CS 204:
Advanced Computer Networks

Jiasi Chen

Lectures: MWF 12:10-1pm

Humanities and Social Sciences 1403

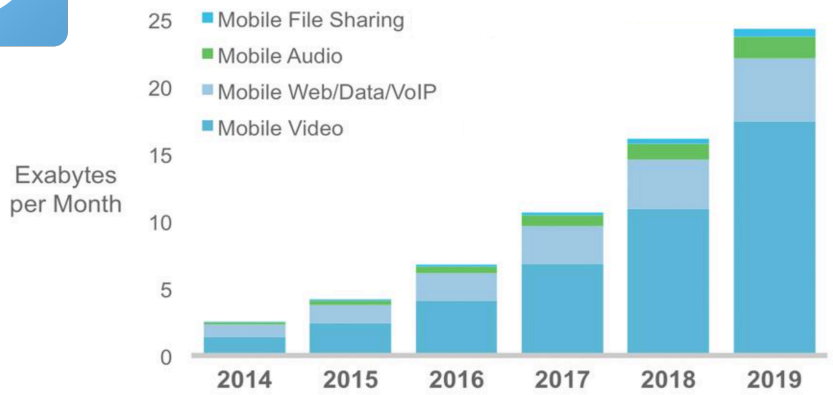
http://www.cs.ucr.edu/~jiasi/teaching/cs204_spring17/

Why Networks?

Supports the applications that we use today…

Social media

Video streaming



Number of Internet users

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

http://www.pewinternet.org/data-trend/internet-use/latest-stats/
https://en.wikipedia.org/wiki/List_of_countries_by_number_of_internet_users

Why Networks?

But also a source of conflict.

Cyber security

A Look Back at the Target Breach

Posted: 04/06/2015 10:30 am EDT | Updated: 06/06/2015 5:59 am EDT

Network neutrality

TECHNOLOGY

T-Mobile Video Plan Could Test F.C.C.'s New Net Neutrality Rules

By CECILIA KANG NOV. 11, 2015

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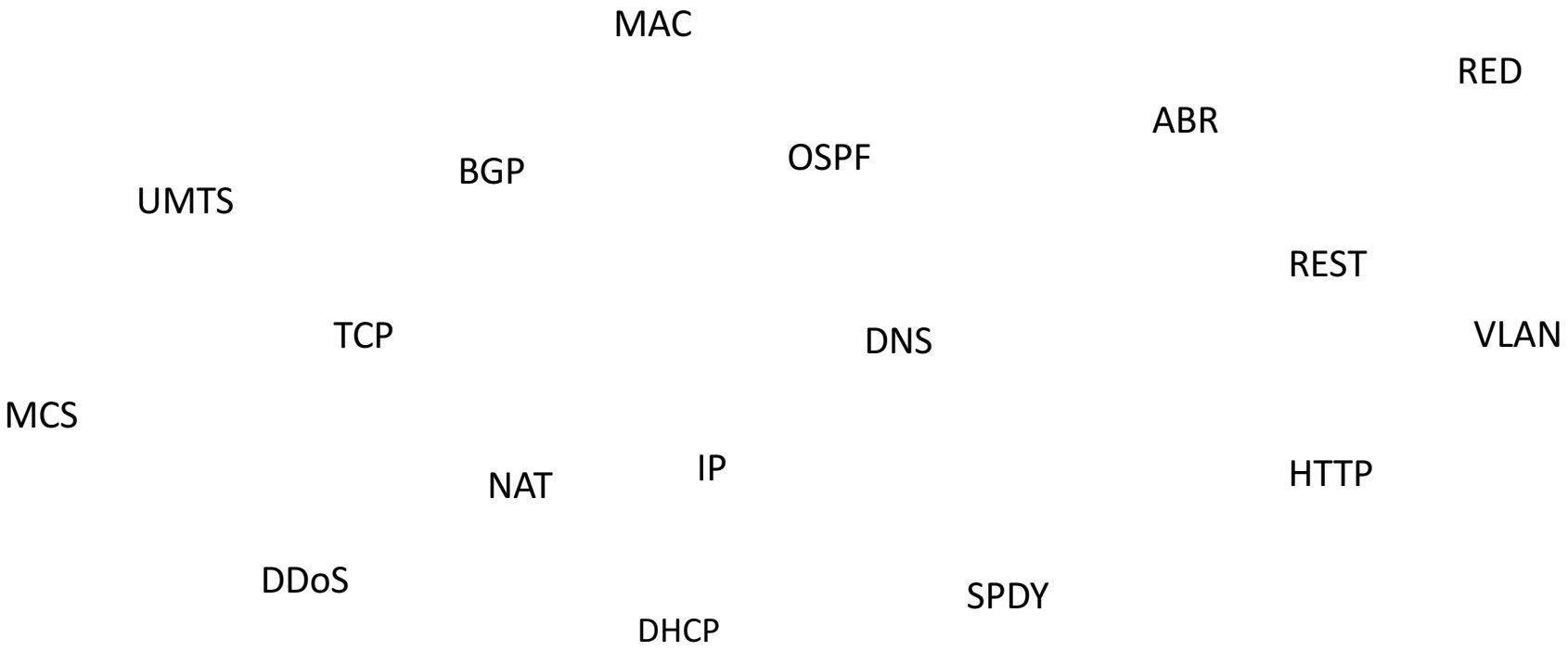
A new plan from T-Mobile USA to allow unlimited streaming of some video services may become the first test of the federal government's rules to prevent favoritism on the Internet.

On Tuesday, T-Mobile, the nation's third-largest wireless carrier, said customers could stream as many videos as they want — regardless of their data plan limits — from more than two dozen video providers, including Hulu and Netflix.

http://www.huffingtonpost.com/eric-dezenhall/a-look-back-at-the-target_b_7000816.html
http://www.nytimes.com/2015/11/12/technology/t-mobile-video-plan-could-test-fccs-new-net-neutrality-rules.html

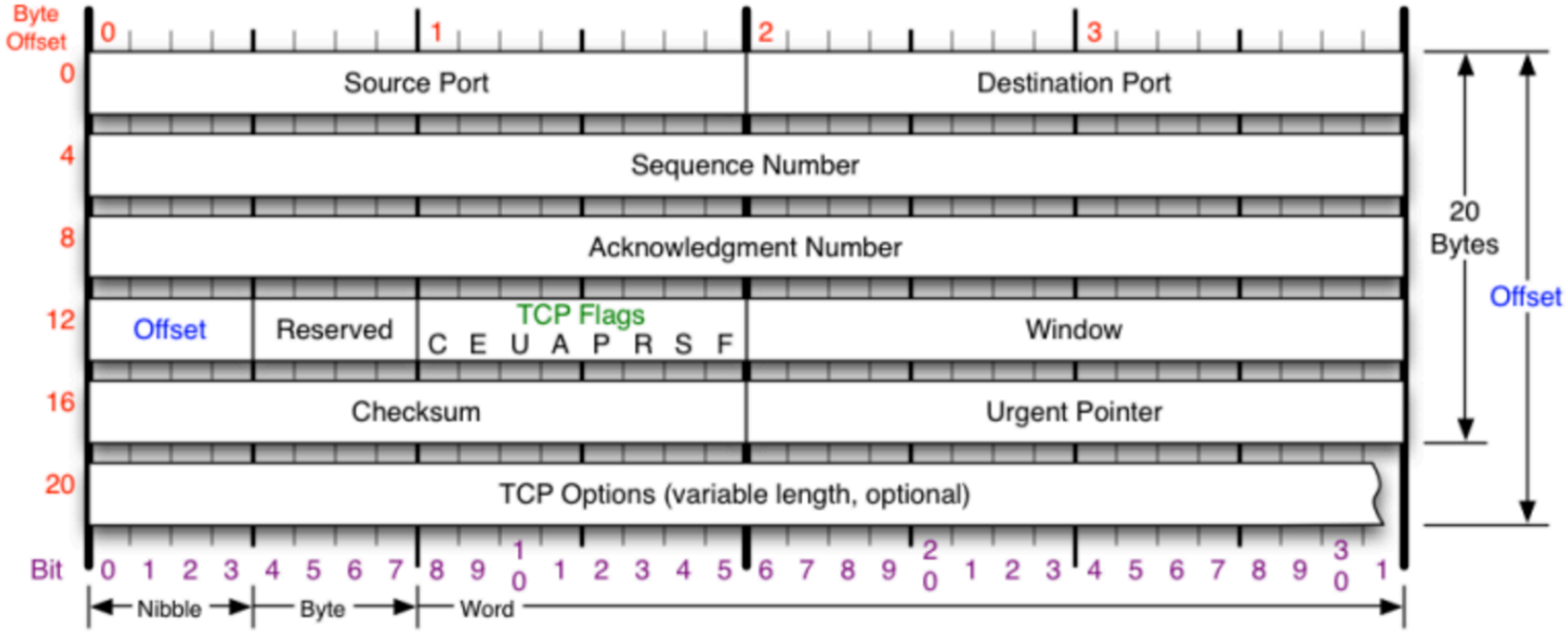
What is networking?

- Bunch of acronyms?



What is networking?

- Bunch of headers?



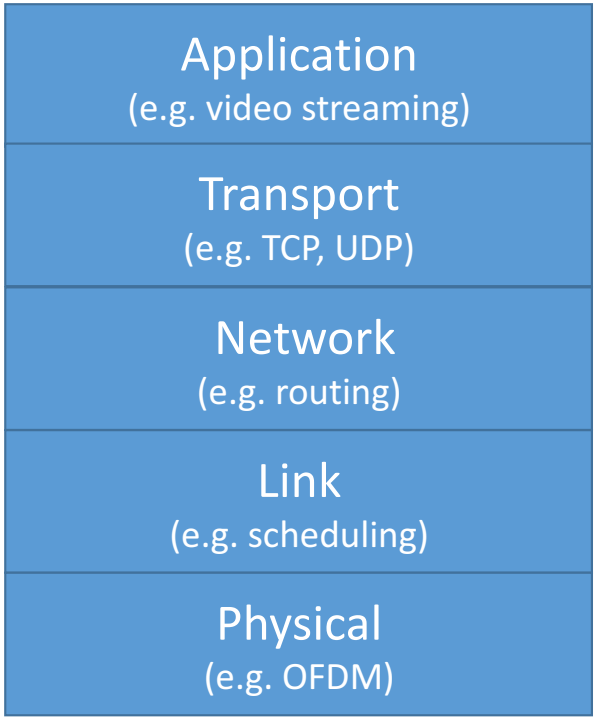
Source: https://nmap.org/book/tcpip-ref.html

Networking is…

The search for general principles to guide communication

Some Research 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 talk to other layers?
- Resource allocation
  - How to share limited resources between competing users?
- Wireless
  - How to provide a one-to-one communication in an inherently broadcast environment



What You Will Learn in this Course

- Knowledge
  - 1/3: Link layer through application layer
  - 2/3: current topics in networking (wireless, multimedia, data centers, etc.)

- Skills
  - How to read
  - How to present
  - How to discuss
  - How to use common networking tools

Course Structure

- Paper reading
  - 2-3 papers per week
- Classroom time
  - Lecture
  - Paper discussion
- Programming assignments
  - Multipath-TCP
  - Mininet + OpenFlow
- Project
  - Proposal, presentation, and final report
  - Can work individually in or in groups
  - Can be an extension of existing work or research (subject to approval)

Calendar

Week	Topic	Assignment
1	Introduction + MAC layer	
2	Network layer	
3	Transport layer	MPTCP assignment
4	Application layer	
5	Content distribution	Project proposal
6	Data centers	
7	Wireless	
8	Security	SDN assignment
9	Future Internet (SDN, IoT)	
10	Project presentations	
Finals week		Final report due

Grading

- Paper summaries (20%)
  - Write a one-paragraph review for each paper
- Class participation (20%)
  - Speak up during discussion!
- Assignments (20%)
  - 2 programming assignments
- Project (40%)

Review

1.1 what *is* the Internet?

1.2 network edge

- end systems, access networks, links

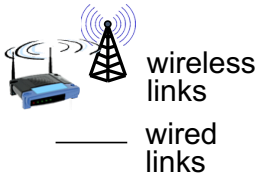
1.3 network core

- packet switching, circuit switching, network structure

1.4 protocol layers, service models

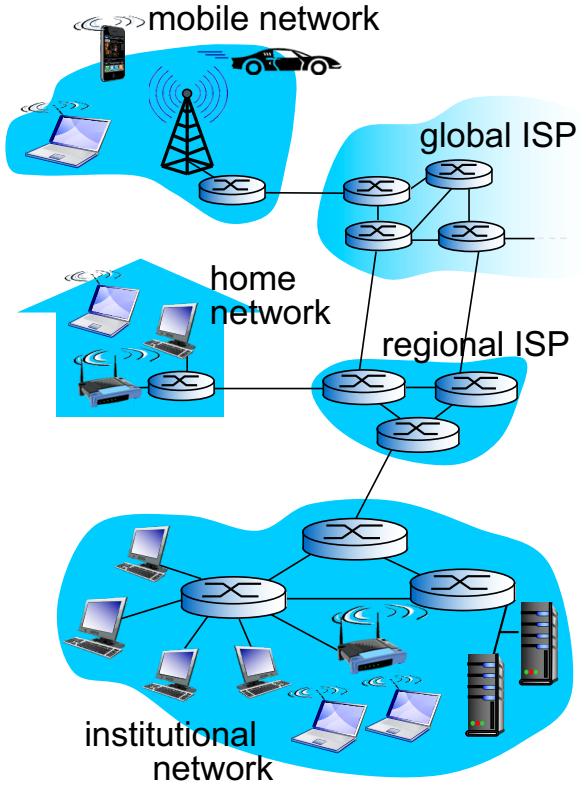
What's the Internet: "nuts and bolts" view

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



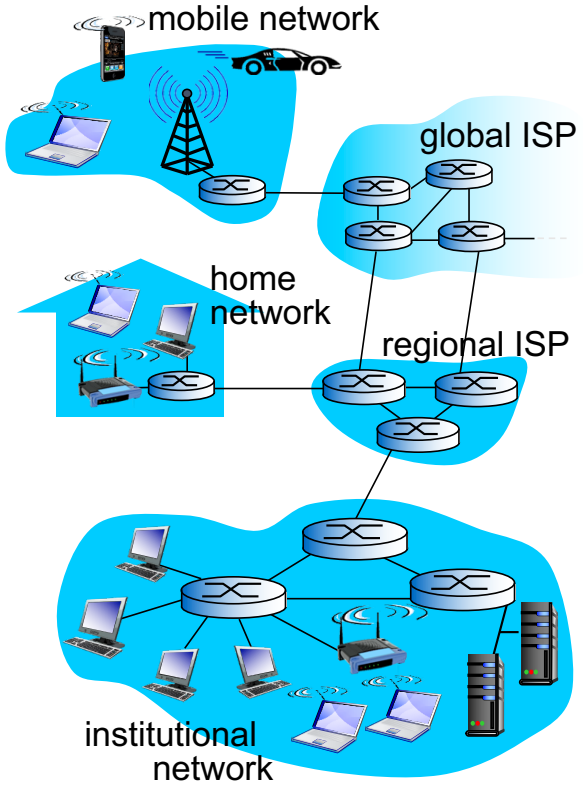
- *communication links*
  - fiber, copper, radio, satellite
  - transmission rate: *bandwidth*

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



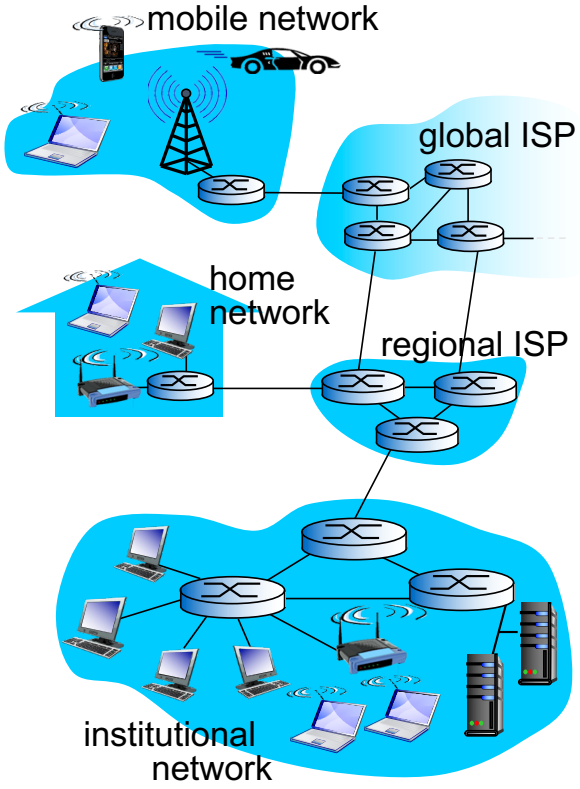
What's the Internet: "nuts and bolts" view

- *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

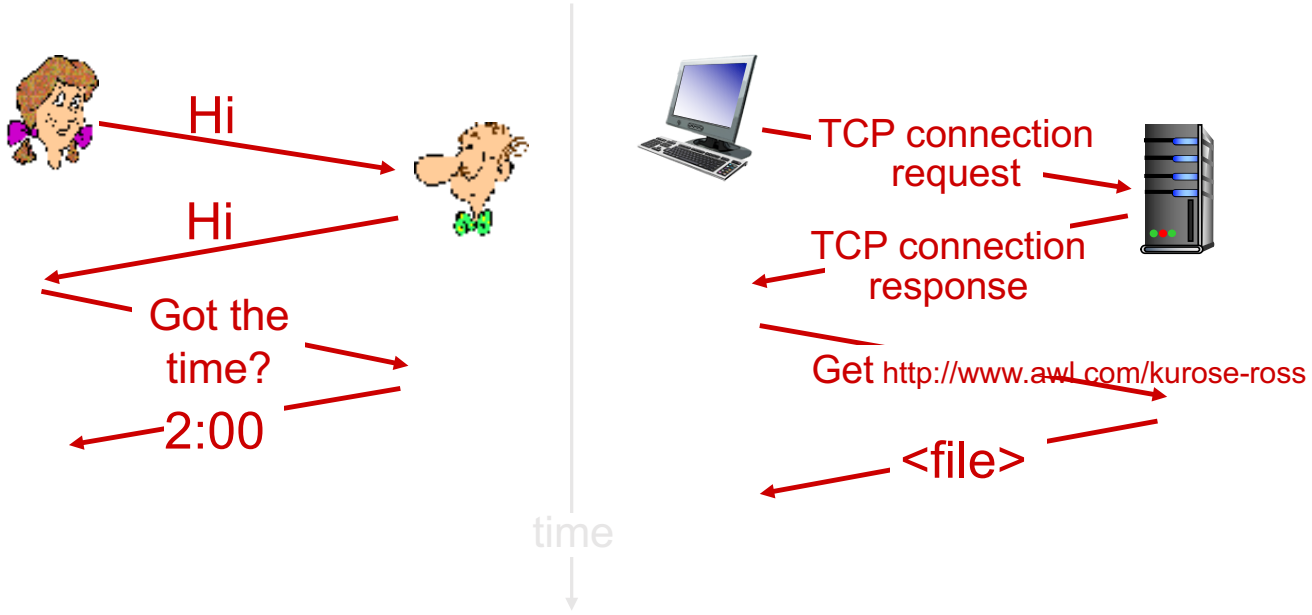
network protocols:

- 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?

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1.3 network core

- packet switching, circuit switching, network structure

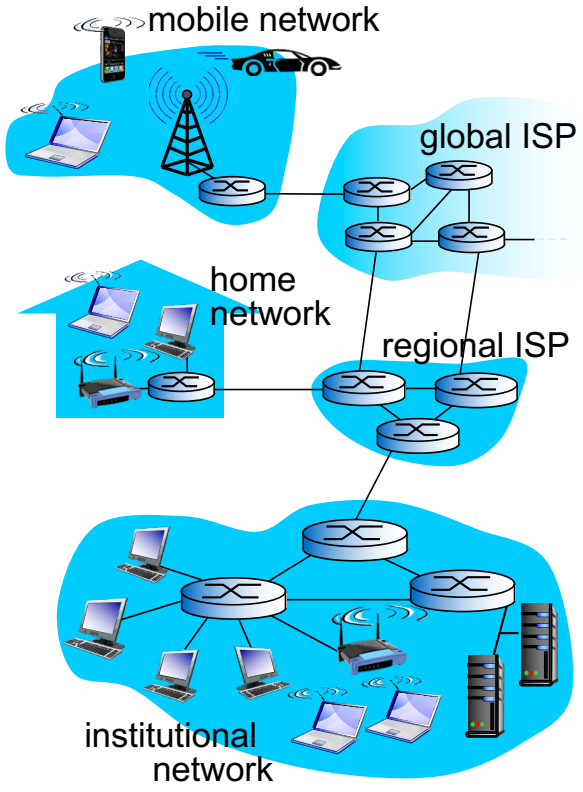
1.4 protocol layers, service models

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



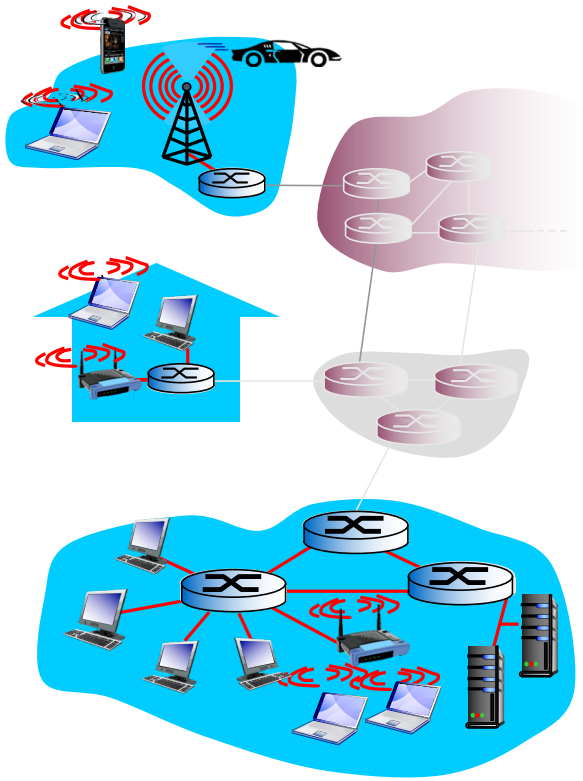
Access networks and physical media

Q: How to connect end systems to edge router?

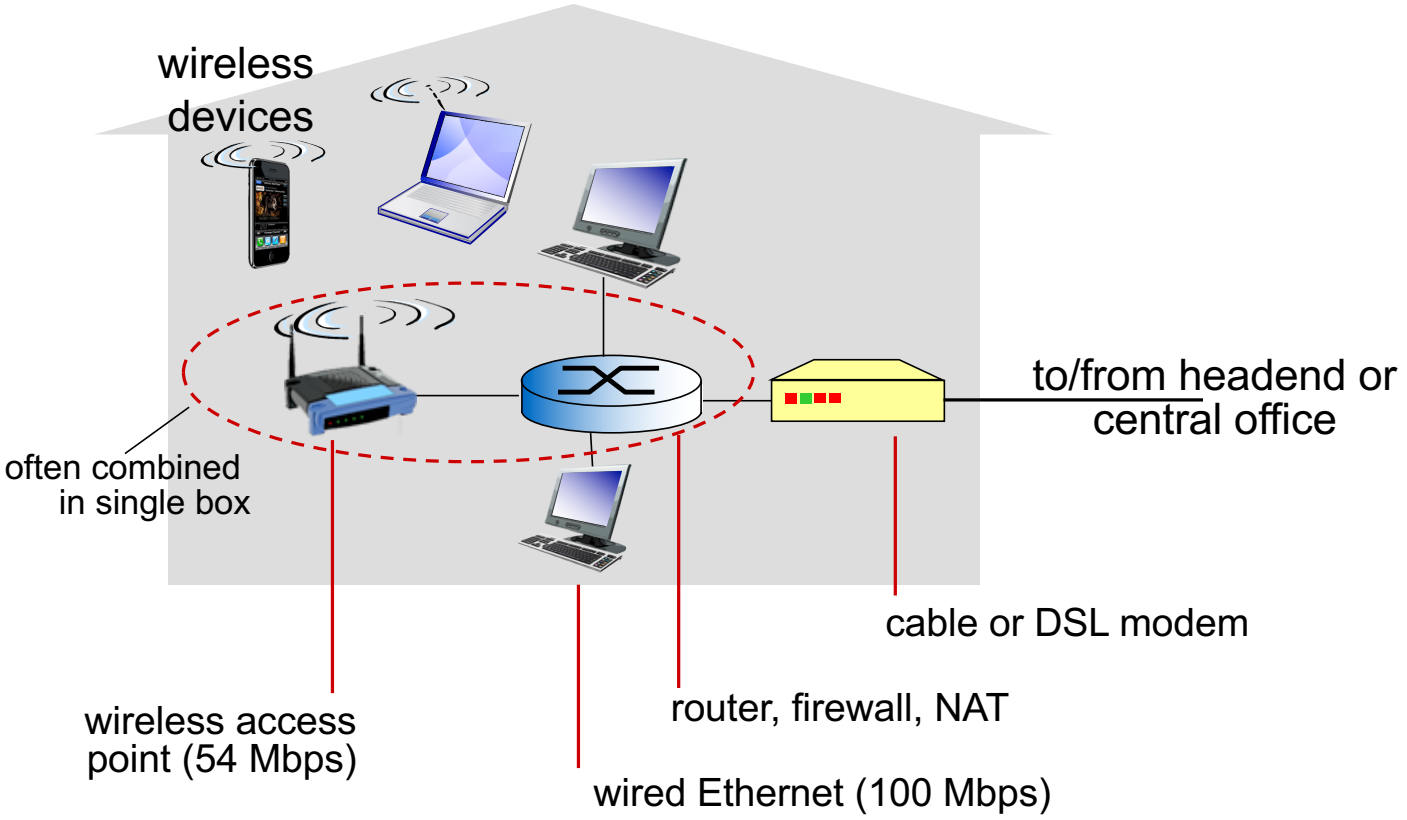
- residential access nets
- institutional access networks (school, company)
- mobile access networks

keep in mind:

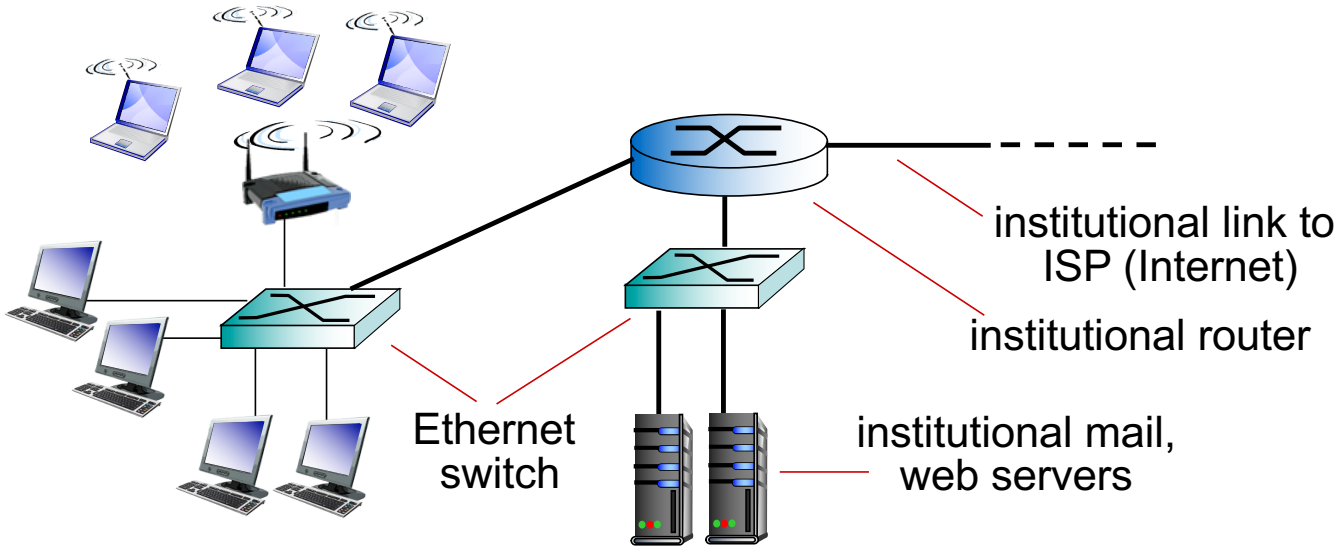
- bandwidth (bits per second) of access network?
- shared or dedicated?



Access net: home network



Enterprise access networks (Ethernet)



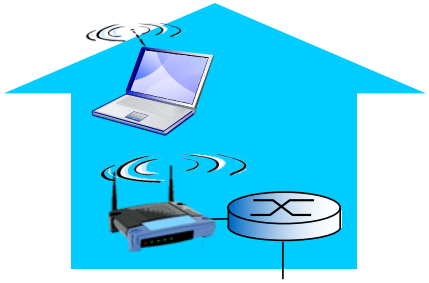
- typically used in companies, universities, etc
  - 10 Mbps, 100Mbps, 1Gbps, 10Gbps transmission rates
  - today, end systems typically connect into Ethernet switch

Wireless access networks

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

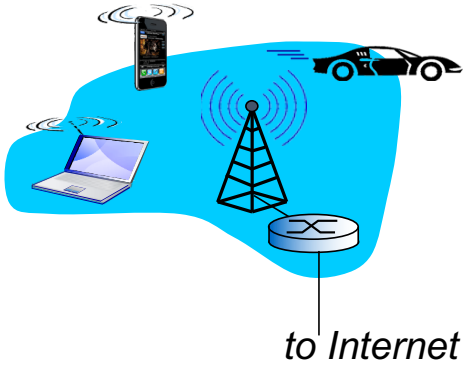
wireless LANs:

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



wide-area wireless access

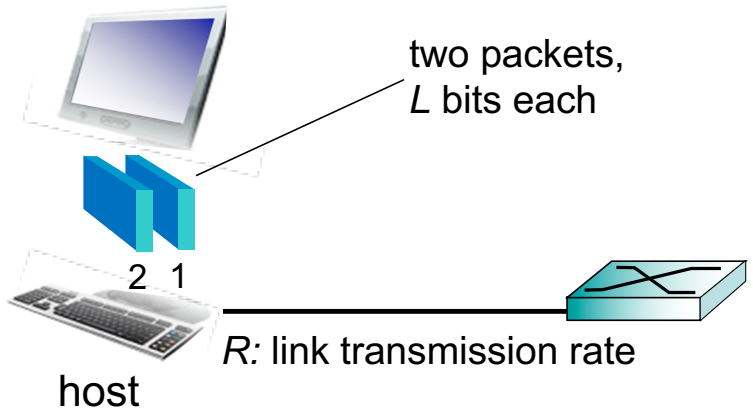
- provided by telco (cellular) operator, 10's km
- between 1 and 10 Mbps
- 3G, 4G: LTE



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*



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

Review

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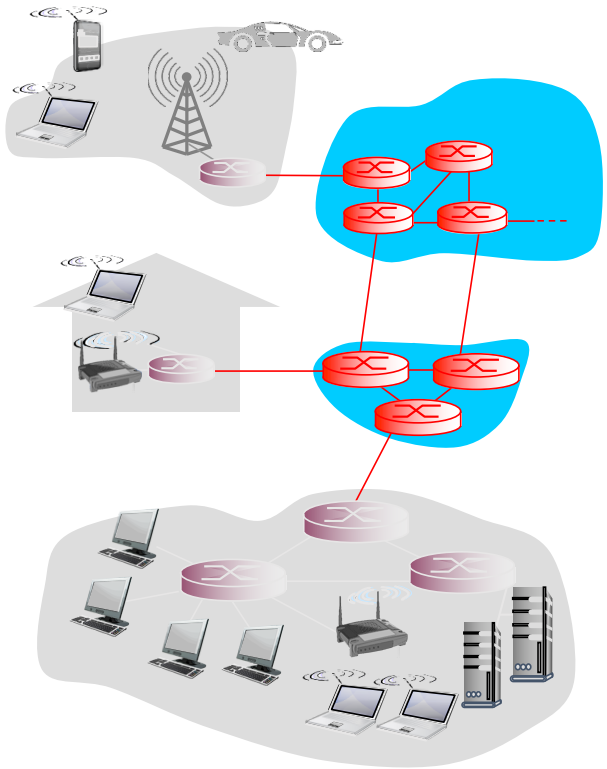
- packet switching, circuit switching, network structure

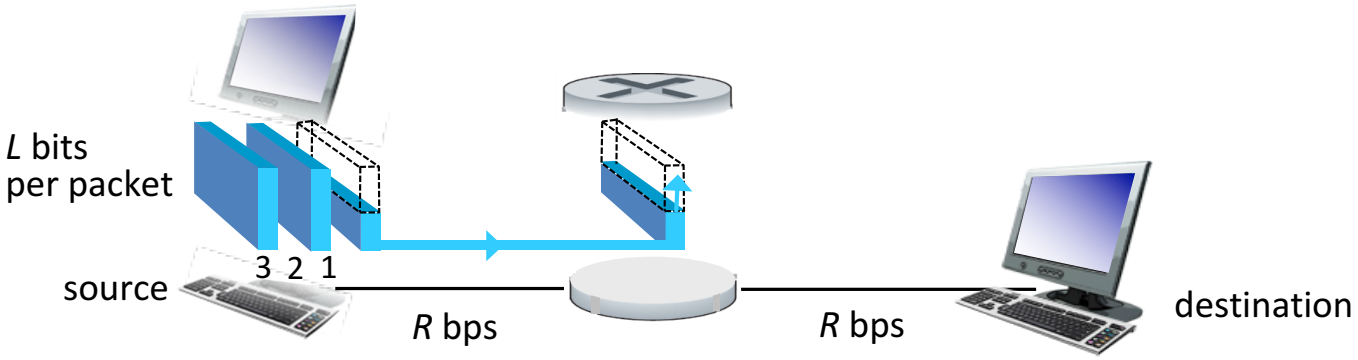
1.4 protocol layers, service models

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

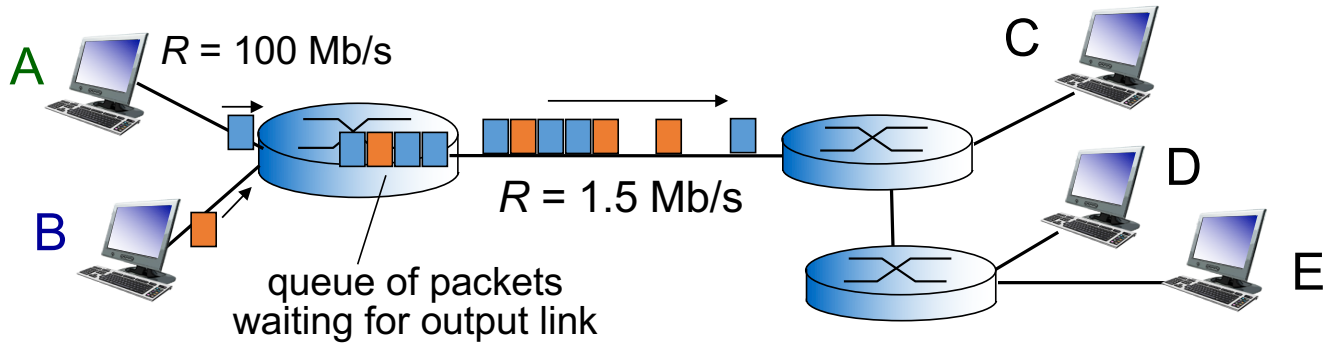


- takes L/R seconds to transmit (push out) L-bit packet into link at R bps
- *store and forward:* entire packet must arrive at router before it can be transmitted on next link
- ❖ end-end delay = $2L/R$ (assuming zero propagation delay)

one-hop numerical example:

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

Packet Switching: queueing delay, loss



queuing and loss:

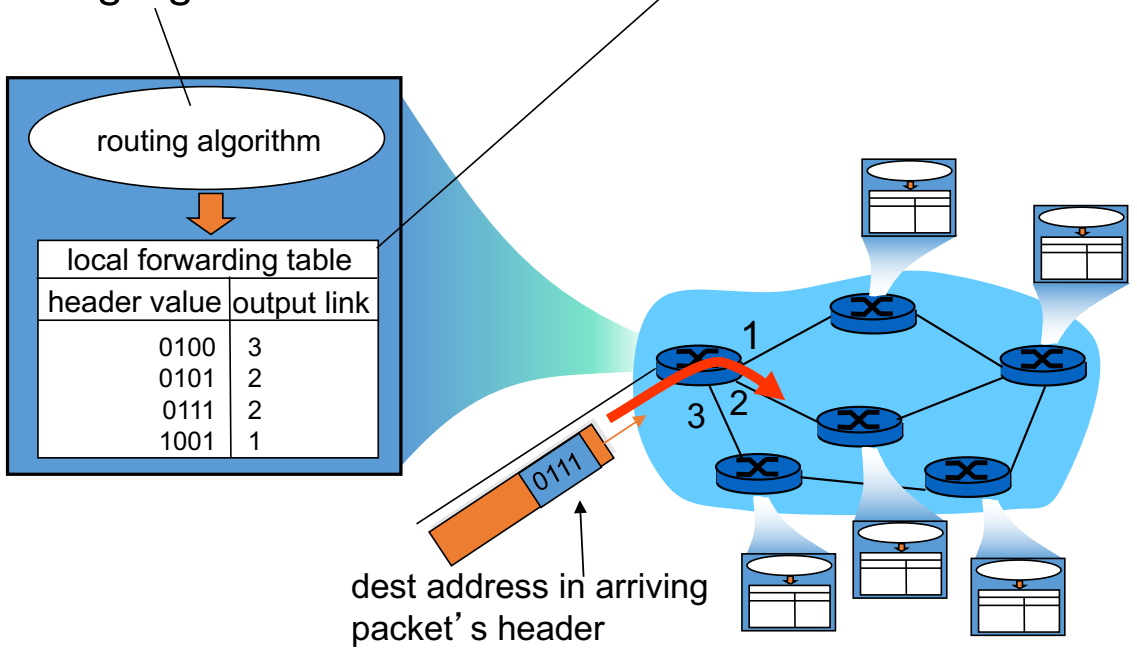
- If arrival rate (in bits) to link exceeds transmission rate of link for a period of time:
  - packets will queue, wait to be transmitted on link
  - packets can be dropped (lost) if memory (buffer) fills up

Two key network-core functions

routing: determines source-destination route taken by packets

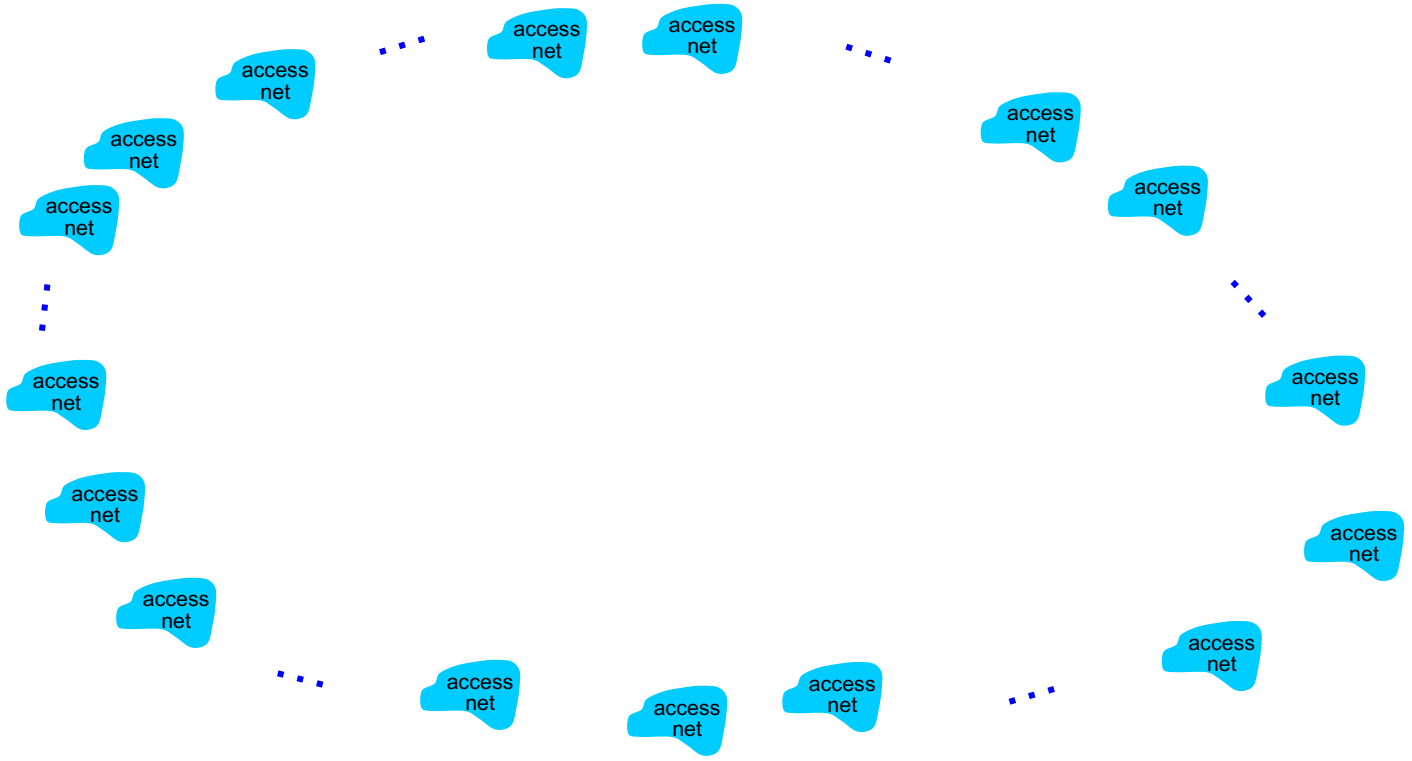
- *routing algorithms*

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



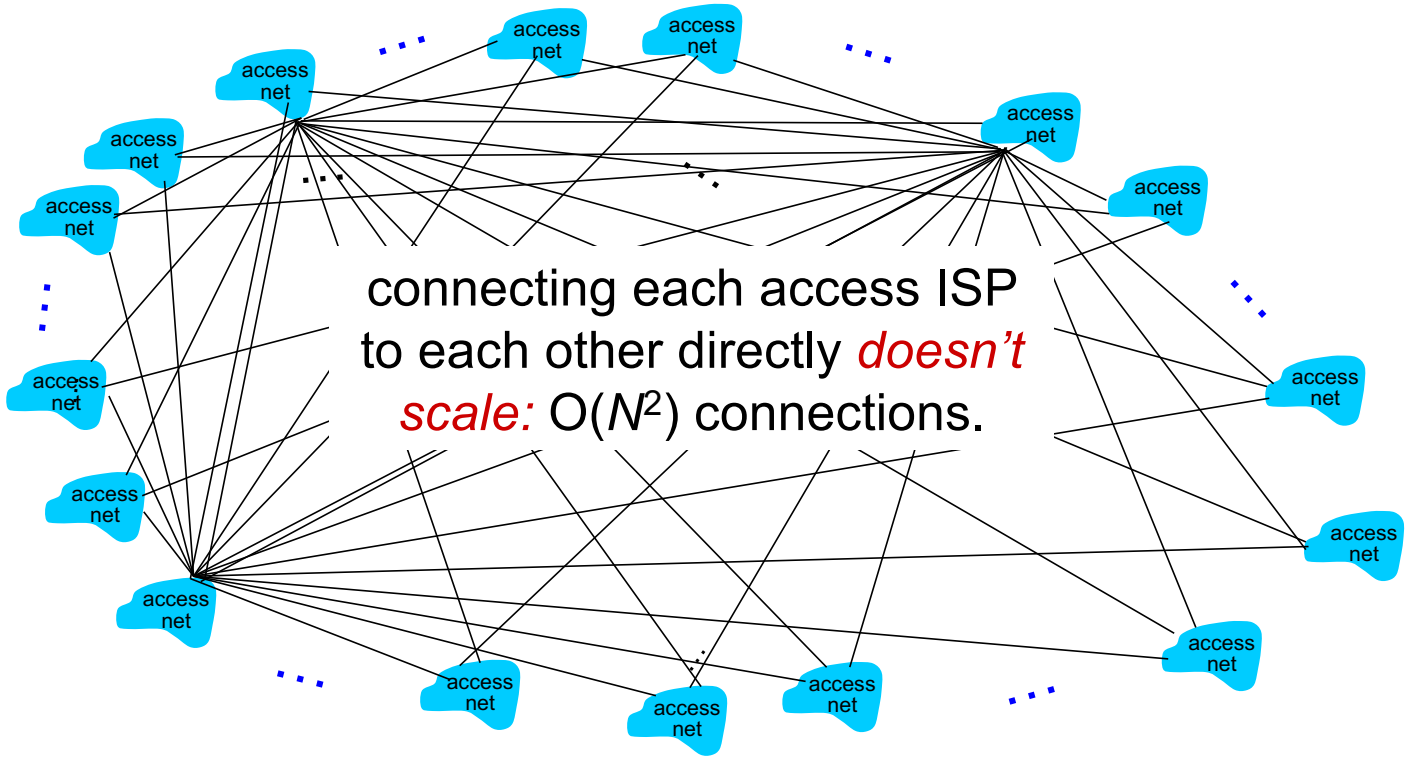
Internet structure: network of networks

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



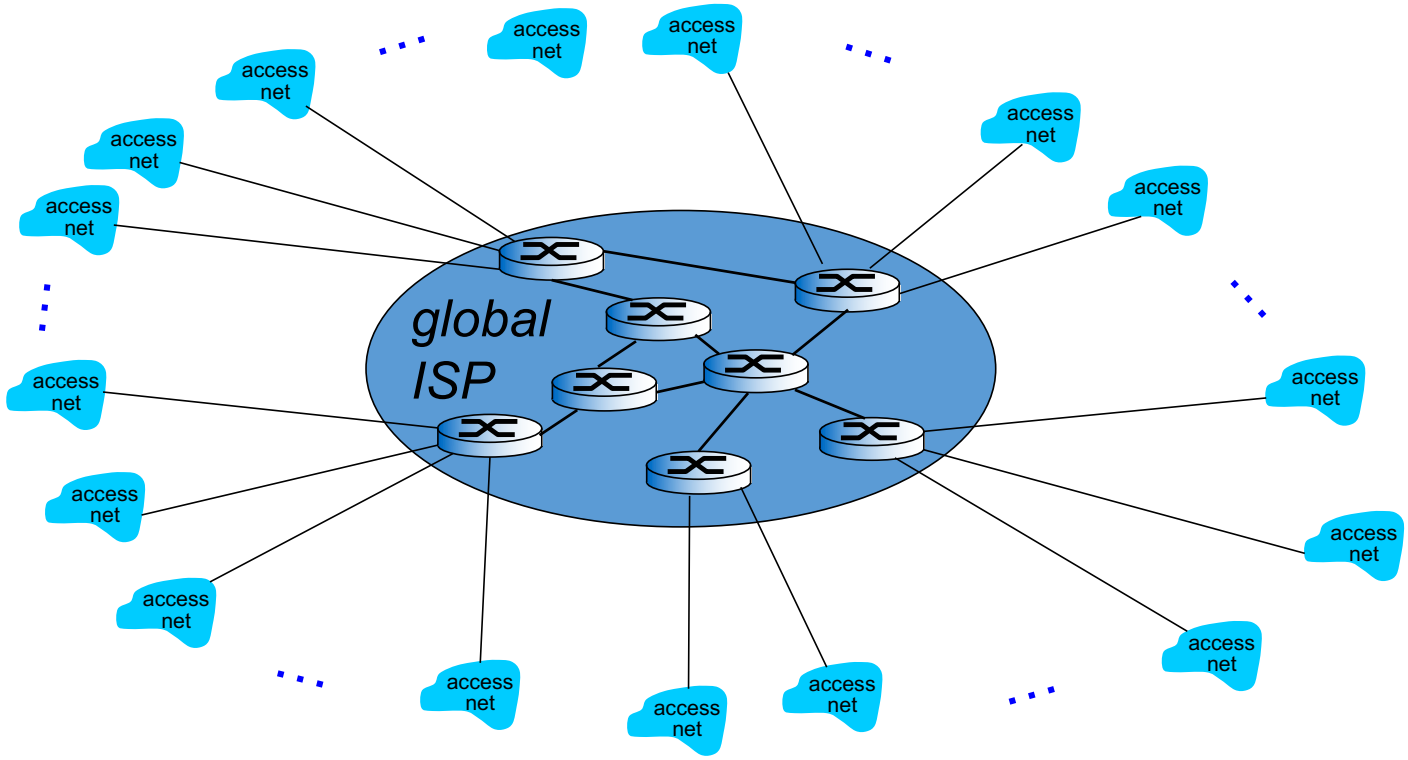
Internet structure: network of networks

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



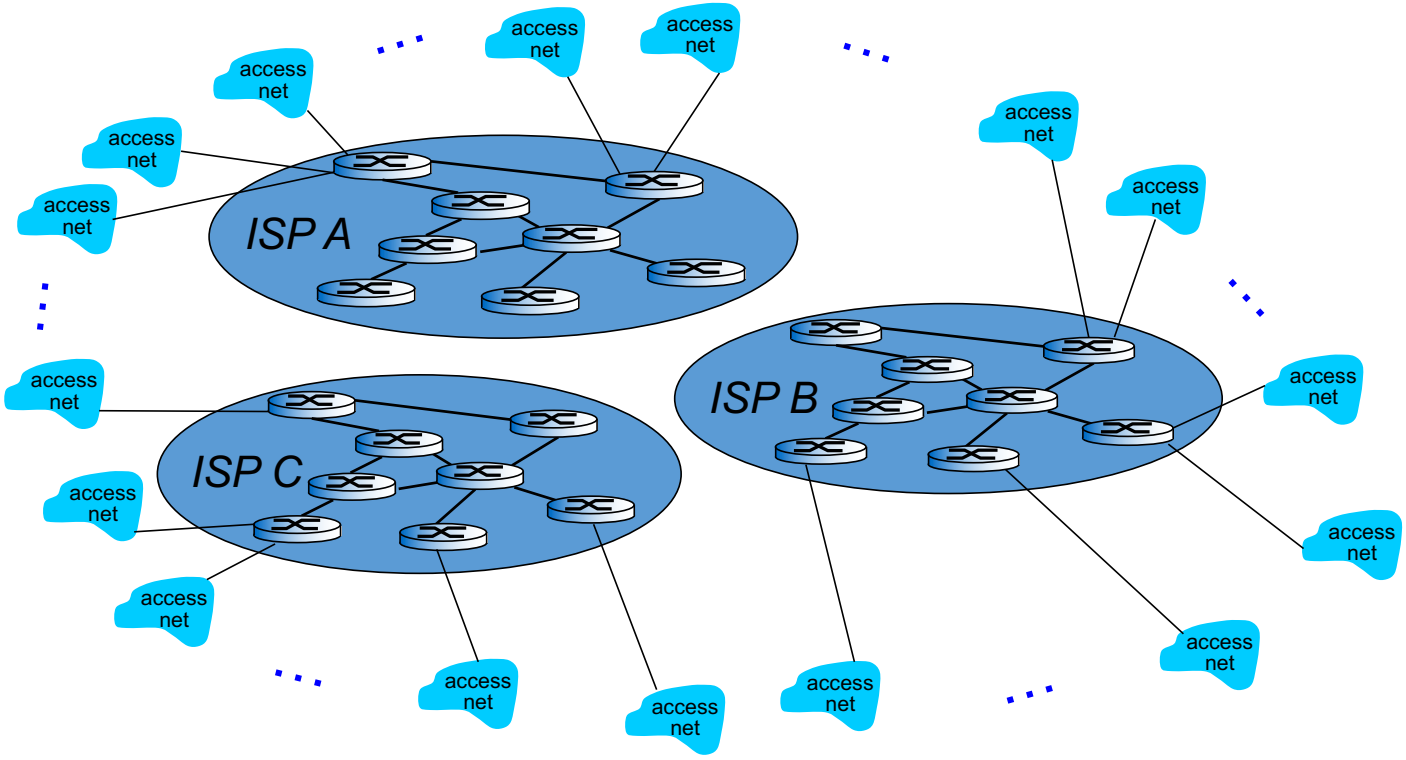
Internet structure: network of networks

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



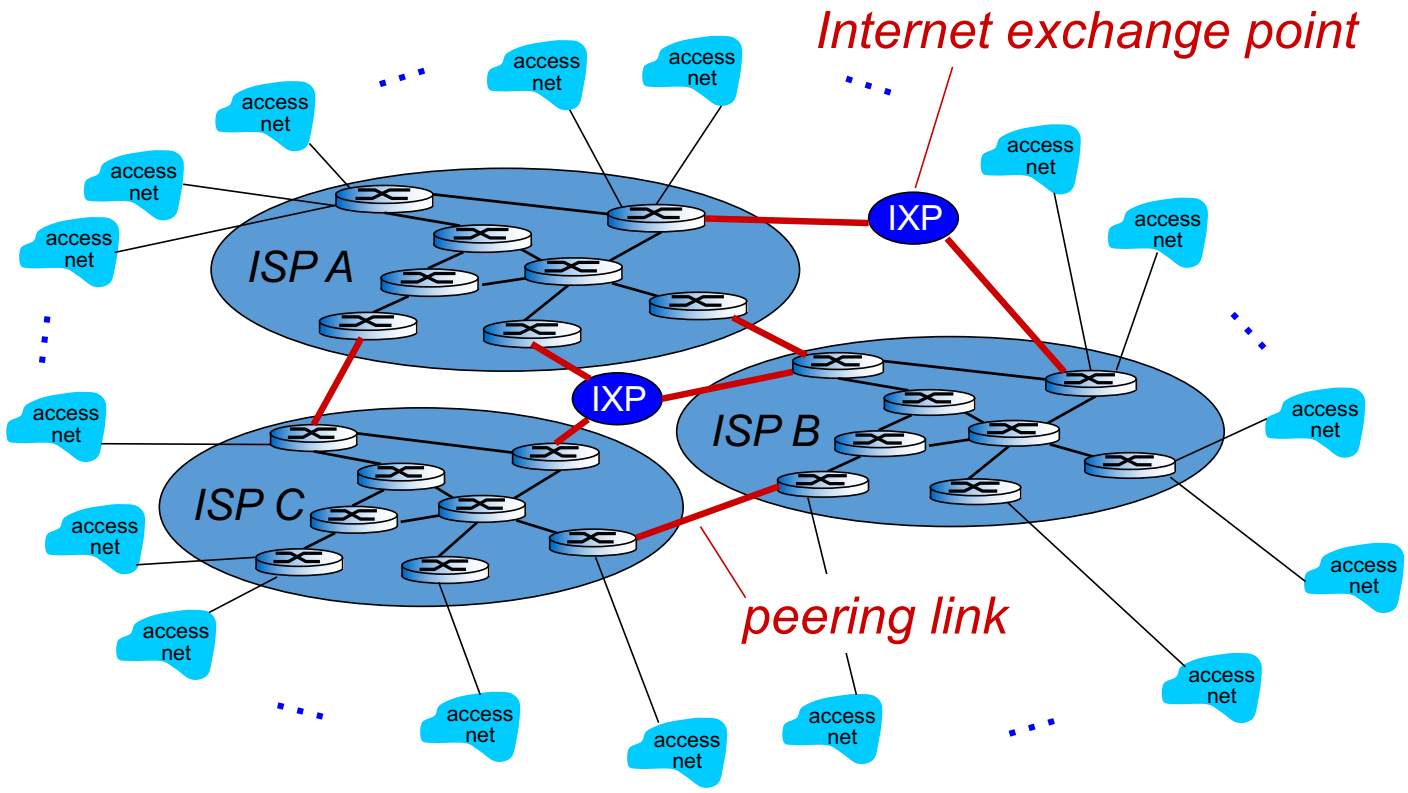
Internet structure: network of networks

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



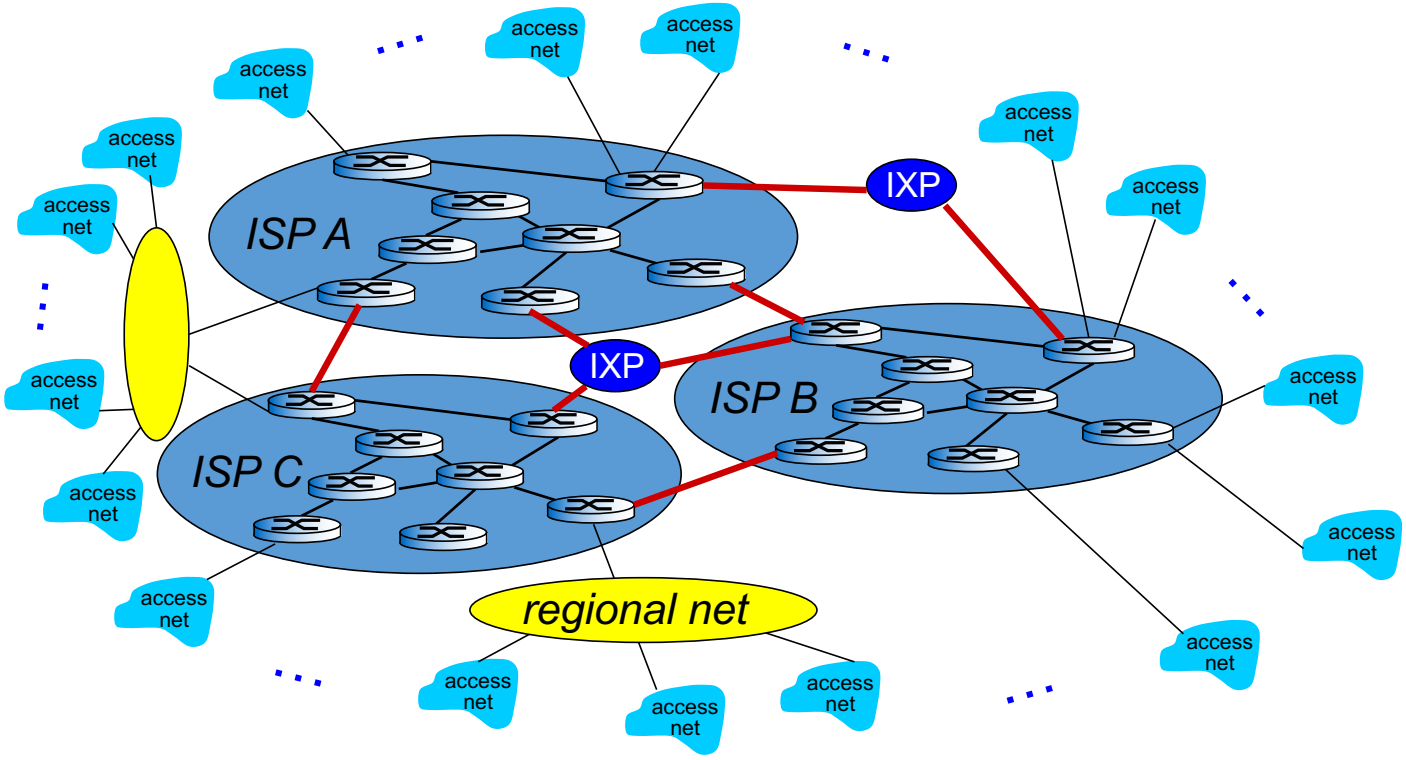
Internet structure: network of networks

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

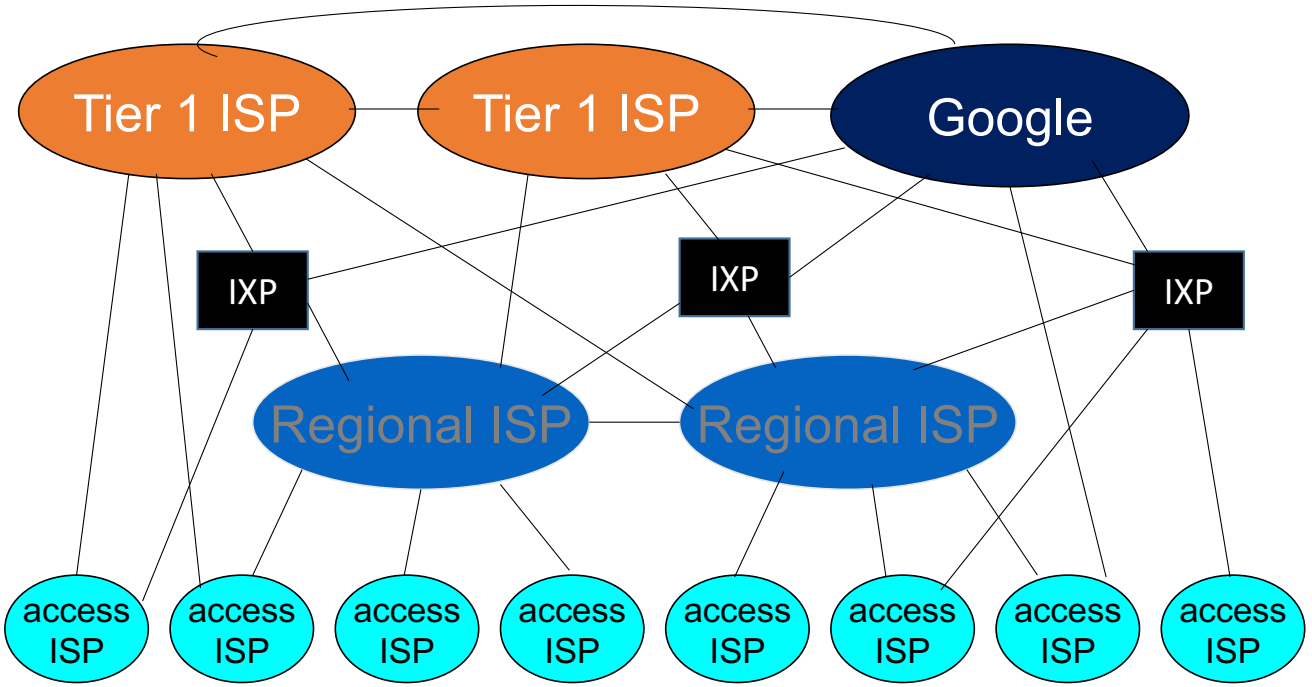


Internet structure: network of networks

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

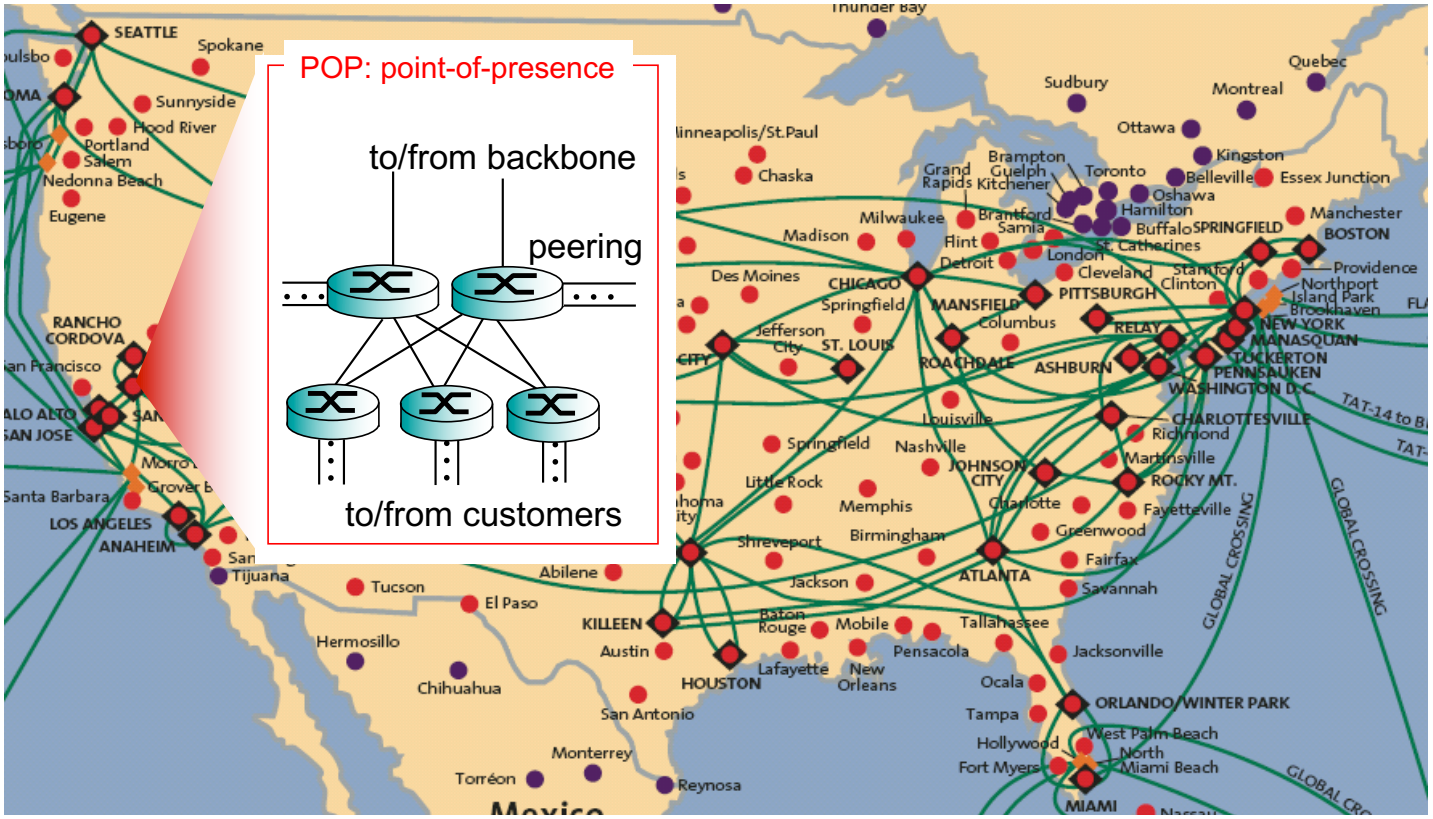


Internet structure: network of networks



- 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

Tier-1 ISP: e.g., Sprint



Roadmap

1.1 what *is* the Internet?

1.2 network edge

- end systems, access networks, links

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1.4 protocol layers, service models

Protocol "layers"

Networks are complex, with many "pieces":

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

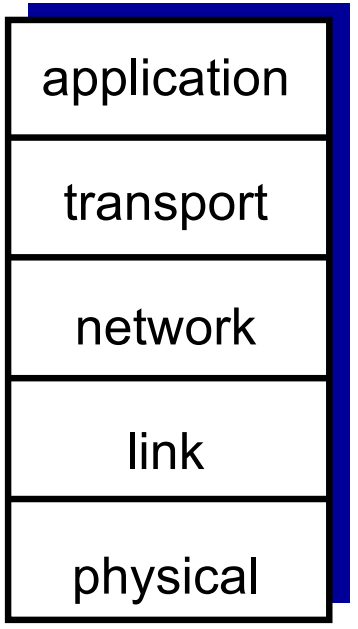
Question:

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"



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?

Layering of post office functionality

Sender writes letter
Sender drops off letter at post office
Post office X sends mail to city Y

Sender city X

airplane routing

intermediate air-traffic control centers

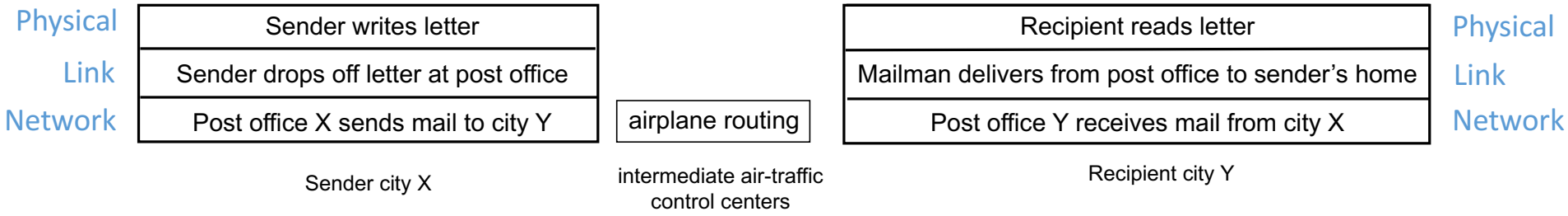
Recipient reads letter
Mailman delivers from post office to sender's home
Post office Y receives mail from city X

Recipient city Y

layers: each layer implements a service

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

Layering of post office functionality

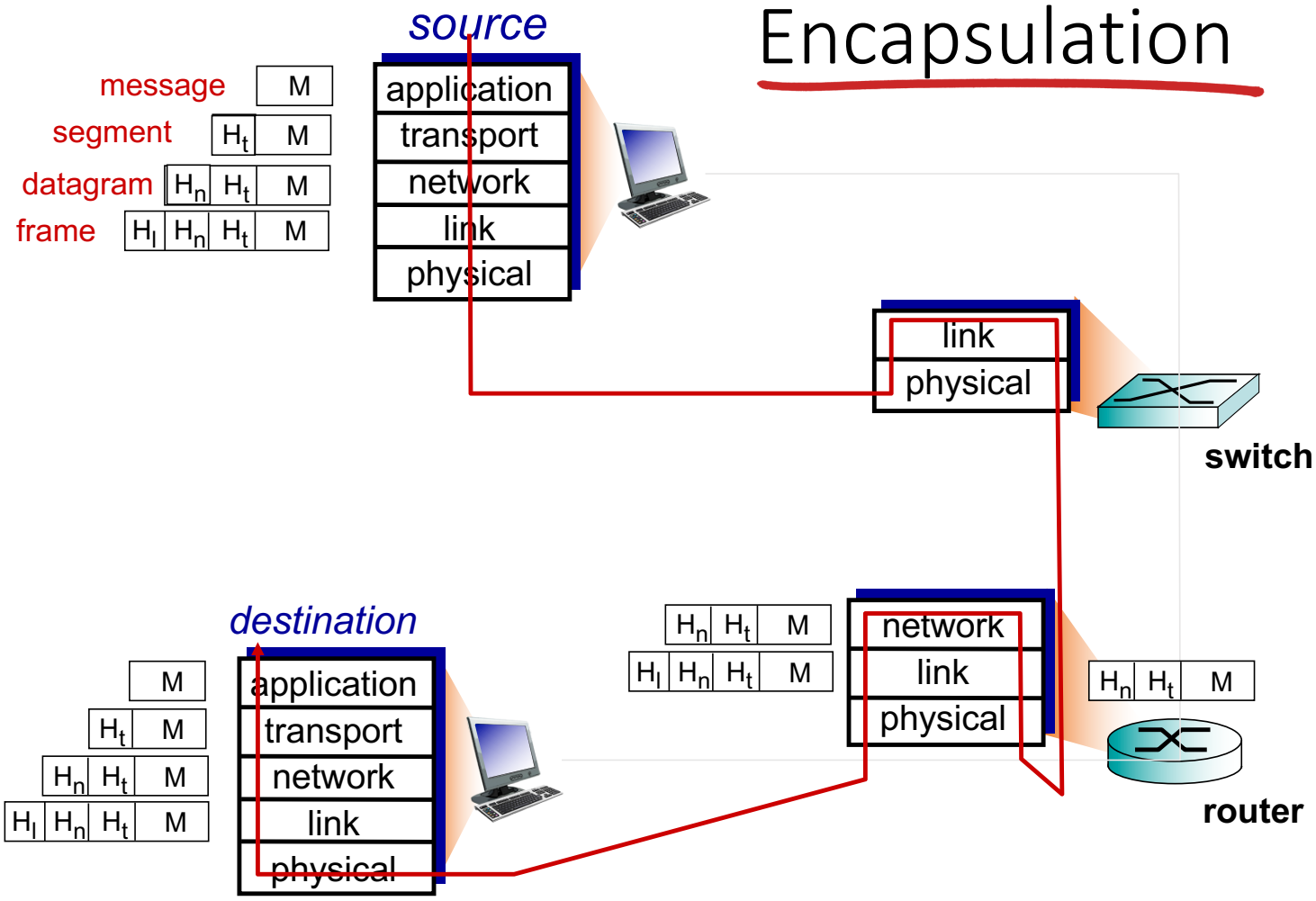


layers: each layer implements a service

- 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



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For Next Time

- Reading
  - The Design Philosophy of the DARPA Internet Protocols
  - How to Read a Paper