Lecture 1 – Introduction to Networks

COMP1002 (Cybersecurity and Networks)

Staff Contacts

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Part 1

Brief Introduction of the Module (Networks Part)

What will be covered?

- Introduction to Computer Networks
- Application Layer (HTTP/DNS)
- Transport Layer (TCP/UDP)
- Network Layer (IP)
- Link Layer (Ethernet)
- IP Addressing/Subnetting
- Routing (static/dynamic routing)
- Enterprise switching and VLANs
- Access Control Lists (ACLs)

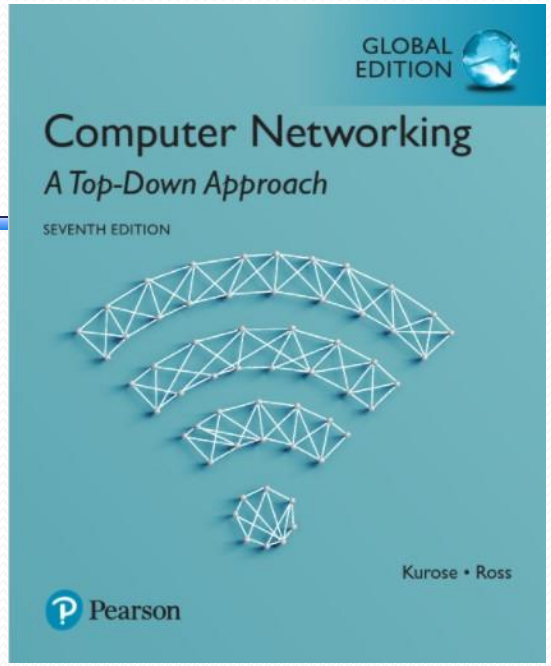
(Network activity practice - Cisco Packet Tracer)

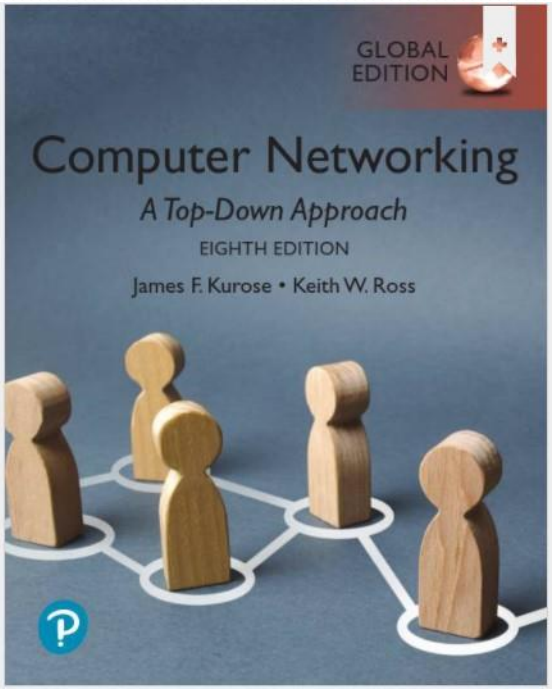
The Assessment

- 100% coursework
  - Cyber Security (50%)
  - Networks (50%)
- Set exercises (30%)
- Report (70%)

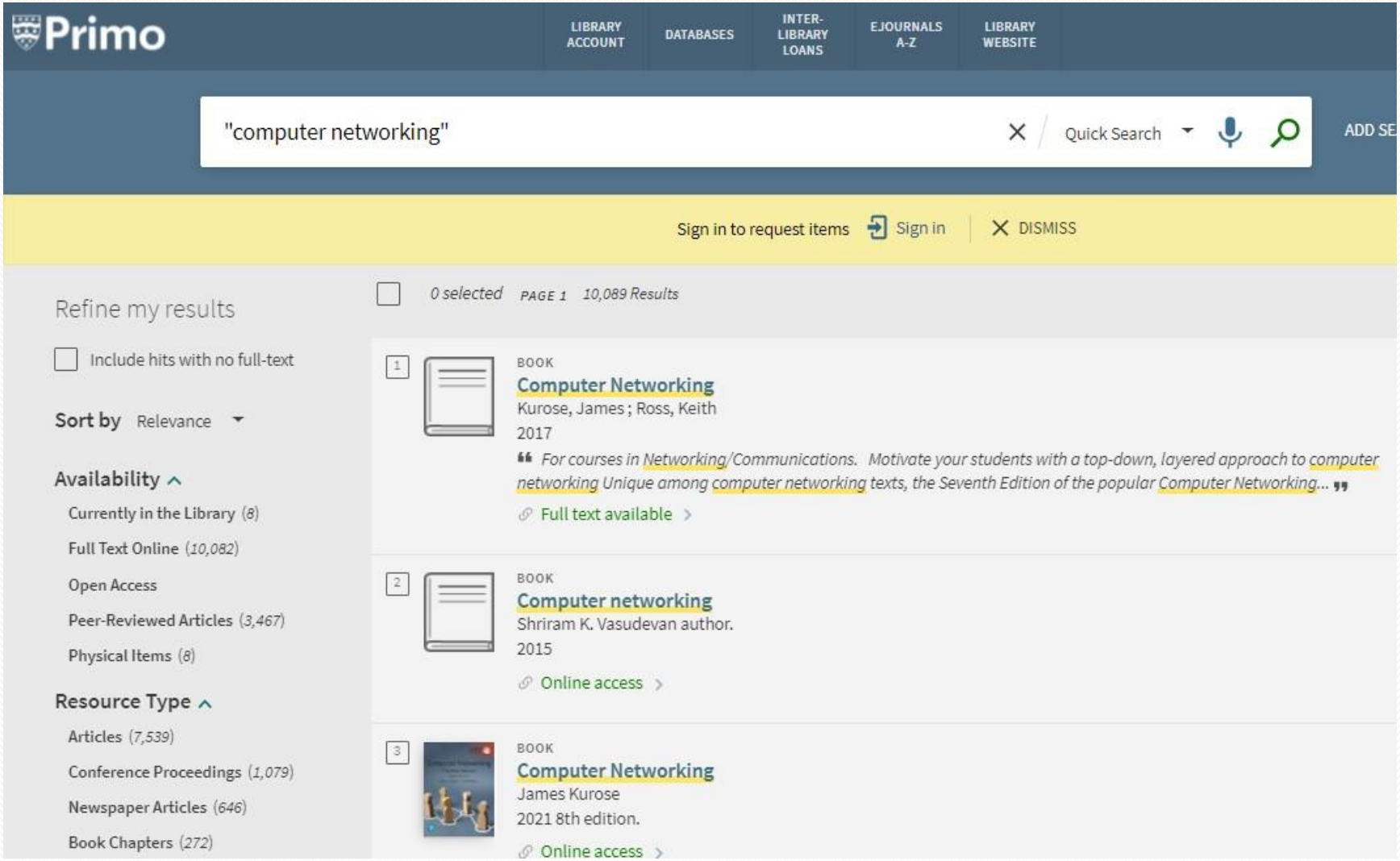
Text Book

- James Kurose and Keith Ross, "Computer Networking: A Top-Down Approach" by Pearson.
- E-version available via library primo (limited concurrent users for 7th and 8th Editions)
- http://primo.plymouth.ac.uk
- Some lecture slides: adapted from the book slides.



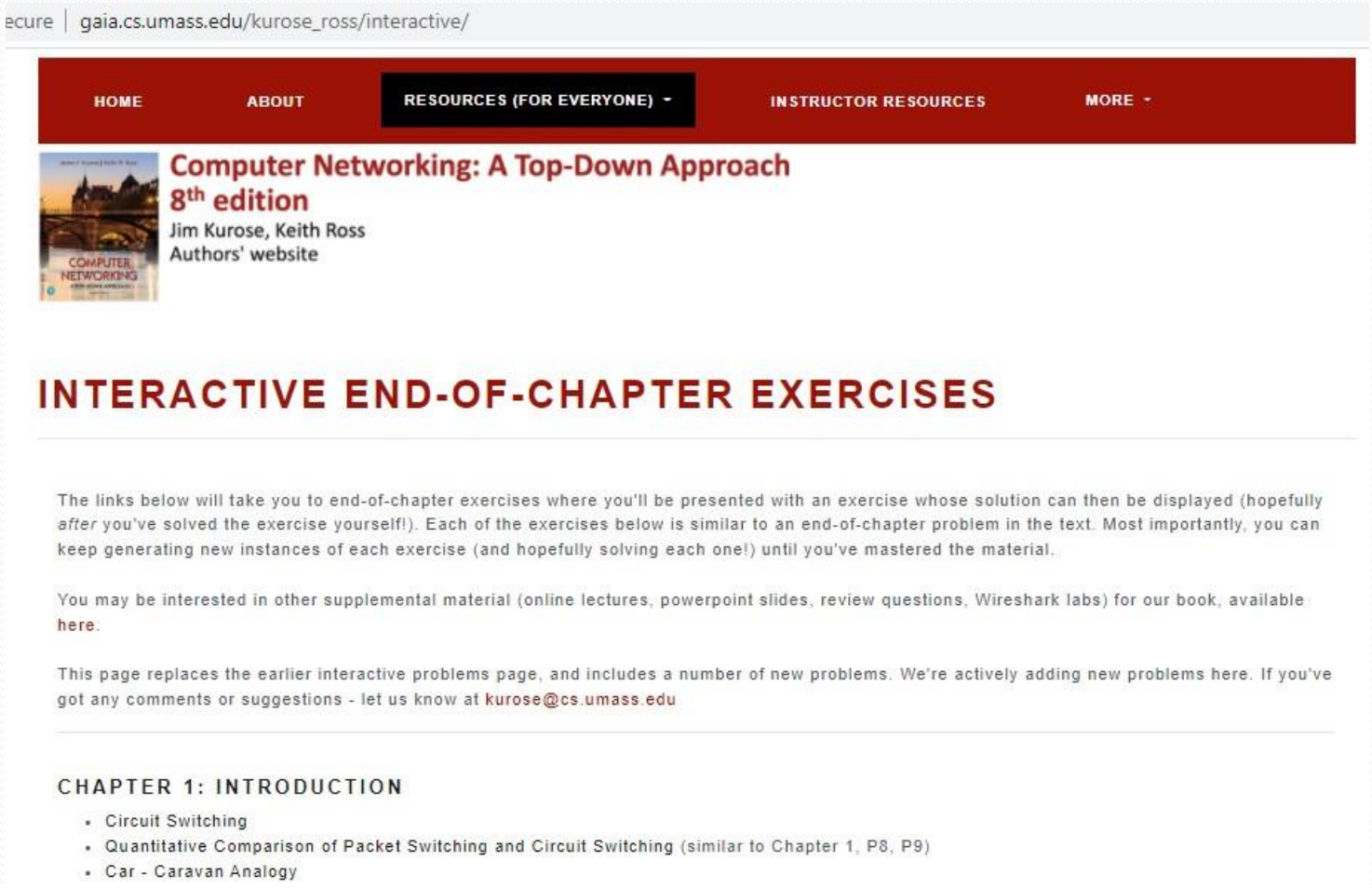


From Primo


Primo
LIBRARY ACCOUNT
DATABASES
INTER-LIBRARY LOANS
EJOURNALS A-Z
LIBRARY WEBSITE
"computer networking"
Quick Search
ADD SE
Sign in to request items
Sign in
DISMISS
Refine my results
Include hits with no full-text
Sort by Relevance
Availability
Currently in the Library (8)
Full Text Online (10,082)
Open Access
Peer-Reviewed Articles (3,467)
Physical Items (8)
Resource Type
Articles (7,539)
Conference Proceedings (1,079)
Newspaper Articles (646)
Book Chapters (272)
0 selected
PAGE 1
10,089 Results
1
BOOK
Computer Networking
Kurose, James ; Ross, Keith
2017
For courses in Networking/Communications. Motivate your students with a top-down, layered approach to computer networking Unique among computer networking texts, the Seventh Edition of the popular Computer Networking...
Full text available
2
BOOK
Computer networking
Shriram K. Vasudevan author.
2015
Online access
3
BOOK
Computer Networking
James Kurose
2021 8th edition.
Online access

Textbook Authors' website

- Interactive exercises for questions and solutions
  - http://gaia.cs.umass.edu/kurose_ross/interactive



Online resources from Cisco

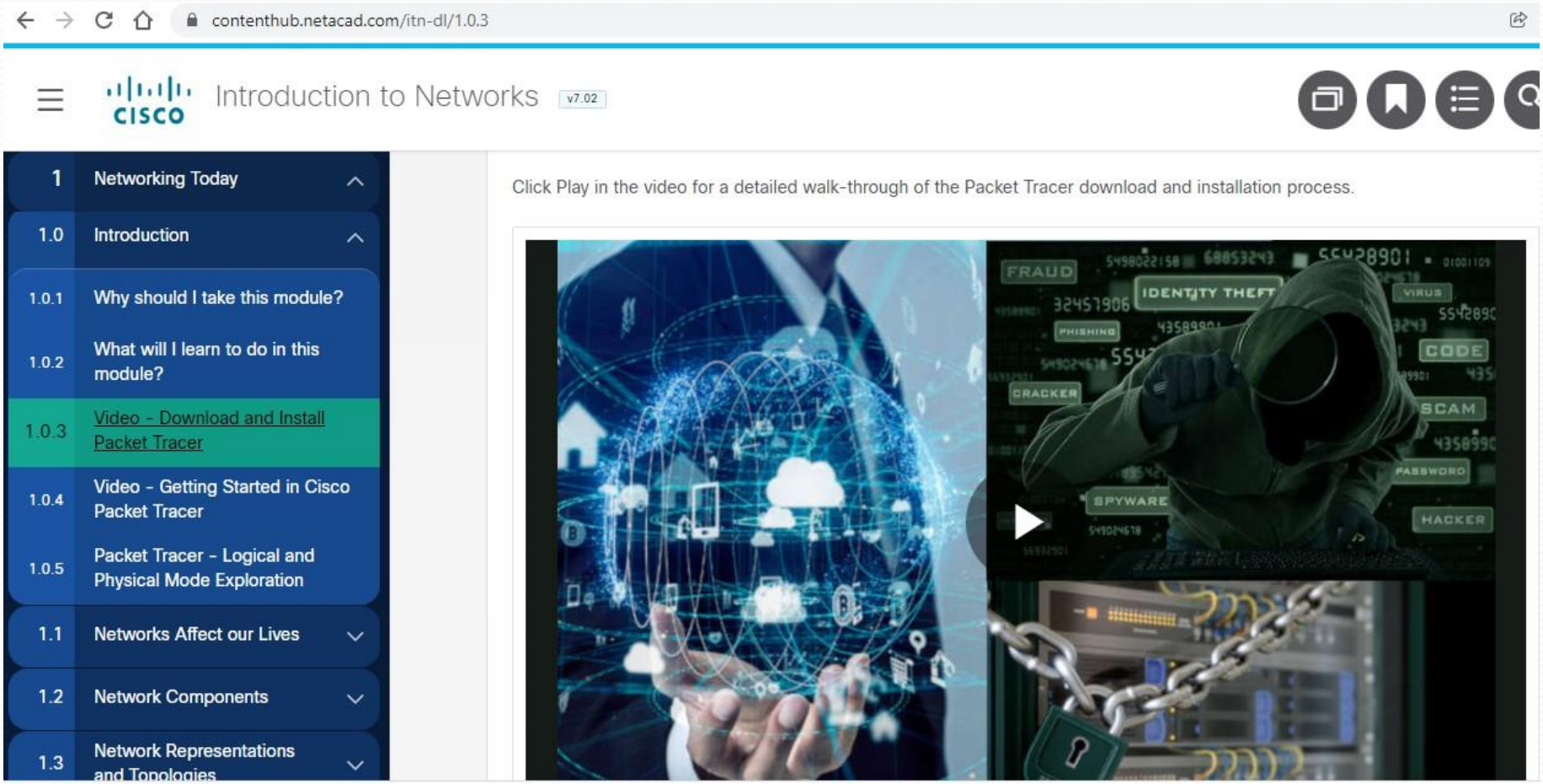
- Course using Cisco online resources from Cisco Networking Academy
- All materials available on www.netacad.com
- Practical based on Network Simulator – PacketTracer
  - https://www.netacad.com/portal/resources/packet-tracer
- Each student is provided with an account to access the website (you should have received an email from Cisco NetAcad on how to login/access to NetAcad)

Cisco Networking Academy (NetAcad)

- Cisco Networking Academy (www.netacad.com)
- Two Courses Created:
- COMP1002A – CCNA1 – 2022/23 (CCNAv7: Introduction to Networks)
- COMP1002B – CCNA2 – 2022/23 (CCNAv7: Switching, Routing, and Wireless Essentials)

Packet Tracer

Download and install Packet Tracer for networking activities practice.



Part 2

Introduction to Networks

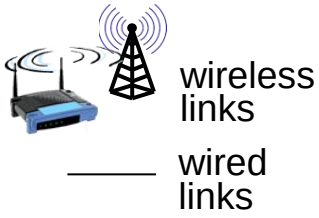
Outline

- What is the Internet?
- Network edge
  - End systems, access networks, links
- Network core
  - Packet switching, Internet Structure
- Performance - Delay, Loss, Throughput in Networks

Note: the contents are in Chapter 1 of the textbook.

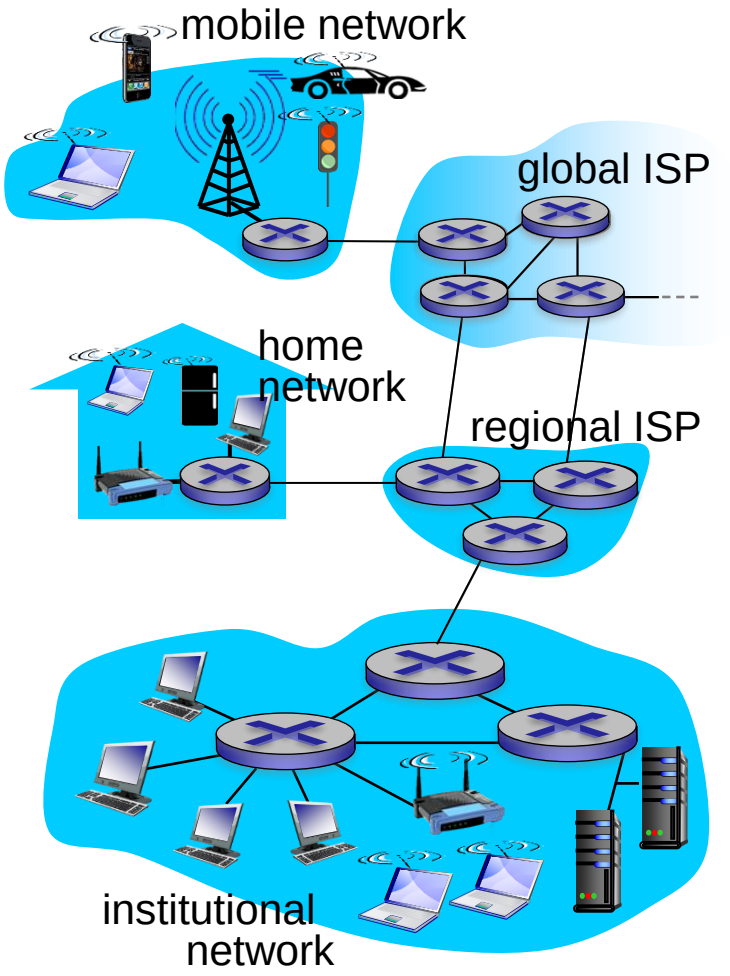
What's the Internet: "nuts and bolts" view

- 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*



"Fun" Internet-connected devices

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

Web-enabled toaster +
weather forecaster

Tweet-a-watt:
monitor energy use

Internet
refrigerator

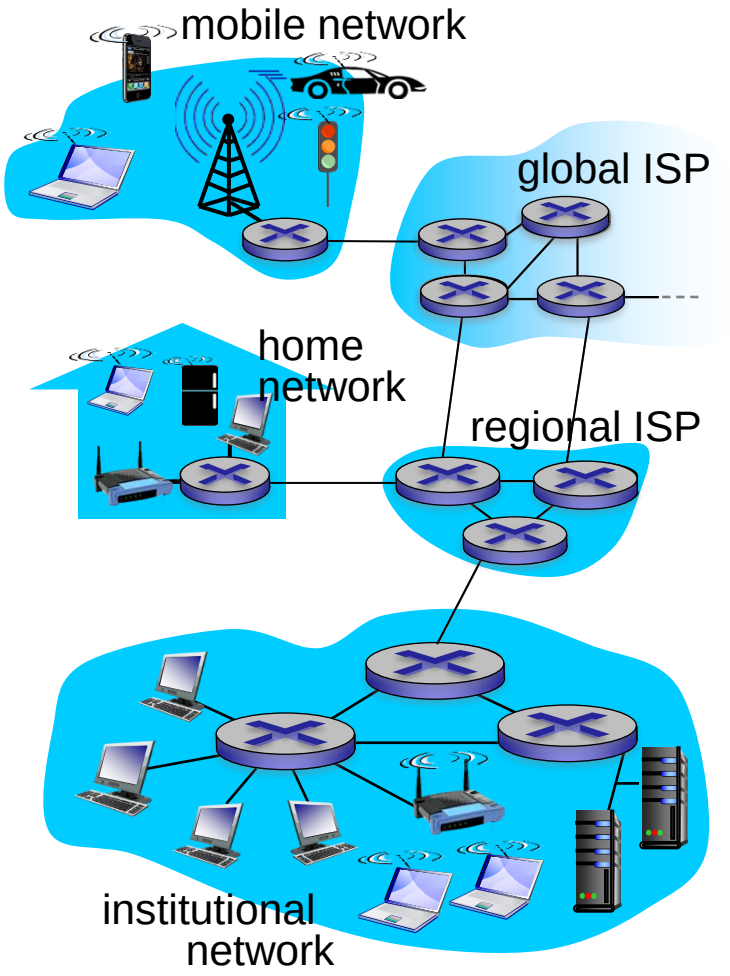
Slingbox: watch,
control cable TV remotely

sensorized,
bed
mattress

Internet phones

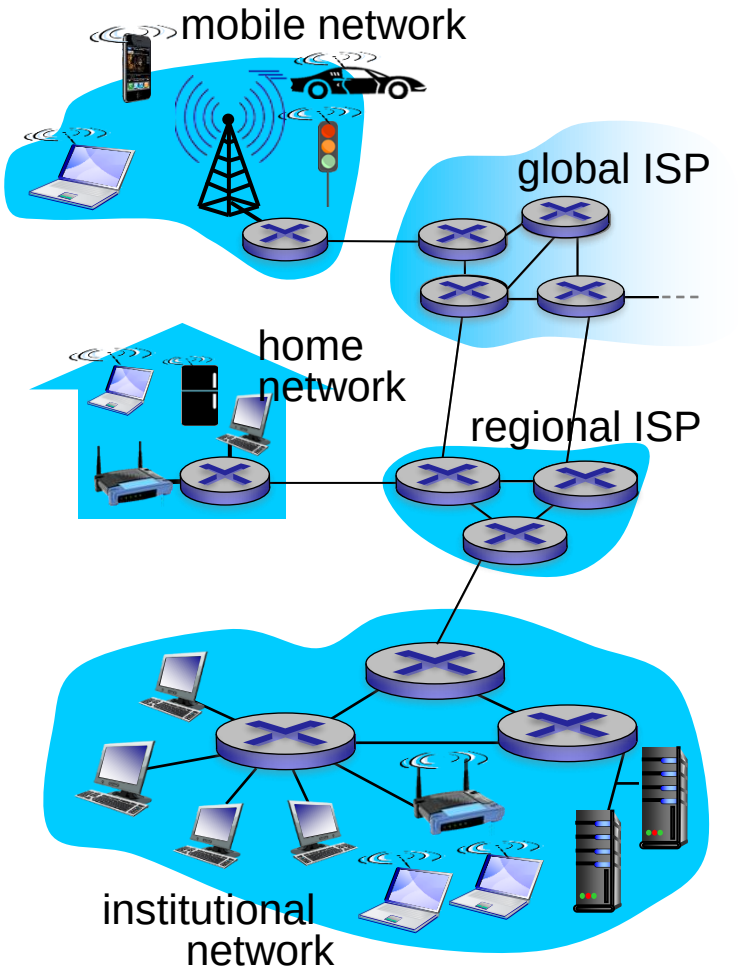
What's the Internet: "nuts and bolts" view

- *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

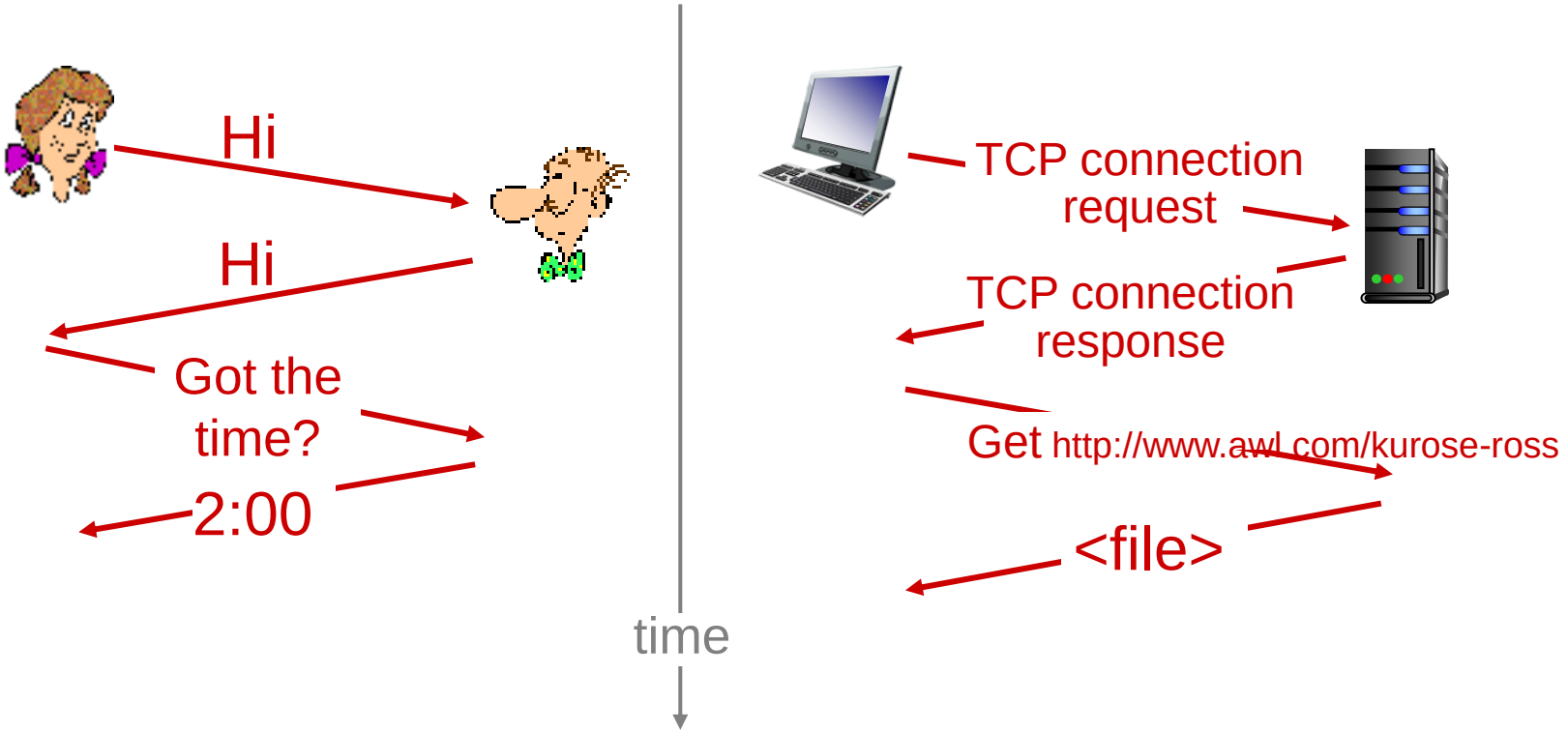
network protocols:

- 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:



Outline

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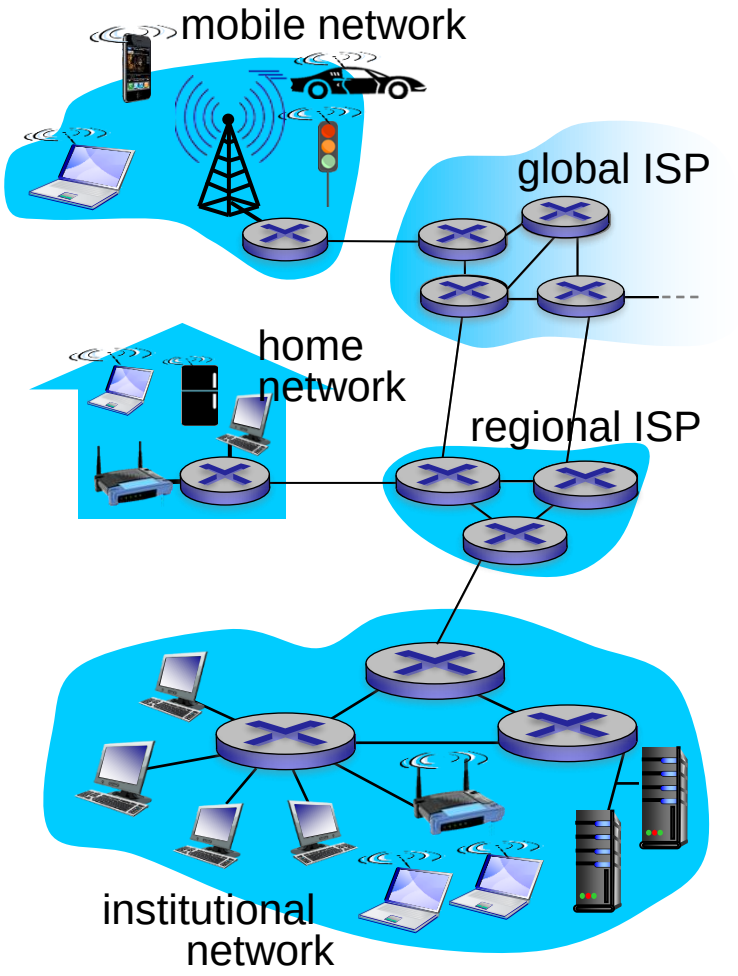
A closer look at network structure:

- *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



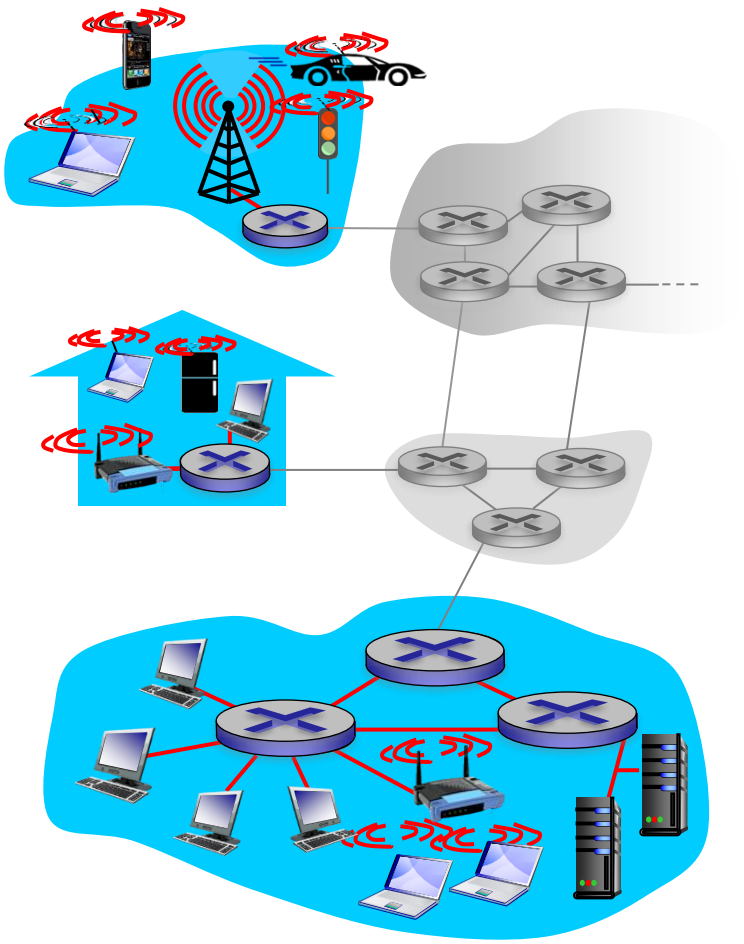
Access networks and physical media

Q: How to connect end systems to edge router?

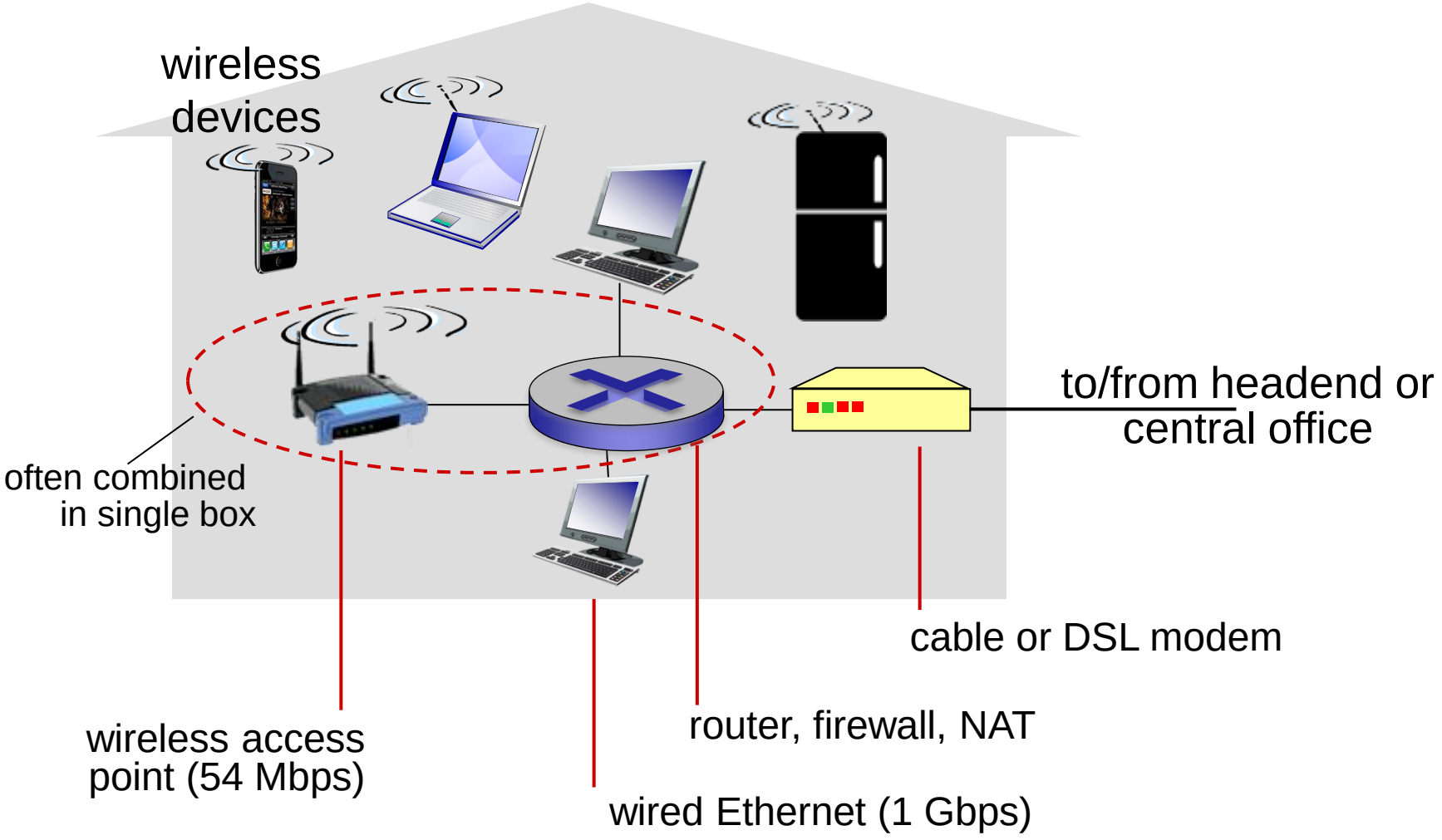
- residential access nets
- institutional access networks (school, company)
- mobile access networks

keep in mind:

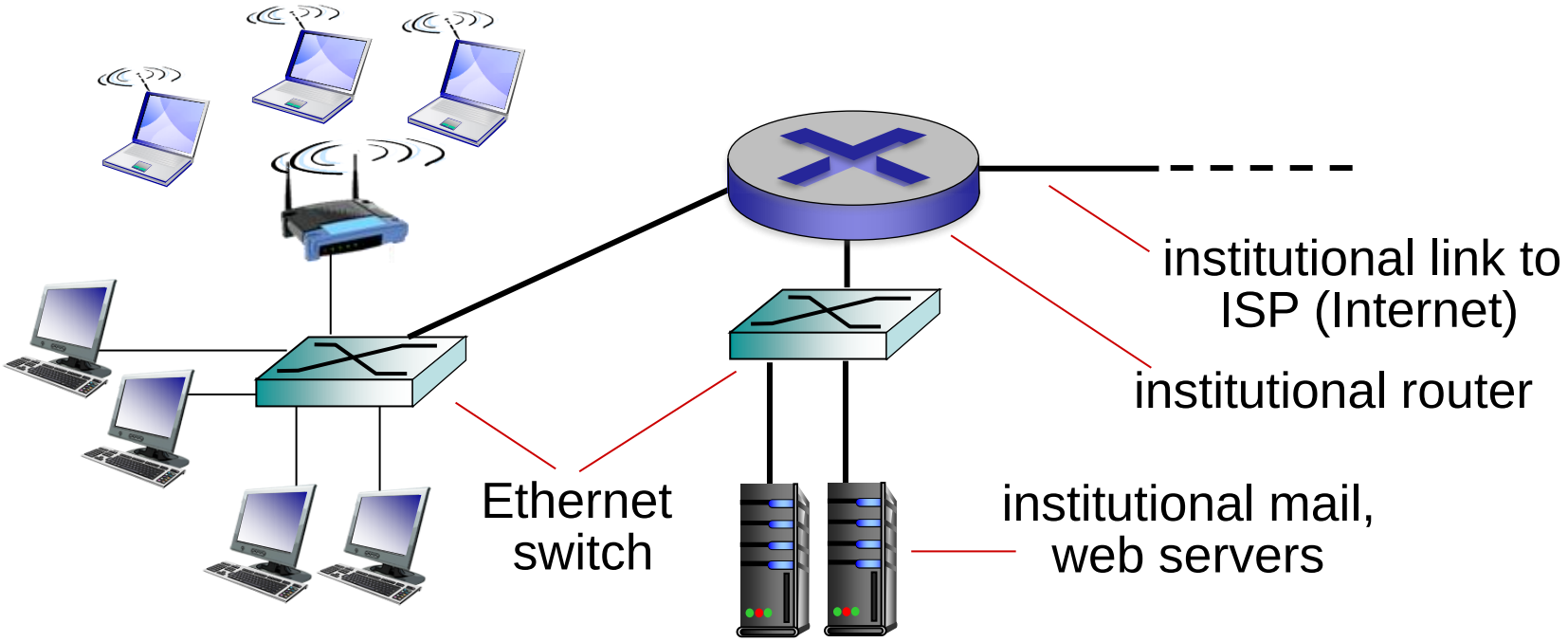
- bandwidth (bits per second) of access network?



Access network: 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

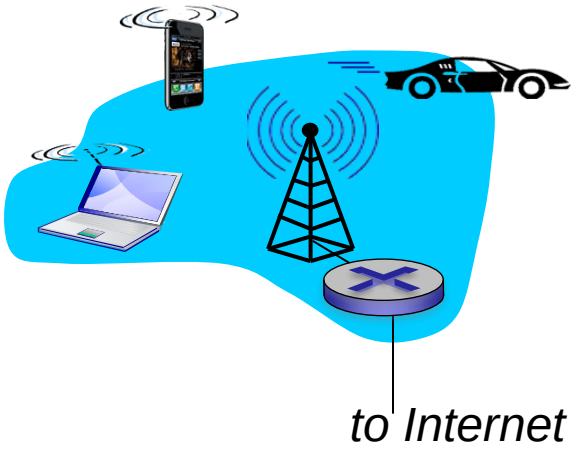
- shared *wireless* access network connects end system to router
  - via base station aka "access point"

wireless LANs:

- within building (100 ft.)
- 802.11b/g/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



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

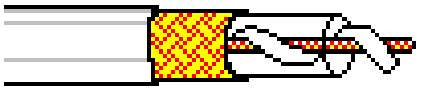
twisted pair (TP)

- 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
- broadband:
  - multiple channels on cable
  - HFC



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

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

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- What is the Internet?
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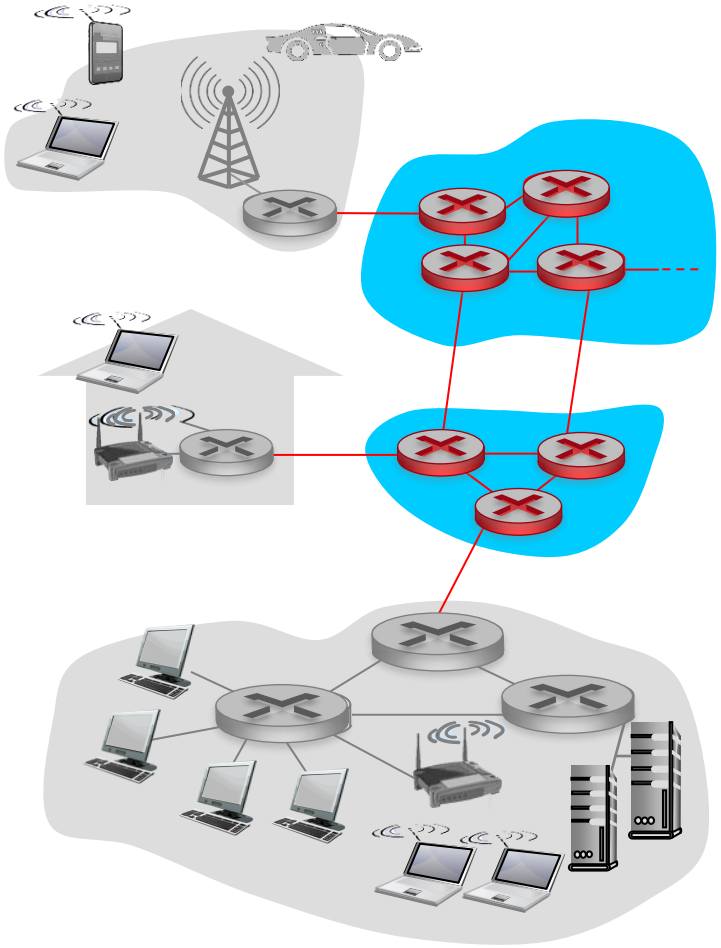
- Protocol layers, service models

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

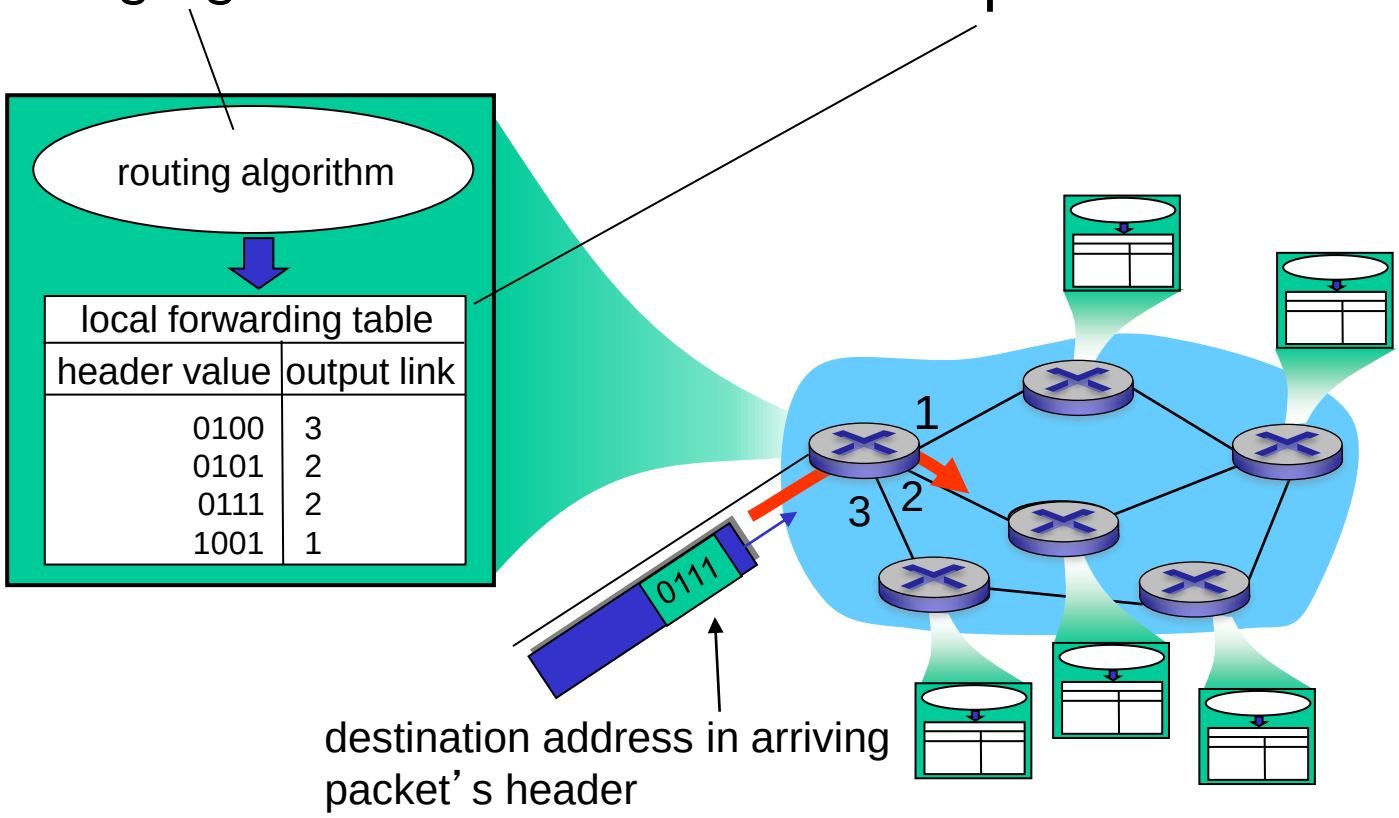


Two key network-core functions

routing: determines source-destination route taken by packets

- *routing algorithms*

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

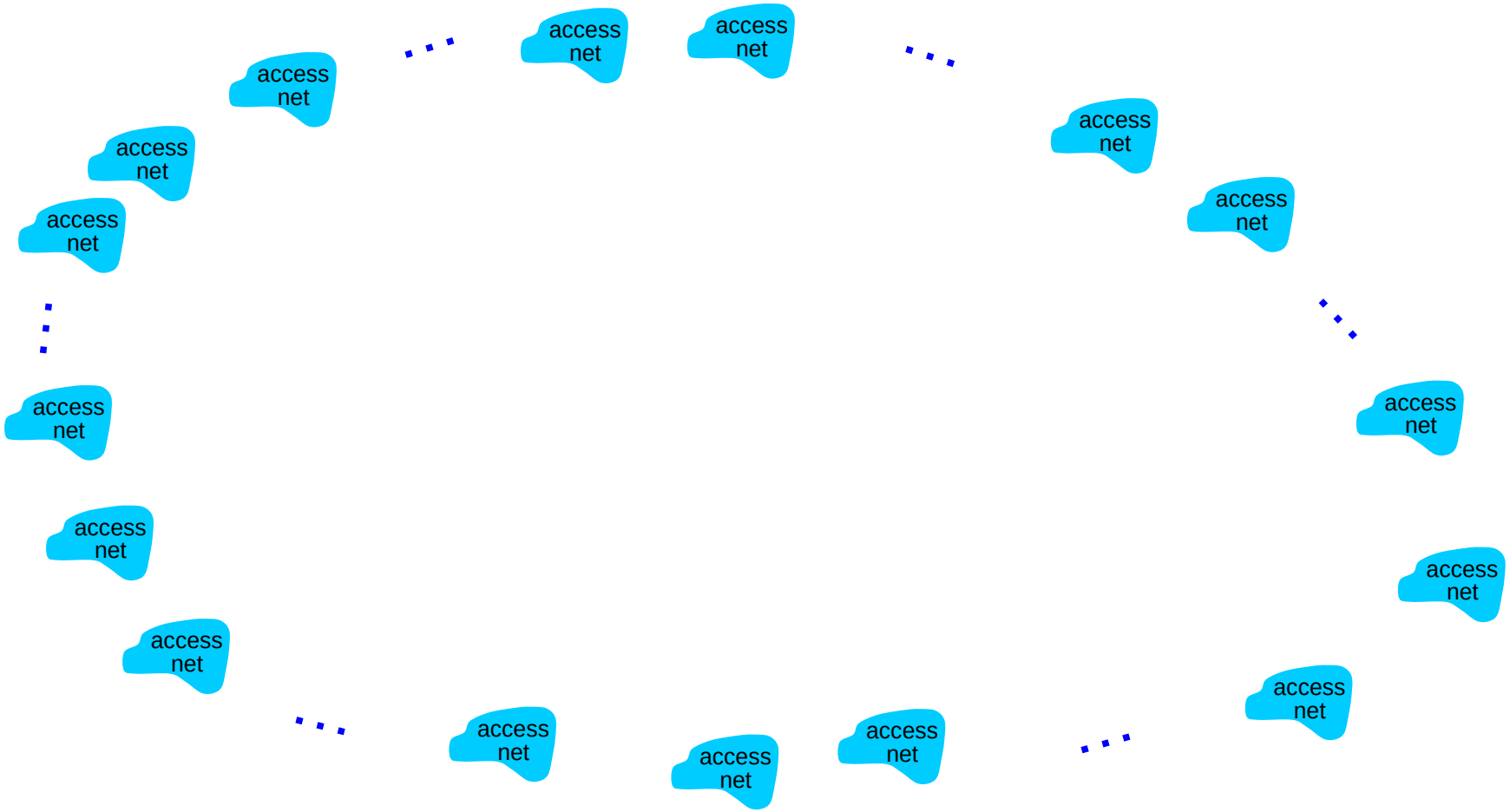


Internet structure: network of networks

- 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
- Let's take a stepwise approach to describe current Internet structure

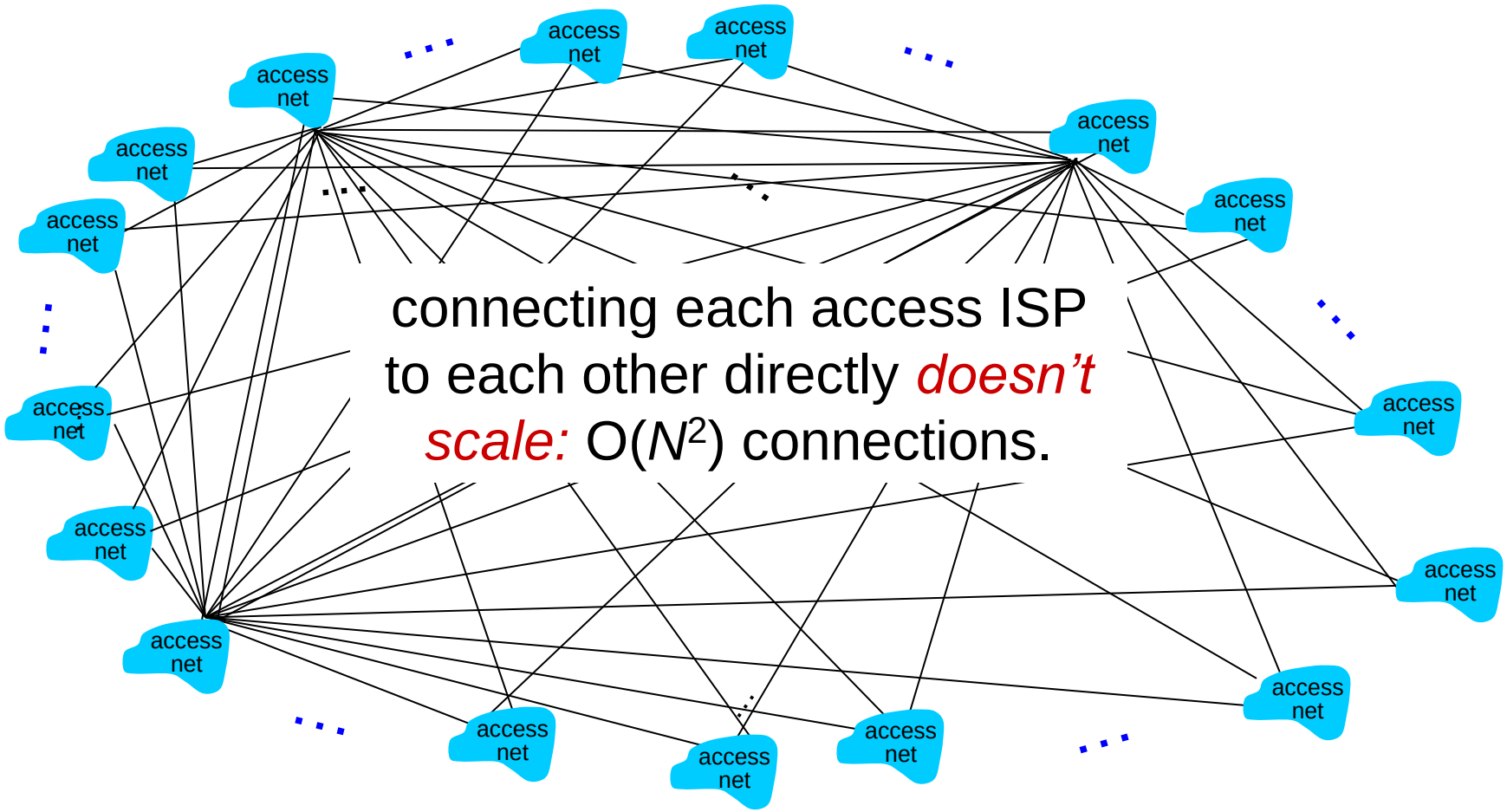
Internet structure: network of networks

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



Internet structure: network of networks

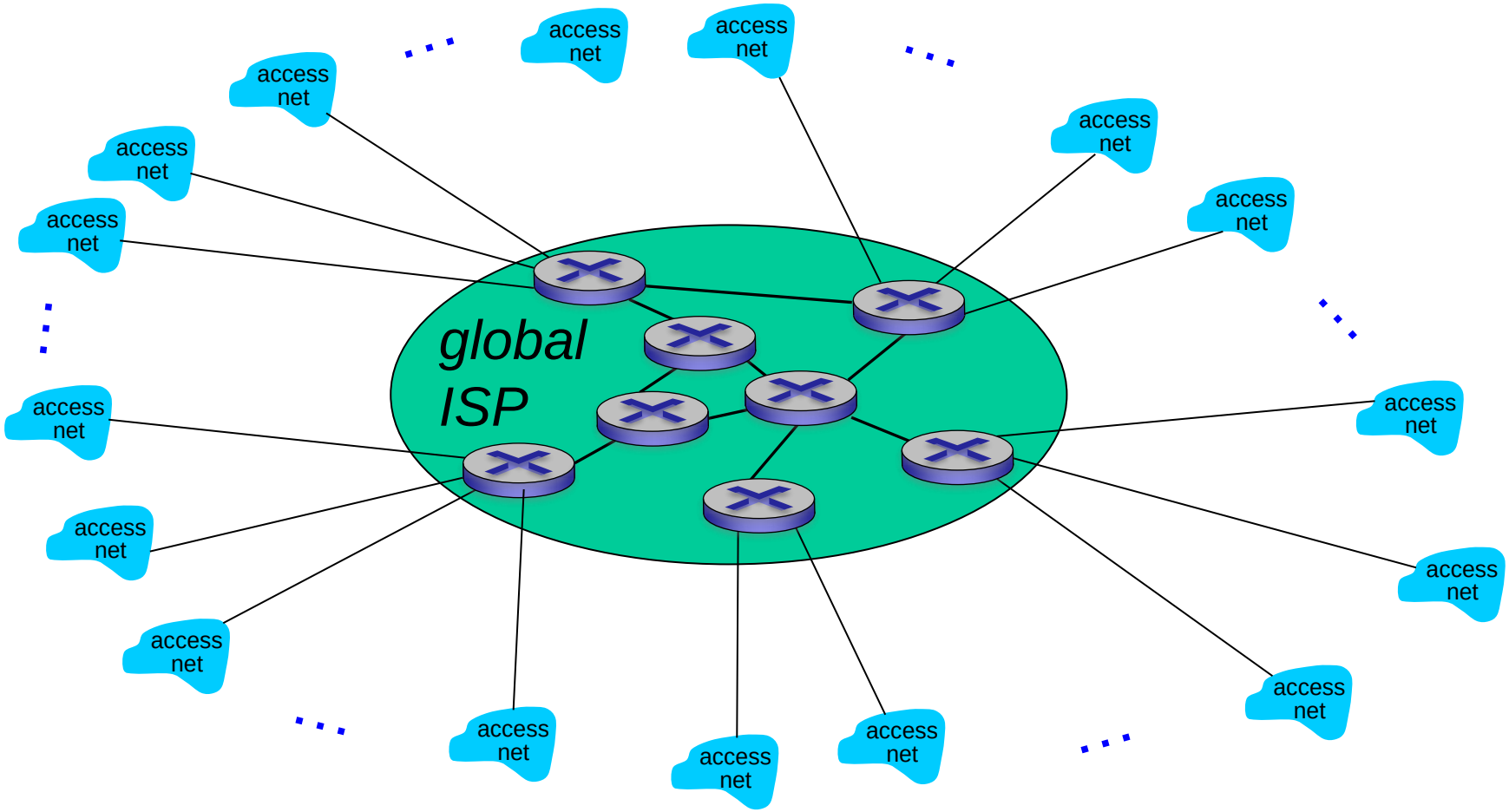
Option: connect each access ISP to every other access ISP?



Internet structure: network of networks

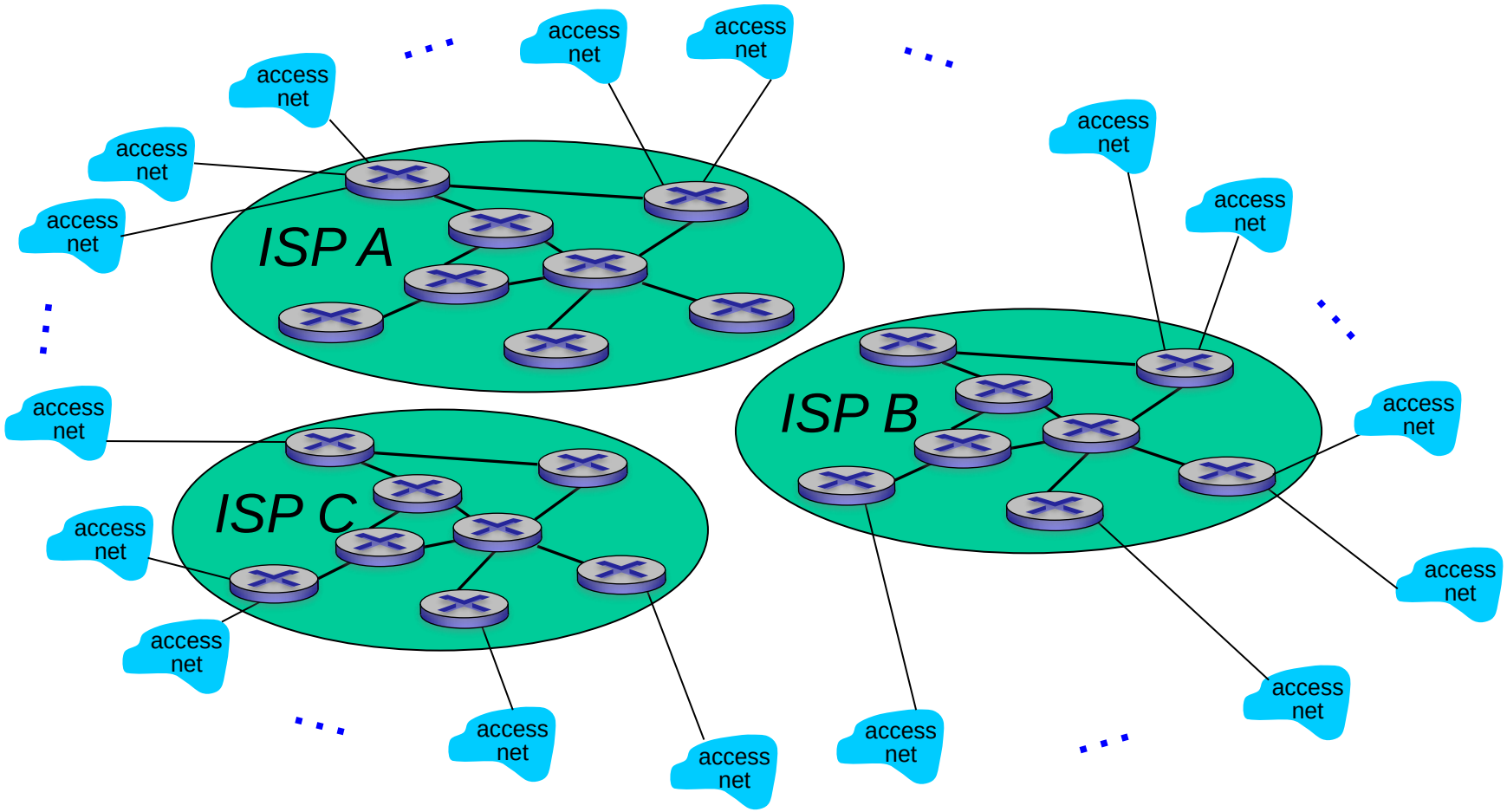
Option: connect each access ISP to one global transit ISP?

Customer and provider ISPs have economic agreement.



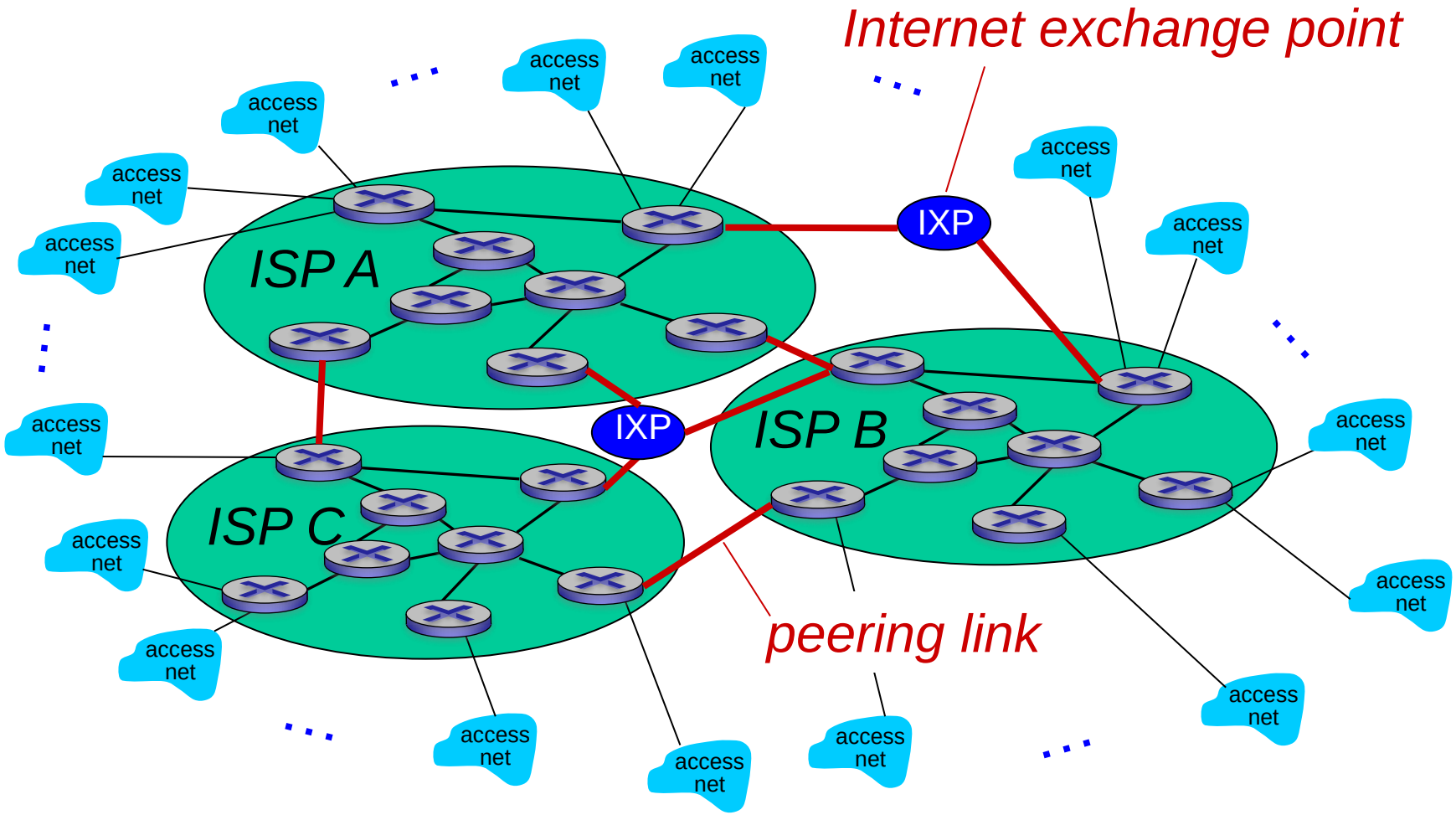
Internet structure: network of networks

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



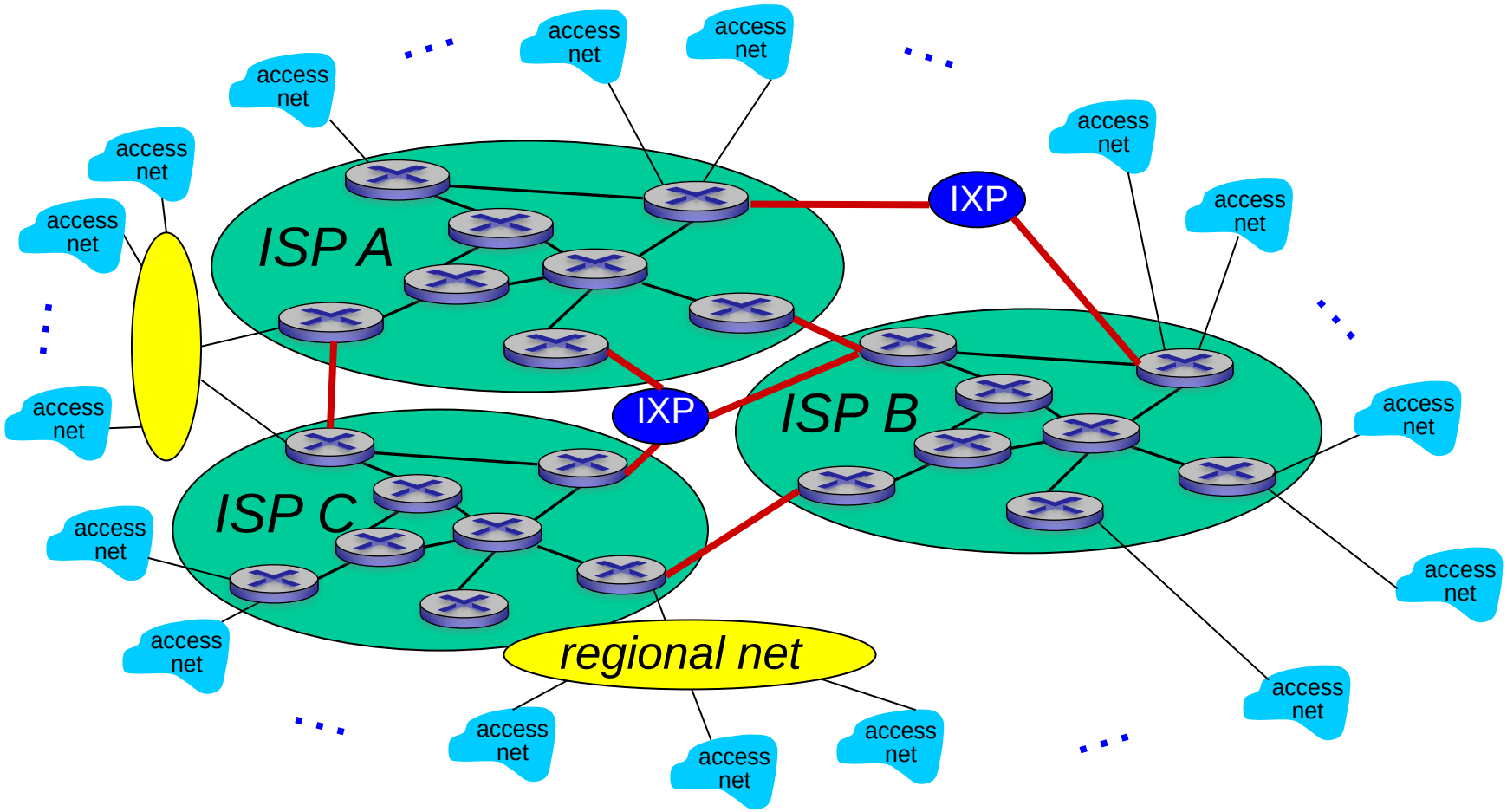
Internet structure: network of networks

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



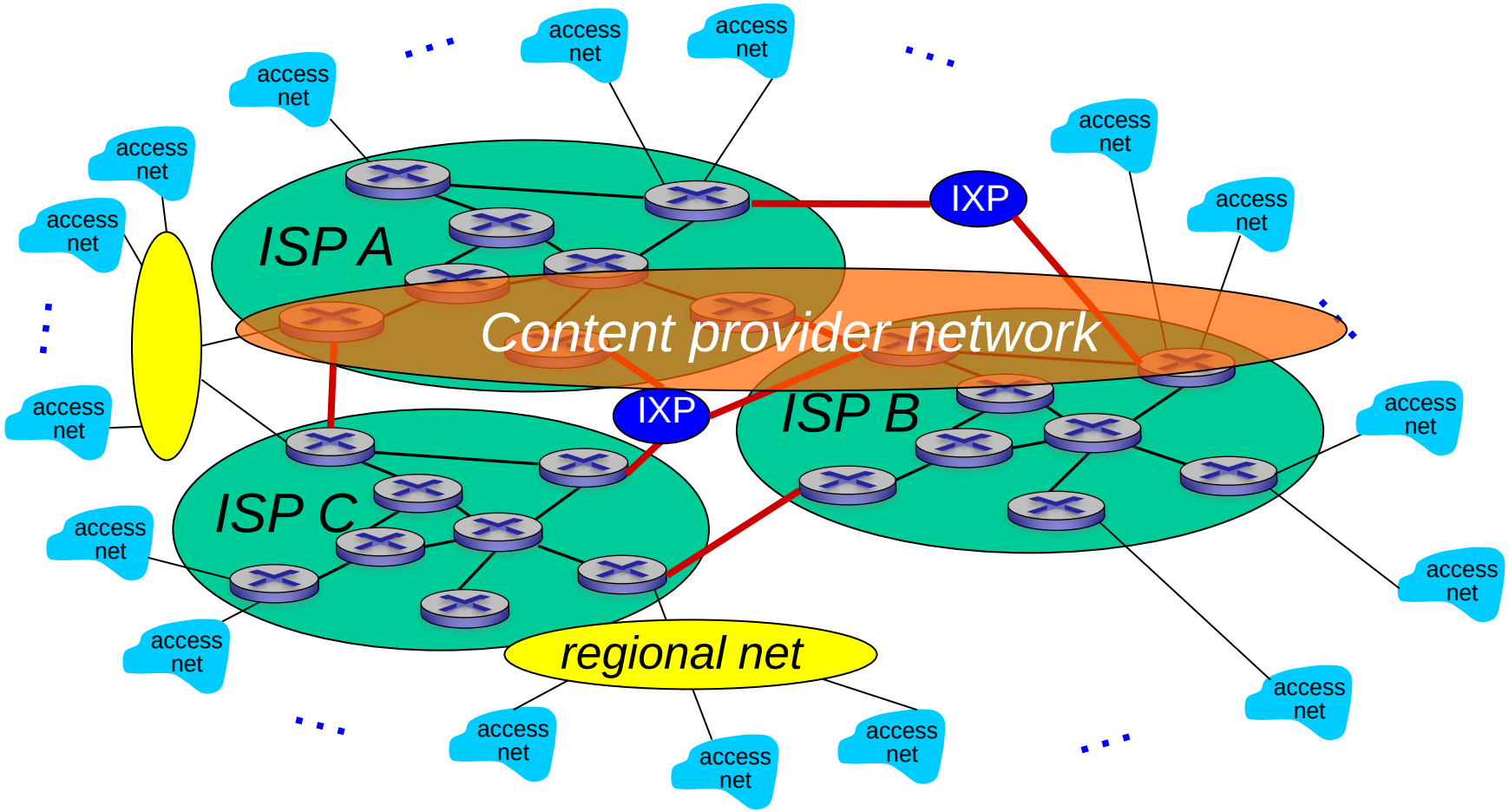
Internet structure: network of networks

… 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



Outline

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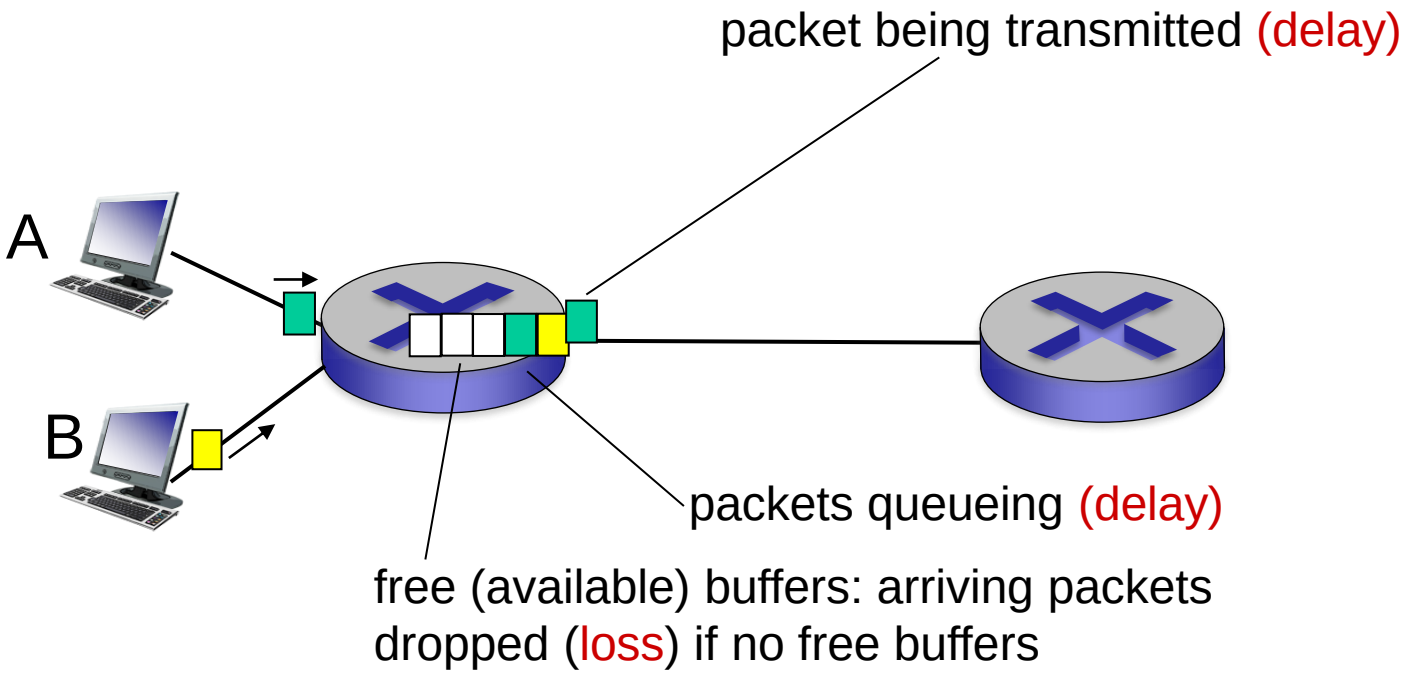
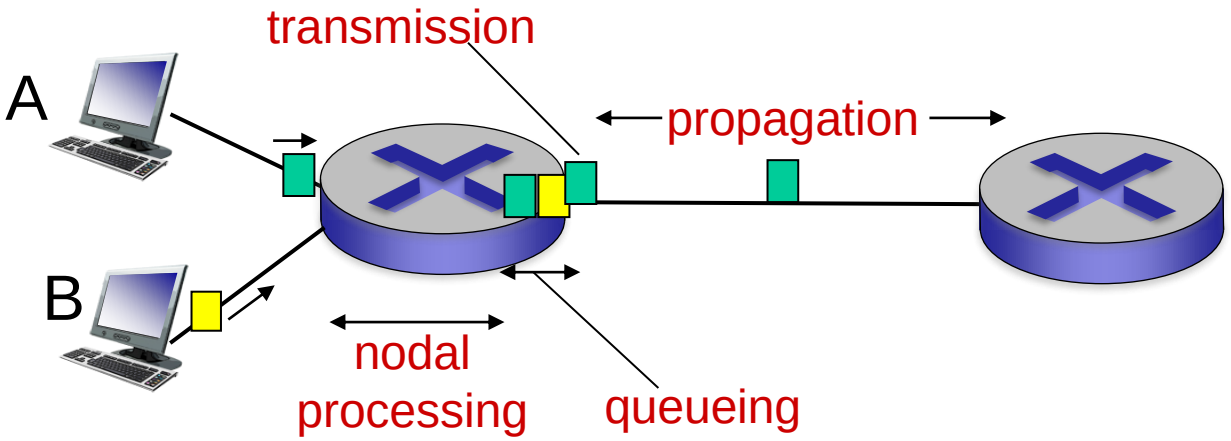
How do loss and delay occur?

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



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

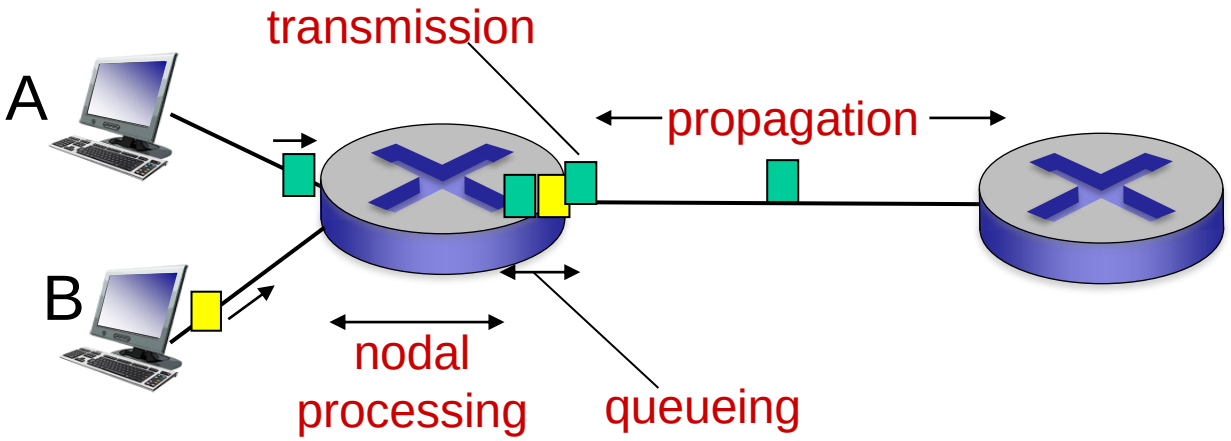
d_{proc}: nodal processing

- 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



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

d_{trans}: transmission delay:

- L: packet length (bits)
- R: link *bandwidth (bps)*
- $d_{trans} = L/R$

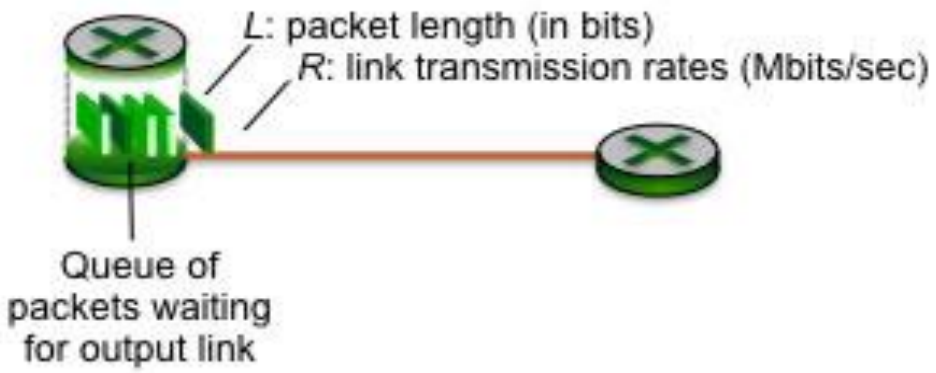
d_{trans} and d_{prop} *very* different

d_{prop}: propagation delay:

- d: length of physical link
- s: propagation speed
- $d_{prop} = d/s$

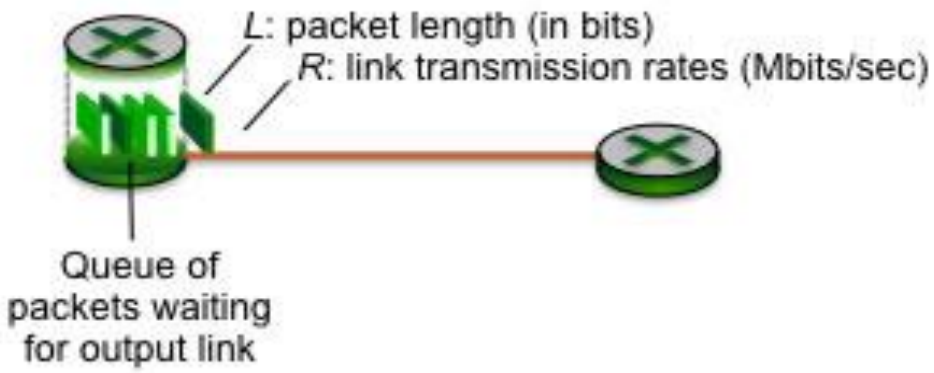
* Check out the online interactive exercises for more examples: http://gaia.cs.umass.edu/kurose_ross/interactive/
* Check out the Java applet for an interactive animation on trans vs. prop delay

Transmission delay - example



- As shown in the figure above, a single router is transmitting packets, each of length L bits, over a link with transmission rate R Mbps.
- Suppose that the packet length is L = 8000 bits, and the link transmission rate R = 100 Mbps.
- What is the transmission delay?

Transmission delay – example (cont.)



- L = 8000 bits, and R = 100 Mbps.
- What is the transmission delay?

trans delay = L/R = 8000 (bits) /100x 10^6 (bps)
= 0.08 x10^{-3} (sec) = 0.08 (msec).

Some online practice:
http://gaia.cs.umass.edu/kurose_ross/interactive/one-hop-delay.php

Propagation Delay

- The time it takes a bit to propagate on the physical distance of the communications path.

  d_{prop}: propagation delay:
  - d: length of physical link
  - s: propagation speed (2 - 3 x10^8 m/sec)
  - $d_{prop} = d/s$

Example: for a packet transmitted over a 1000 km of fibre (speed of 3x10^8 m/sec), the propagation delay is $1000*10^3/(3*10^8)$ = 3.33 (ms)

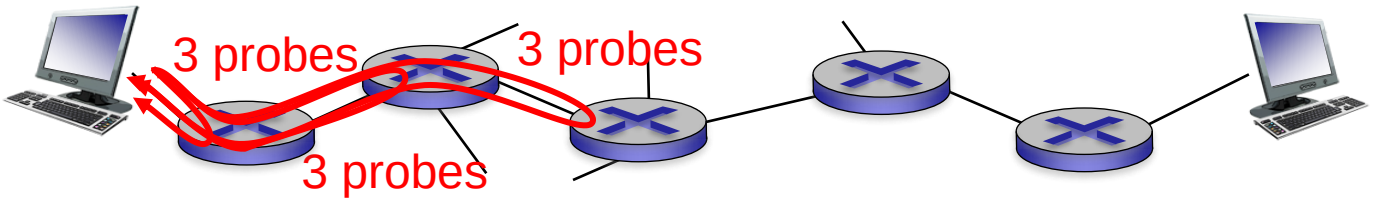
“Real” Internet delays and routes

- What do “real” Internet delay & loss look like?
- Ping program
  - a simplest method to verify reachability
  - using ICMP (Internet Control Message Protocol)
  - measure Response Time or Round Trip Time (RTT), Packet loss percentage …

```
C:\>ping www.yahoo.com

Pinging www.yahoo.akadns.net [68.142.226.32] with 32 bytes of data:

Reply from 68.142.226.32: bytes=32 time=79ms TTL=46
Reply from 68.142.226.32: bytes=32 time=80ms TTL=46
Reply from 68.142.226.32: bytes=32 time=80ms TTL=46
Reply from 68.142.226.32: bytes=32 time=79ms TTL=46

Ping statistics for 68.142.226.32:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 79ms, Maximum = 80ms, Average = 79ms
```

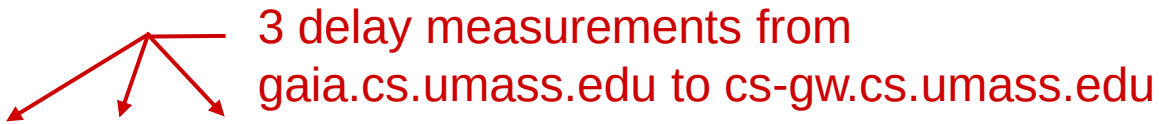
"Real" Internet delays and routes

- 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

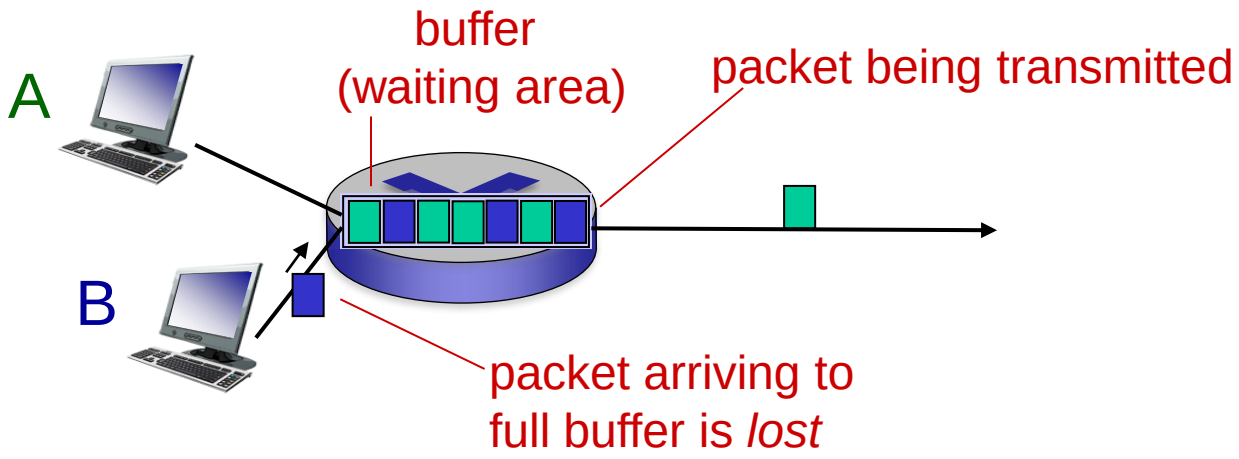
traceroute: gaia.cs.umass.edu to www.eurecom.fr




```
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
```

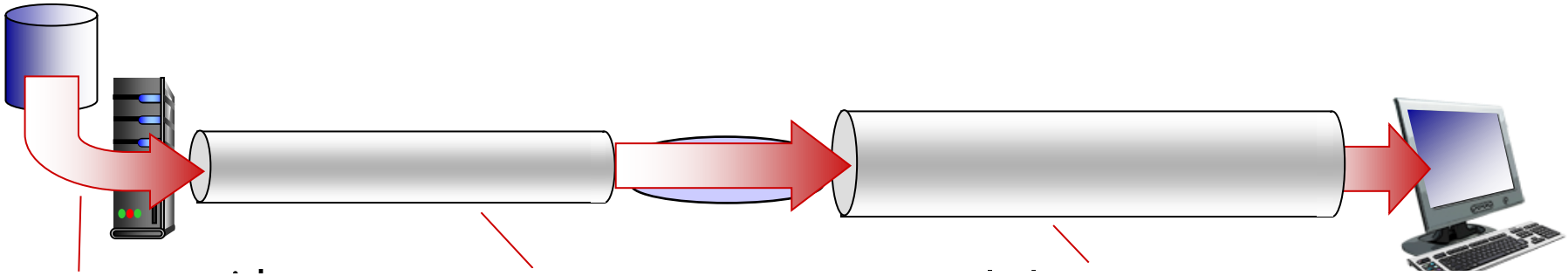
Packet loss

- 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



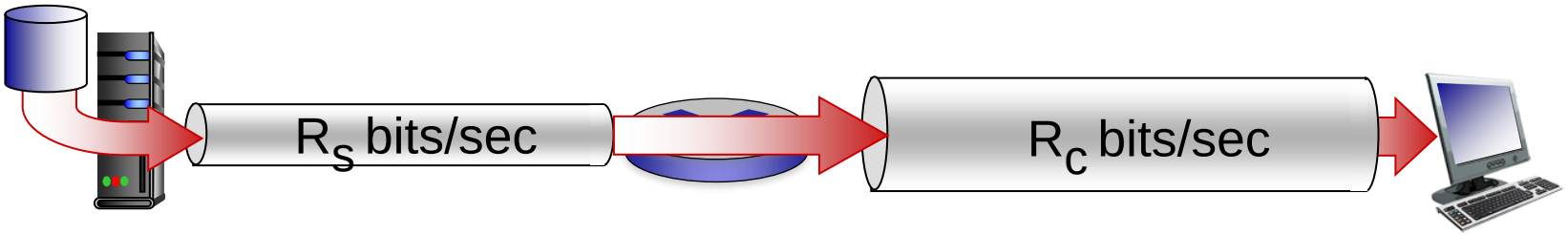
Throughput

- *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

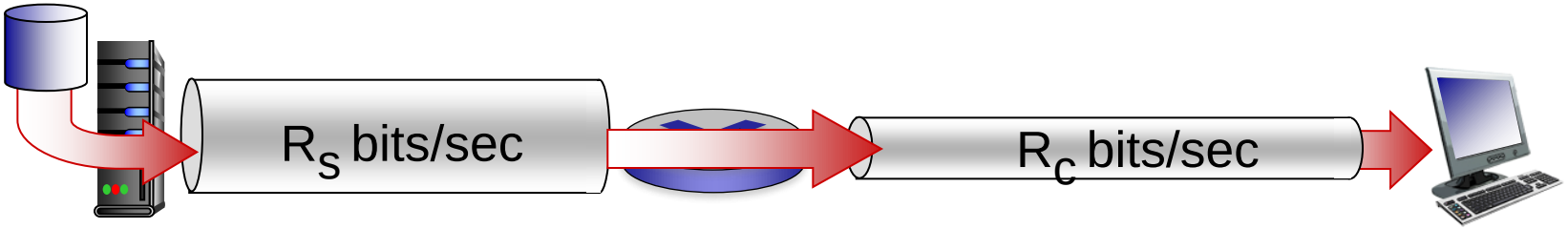


Throughput (more)

- $R_s < R_c$ 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

Summary

- Internet overview
- what's a protocol?
- network edge, core, access network
- performance: loss, delay, throughput