ECS524
“Internet Protocols & Applications”

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Goal

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- Reach an understanding of networking concepts & protocols
- Why? To understand how the Internet and current and future applications work

Interaction

- Share your questions/comments/wishes
- No such thing as a stupid question
- It is your responsibility to ask for clarifications
- Feel free to check resources such as Google & Wikipedia before/during/after the lecture to challenge/question/discuss
- QM+

Reference books

- Main reference:

Computer Networking: a top-down approach featuring the Internet, by J. Kurose and J. Ross, Addison-Wesley, any edition.

- Protocol details:

TCP/IP Illustrated, Vol. 1: The Protocols, by W. Richard Stevens, Addison-Wesley, 1993.

- The Internet…critically…

Approach

- Wednesday (10-12) & Friday (11-12)
  - Interactive lectures
  - Motivation/Concepts/Critical discussions
- Labs: Monday (3 slots) + Wednesday (1 slot)
  - Labs: Wireshark, TCP, Sockets, IP, Dijkstra
  - 25% of the mark

Communication

- Use lecture and lab time to learn!
- Outside lectures
  - By email: {steve.uhlig,felix.cuadrado}@qmul.ac.uk
  - Come to our office (Eng.202 (steve) / 153a (felix))

Exam

- Written, 2.5 hours, closed book.
- Will cover all of TCP/IP: applications, transport, IP, MAC.
- Purpose: check your knowledge and understanding of Internet protocols.
- 75% of the total mark

Module content

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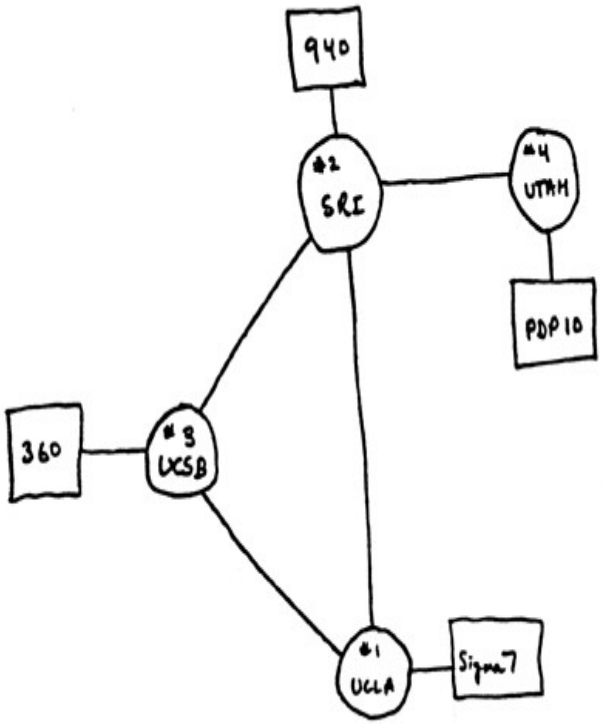
- Introduction to the Internet
- Application layer
- Sockets
- Transport layer
- IP – Network layer
- Routing
- Advanced topics (IPv6/NAT/Security)

Introduction to the Internet

- **Internet history**
- Internet structure

Then and now

1964



Today

Internet history

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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
- late70'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

~750 million hosts

- Smartphones and tablets

Aggressive deployment of broadband access

Increasing ubiquity of high-speed wireless access

Emergence of online social networks:

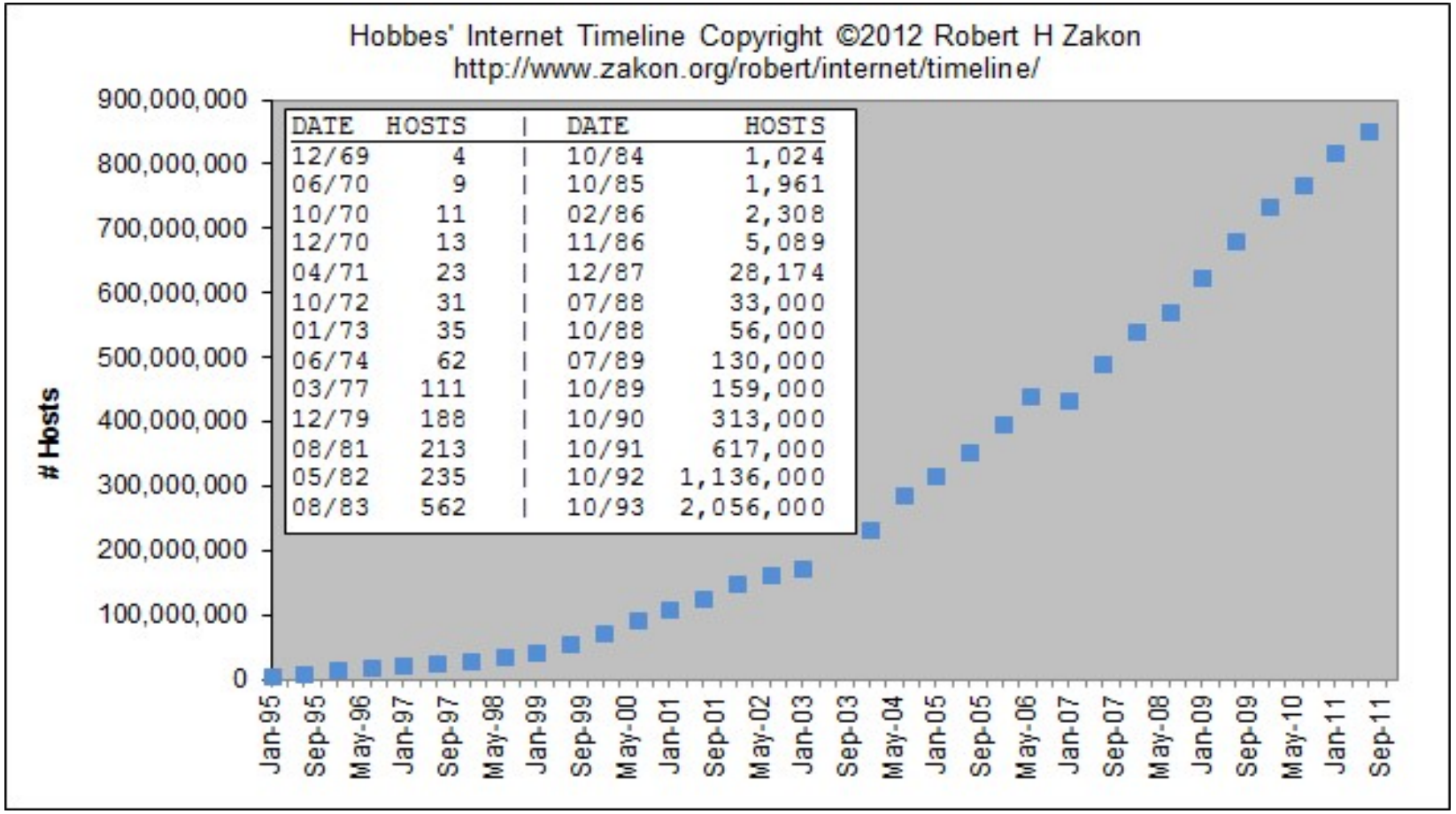
- Facebook: soon one billion users

Service providers (Google, Microsoft) create their own networks

- Bypass Internet, providing "instantaneous" access to search, emai, etc.

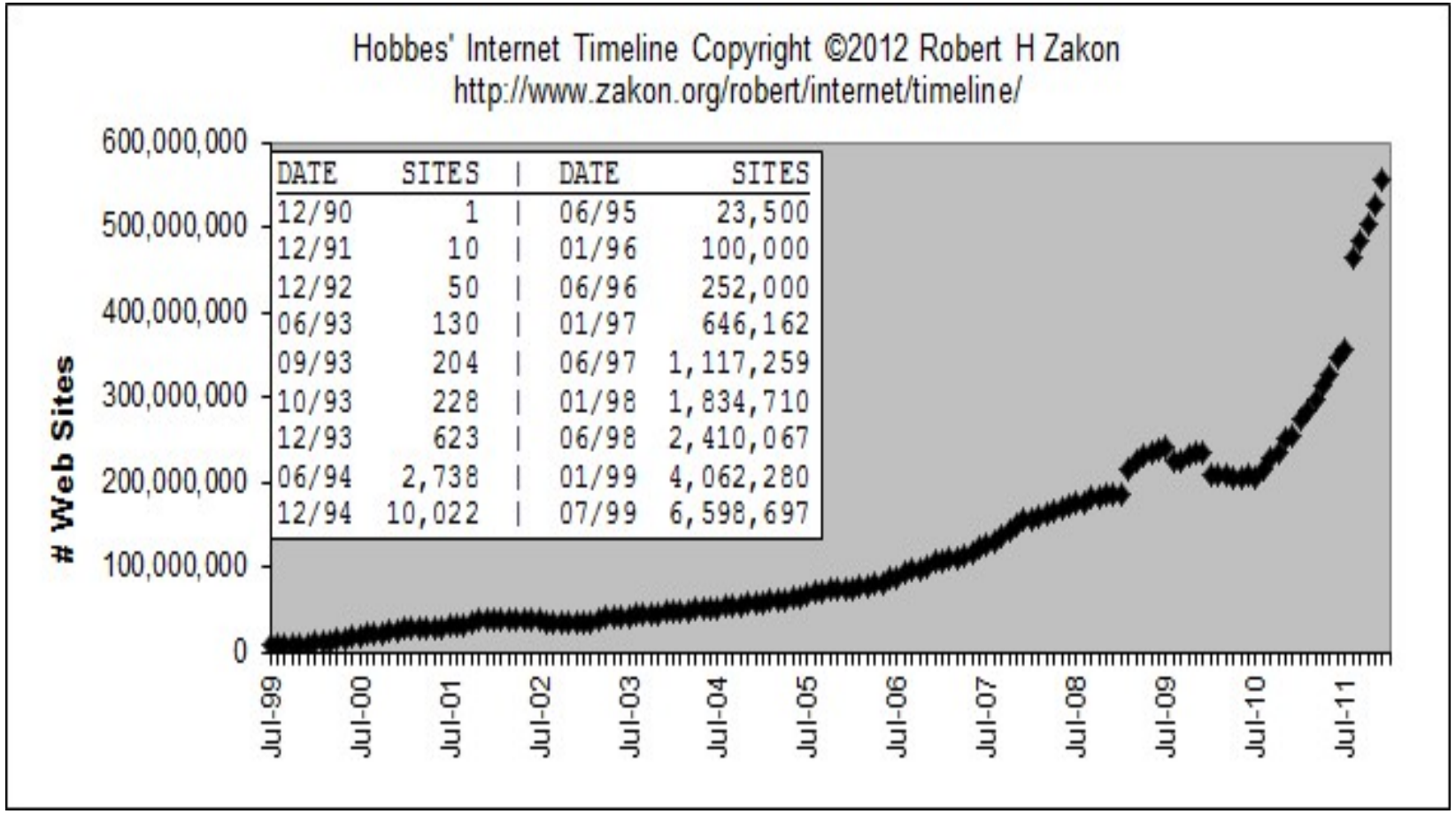
E-commerce, universities, enterprises running their services in "cloud" (eg, Amazon EC2)

Internet hosts



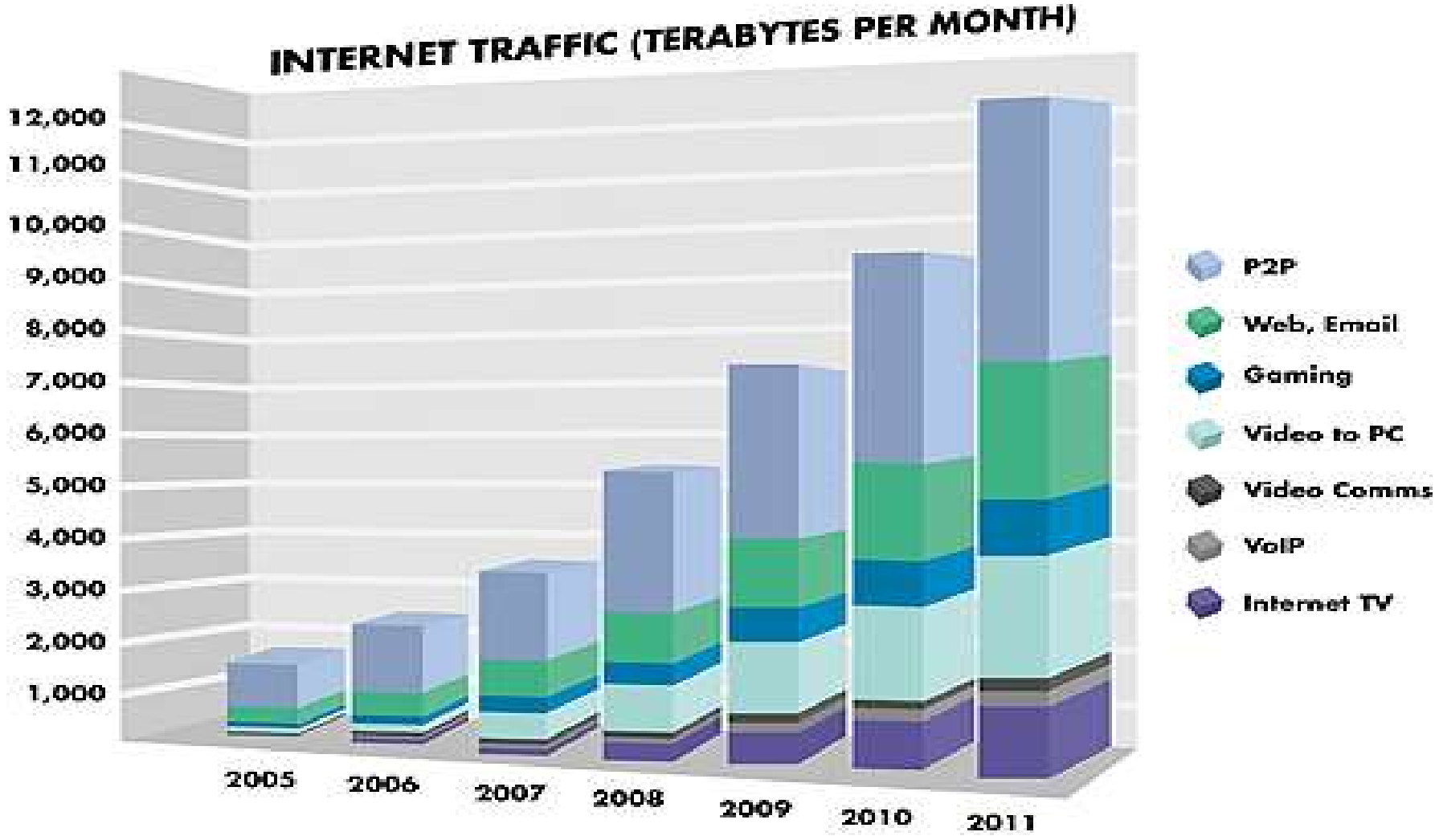
DATE	HOSTS	DATE	HOSTS
12/69	4	10/84	1,024
06/70	9	10/85	1,961
10/70	11	02/86	2,308
12/70	13	11/86	5,089
04/71	23	12/87	28,174
10/72	31	07/88	33,000
01/73	35	10/88	56,000
06/74	62	07/89	130,000
03/77	111	10/89	159,000
12/79	188	10/90	313,000
08/81	213	10/91	617,000
05/82	235	10/92	1,136,000
08/83	562	10/93	2,056,000

www



DATE	SITES	DATE	SITES
12/90	1	06/95	23,500
12/91	10	01/96	100,000
12/92	50	06/96	252,000
06/93	130	01/97	646,162
09/93	204	06/97	1,117,259
10/93	228	01/98	1,834,710
12/93	623	06/98	2,410,067
06/94	2,738	01/99	4,062,280
12/94	10,022	07/99	6,598,697

Popular applications



Introduction to the Internet

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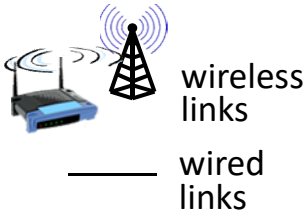
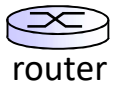
- Internet history
- **Internet structure**

Stuff that makes the Internet

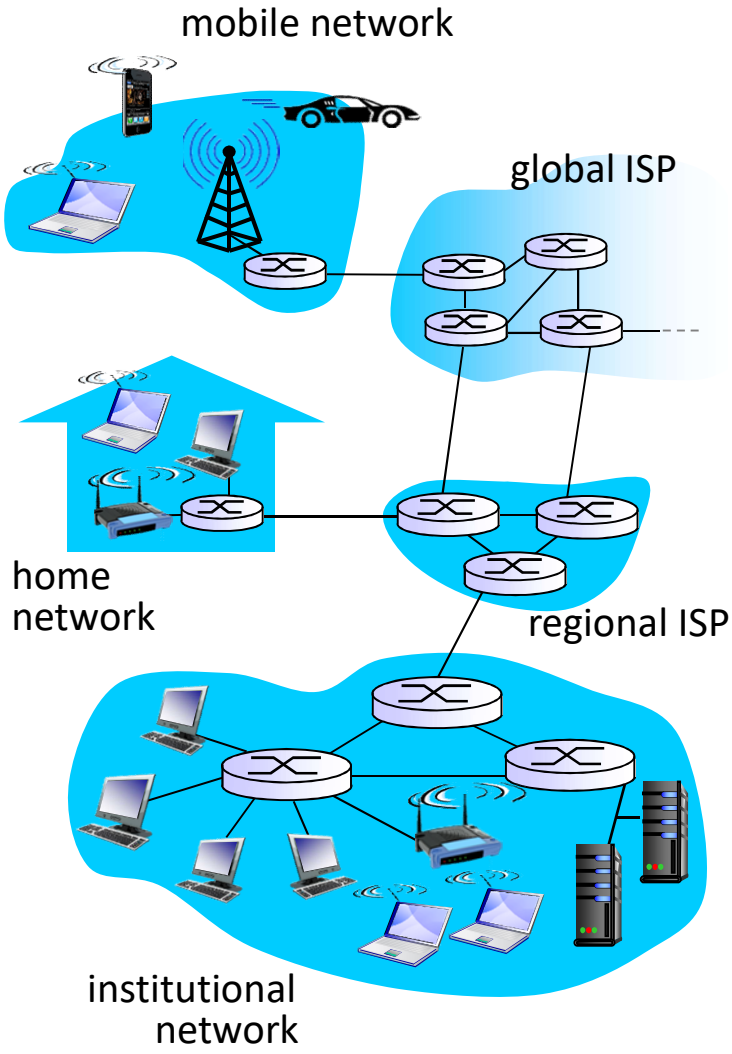
- millions of connected computing devices:
  - *hosts = end systems*
  - running *network apps*



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



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



Fun devices

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

Web-enabled toaster +
weather forecaster

Tweet-a-watt:
monitor energy use

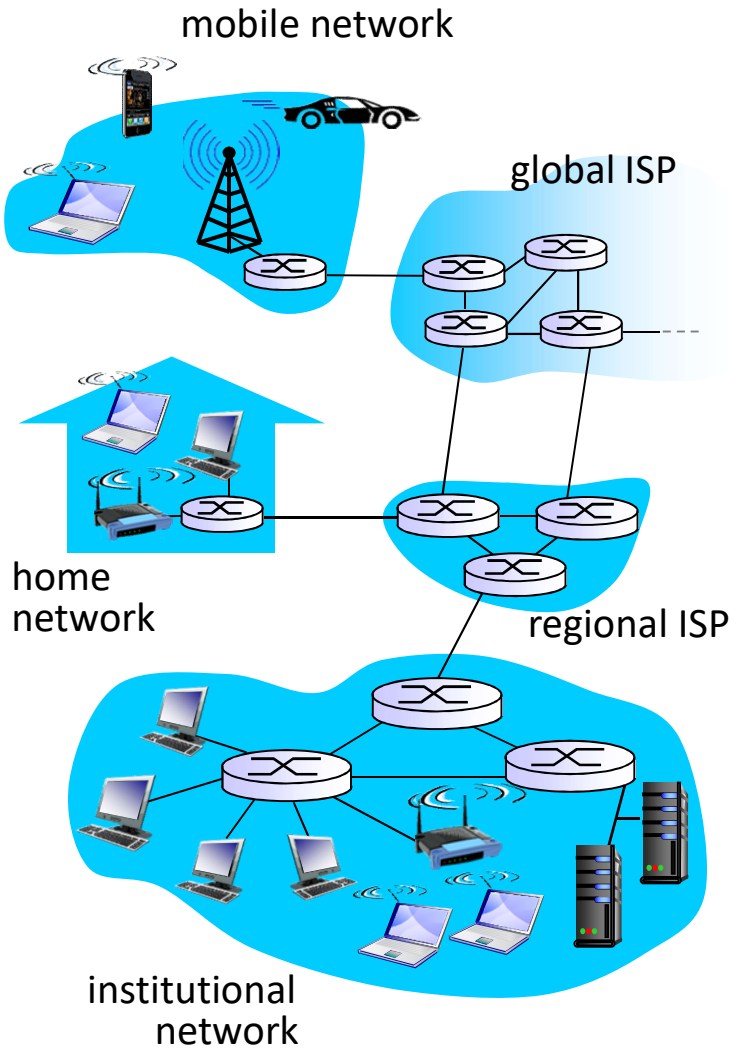
Internet
refrigerator

Slingbox: watch,
control cable TV remotely

Internet phones

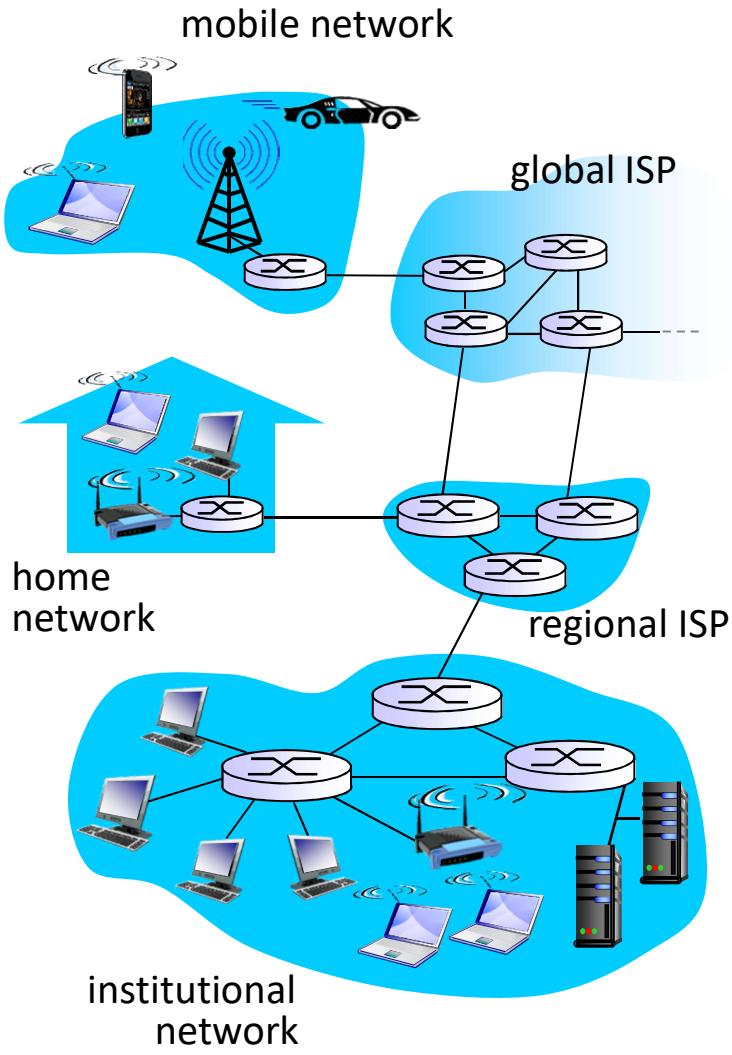
What's the Internet

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



What's the Internet: services

- *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?

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human protocols:

- "what's the time?"
- "I have a question"
- introductions

… specific msgs sent

… specific actions taken when msgs received, or other events

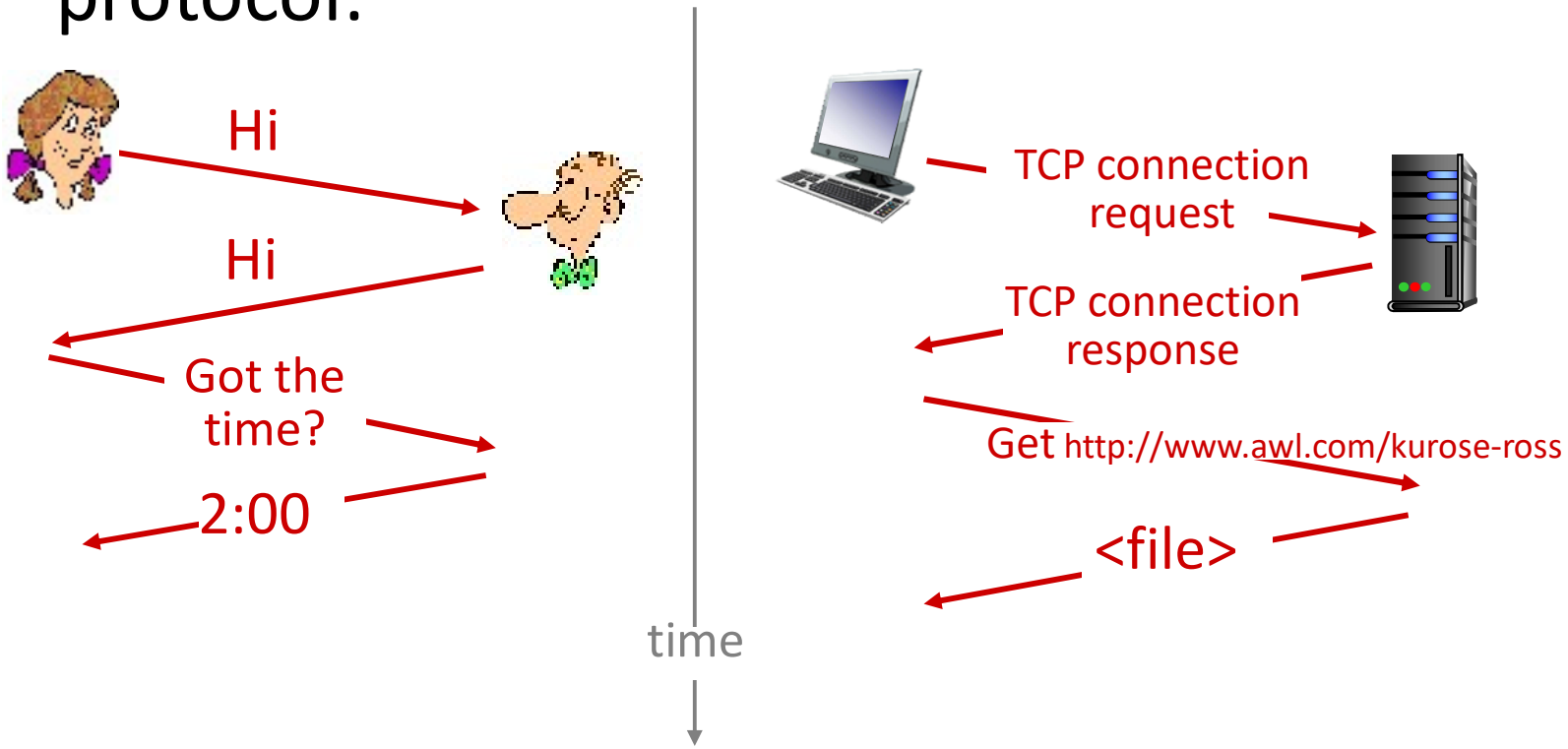
network protocols:

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

protocols define format order of 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:



Q: other human protocols?

Network structure

network edge:

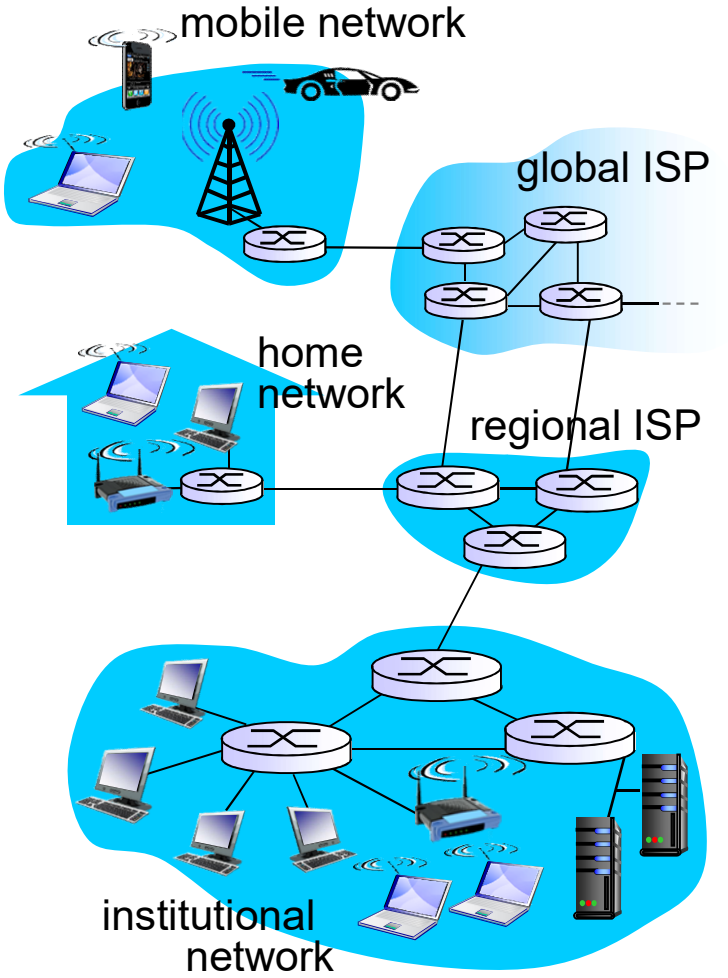
- hosts: clients and servers
- servers often in data centers

access networks, physical media:

- wired, wireless communication links

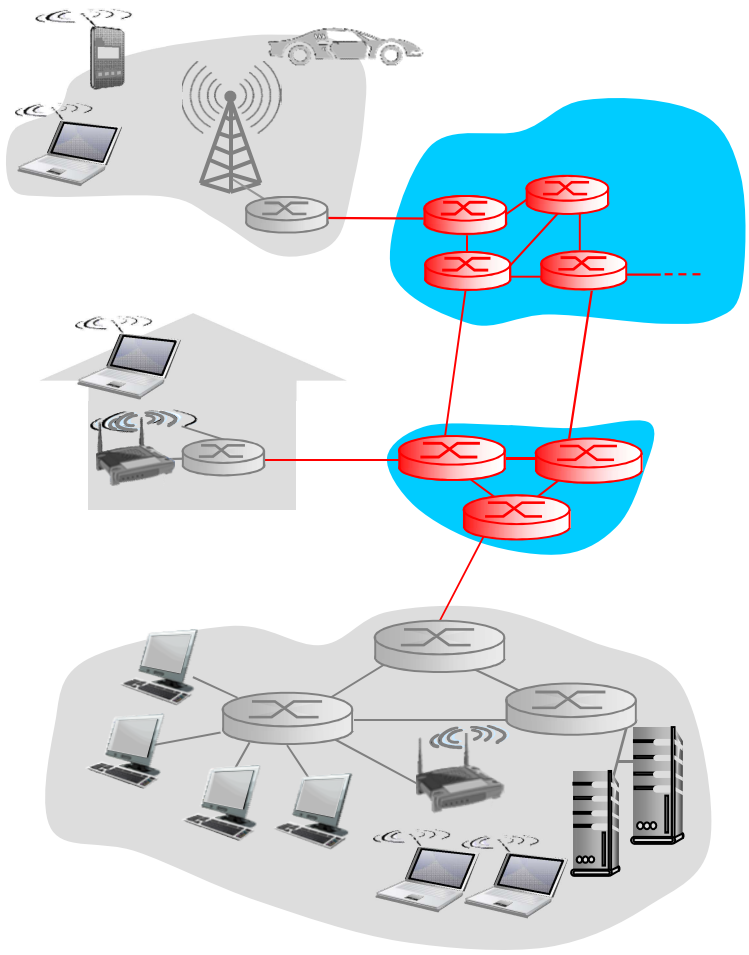
network core:

- interconnected routers
- network of networks



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

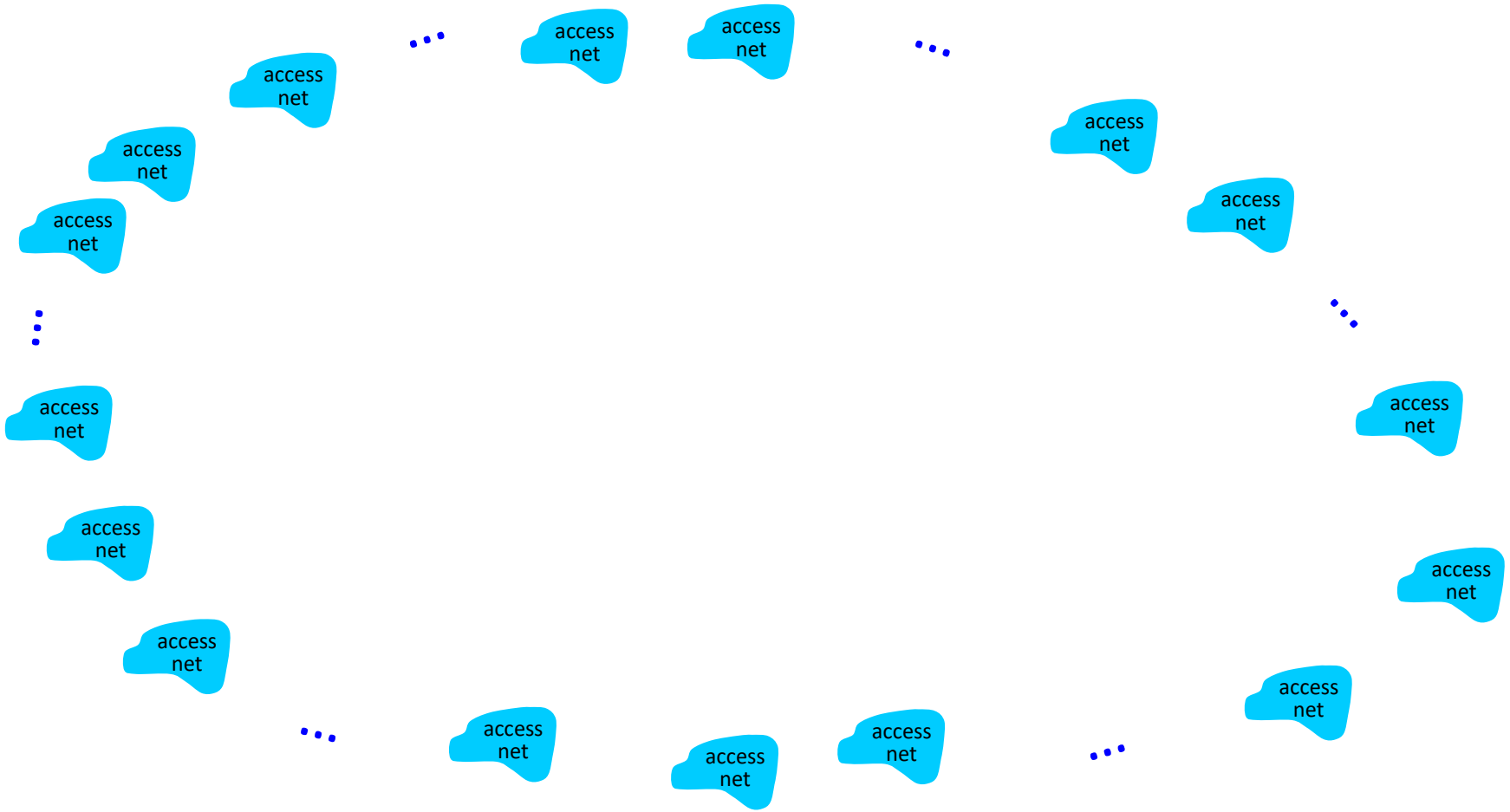


Internet structure

- 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

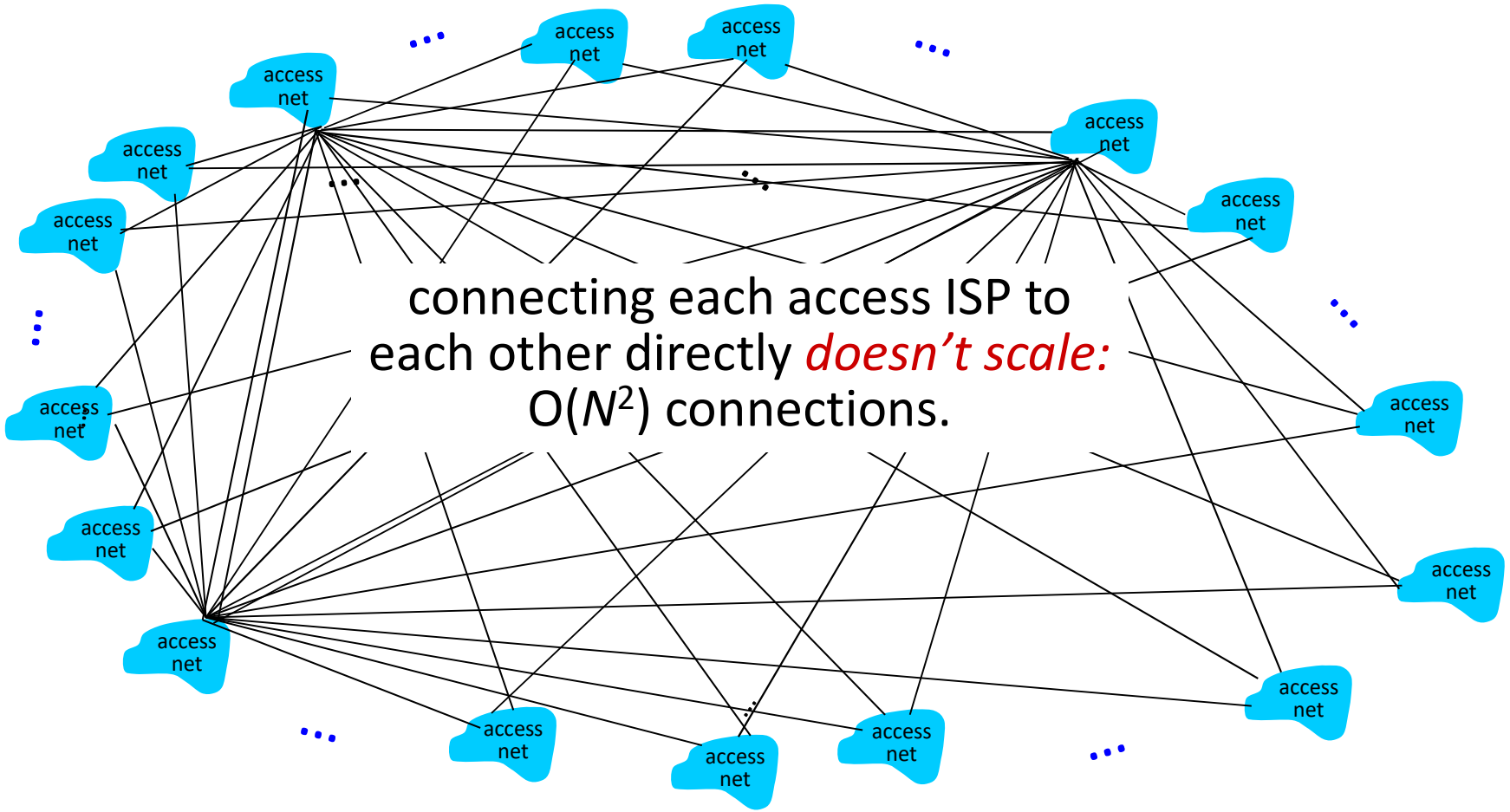
Network of networks

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



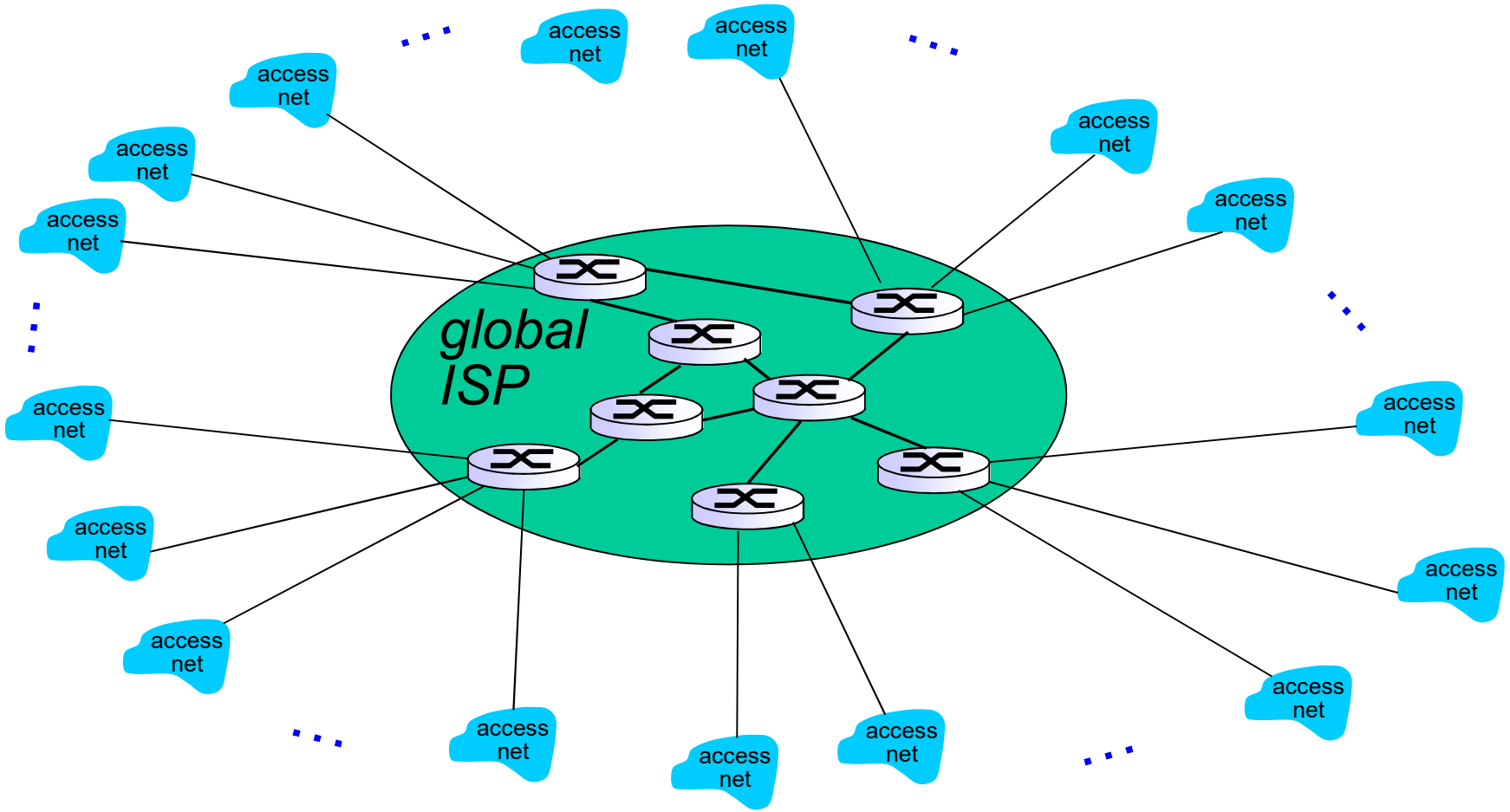
Network of networks

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



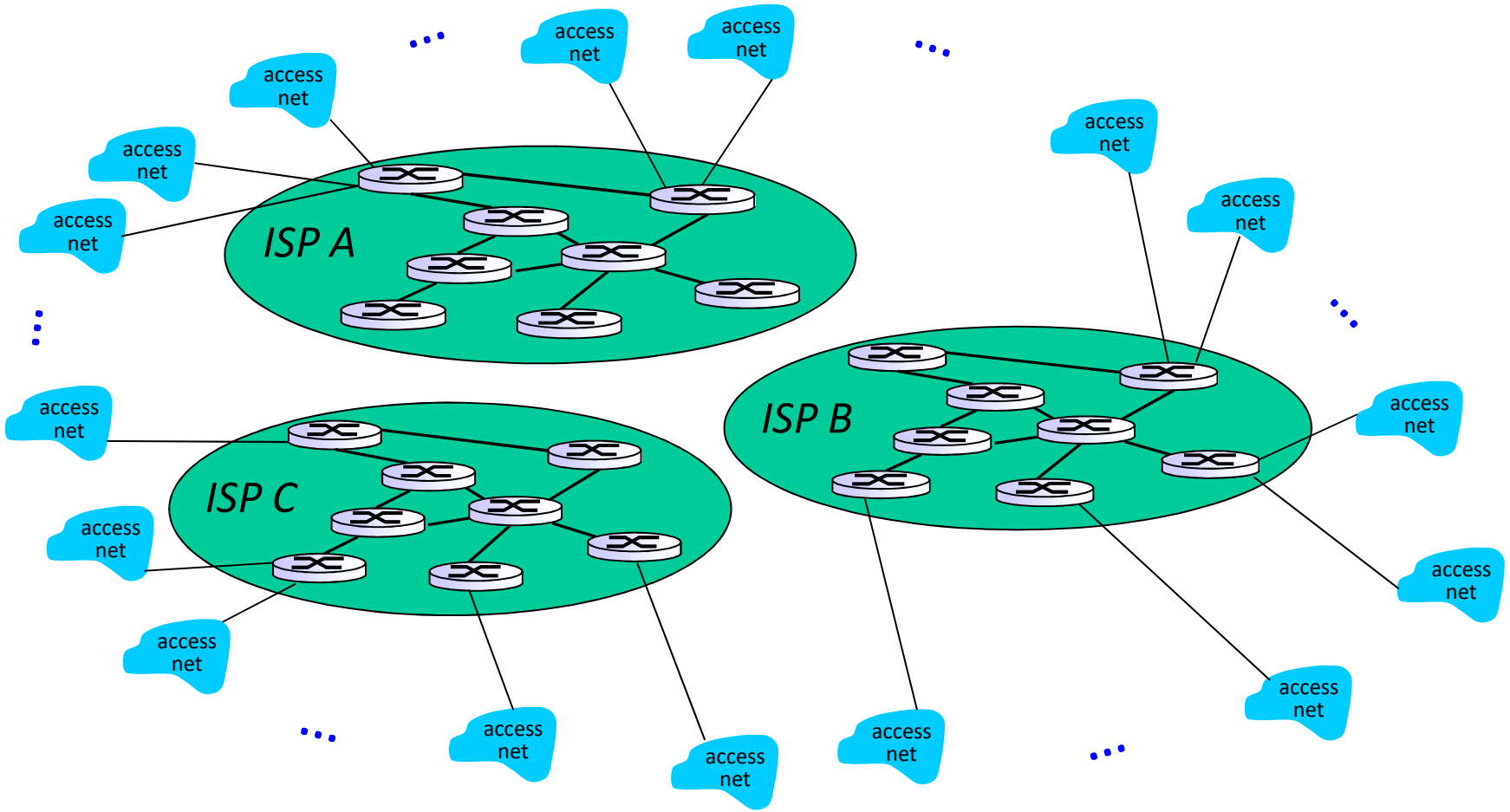
Network of networks

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



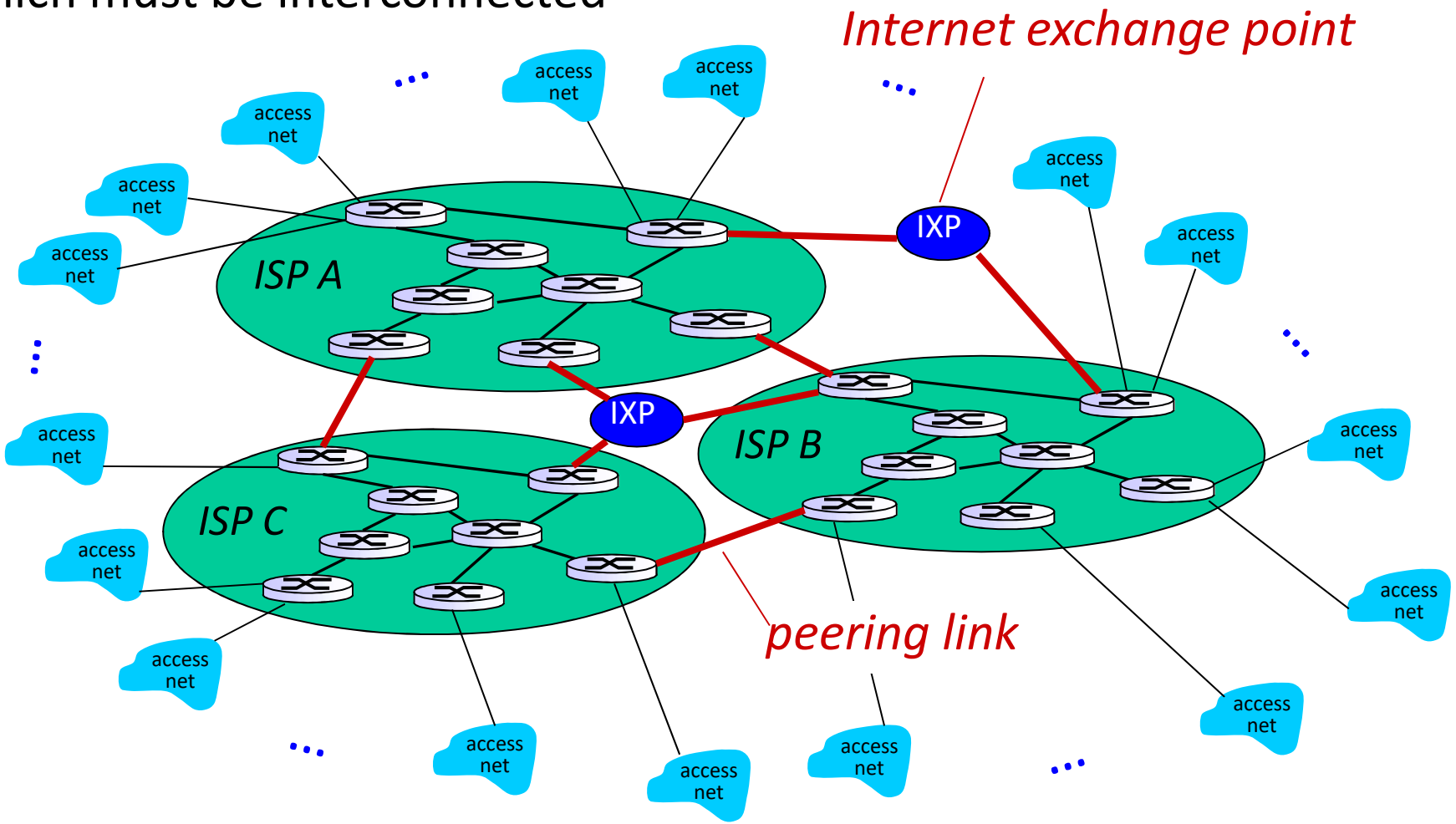
Network of networks

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



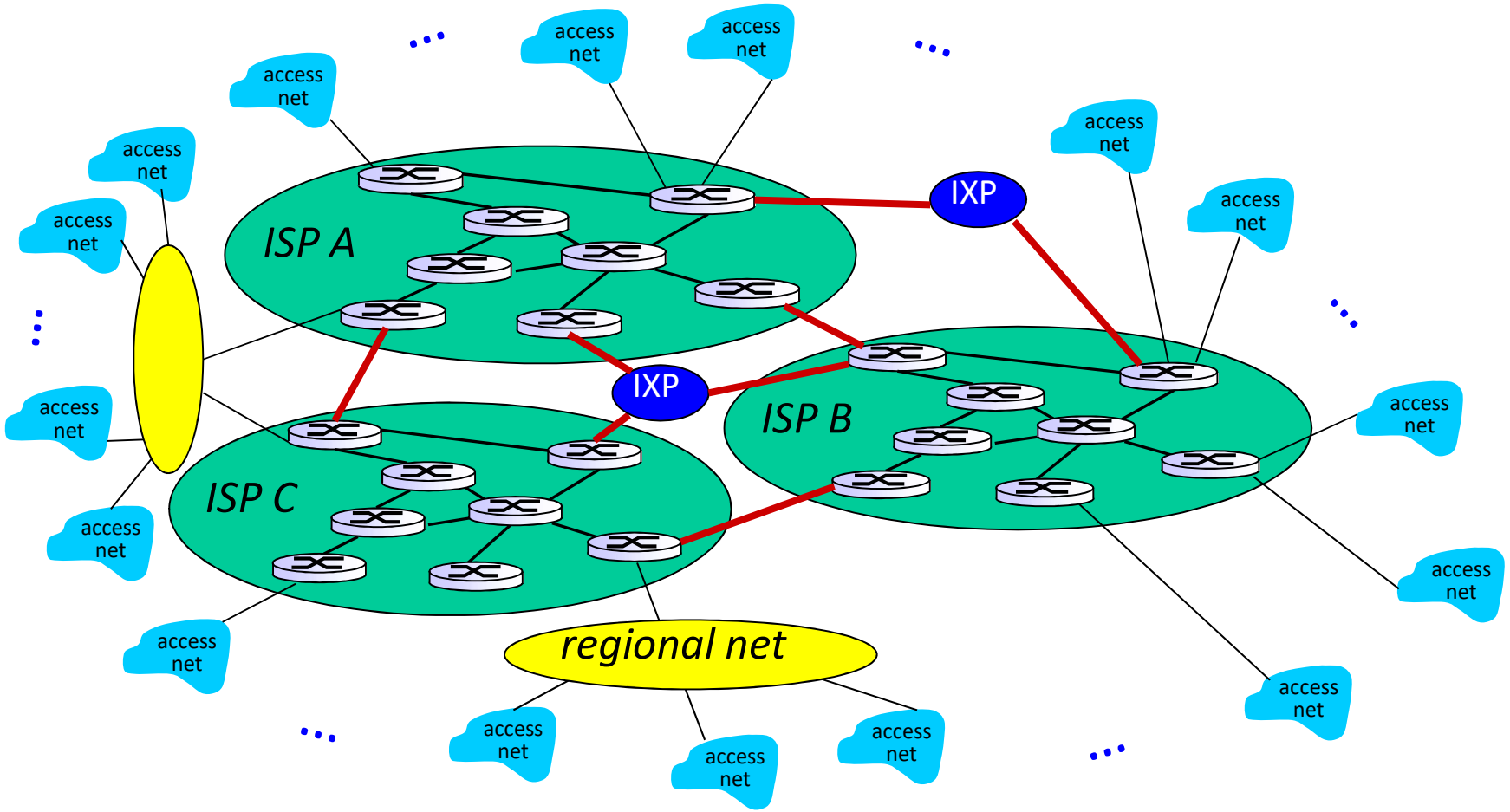
Network of networks

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



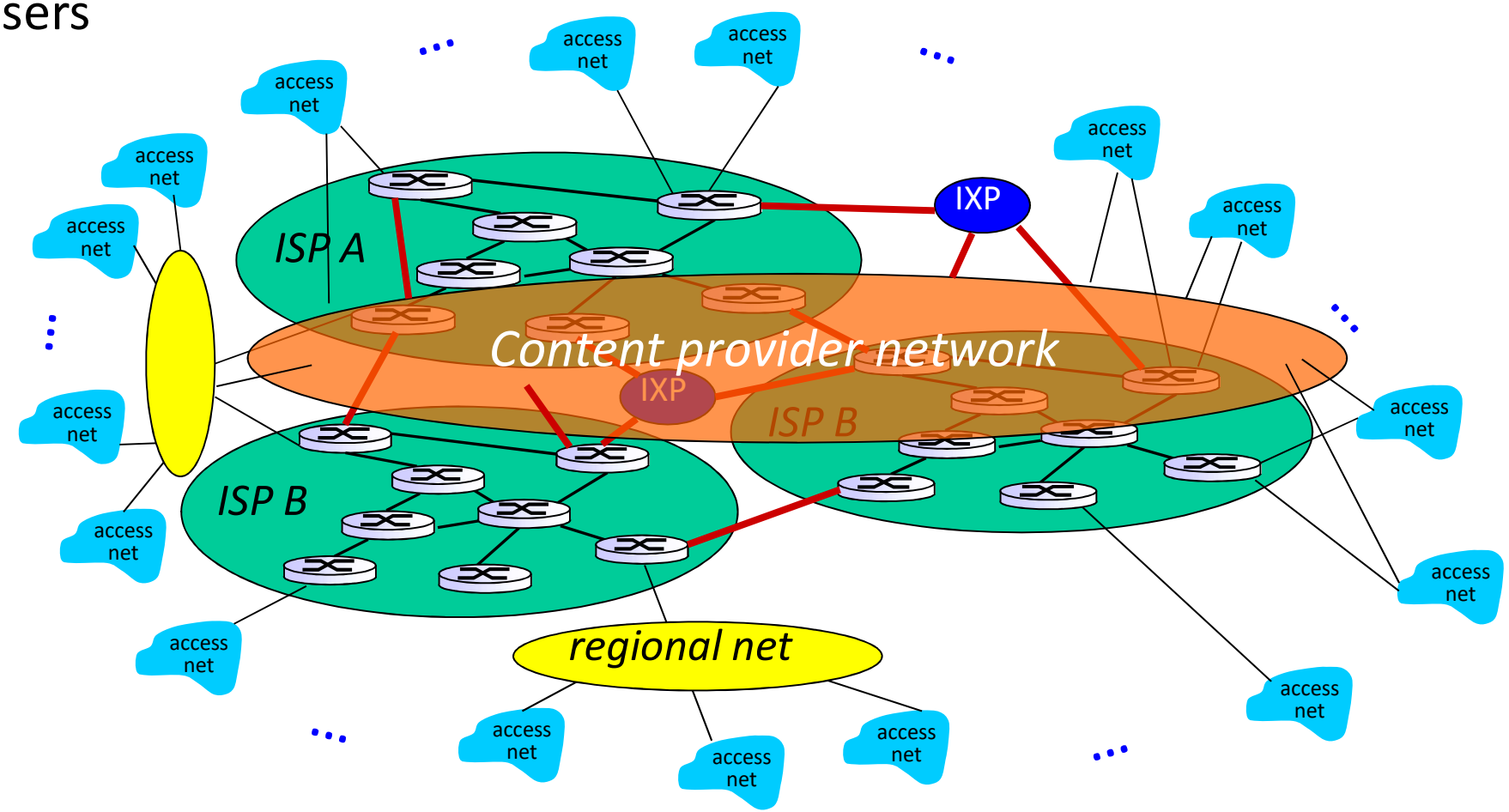
Network of networks

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

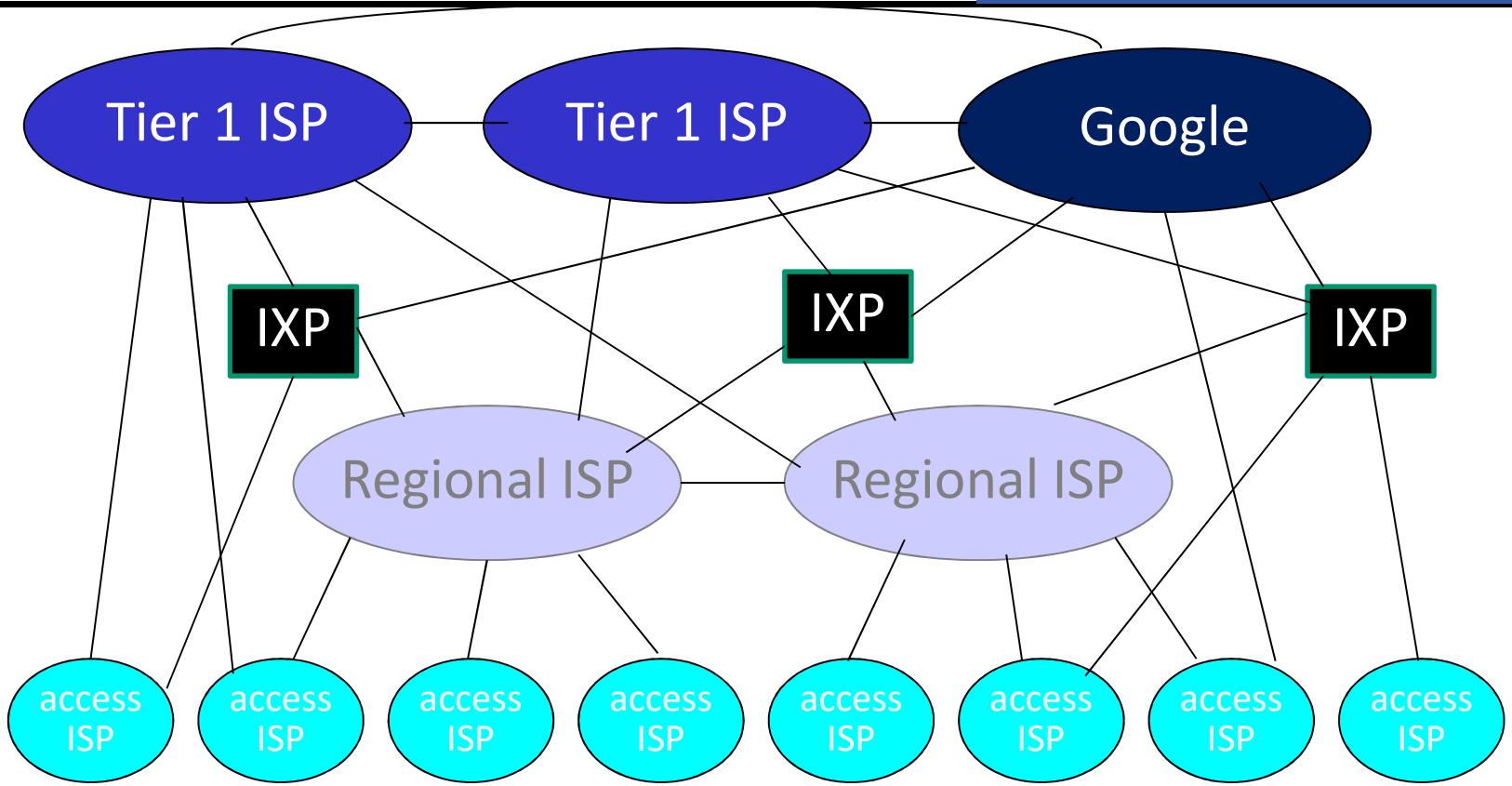


Network of networks

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



Network of networks



at center: small # of well-connected large networks

- "tier-1" commercial ISPs (e.g., Level 3, AT&T), national & international coverage
- content provider network (e.g, Google, Akamai): private network that connects it data centers or racks to Internet, often bypassing tier-1, regional ISPs