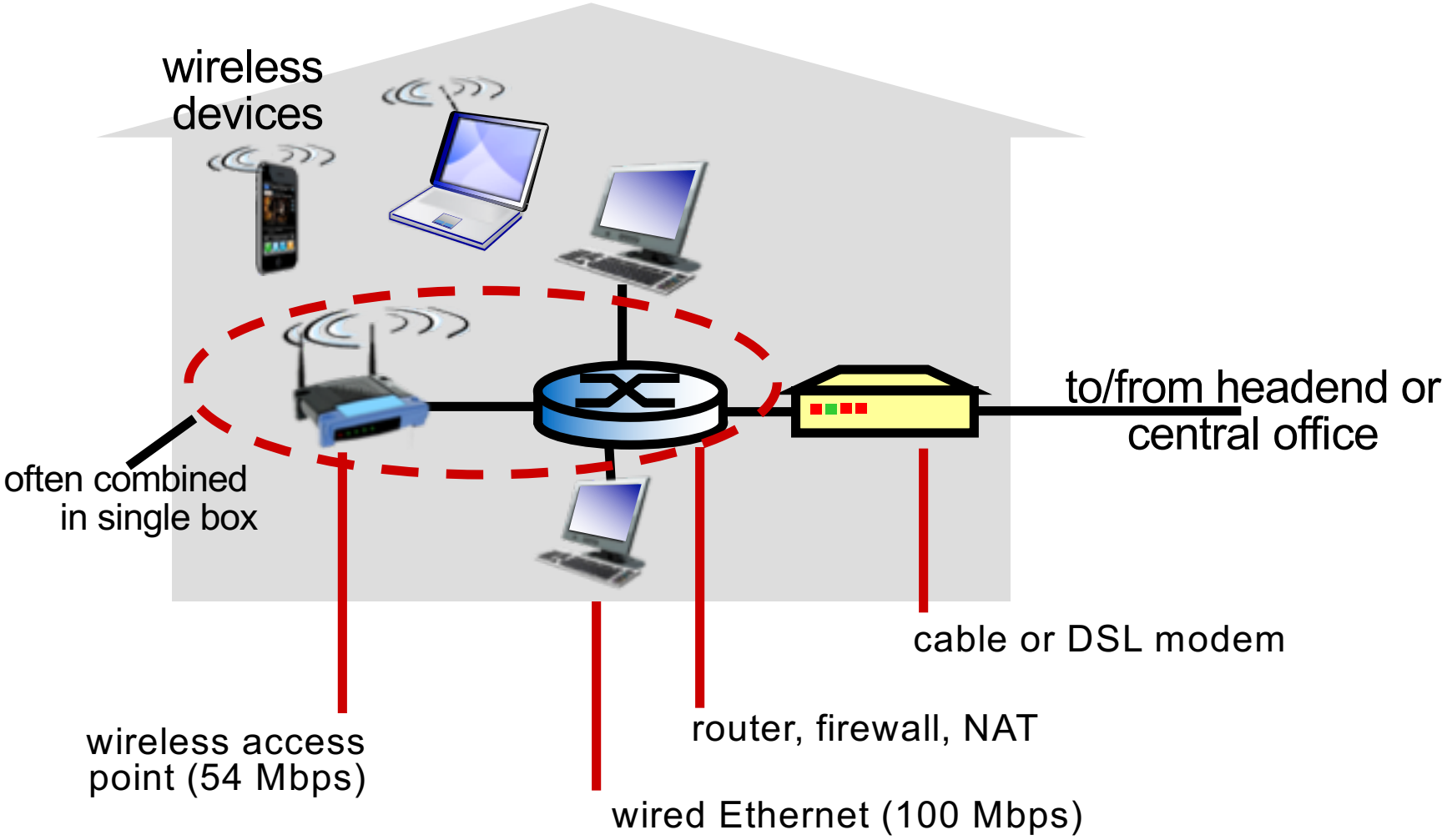
- residential access nets
- institutional access networks (school, company)
- mobile access networks



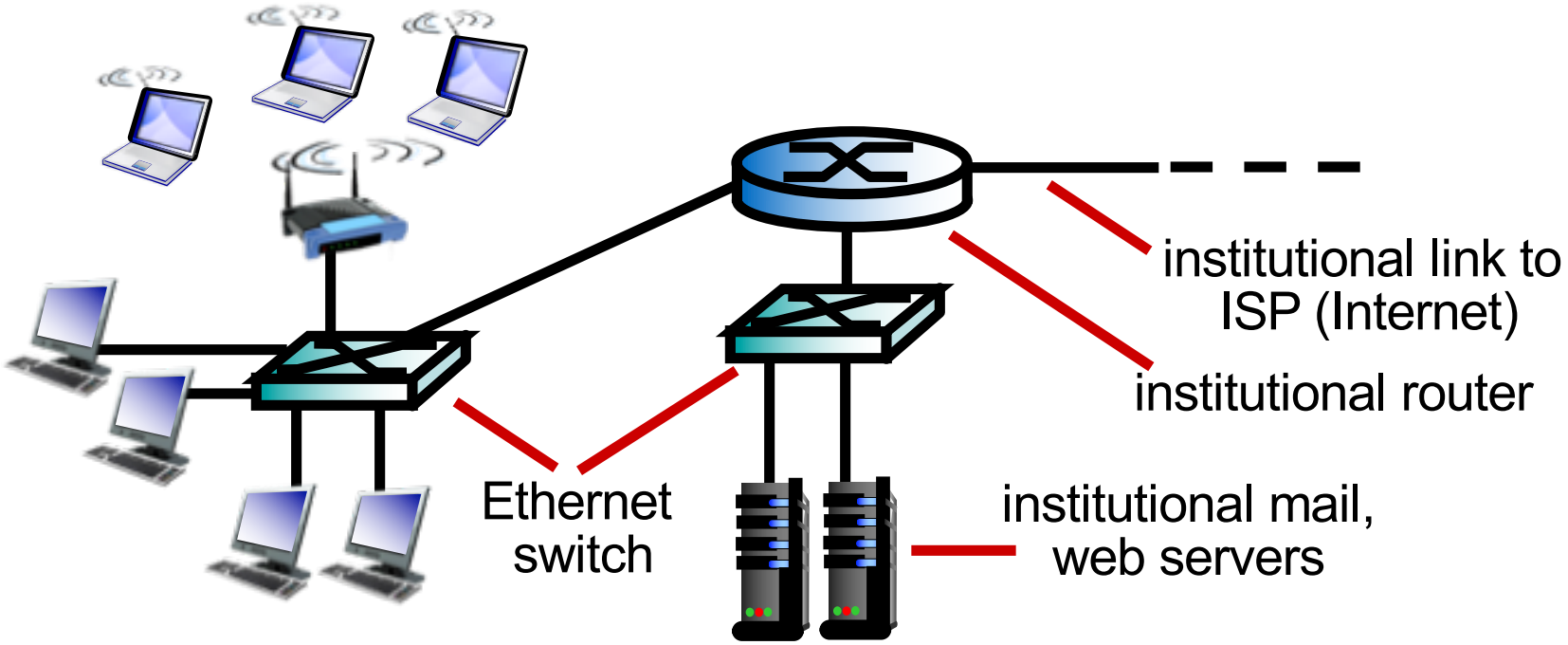
keep in mind:

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

Access net: home network



Enterprise access networks (Ethernet)



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

Wireless access networks

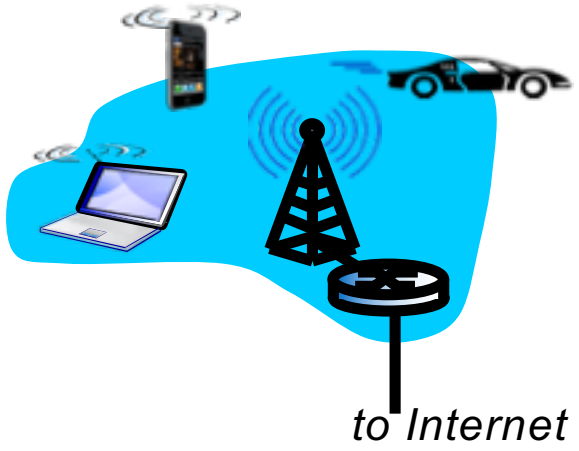
- shared *wireless* access network connects end system to router
  - via base station aka "access point"

wireless LANs:

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

wide-area wireless access

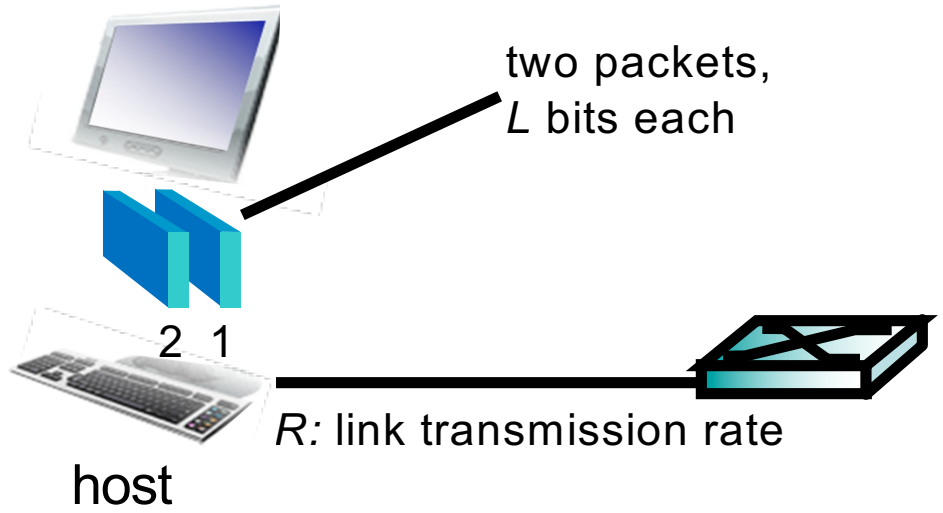
- provided by telco (cellular) operator, 10's km
- between 1 and 10 Mbps
- 3G, 4G: LTE, 5G



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*



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

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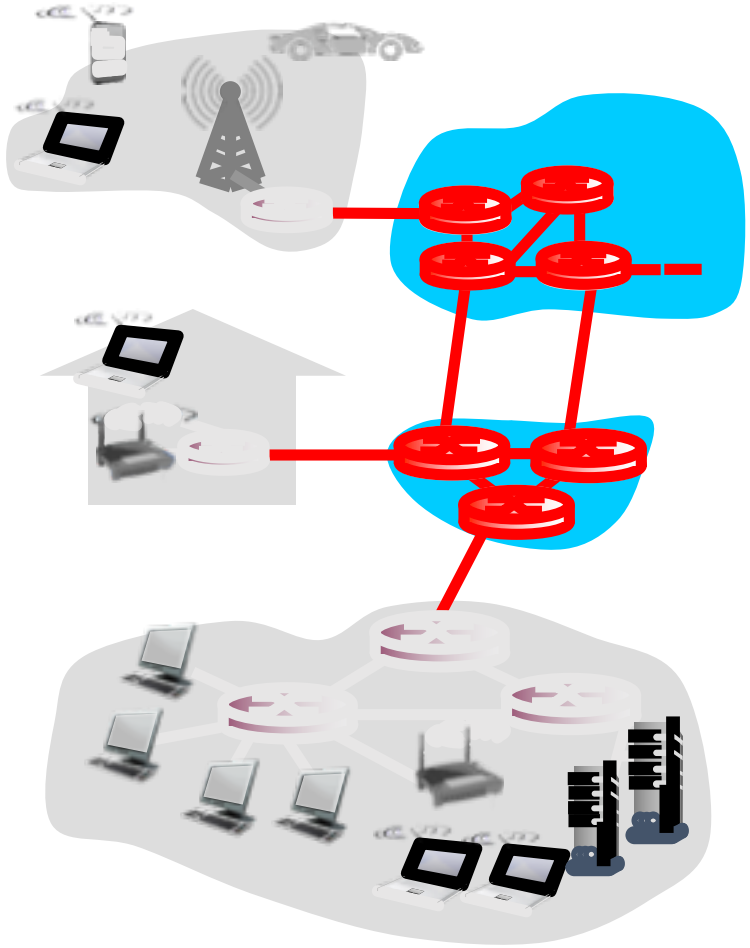
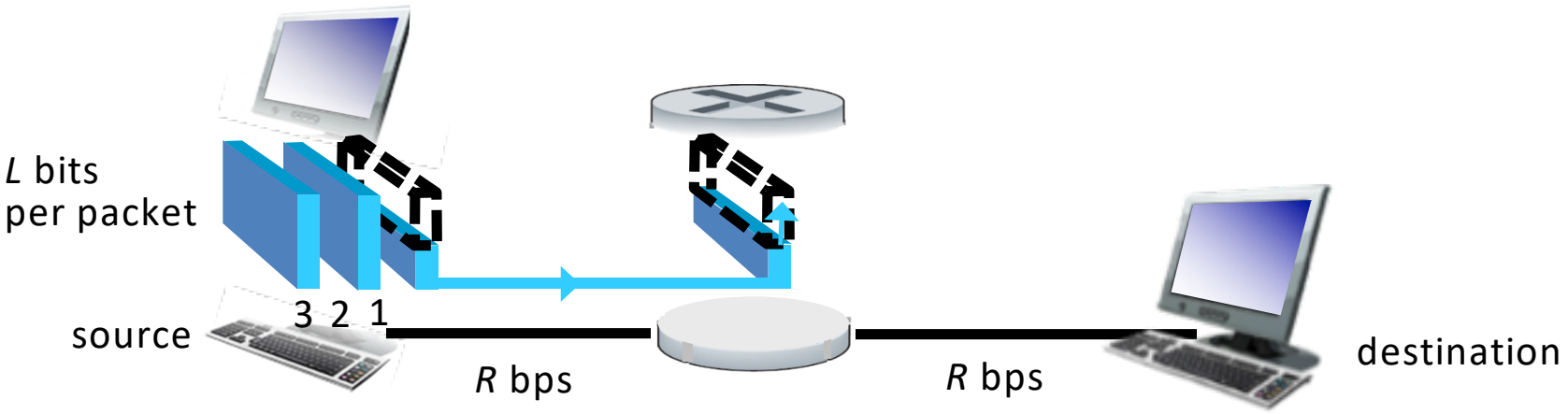
The network core

- 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

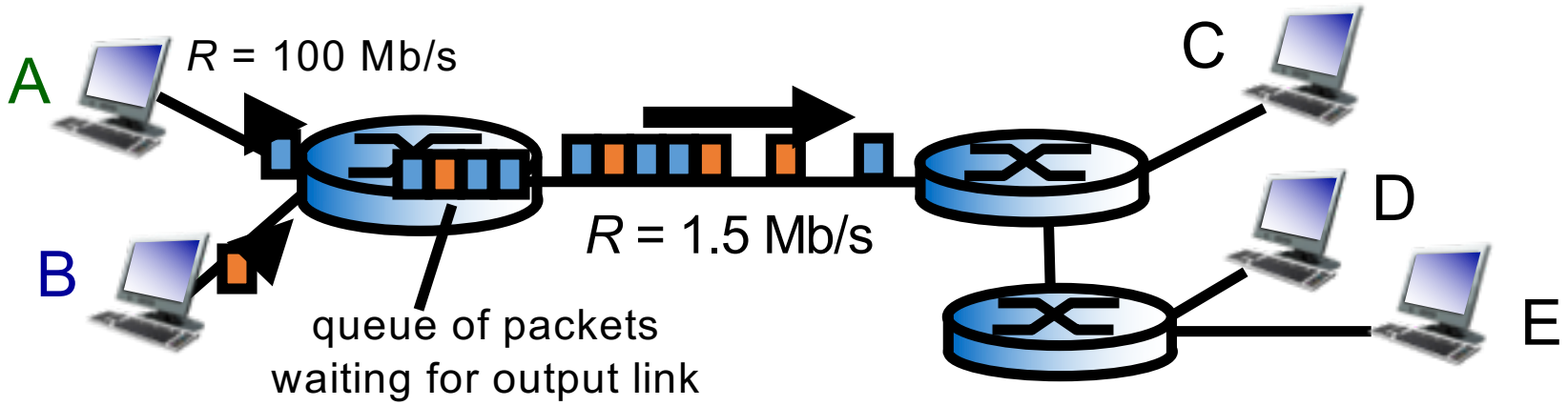
❖ end-end delay = $2L/R$

  ❖ assuming zero propagation and queuing delay

one-hop numerical example:

- L = 7.5 Mbits
- R = 1.5 Mbps
- one-hop transmission delay = 5 sec

Packet Switching: queueing delay, loss



queuing and loss:

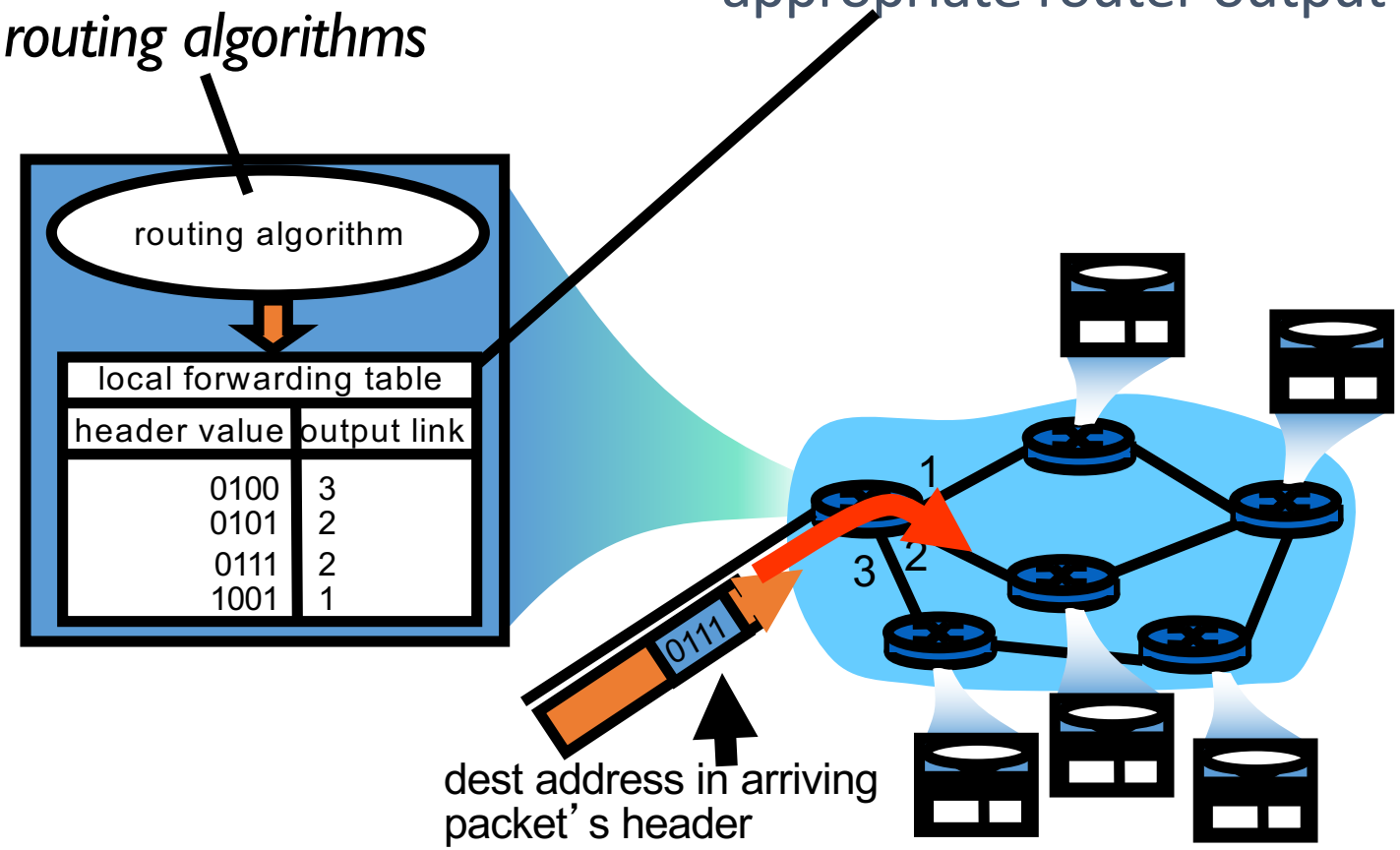
- If arrival rate (in bits) to link exceeds transmission rate of link for a period of time:
  - packets will queue, wait to be transmitted on link
  - packets can be dropped (lost) if memory (buffer) fills up

Two key network-core functions

routing: determines source-destination route taken by packets

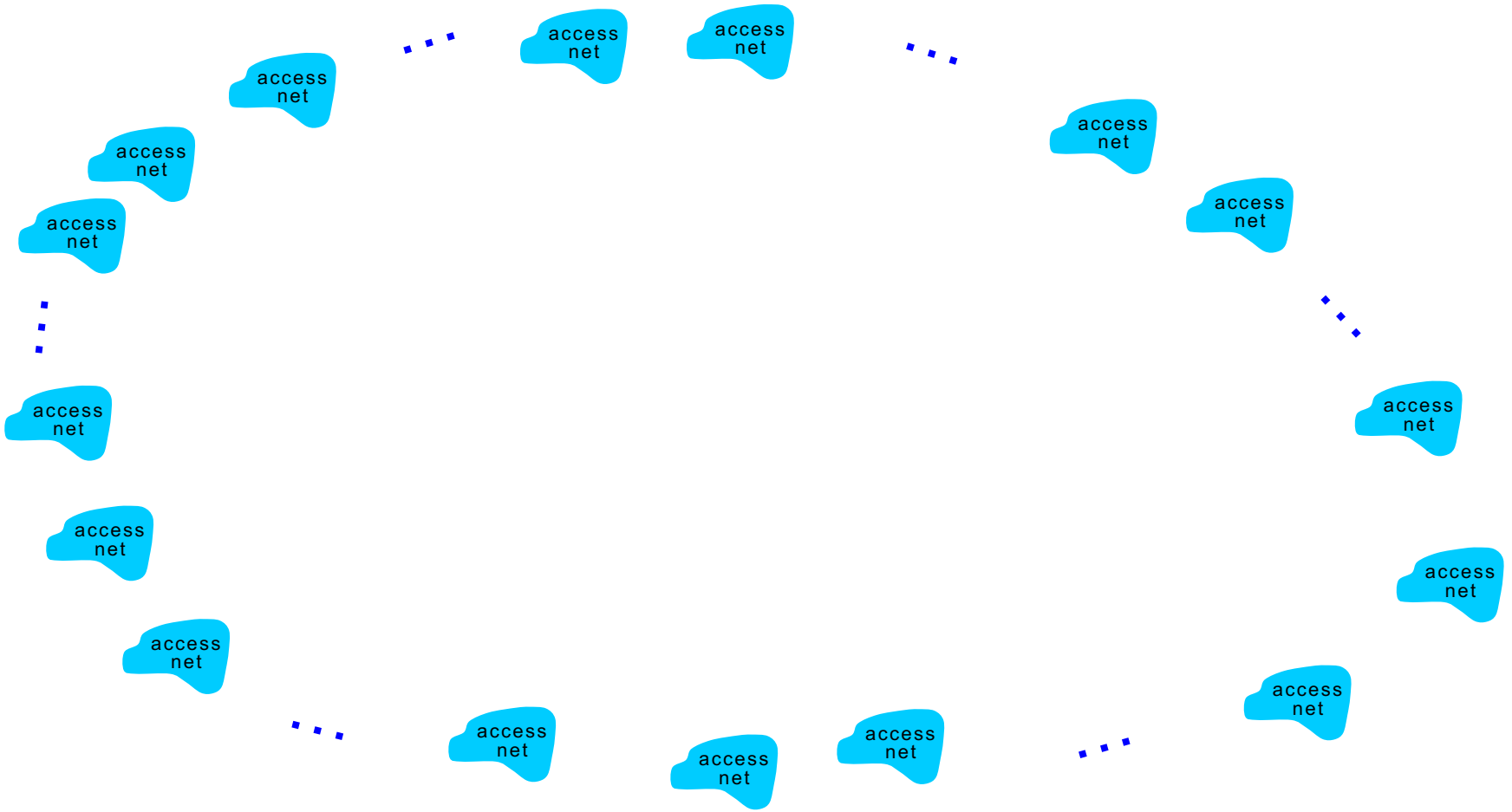
- *routing algorithms*

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



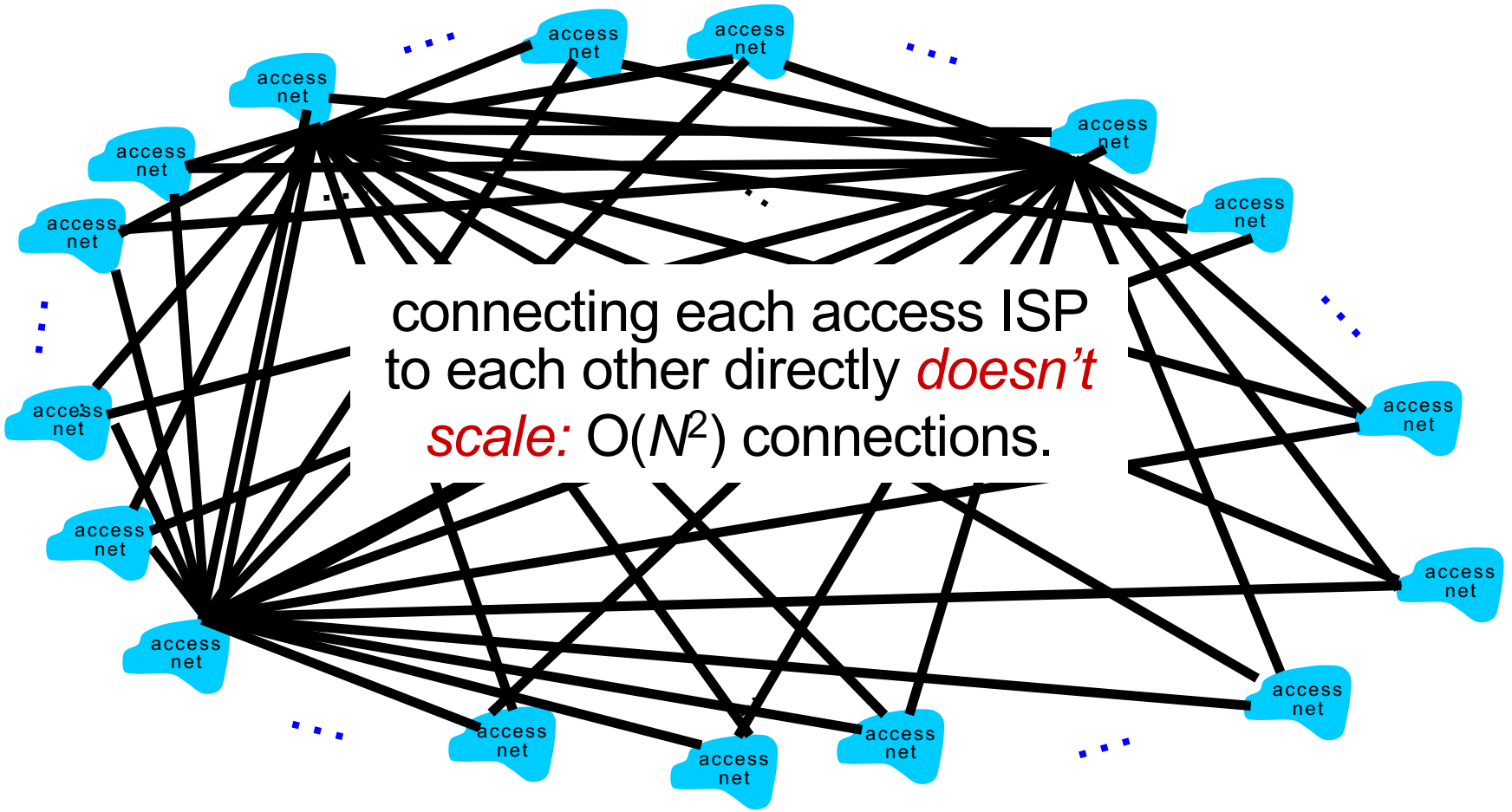
Internet structure: network of networks

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



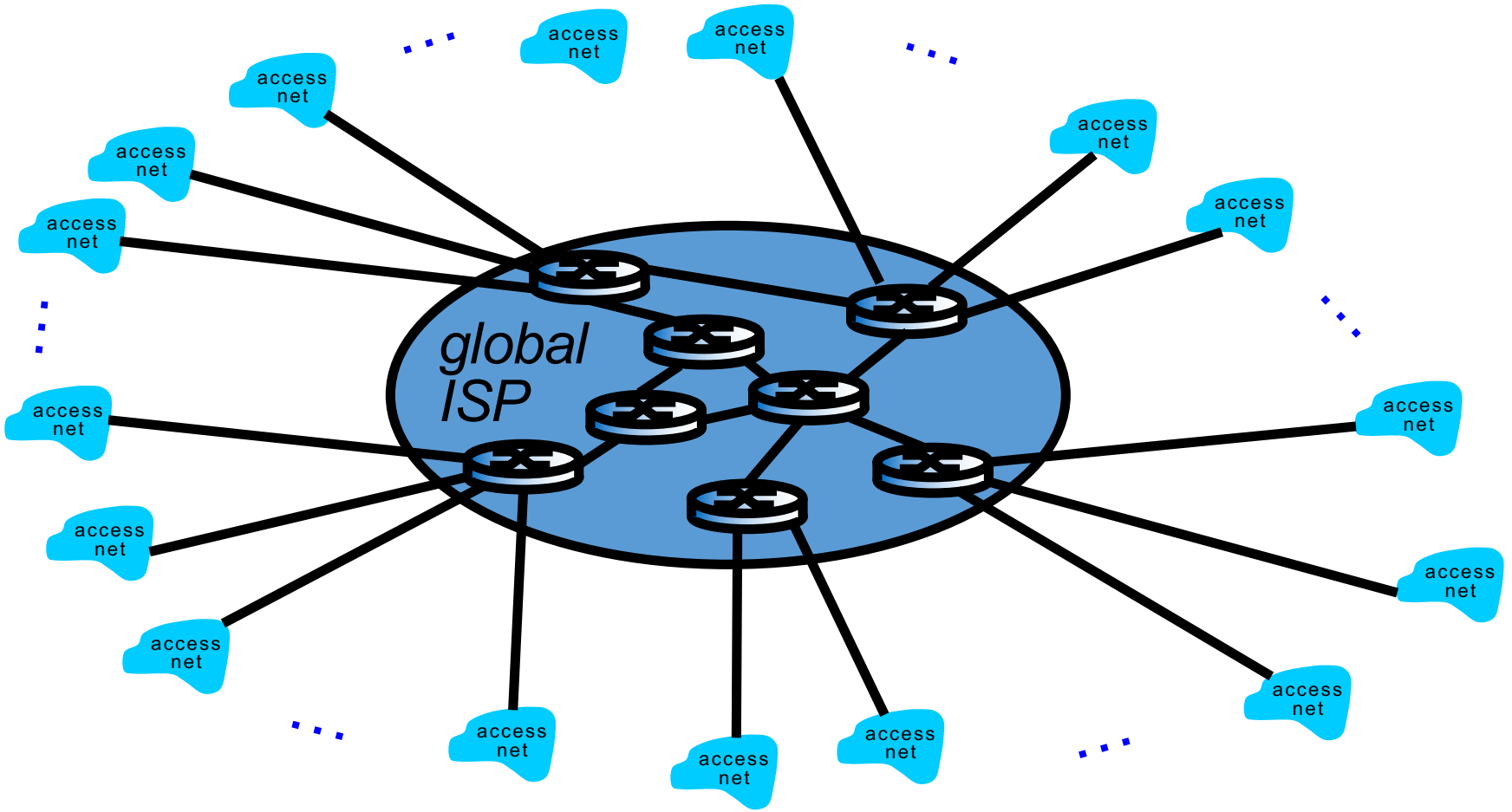
Internet structure: network of networks

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



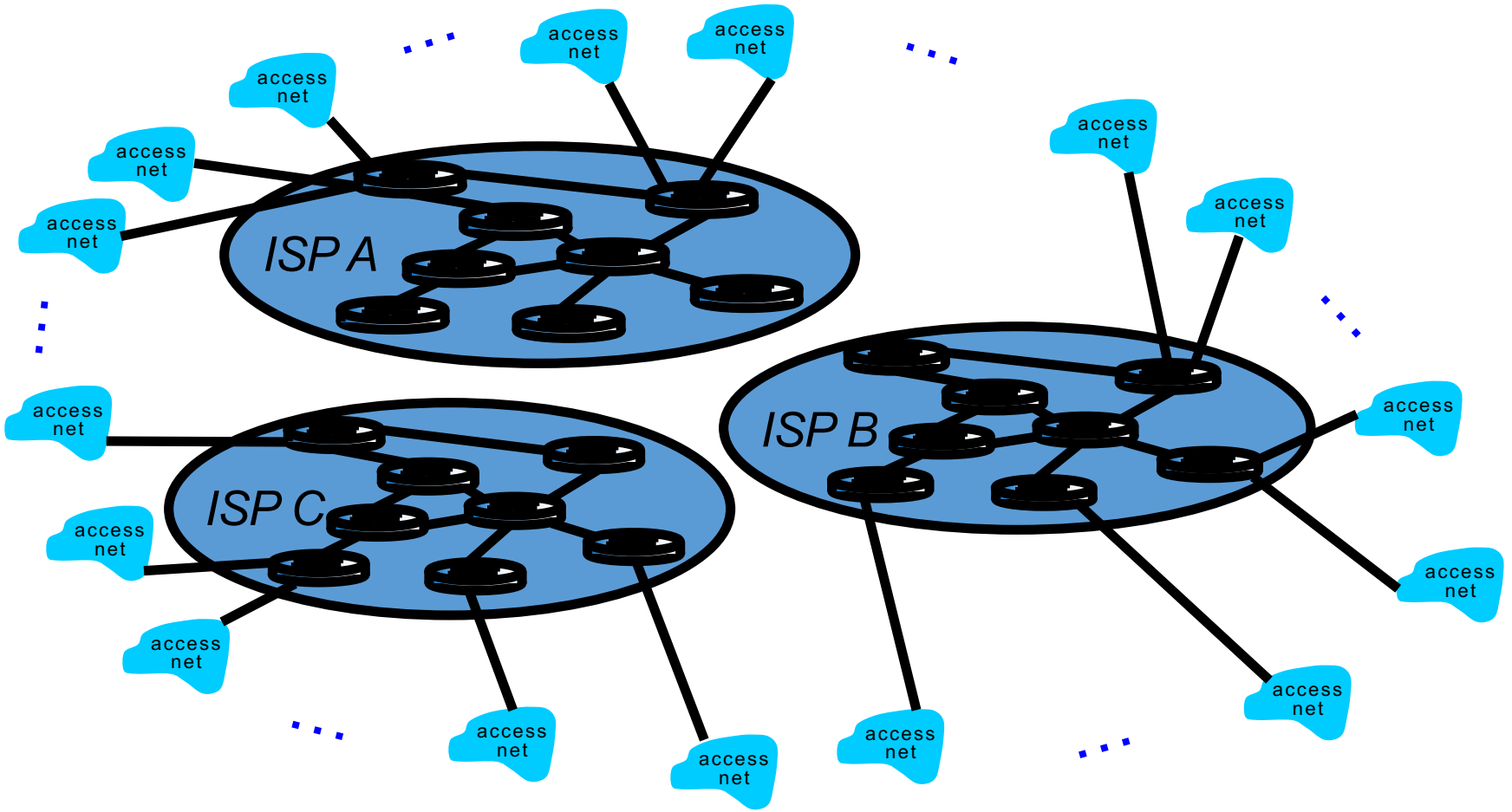
Internet structure: network of networks

Option: connect each access ISP to a global transit ISP? Customer and provider ISPs have economic agreement.



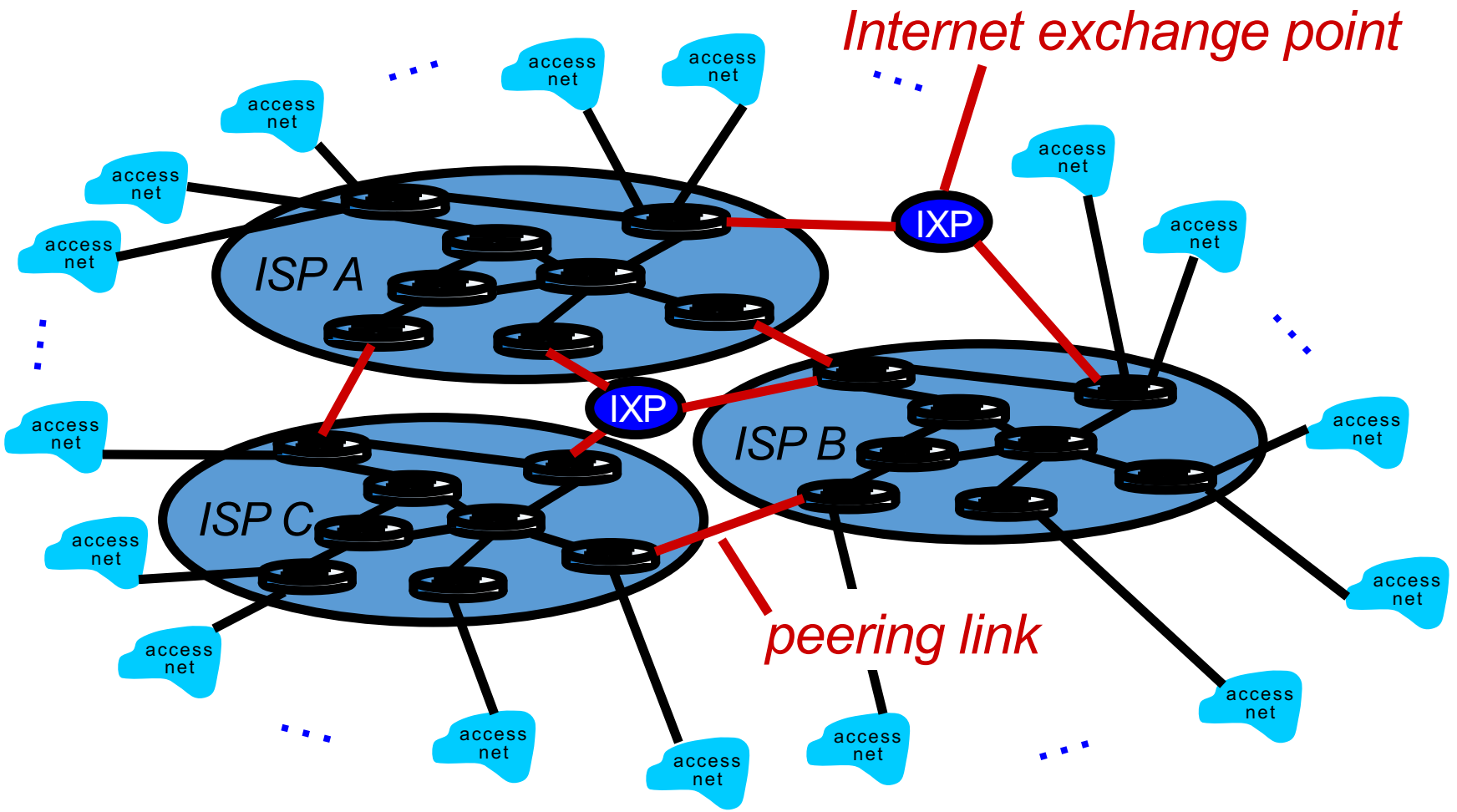
Internet structure: network of networks

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



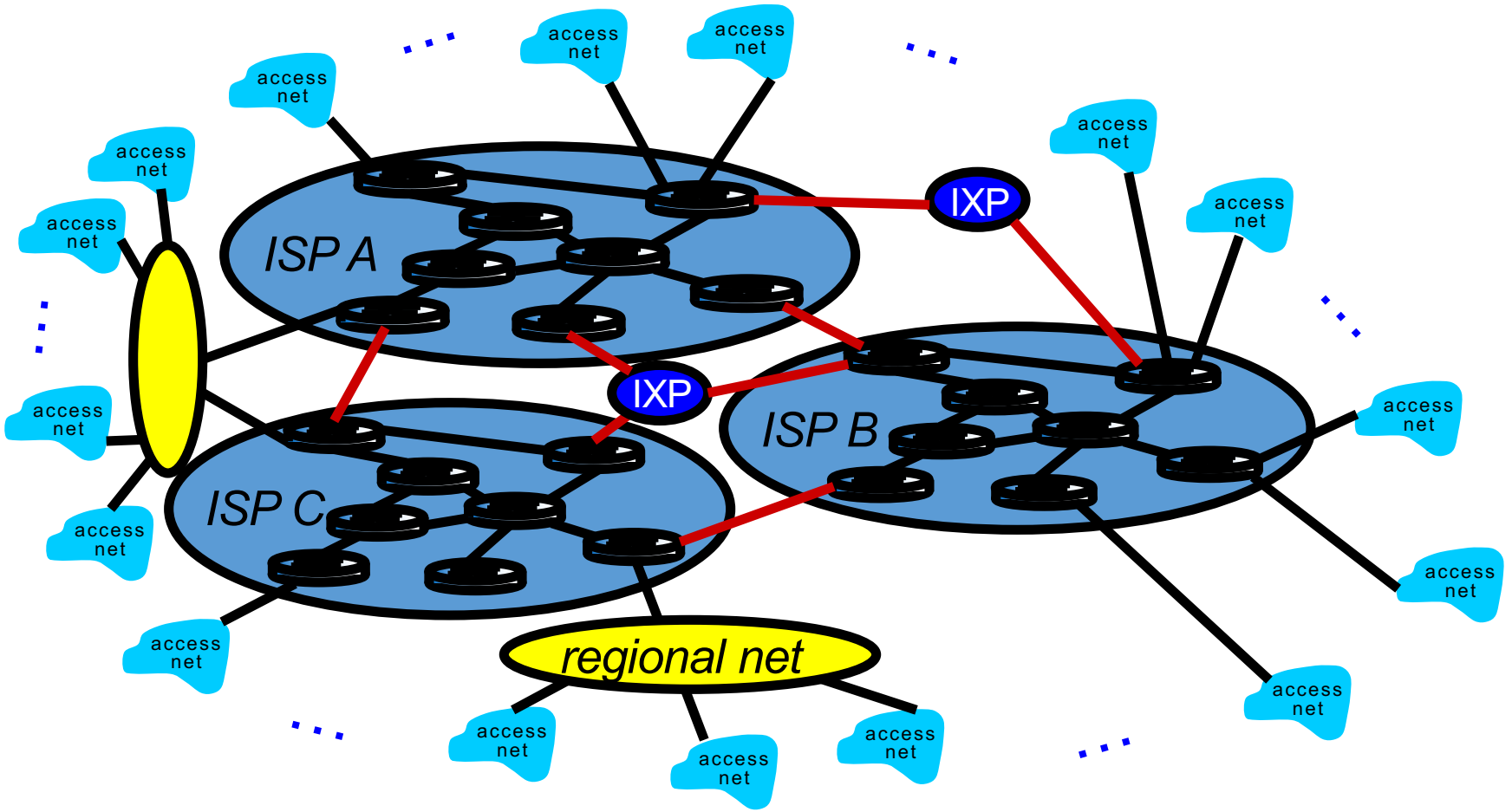
Internet structure: network of networks

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

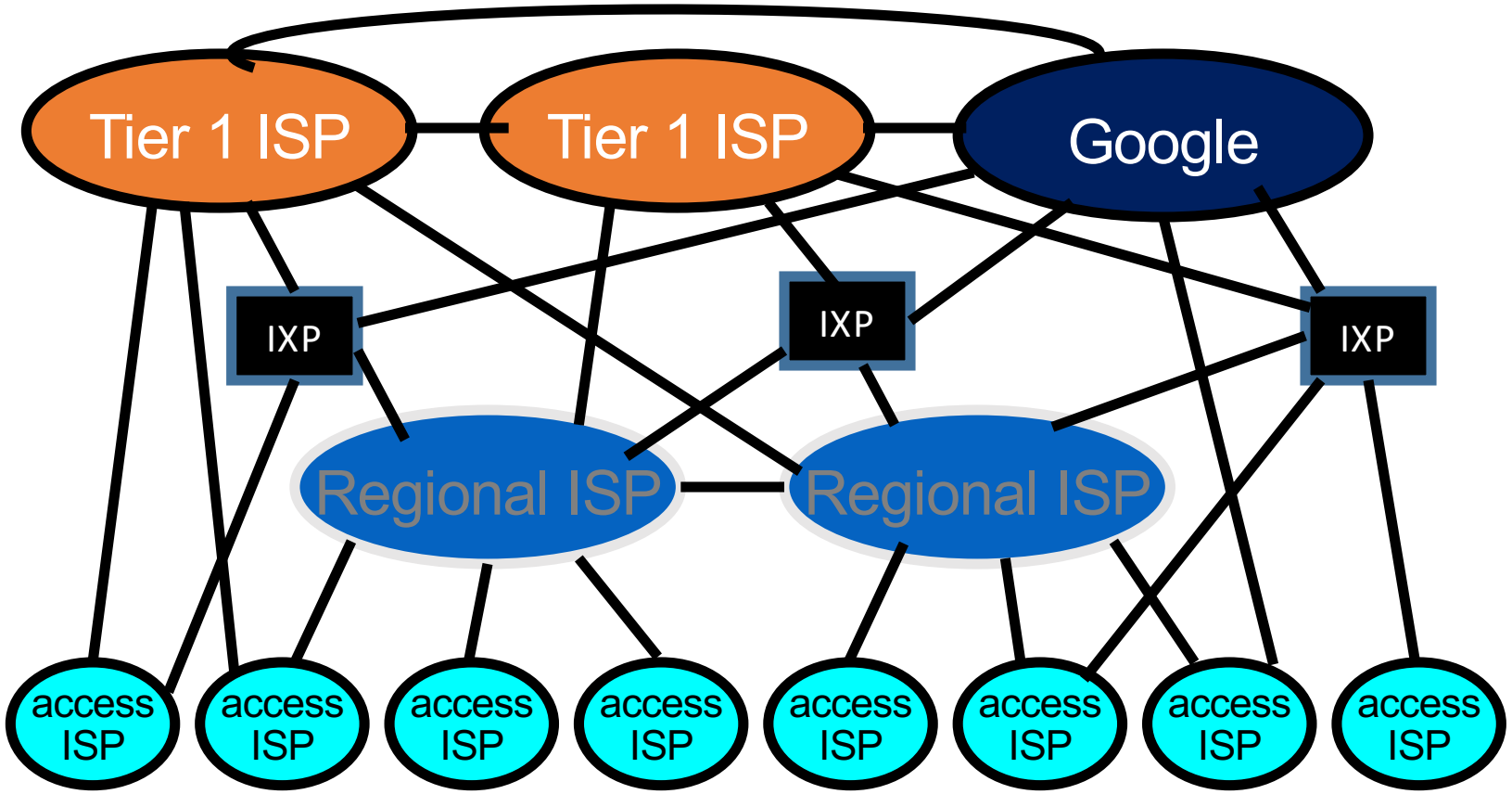


Internet structure: network of networks

… and regional networks may arise to connect access nets to ISPS



Internet structure: network of networks



- 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 it data centers to Internet, often bypassing tier-1, regional ISPs

Roadmap

1.1 what *is* the Internet?

1.2 network edge

- end systems, access networks, links

1.3 network core

- packet switching, circuit switching, network structure

1.4 protocol layers, service models

Protocol "layers"

Networks are complex, with many "pieces":

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

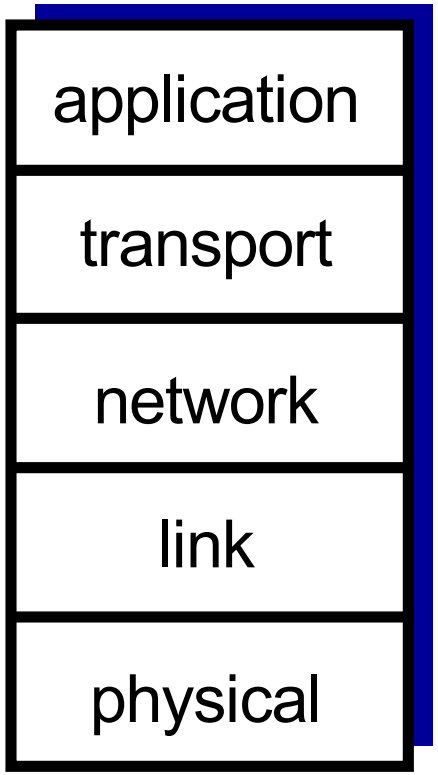
Question:

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

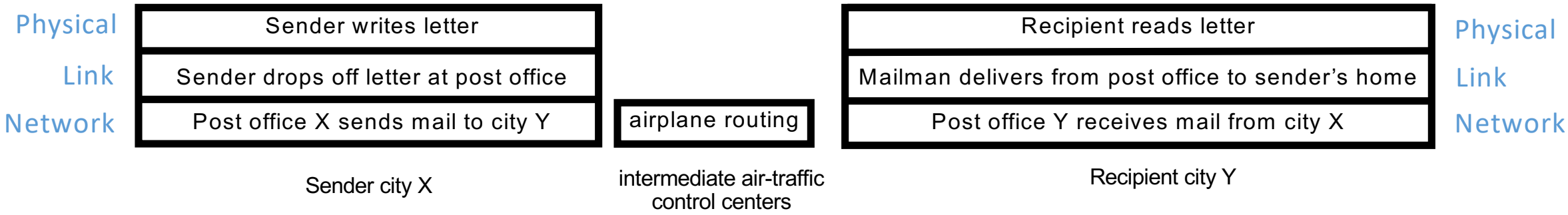
…. or at least our discussion of networks?

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"



Layering of post office functionality

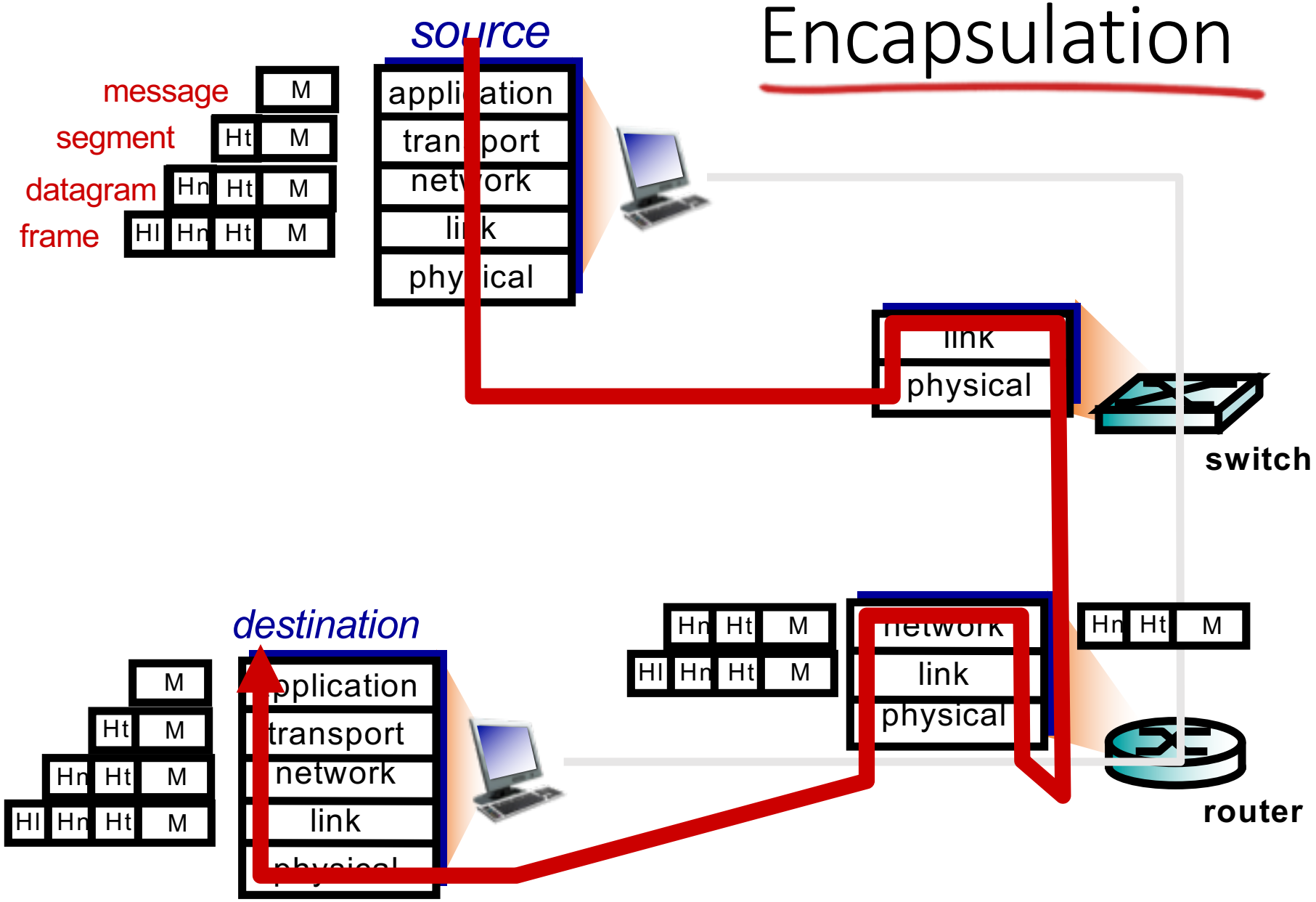


layers: each layer implements a service

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

Transport: Delivery via UPS (signature required) or USPS (no signature required)
Application: the contents of the letter, e.g. photo, video, novel

Encapsulation



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 letter language doesn't affect rest of system

- layering considered harmful?

Next Up

- Read “The Design Philosophy of the DARPA Internet Protocols” by David Clark
  - 9 pages, relatively light read
  - Come prepared to discuss next class