

CS3640

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# Overview (2): Network Edge & Core

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*Computer Science*  
*The University of Iowa*

# Previously on CS3640



## Course administrivia

Why I love networking and so should you!



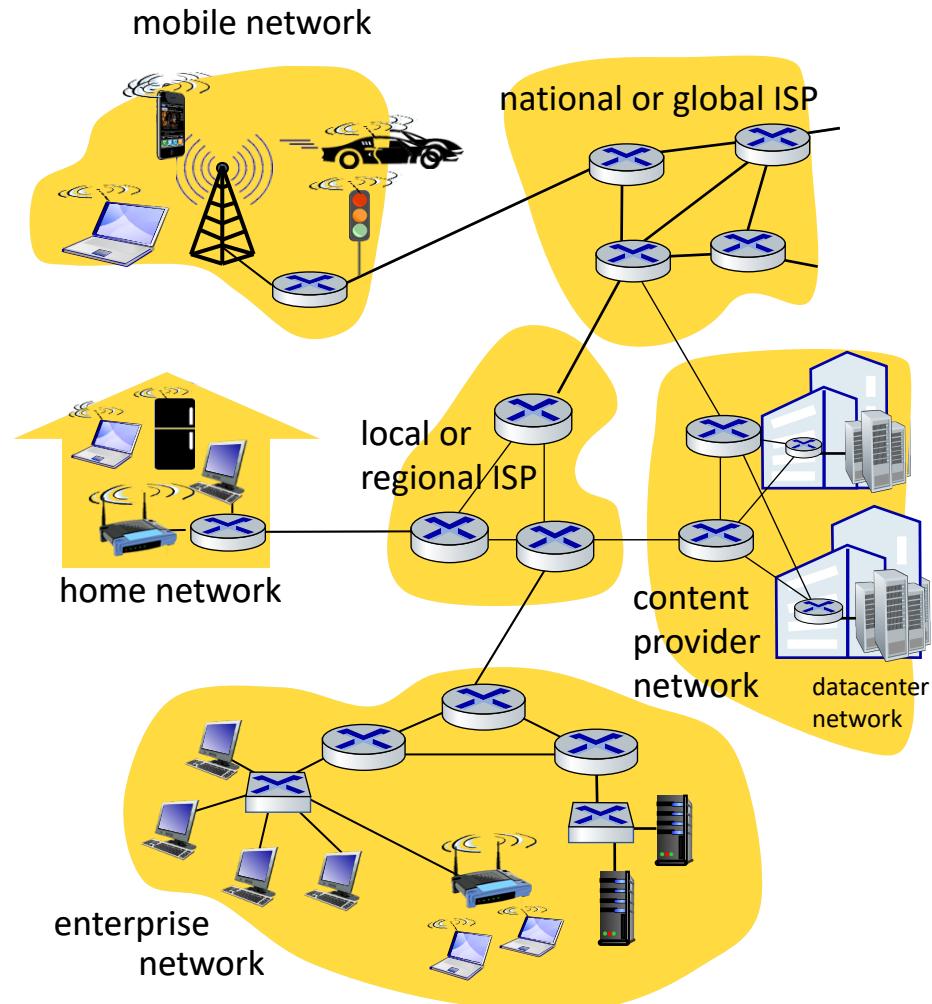
## What is the *Internet*?

A nuts and bolts engineering-centric view



## What is a networking *protocol*?

Think about a knock-knock joke

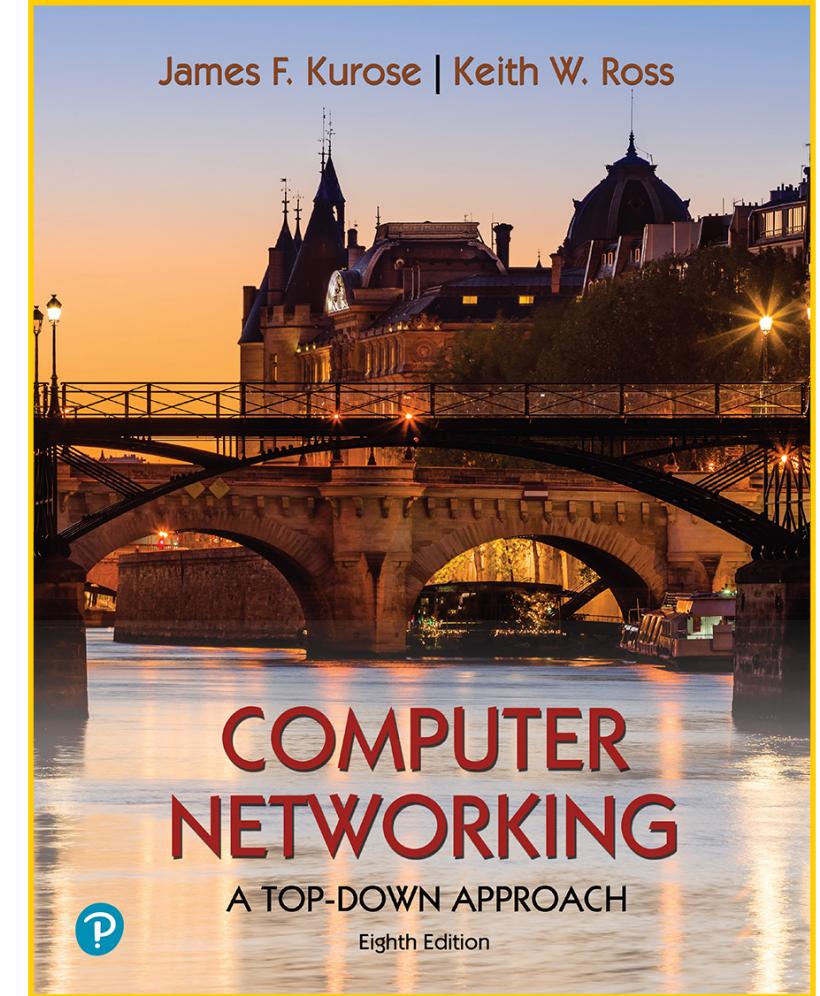


# Lecture goals

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*In-depth look into the structure and functioning of the Internet*

- *Network Edge*
- *Network Core*
- *Packet Switching*

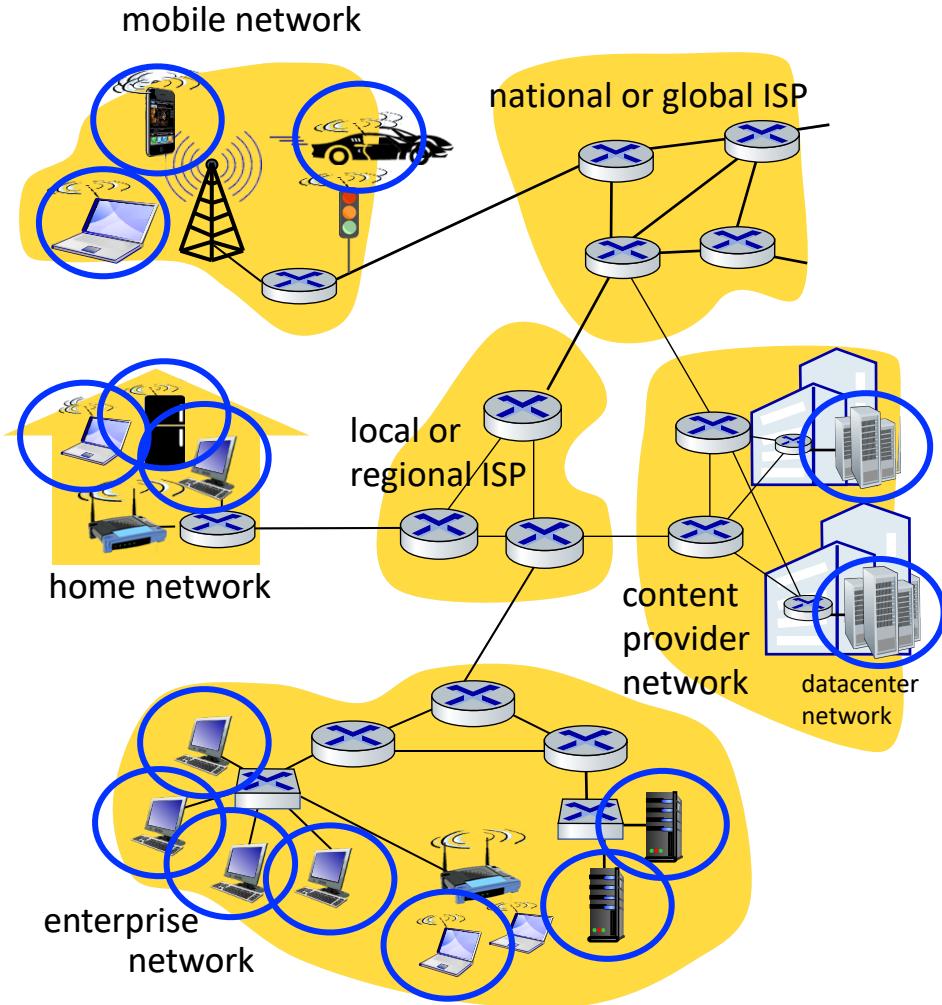


Chapter 1.2 - 1.3

# A closer look at Internet structure

## Network edge

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



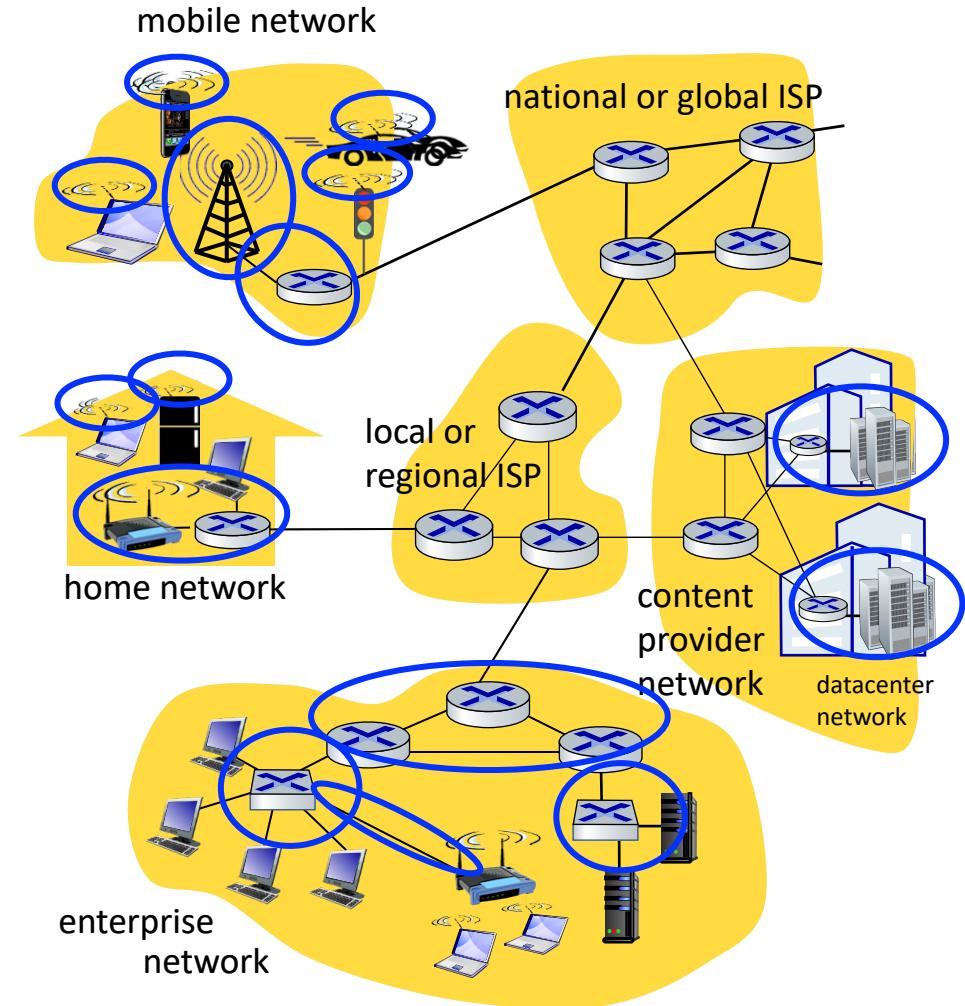
# A closer look at Internet structure

## Network edge

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

## Access networks

- wired, wireless communication links



# A closer look at Internet structure

## Network edge

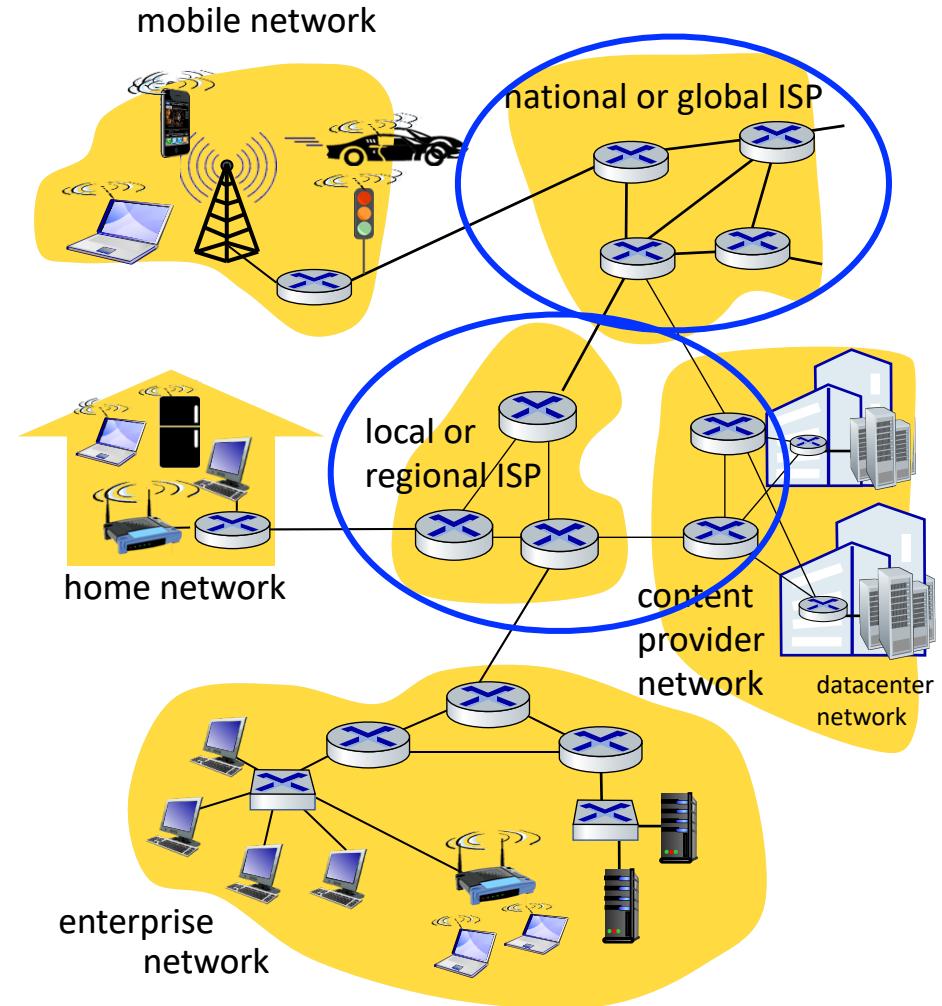
- hosts: clients and servers
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## Access networks

- wired, wireless communication links

## Network core

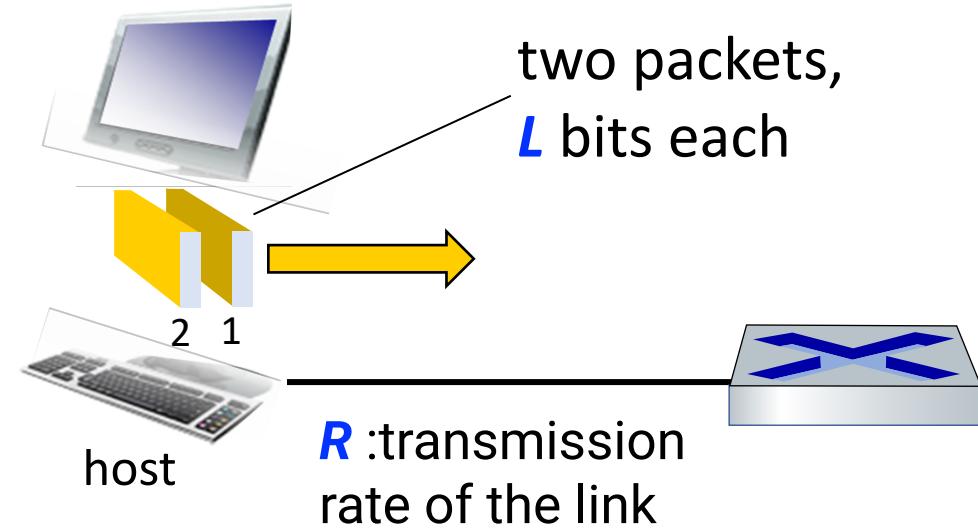
- interconnected routers
- network of networks



# Host perspective: sending packets of data

## Packet sending function

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



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

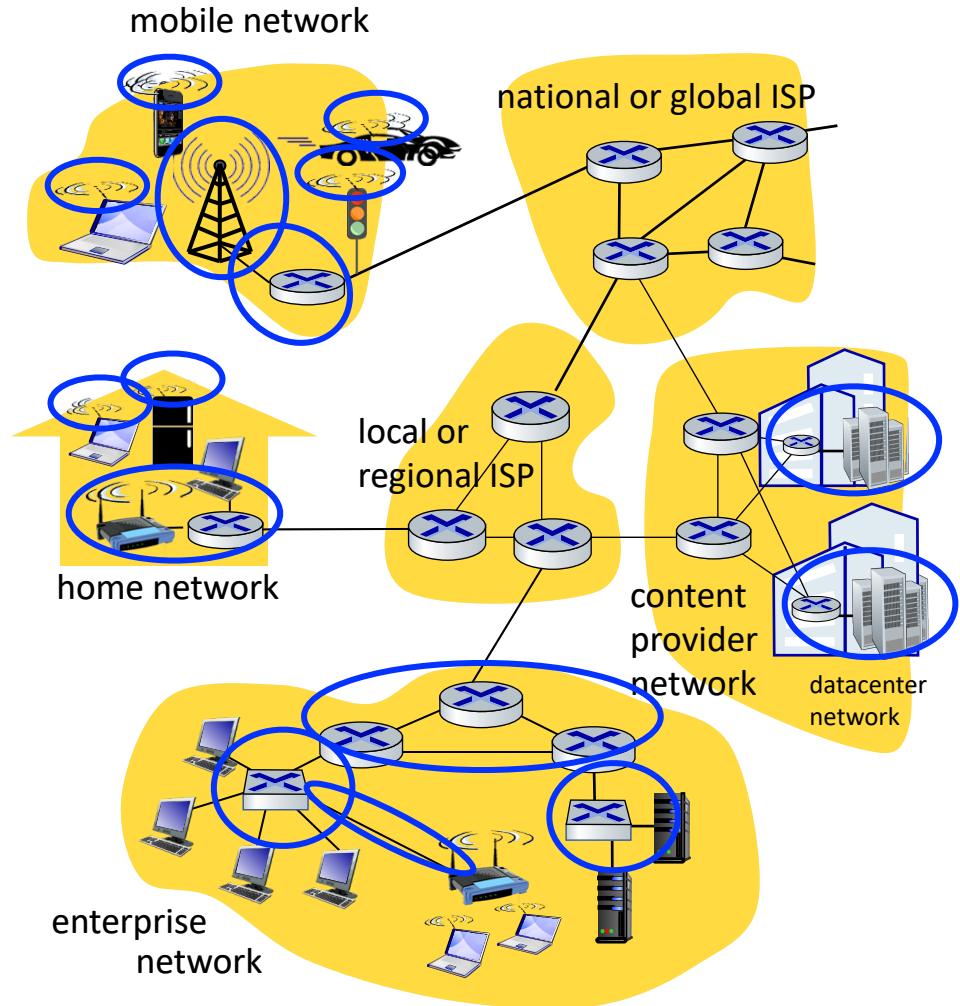
# Access networks

Q: How are edge devices connected to the network core?

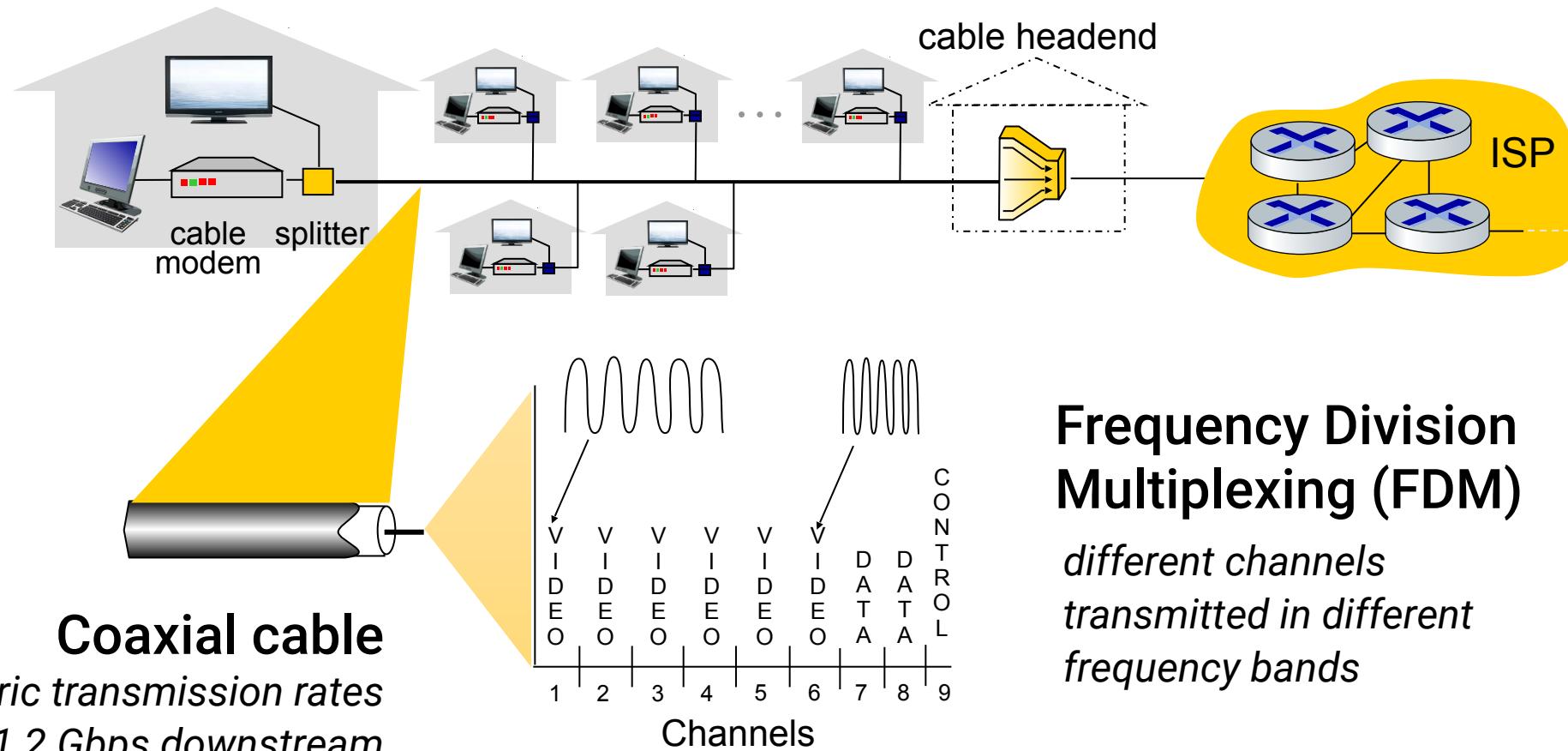
- **cable** based access
- **telephone line** based access
- **wireless or cellular** access
- **satellite** access

Access network characteristics

- Capacity of access networks
- Dedicated or shared access among hosts



# Access technology: cable-based

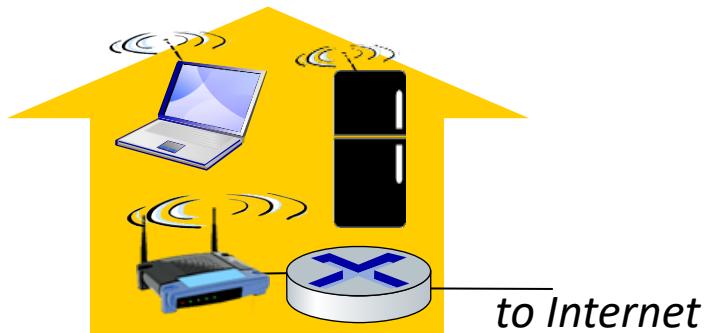


shared access

# Access technology: wireless

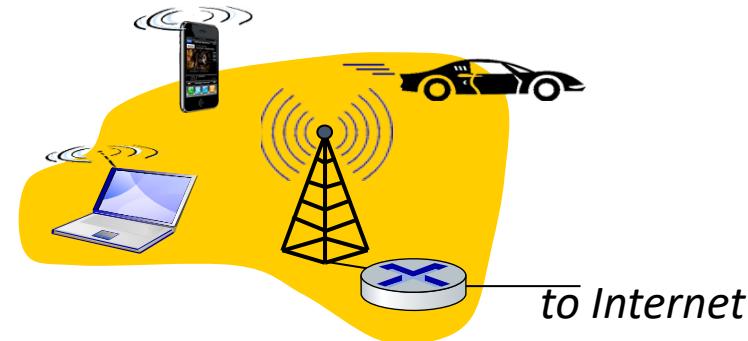
## Wireless local area networks (WLANs)

- 802.11b/g/n (WiFi)
- Within or around building (~100 ft)
- 11 - 450 Mbps transmission rate



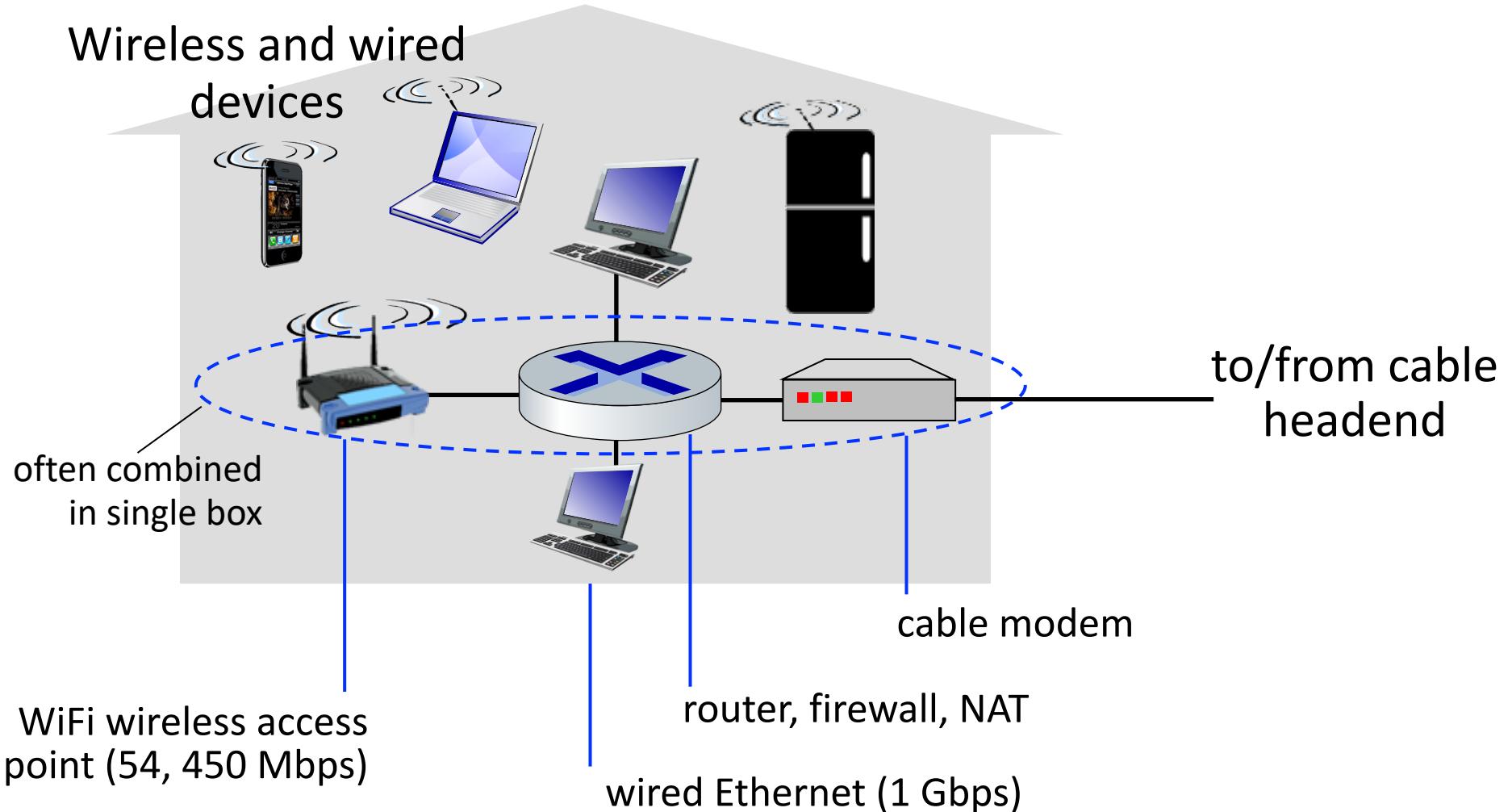
## Wide-area cellular networks

- Provided by cellular operators
- 3G and 4G cellular networks
- Range of 10's miles
- 10's Mbps transmission rate

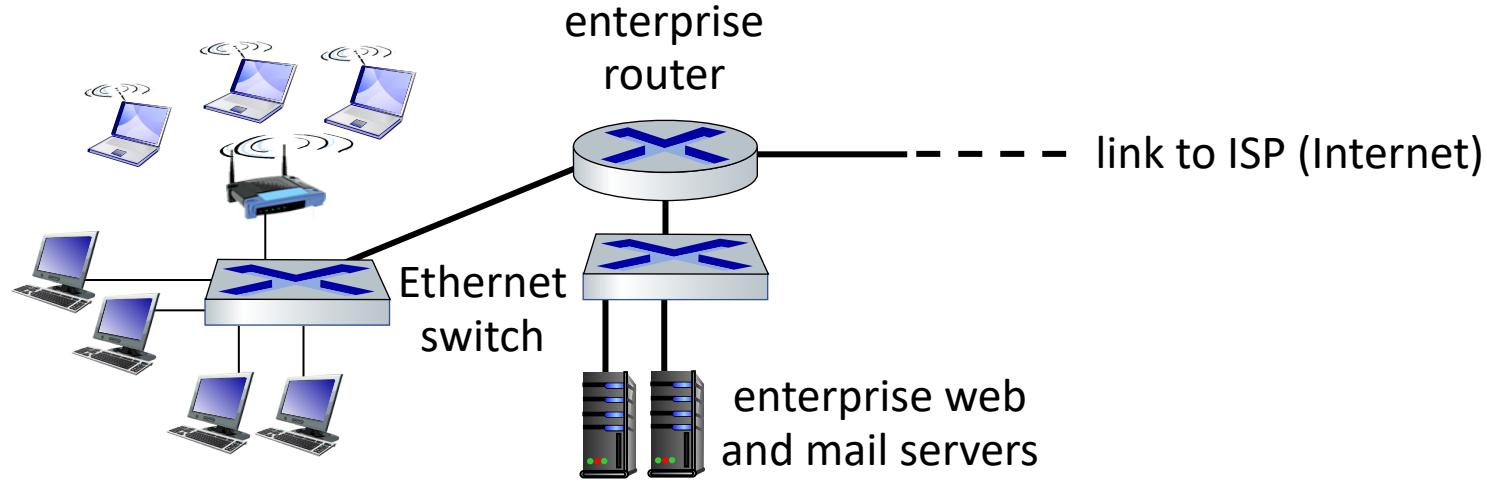


**shared access**

# Access networks: residential



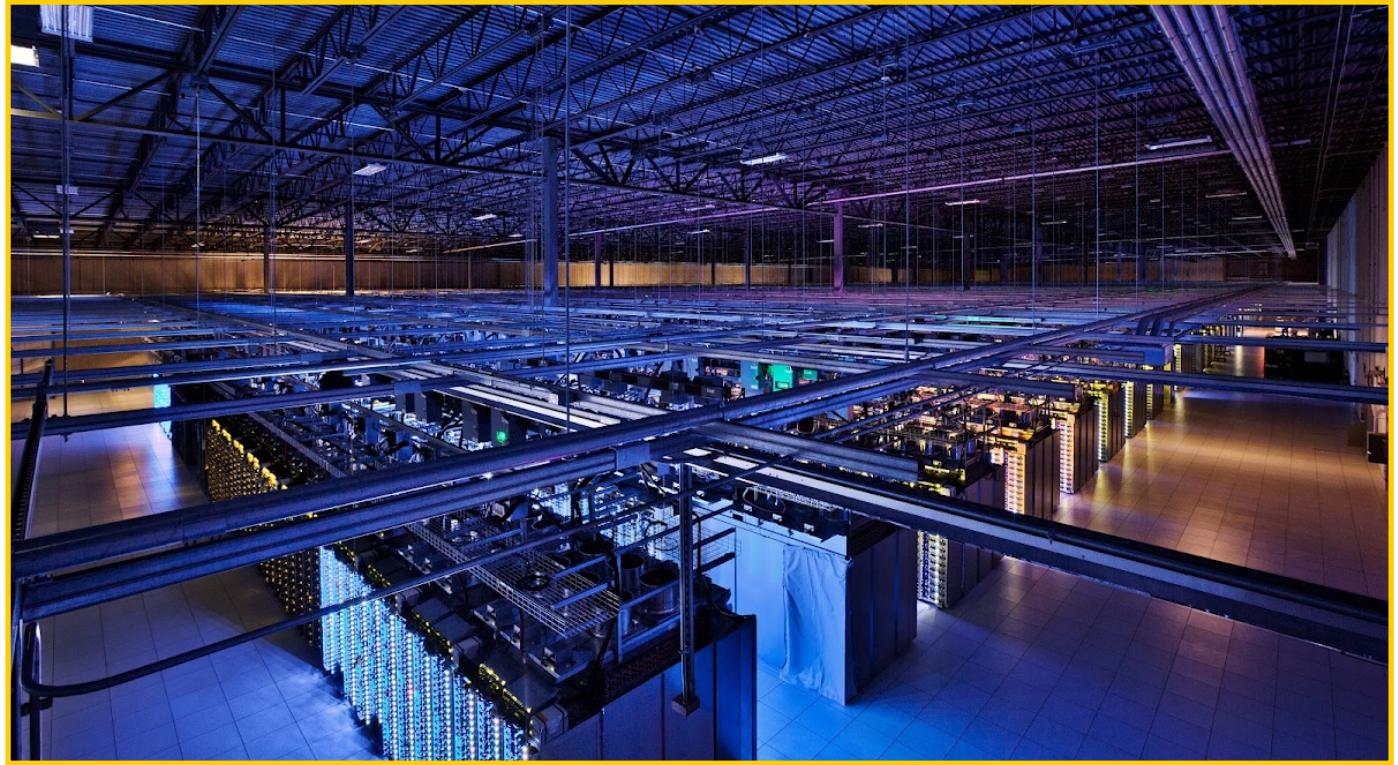
# Access networks: enterprise



- *Companies, universities, government agencies etc.,*
- *Mix of wired (e.g., Ethernet) and wireless (e.g., WiFi) technologies*
- *Connected with a hierarchy of switches and routers*

# Access networks: data center networks

- Hundreds to thousands of servers connected to each other and to Internet
- High-bandwidth wired links (1 to 100s Gbps)
- Switches and routers organized in intricate **topologies** to maximize bandwidth and minimize latency

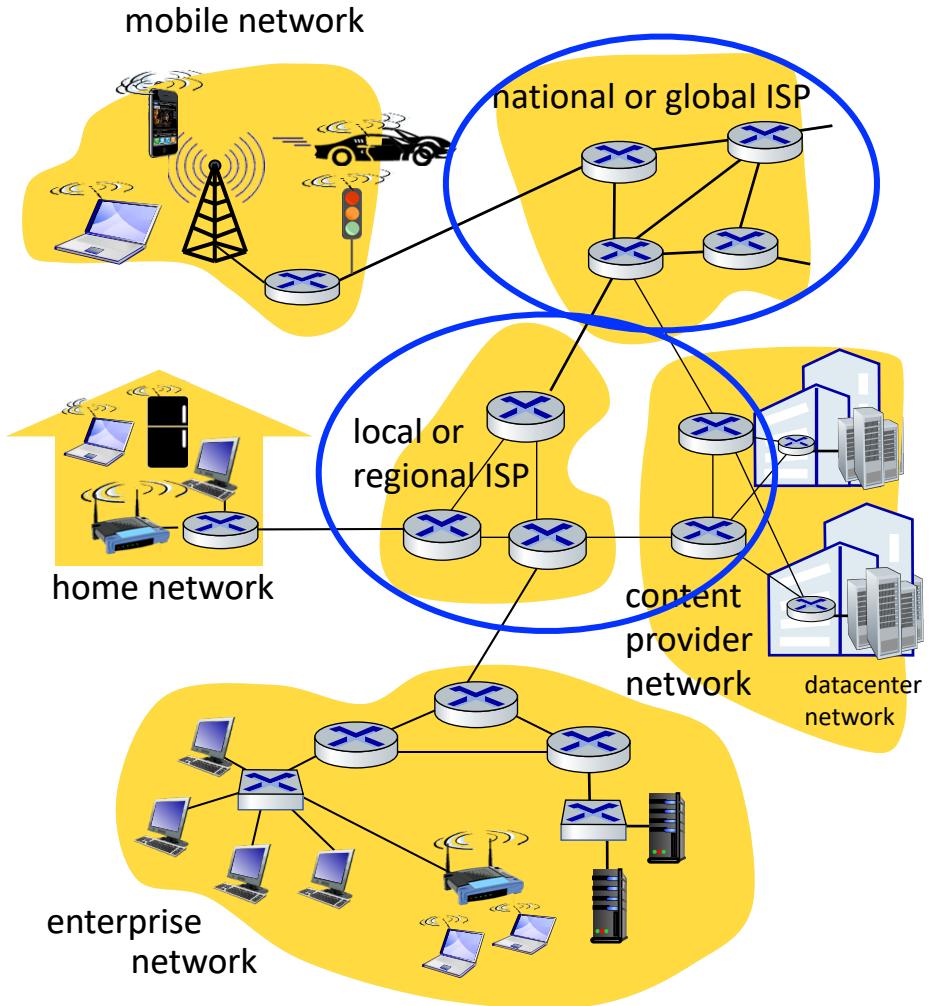


Google Datacenter in Council Bluffs, Iowa

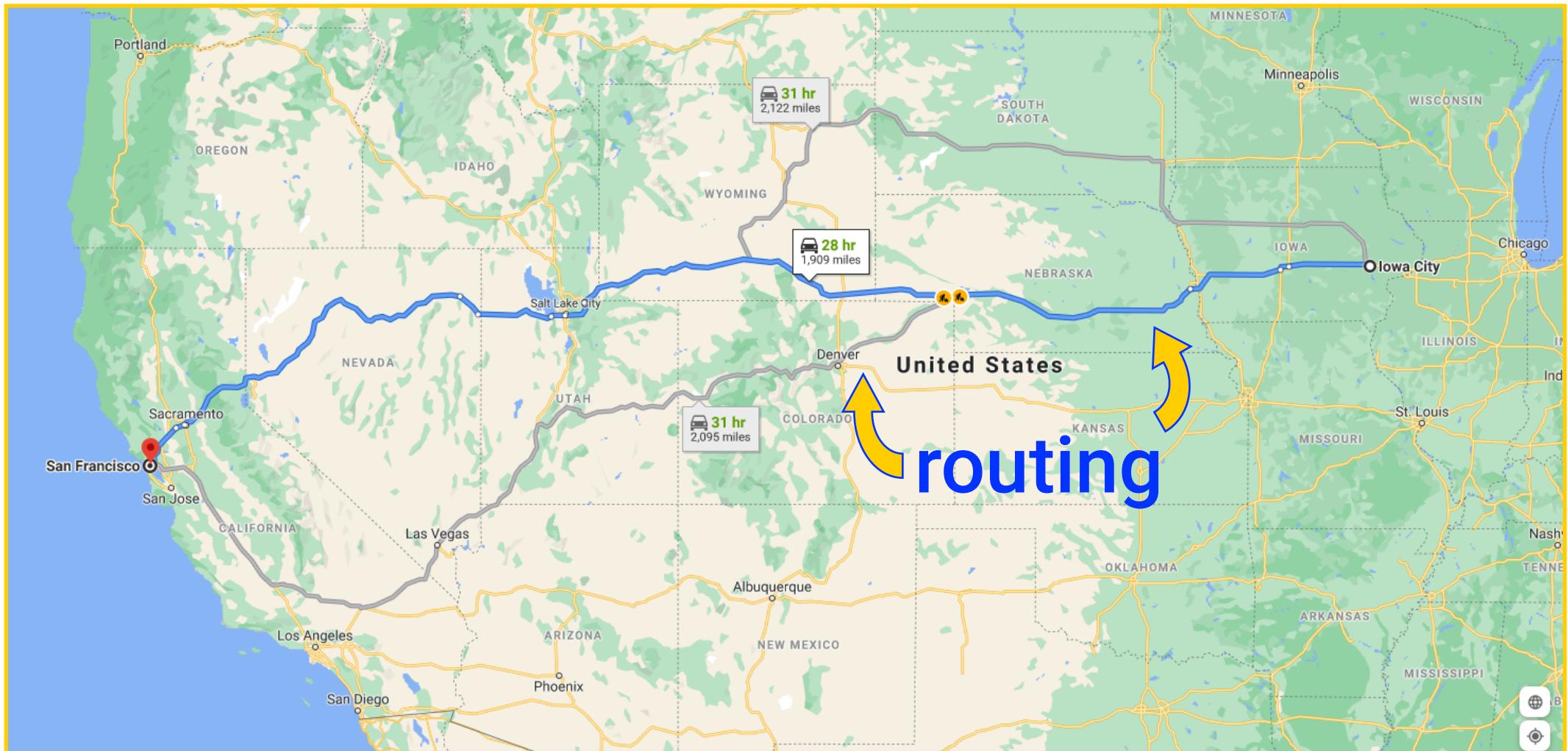
# **Network core and switching**

# The network core

- it is a mesh of interconnected routers
- it performs two key functionalities to move packets from source to destination
  - ➡ *routing*
  - ➡ *forwarding*



# Routing vs. forwarding



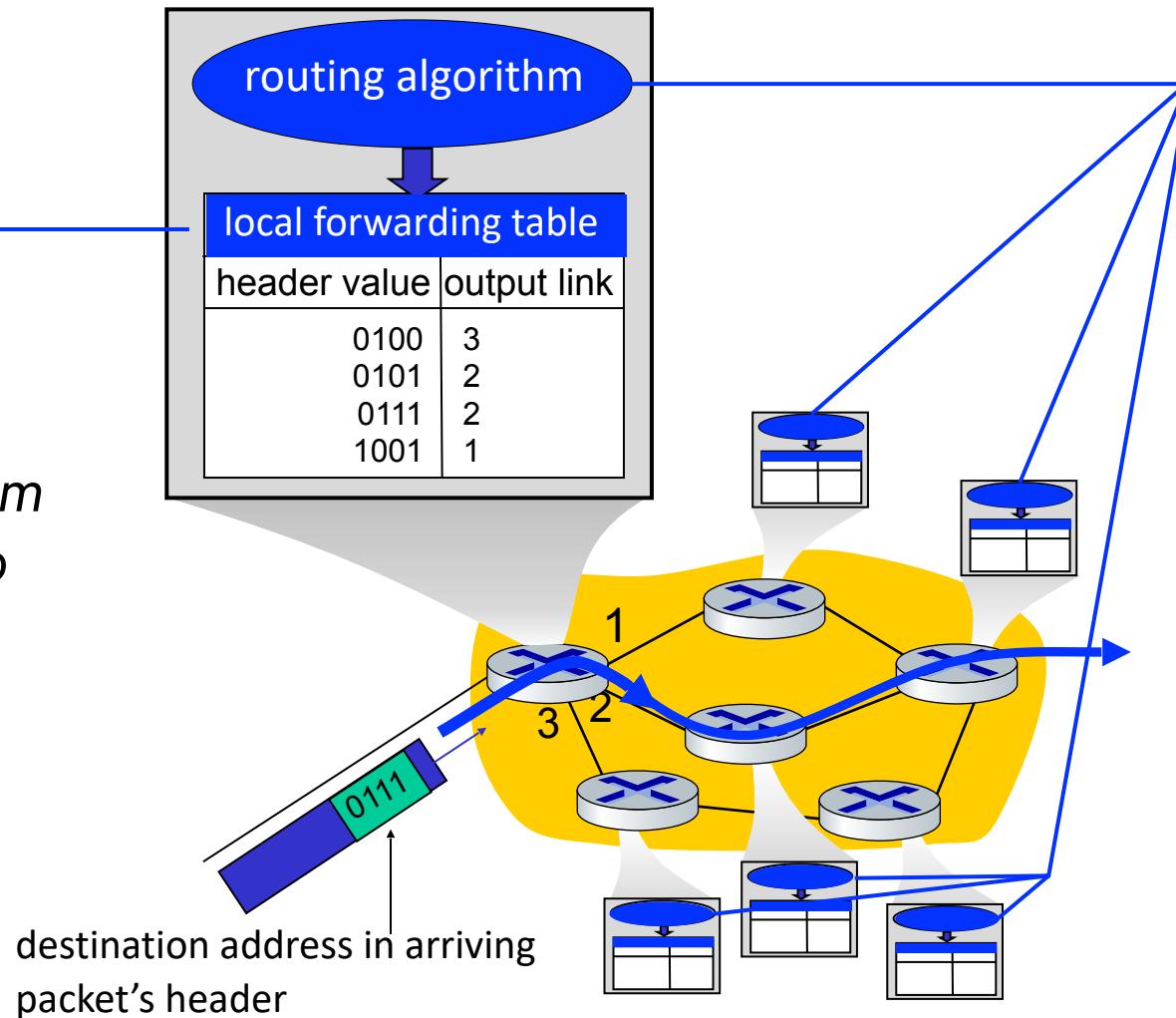
# Routing vs. forwarding



# Two key network-core functions

## Forwarding

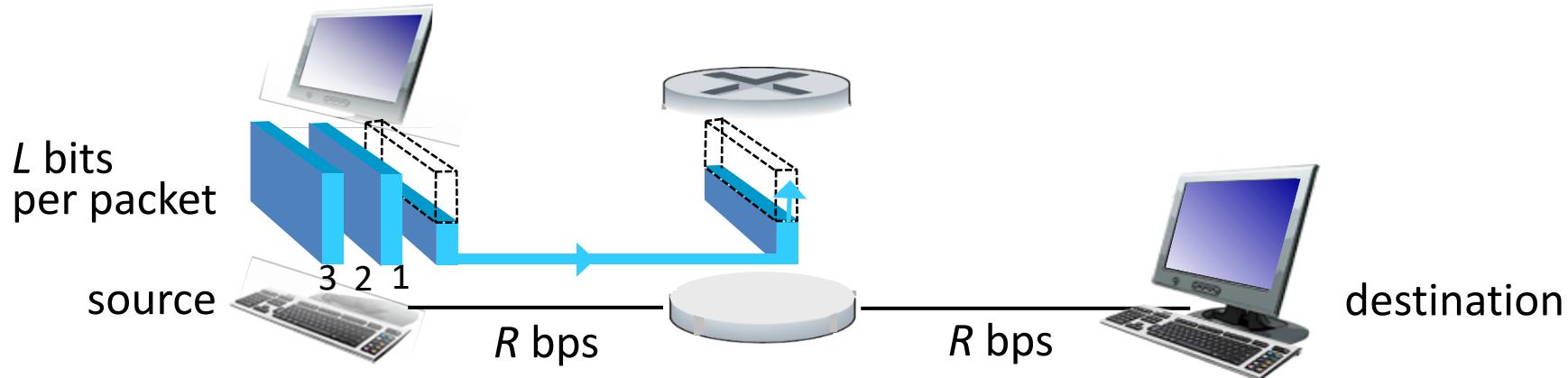
- aka “switching”
- **local action:** move arriving packets from router’s *input link* to appropriate router *output link*



## Routing

- **global action:** determine source-destination paths taken by packets
- **routing algorithms**

# Packet-switching: store-and-forward



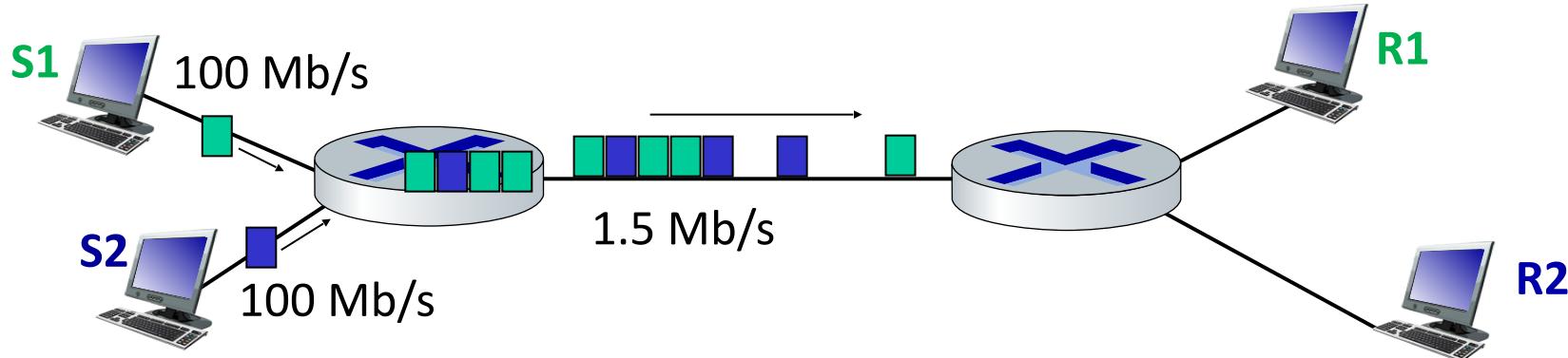
**packet transmission delay:** takes  $L/R$  seconds to transmit (push out)  $L$ -bit packet into link at  $R$  bps

**store and forward:** entire packet must arrive at router before it can be transmitted on next link

## One-hop example

- $L = 10 \text{ Kbits}$
- $R = 100 \text{ Mbps}$
- one-hop transmission delay =  $0.1 \text{ msec}$

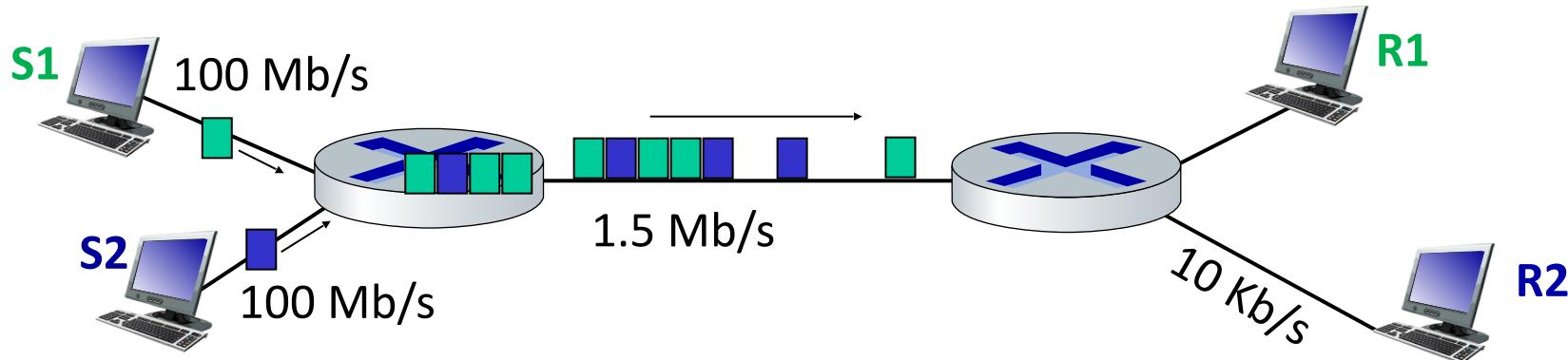
# Packet-switching: queueing



*Queueing* occurs when  
work arrives faster than it  
can be serviced



# Packet-switching: queueing



## Packet queuing and loss

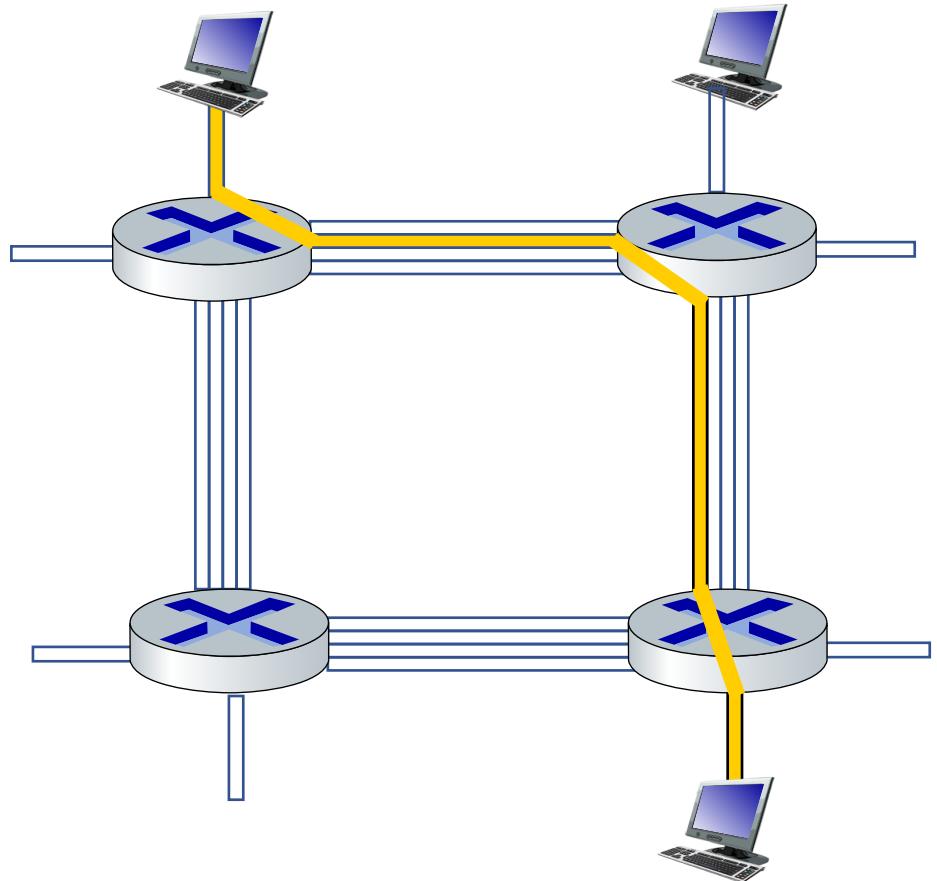
*if arrival rate to link exceeds its transmission for some period of time,*

- packets will queue, waiting to be transmitted on output link
- packets can be dropped (lost) if memory (buffer) in router fills up

# An alternative: circuit switching

End-end resources are allocated and reserved for the “call” between source and destination

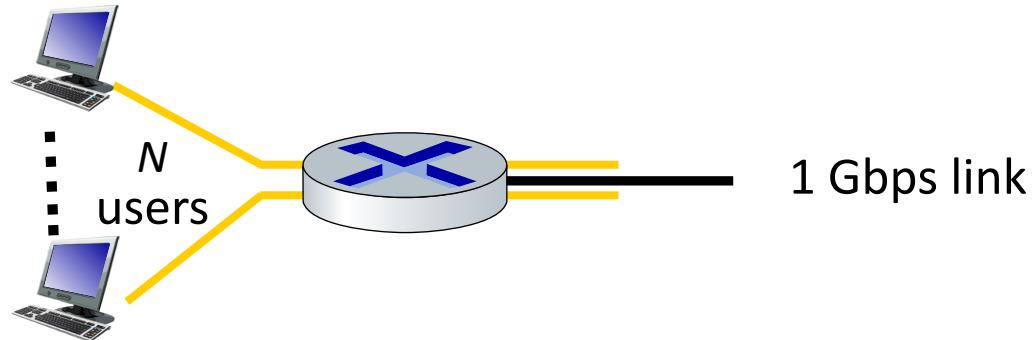
- each link has four circuits
- our call is allocated 2nd circuit in top link and 1st circuit in right link
- dedicated resources: no sharing
- guaranteed performance
- circuit segments remain idle if not used by call
- commonly used in traditional telephone networks



# Packet switching vs. circuit switching

N users, each of them is

- active 10% of time
- use 100 Mb/s when “active”



How many users can use this network under circuit-switching and packet switching?

**10**

*Circuit switching*

**>10**

*Packet switching*

With **35** users  
probability that **>10**  
are active at the same time is

**< 0.0004**

# Packet switching vs. circuit switching

Is packet switching a “slam dunk winner”?

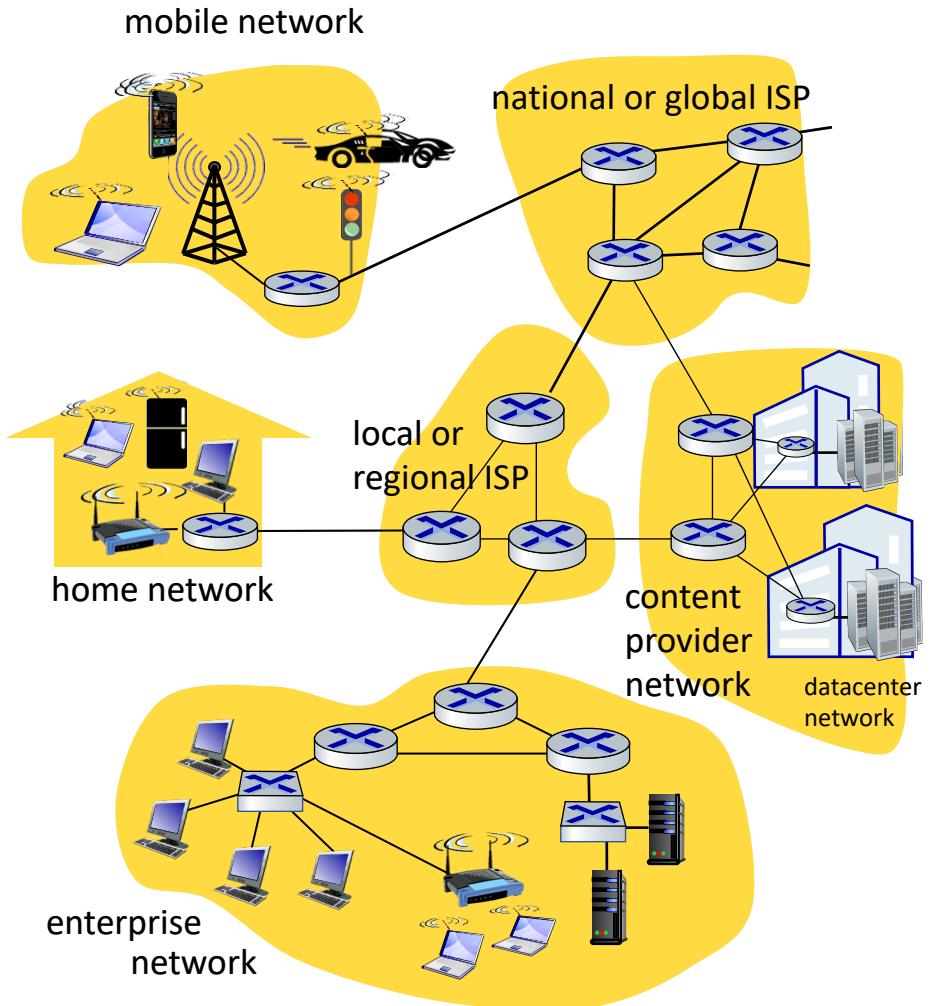
- Great for “bursty” data
  - *efficient resource sharing via statistical multiplexing*
  - *simpler call setup with no a priori reservations*
- Congestion could occur
  - *packets could be delayed or lost due to buffer overflow*
  - *protocols are needed for reliable data transfer, congestion control*

Is there a way to get circuit-like behavior with packet switching?

- Possible but complicated (*we have three dedicated lectures studying TCP*)

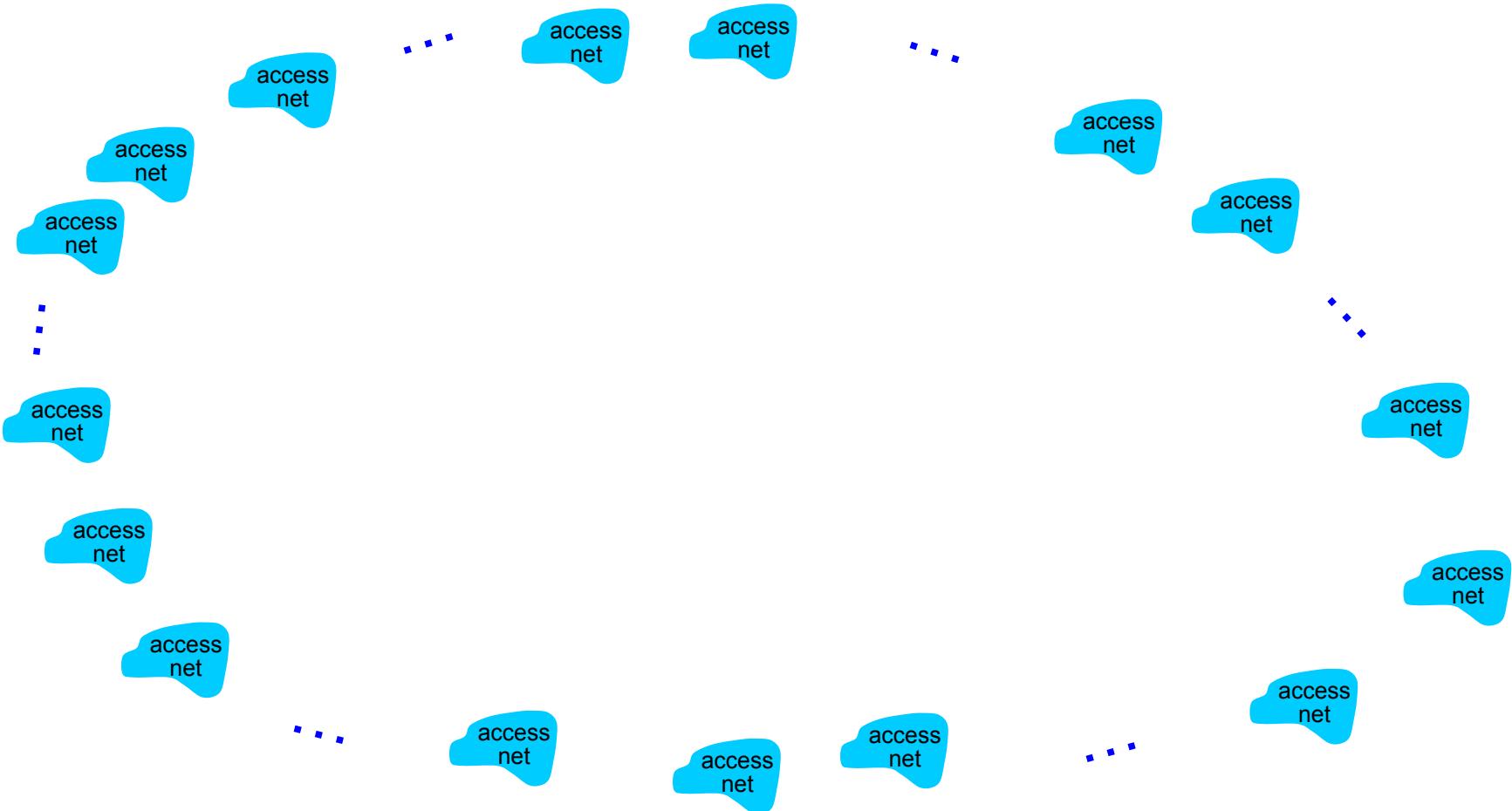
# Internet structure: a network of networks

- hosts connect to Internet via access **Internet Service Providers (ISPs)**
- these access ISPs in turn must be interconnected
  - ▶ *to allow that any pair of hosts (anywhere!) to send packets to each other*
- resulting network of networks is complex
  - ▶ *evolution driven by economics, national policies*



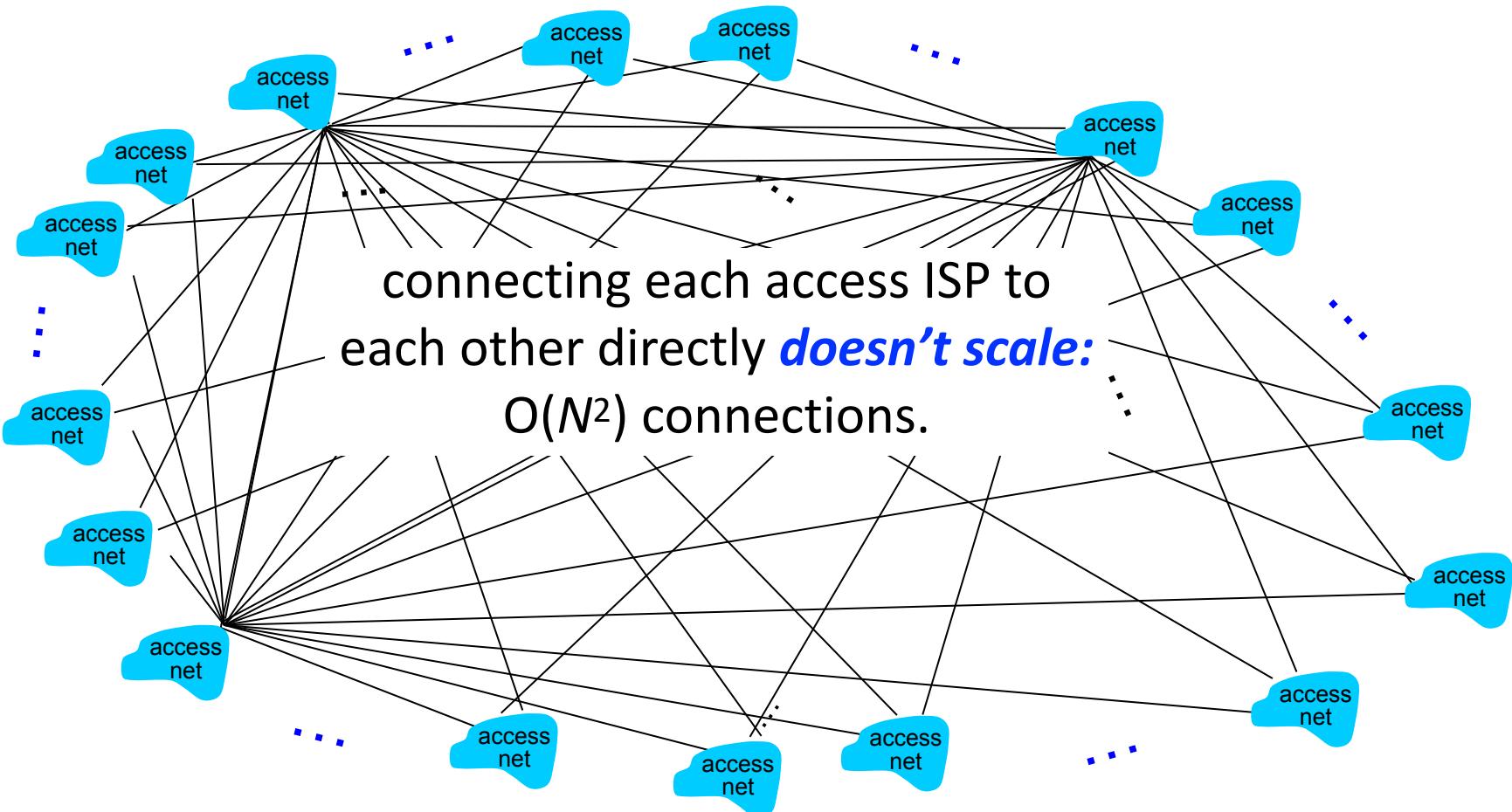
# Internet structure: a network of networks

How to connect *millions* of access ISPs together?



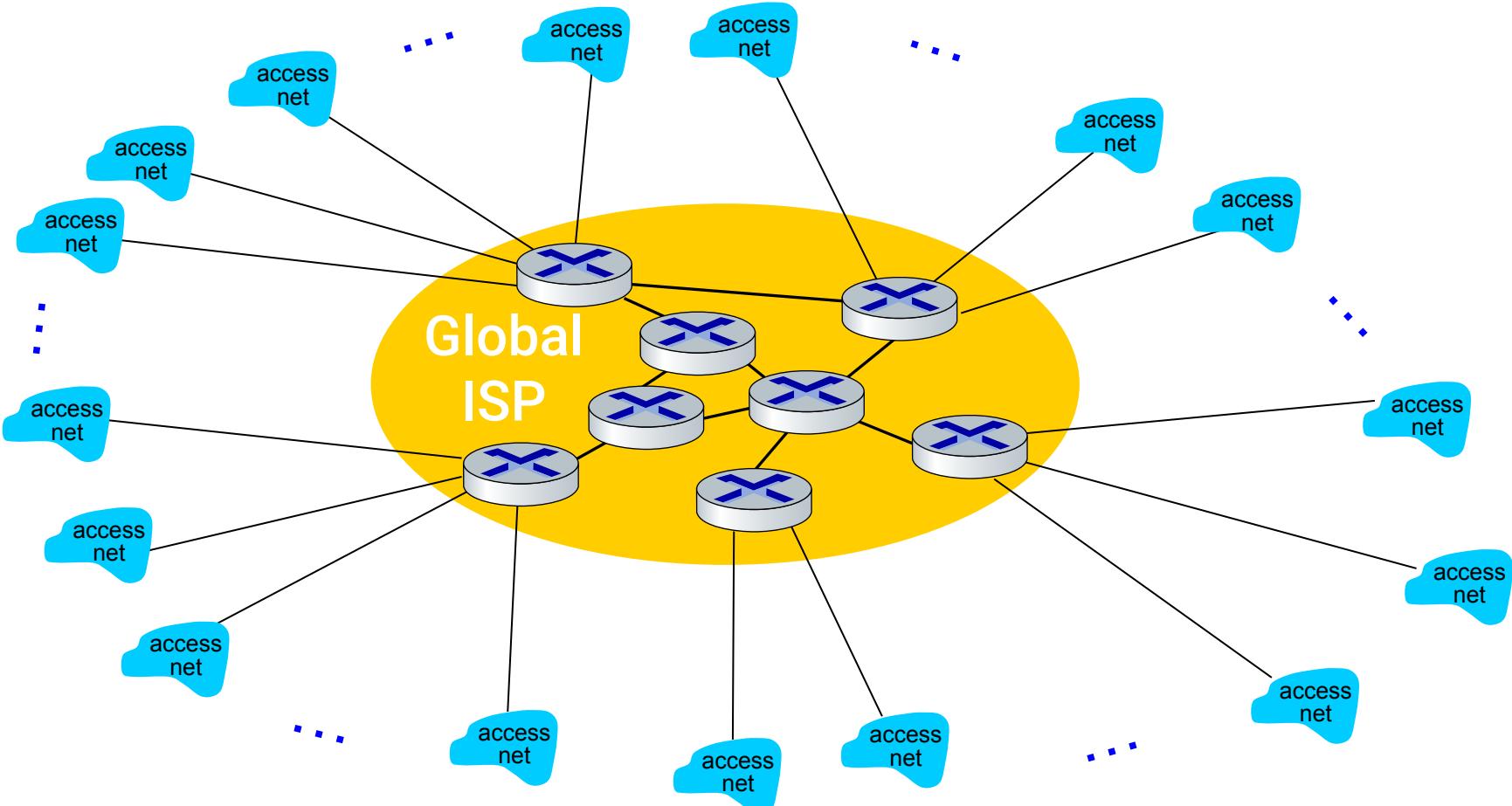
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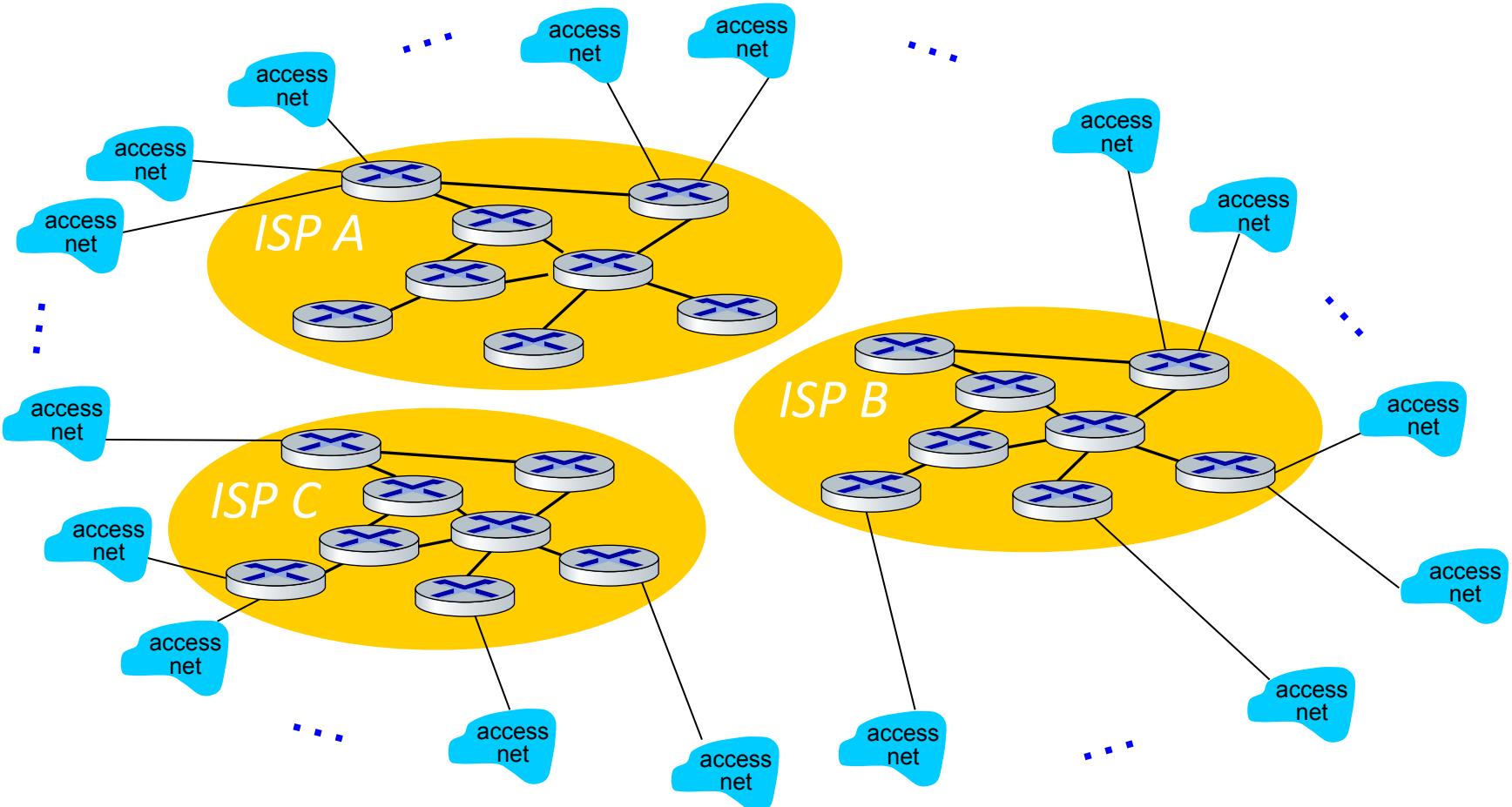
# Internet structure: a network of networks

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



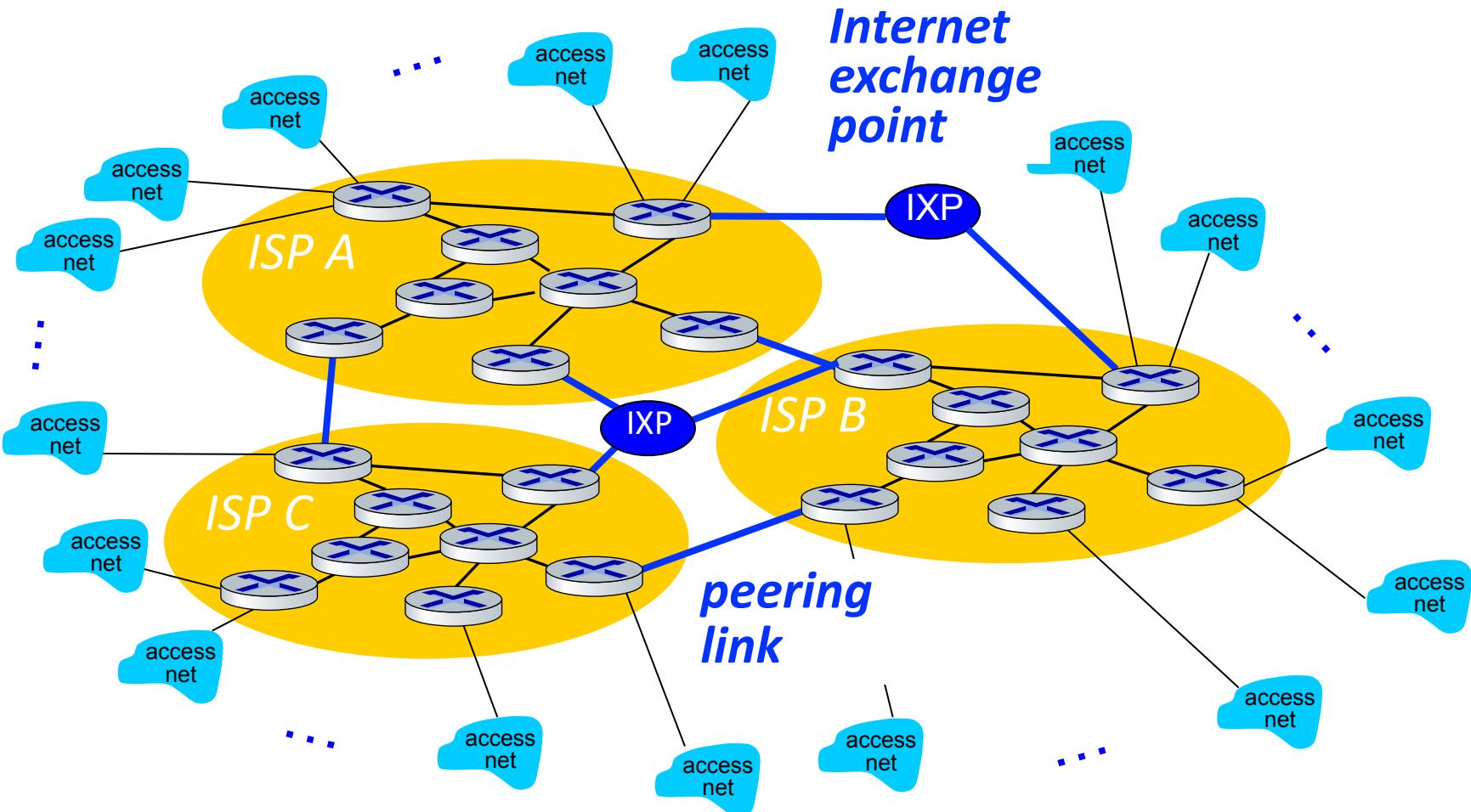
# Internet structure: a network of networks

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



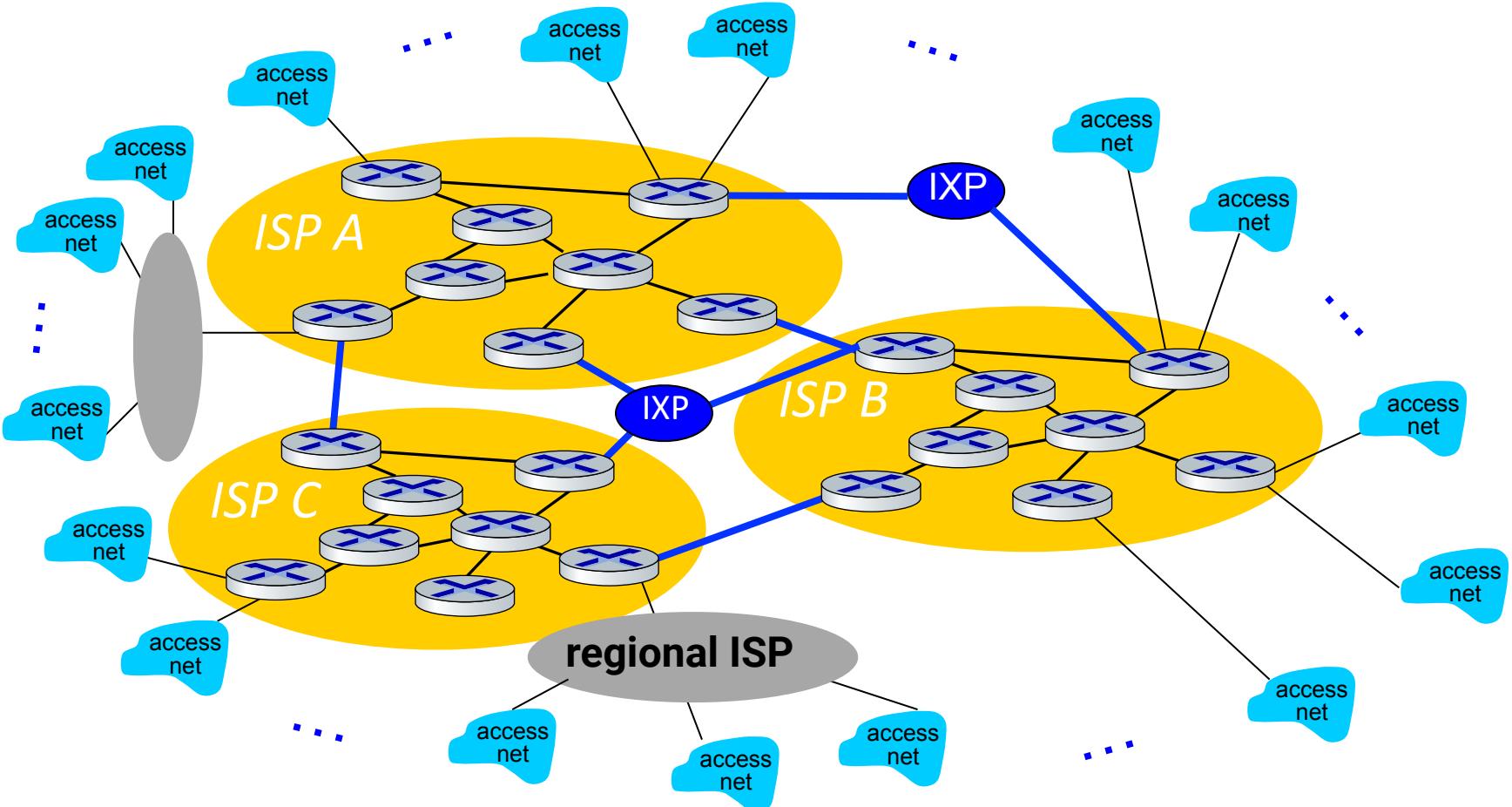
# Internet structure: a network of networks

But if one global ISP is viable business, there will be competitors...  
who will want to be connected



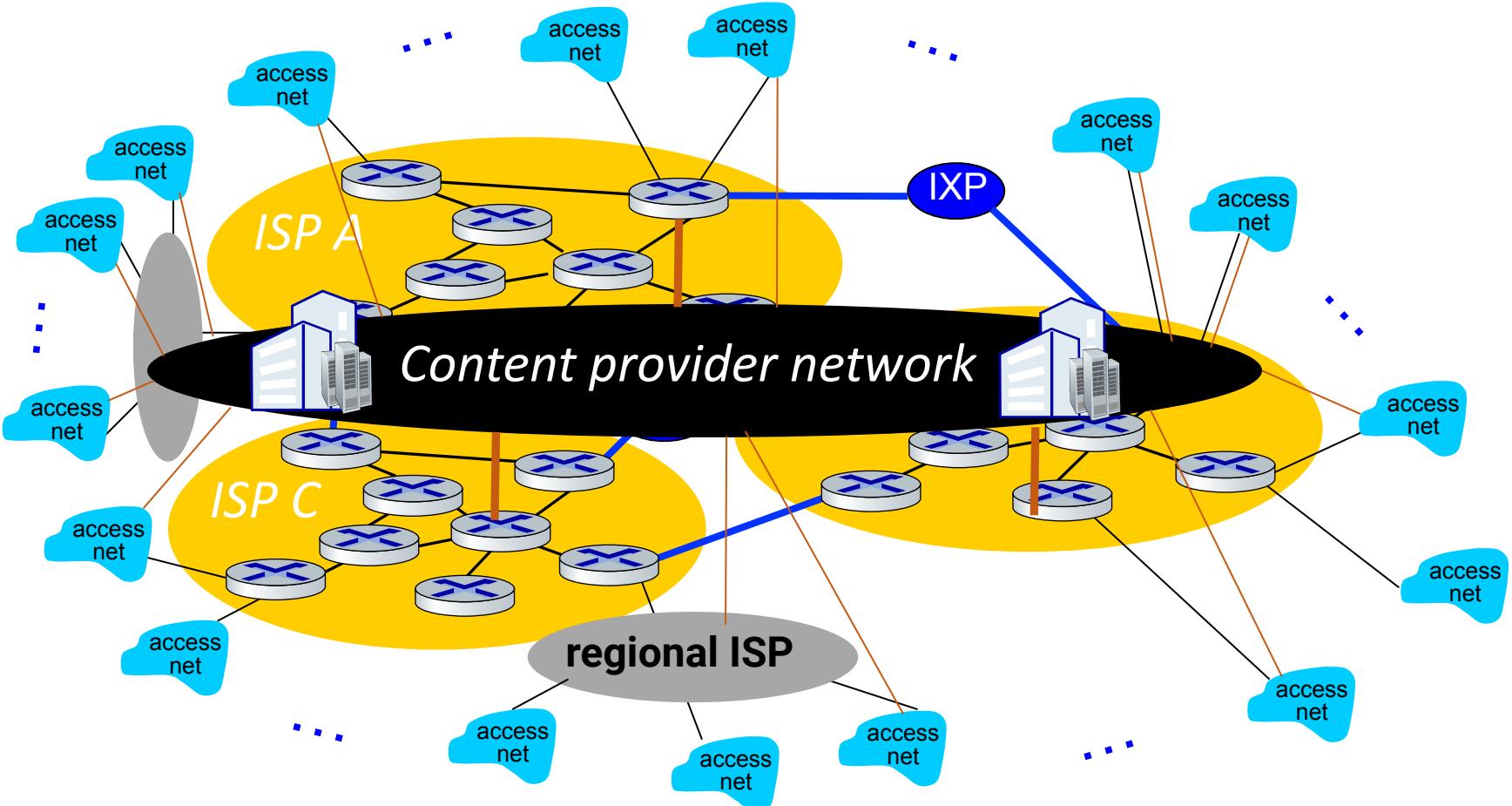
# Internet structure: a network of networks

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

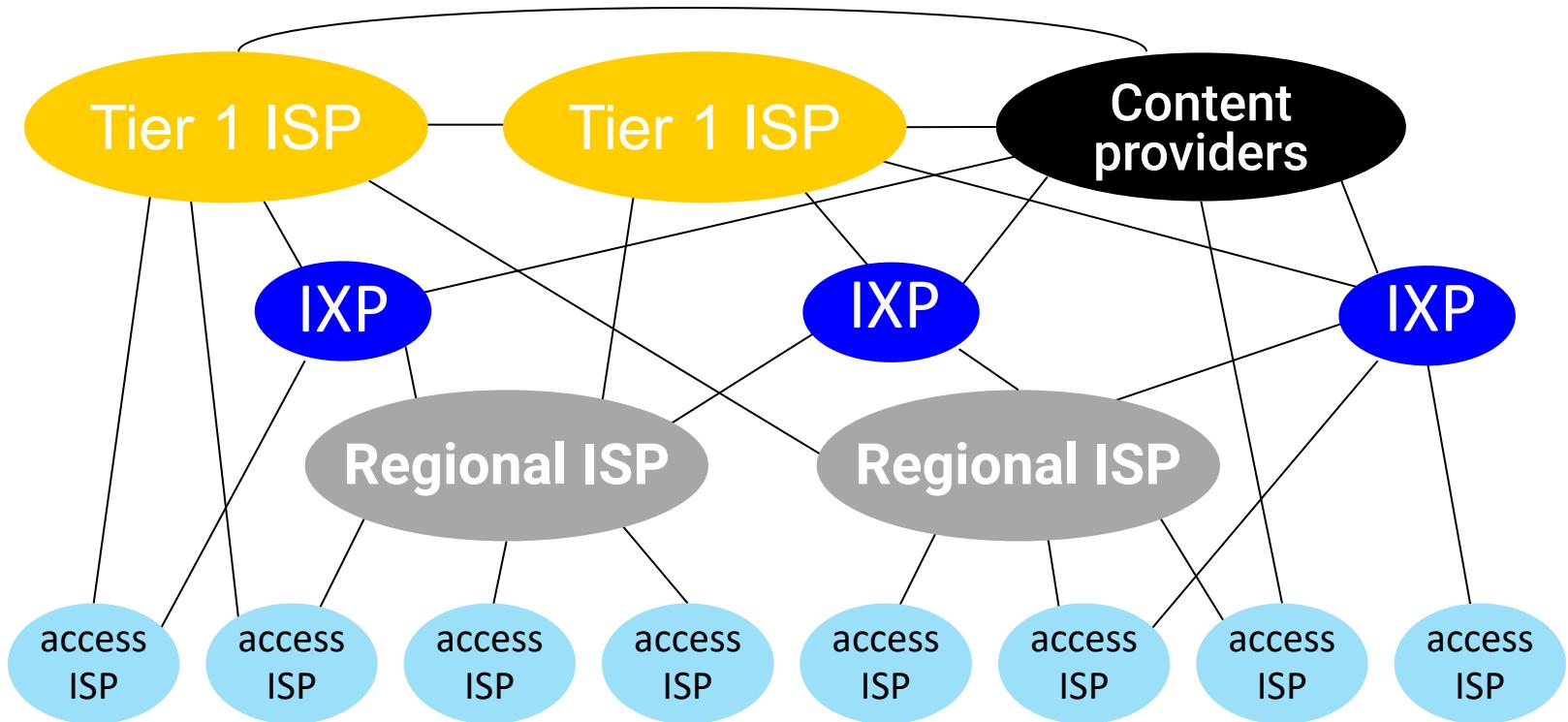


# Internet structure: a network of networks

... and content providers (e.g., Google, Akamai, Amazon) may run their own network



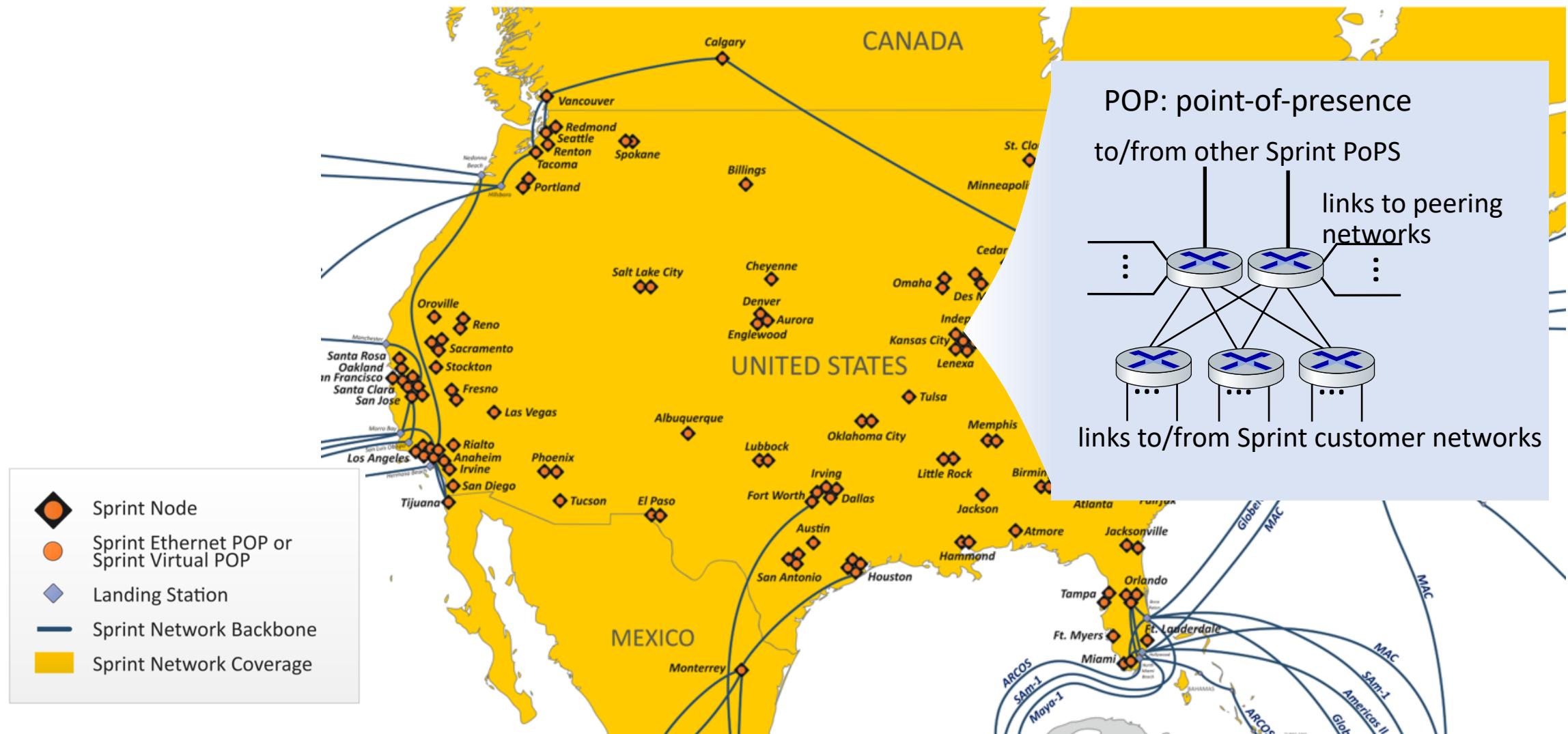
# Internet structure: a network of networks



**At the center: a small number of well-connected large networks**

- “tier-1” commercial ISPs (e.g., Level 3, Sprint, AT&T) for national & international coverage
- content provider networks (e.g., Google, Akamai, Amazon): private networks that connect data centers to Internet, often bypassing tier-1 and regional ISPs

# Tier-1 ISP network: Sprint (circa 2019)



# Content provider network: Google (circa 2017)

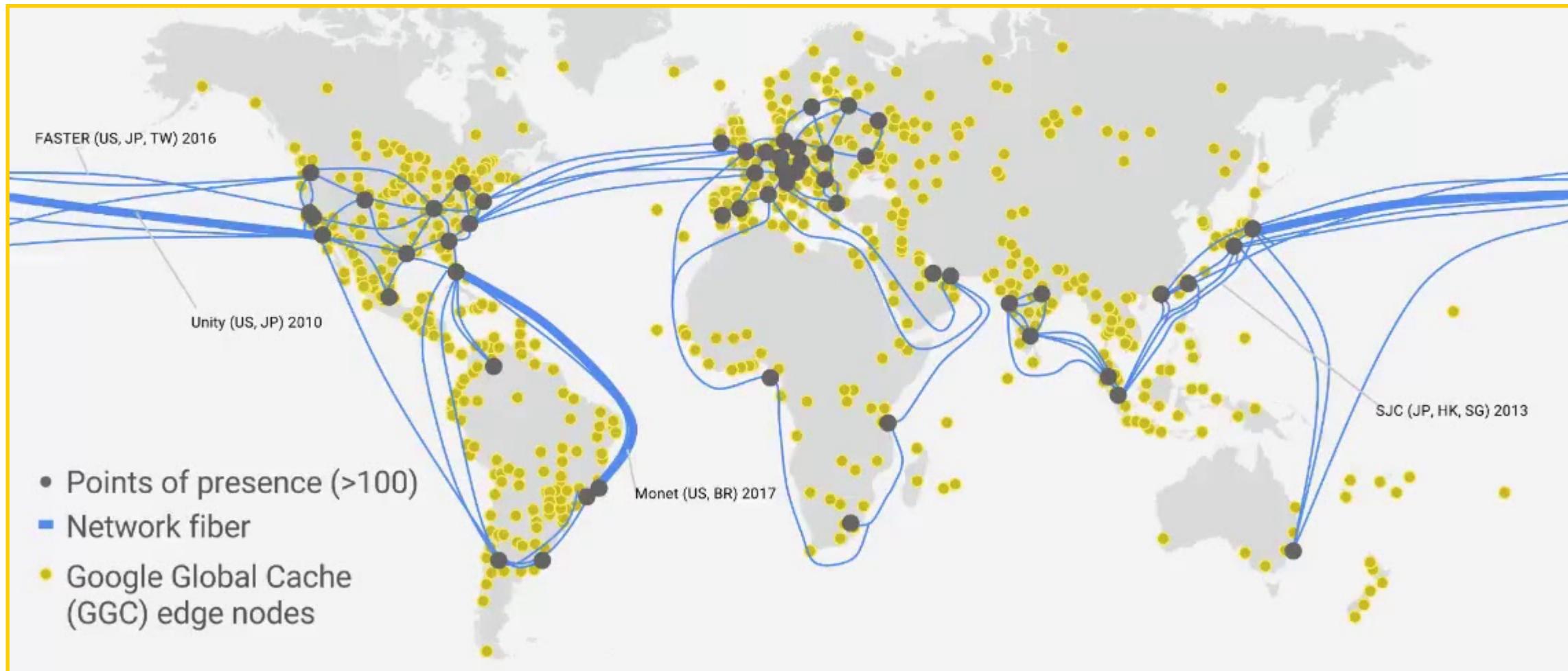


Image courtesy: Google cloud

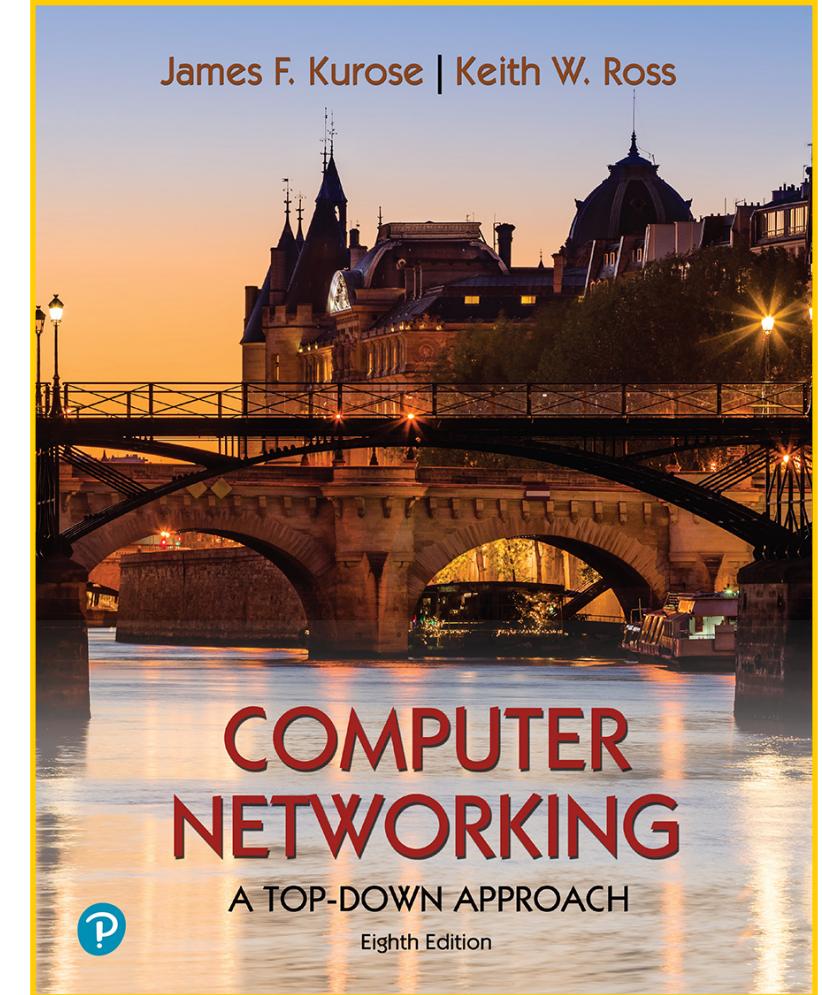
James F. Kurose | Keith W. Ross

# Next Lecture

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*Continuing our in-depth exploration  
into the structure and functioning  
of the Internet*

- *Network performance*
- *Protocol architecture*



Chapter 1.4 - 1.5

# **Spot Quiz (ICON)**