Chapter 1 Introduction

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adapted from textbook slides by JFK/KWR

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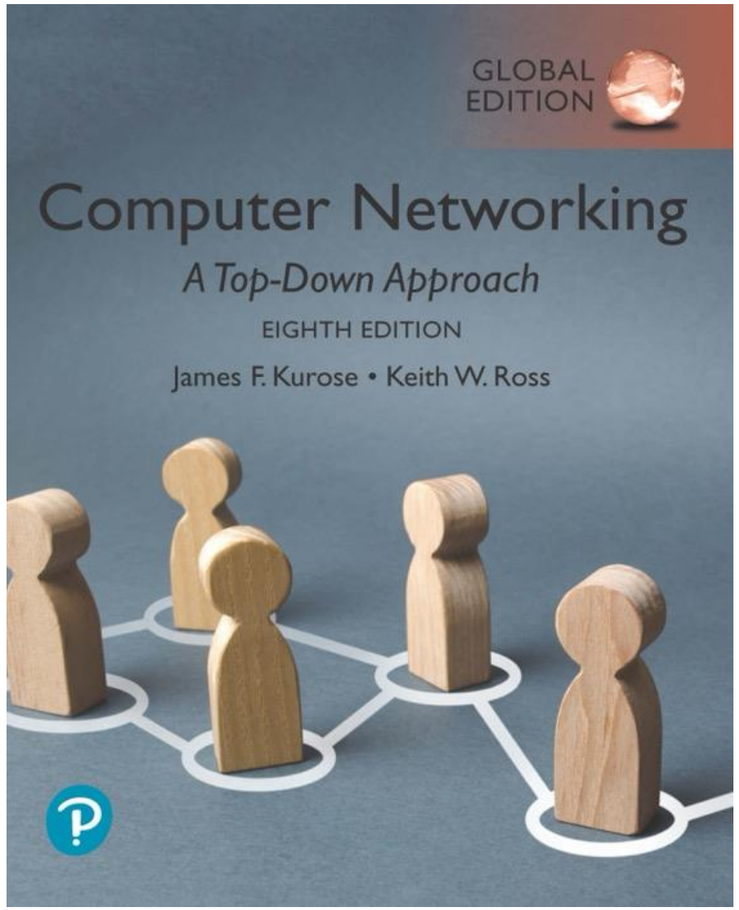


Computer Networking: A Top-Down Approach
8th edition, Global Edition
Jim Kurose, Keith Ross

Chapter 1: roadmap

1.1 What is the Internet?

1.2 Network edge: hosts, access network, physical media

1.3 Network core: packet/circuit switching, internet structure

1.4 Performance: loss, delay, throughput

1.5 Protocol layers, service models

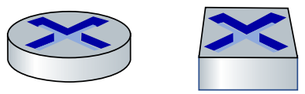
~~1.6 Network Under Attack~~

1.7 History

The Internet: a "nuts and bolts" view

Billions of connected computing *devices*:

- *hosts = end systems*
- running *network apps* at Internet's "edge"



Packet switches: forward packets (chunks of data)

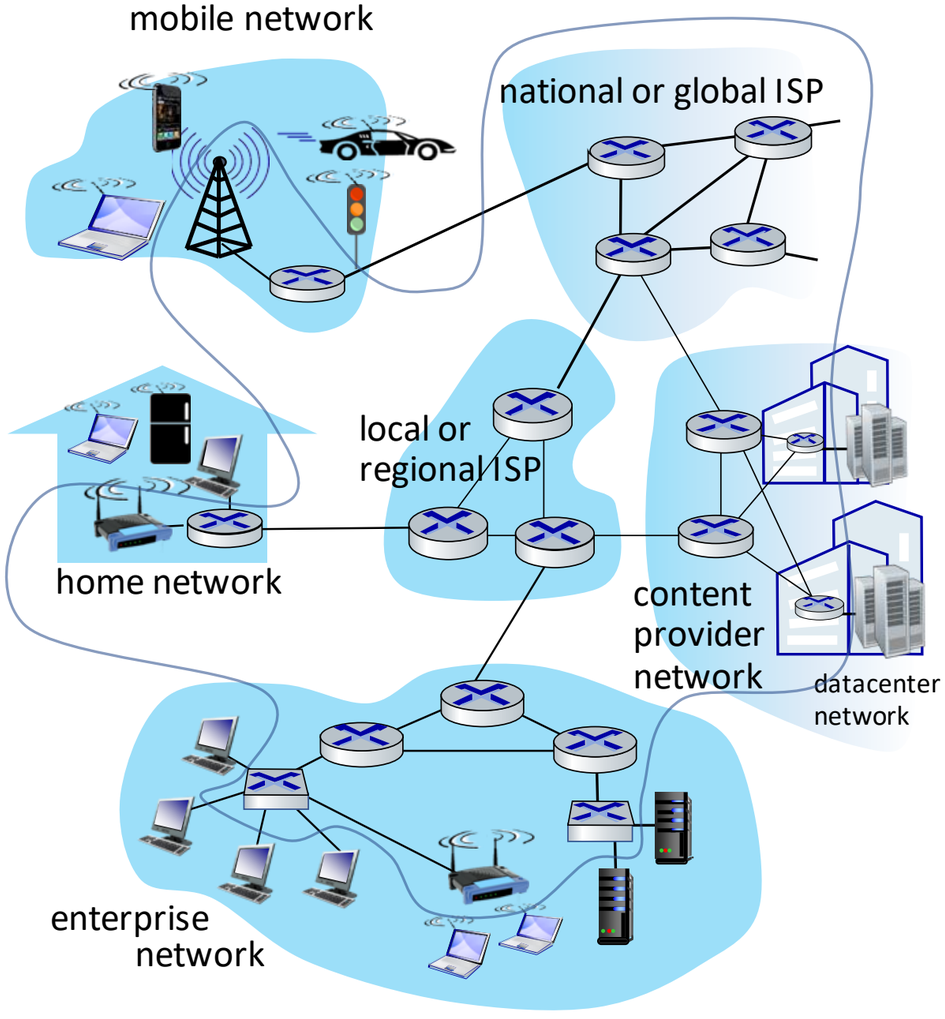
- *routers, switches*

Communication links

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

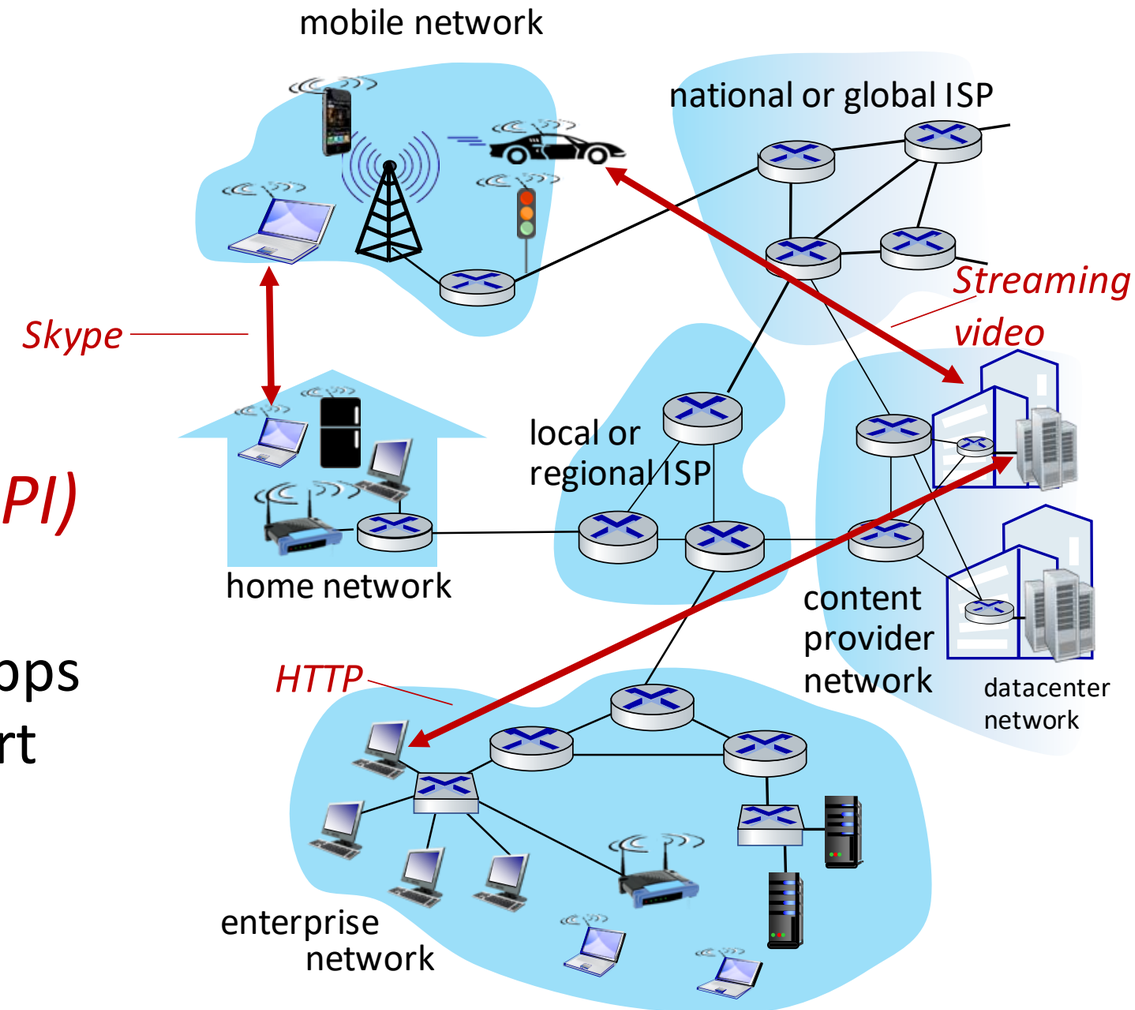
Networks

- collection of devices, routers, links: managed by an organization



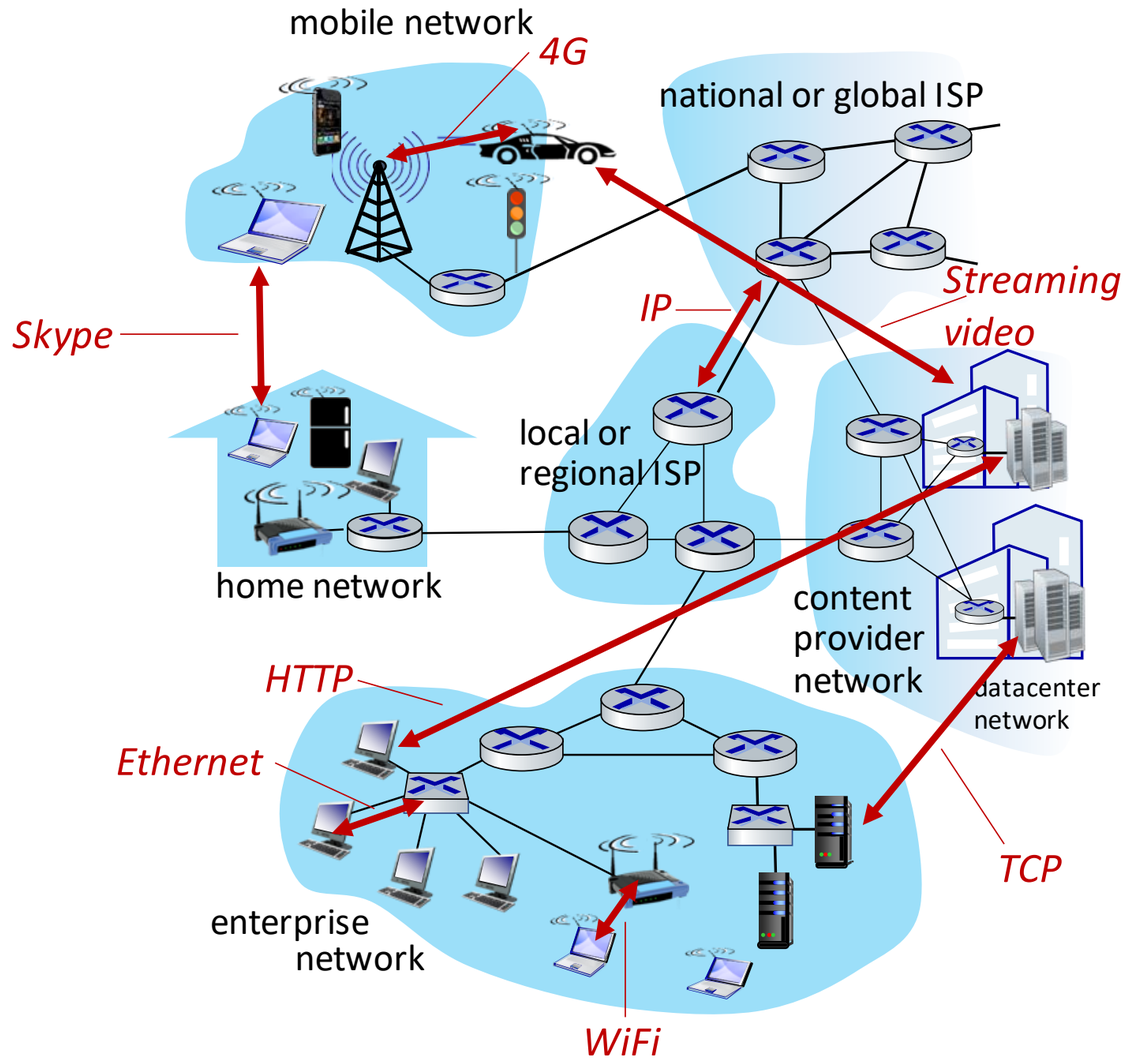
The Internet: a "service" view

- *Infrastructure* that provides services to applications:
  - Web, streaming video, multimedia teleconferencing, email, games, e-commerce, social media, inter-connected appliances, …
- provides *programming interface (API)* to distributed applications:
  - "hooks" allowing sending/receiving apps to "connect" to, use Internet transport service
  - *API Protocols:* e.g., HTTP (Web), streaming video, Zoom, TCP, IP,



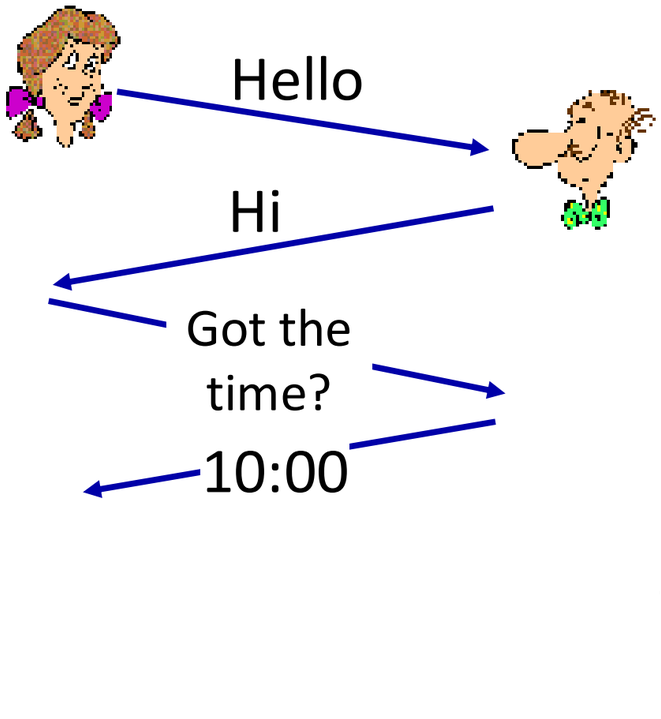
The Internet: a "Network" view

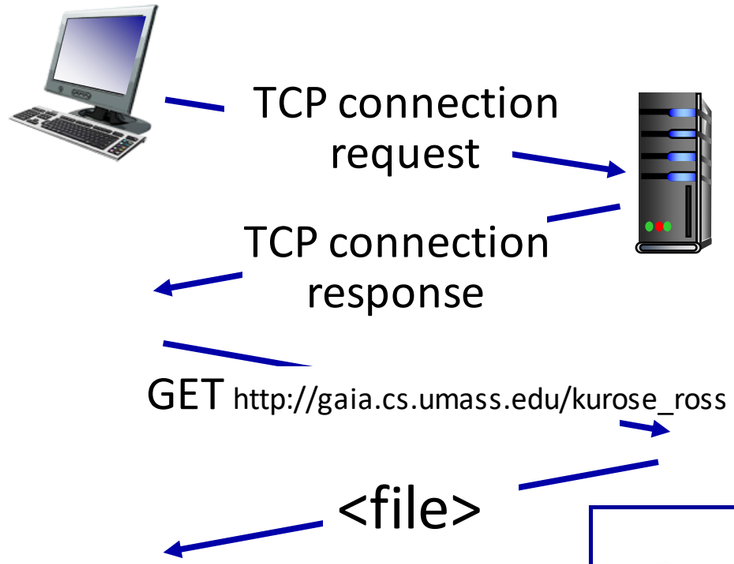
- *Internet:* "network of networks"
  - Interconnected ISPs
- *Network Protocols*
  - control sending, receiving of messages
  - e.g., WiFi, 4G, Ethernet, ADSL, HFC
- *Internet standards*
  - RFC: Request for Comments
  - IETF: Internet Engineering Task Force



What's a protocol?

A human protocol and a computer network protocol:





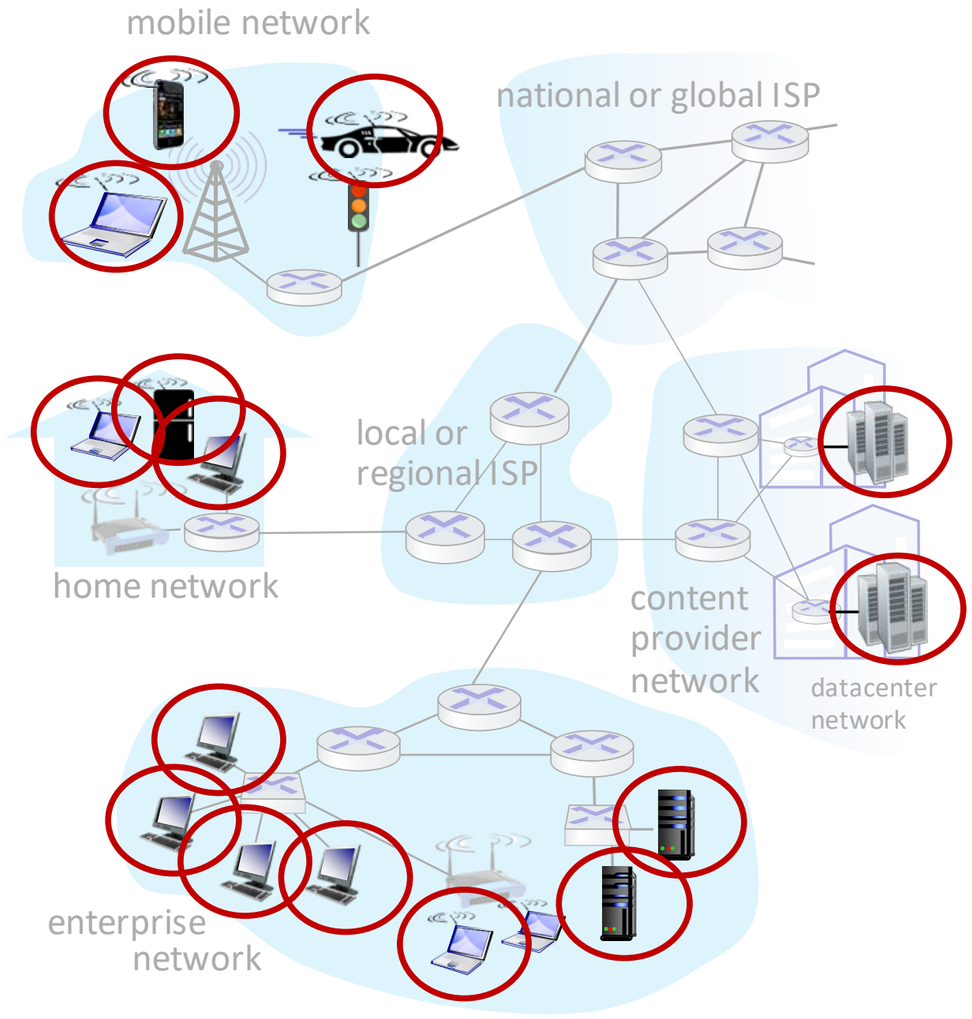
Protocols define the format, order of messages sent and received among network entities, and actions taken on msg transmission, receipt

Q: other human protocols?

A closer look at Internet structure

Network edge:

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



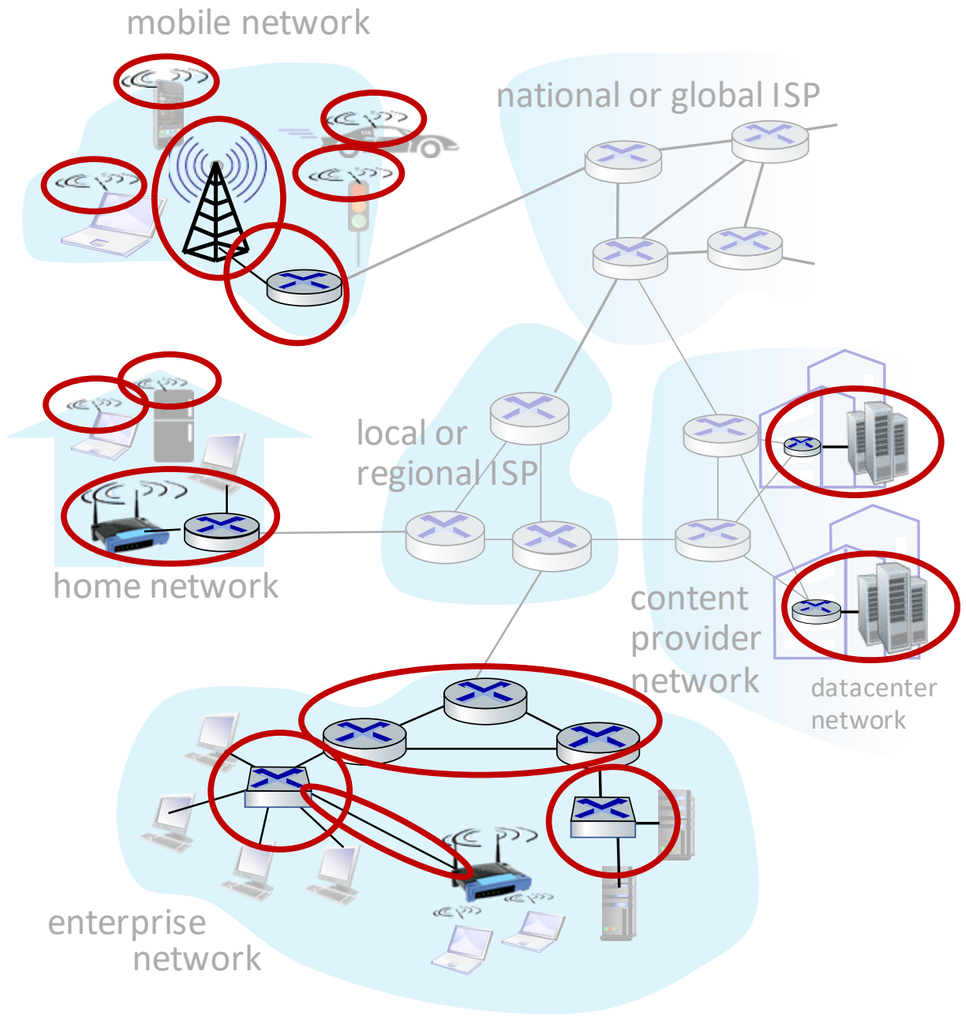
A closer look at Internet structure

Network edge:

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

Access networks, physical media:

- wired, wireless communication links



A closer look at Internet structure

Network edge:

- hosts: clients and servers
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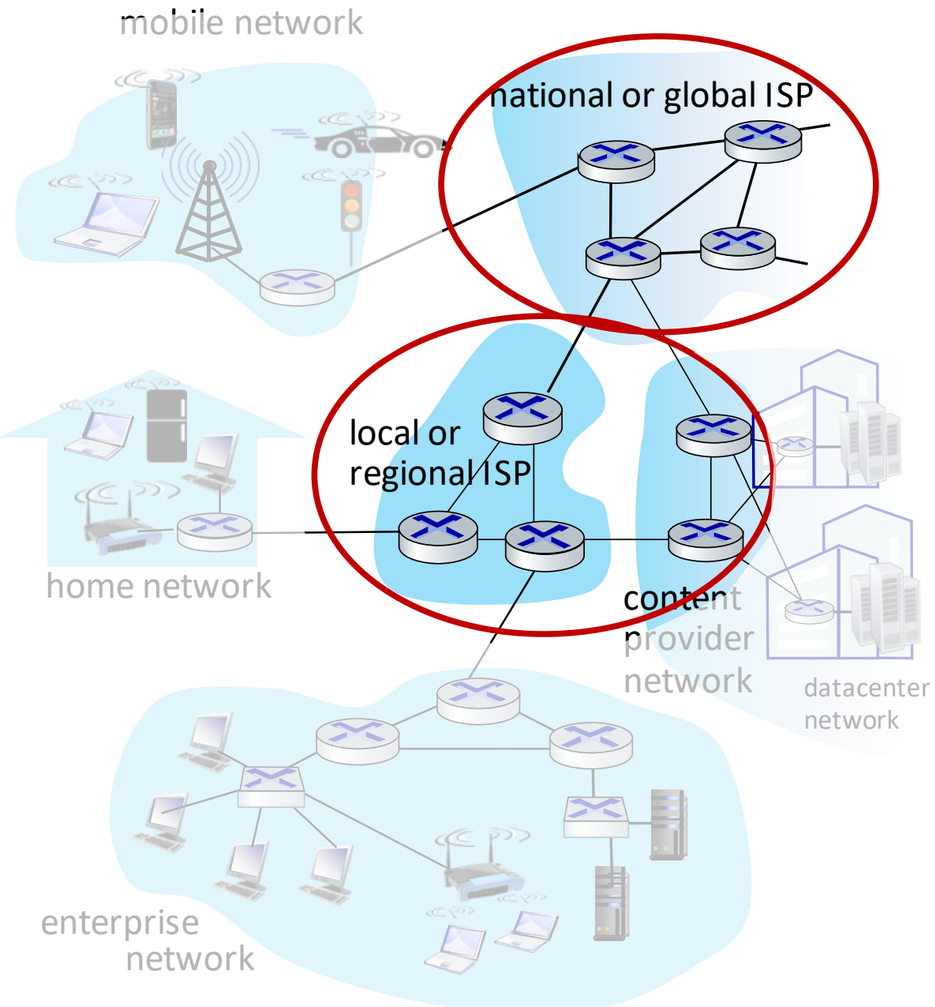
Access networks, physical media:

- wired, wireless communication links

Network core:

- interconnected routers
- network of networks



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1.7 History

Prof Ray Owen

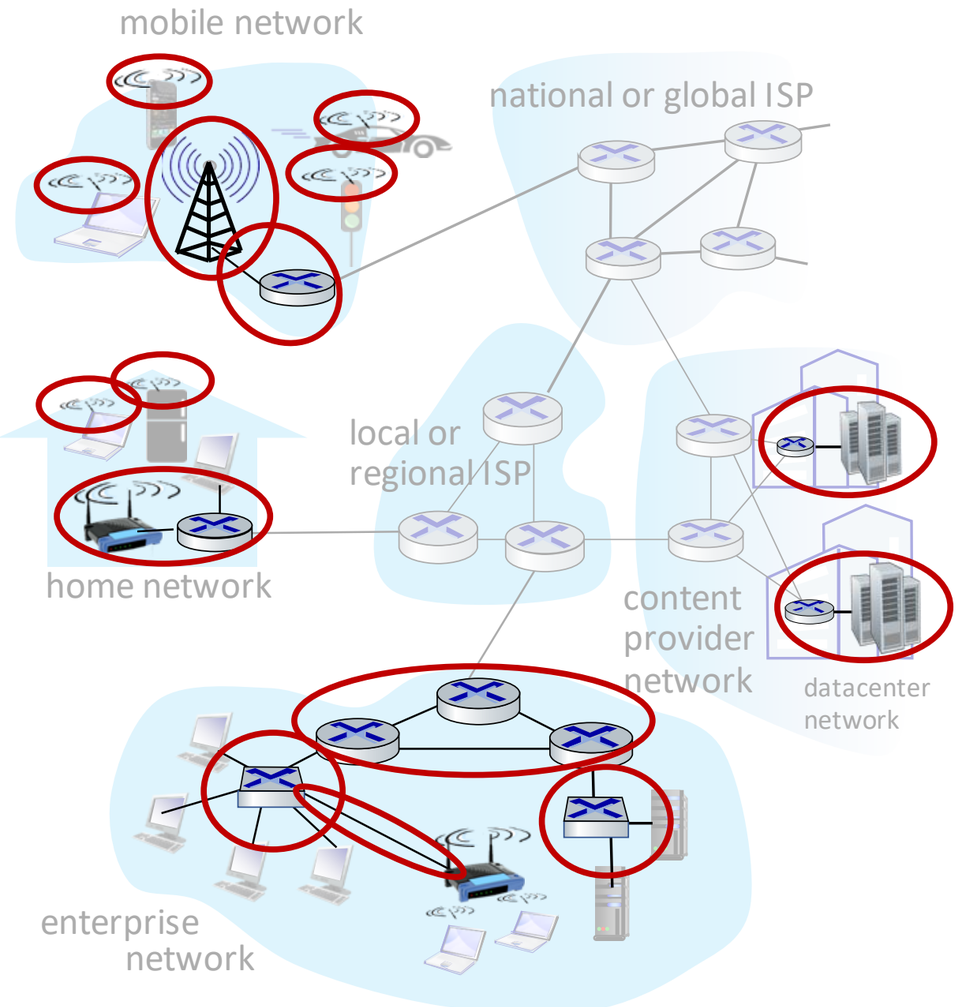
- Industry Professor, UTS
- Chief Technology Officer, NBN Co.
- Vice President and Managing Director, Nokia (Aus)

Access networks and physical media

Q: How to connect end systems to edge router?

- home network
- residential access nets
- enterprise networks (school, company)
- mobile networks (WiFi, 4G/5G)

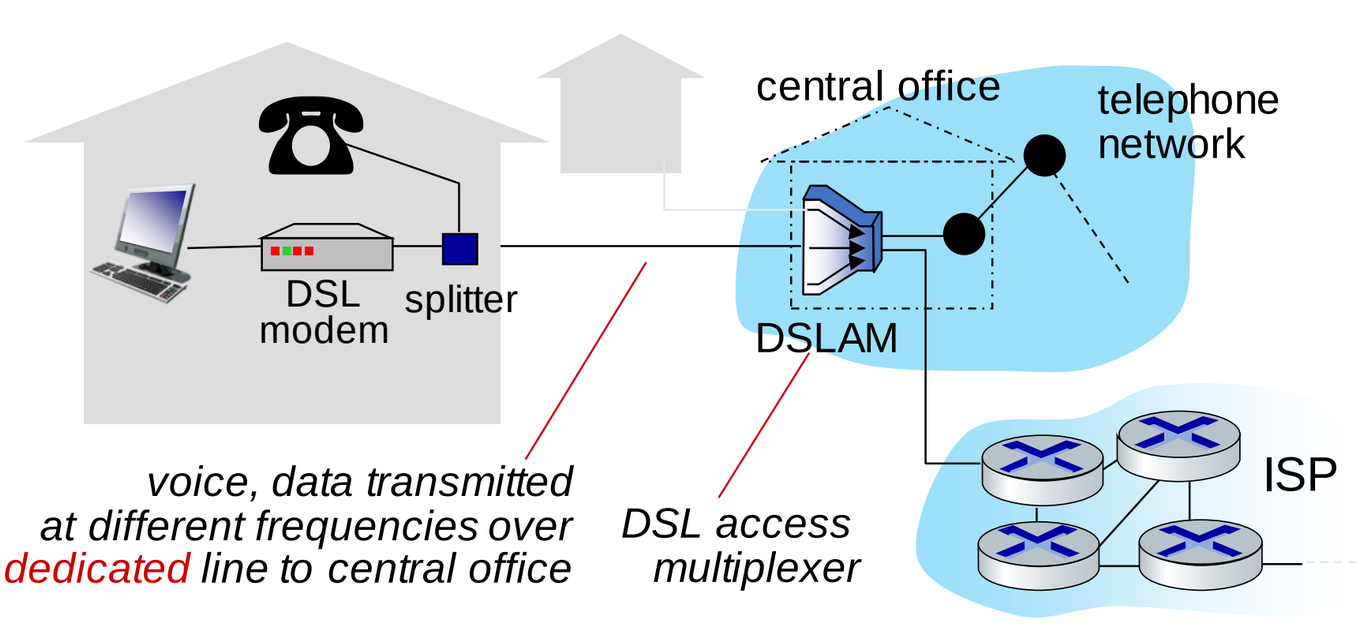
Last Mile Problem



What to look for:

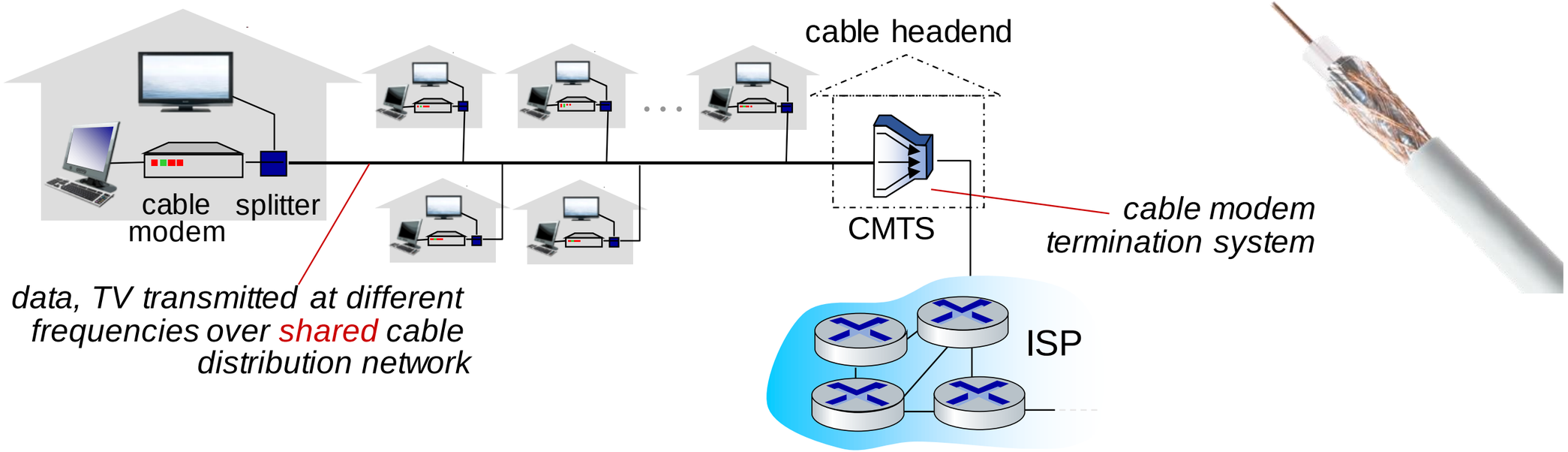
- transmission rate (bits per second) of access network?
- shared or dedicated access among users?

Access networks: digital subscriber line (DSL)



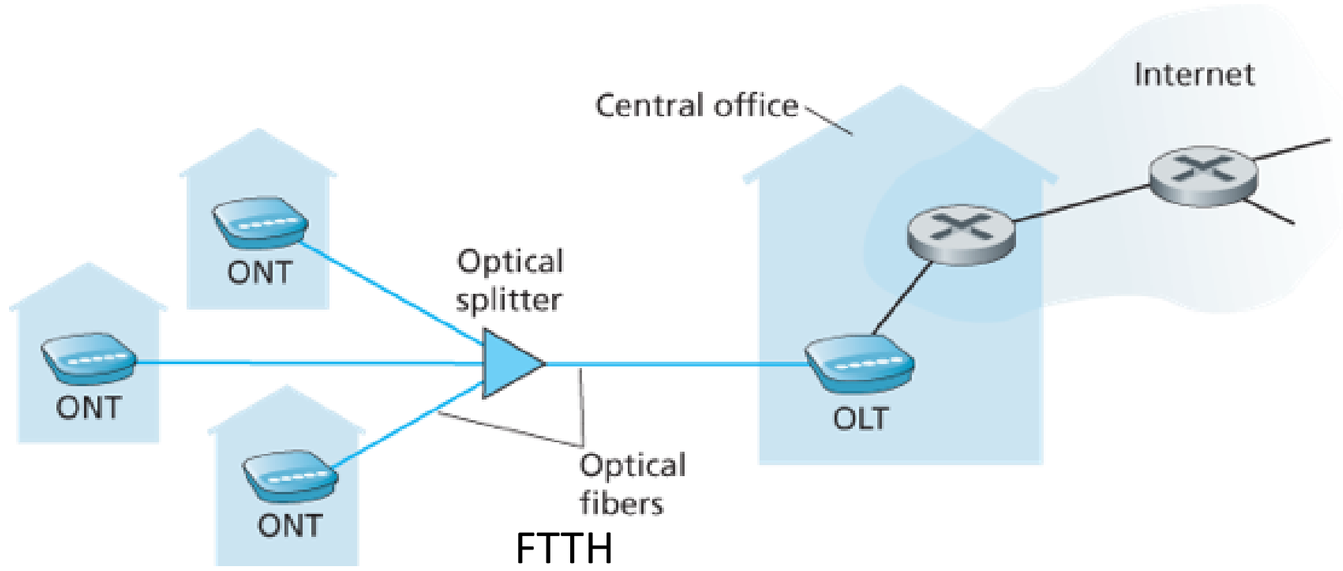
- use *existing* *dedicated* telephone line to central office DSLAM
  - data over DSL phone line goes to Internet
  - voice over DSL phone line goes to telephone net
- 24-52 Mbps dedicated downstream transmission rate
- 3.5-16 Mbps dedicated upstream transmission rate

Access networks: cable-based - HFC



- HFC: hybrid fiber coax
  - asymmetric: up to 40 Mbps – 1.2 Gbs downstream transmission rate,
  - 30-100 Mbps upstream transmission rate
- network of cable, fiber attaches homes to ISP router
  - homes *share access network* to cable headend

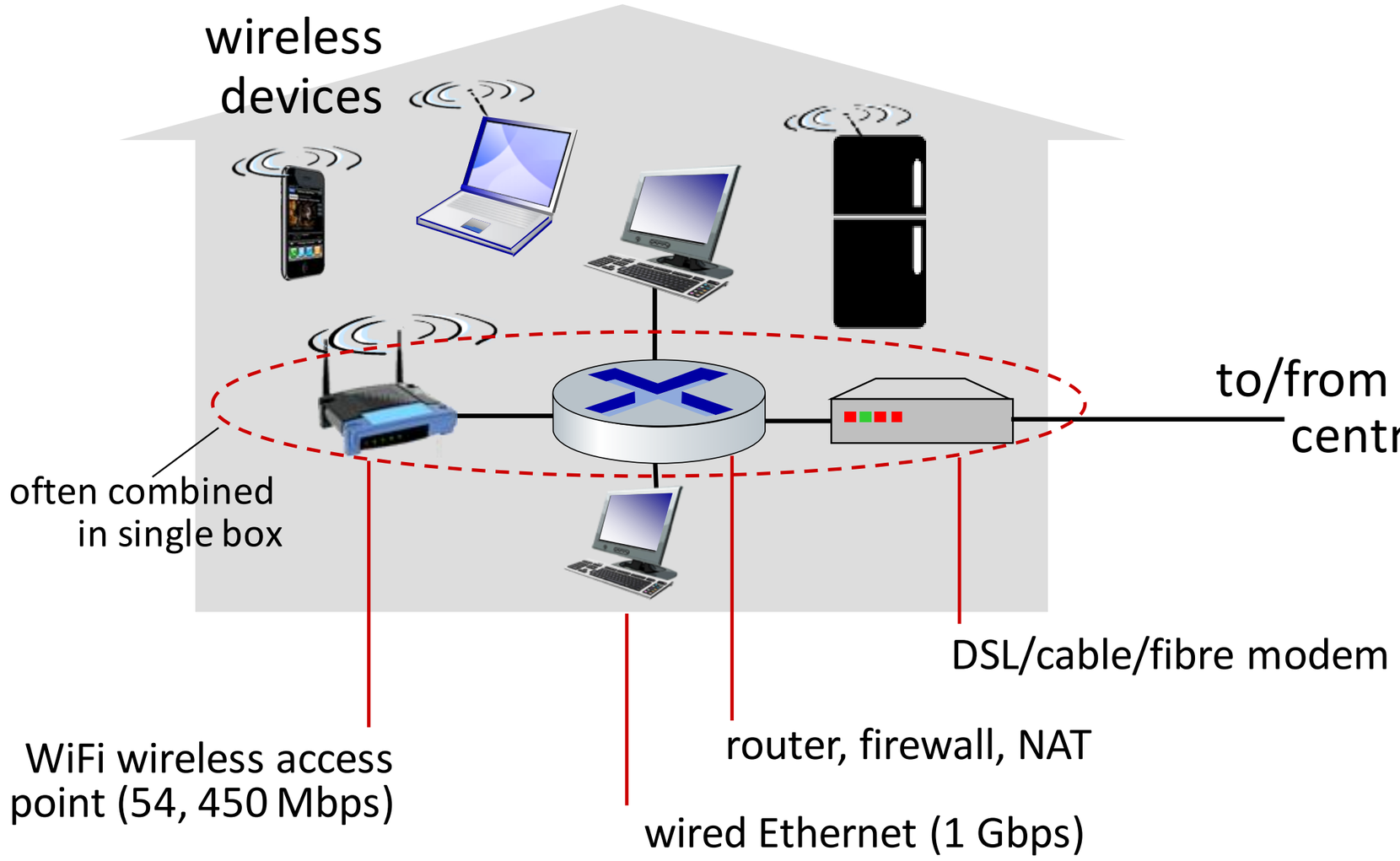
What is NBN



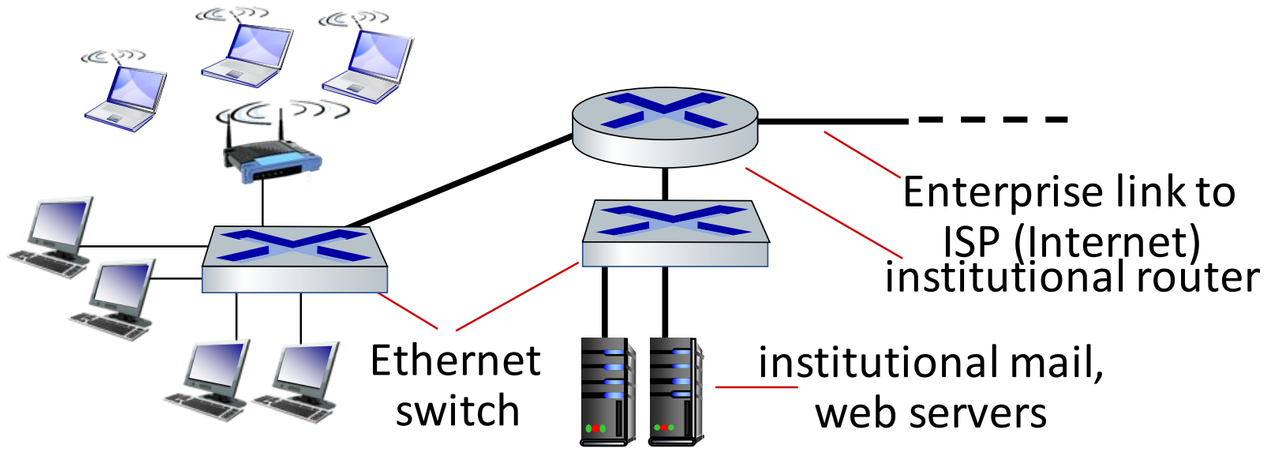
- What Access technologies are used in NBN?
- What is FTTH?
- What are the data rates for each technology?
- How much $ are they?
- Discuss Pros and Cons for each

Discuss in your Tutorial Class

Access networks: home networks



Access networks: enterprise networks



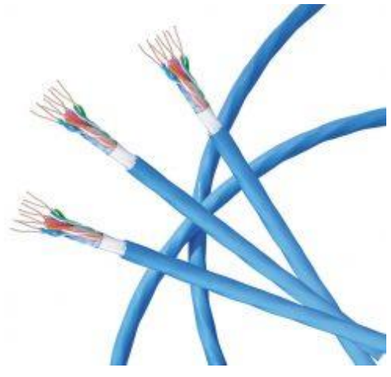
- companies, universities, etc.
- mix of wired, wireless link technologies, connecting a mix of switches and routers (we'll cover differences shortly)
  - Ethernet: wired access at 100Mbps, 1Gbps, 10Gbps
  - WiFi: wireless access points at 11, 54, 450 Mbps

Links: physical media

- bit: propagates between transmitter/receiver pairs
- physical link: what lies between transmitter & receiver
- guided media: aka wired
  - signals propagate in solid media: copper, fiber, coax
- unguided media: aka wireless
  - signals propagate freely, e.g., radio

Twisted pair (TP)

- two insulated copper wires
  - Category 5: 100 Mbps, 1 Gbps Ethernet
  - Category 6: 10Gbps Ethernet



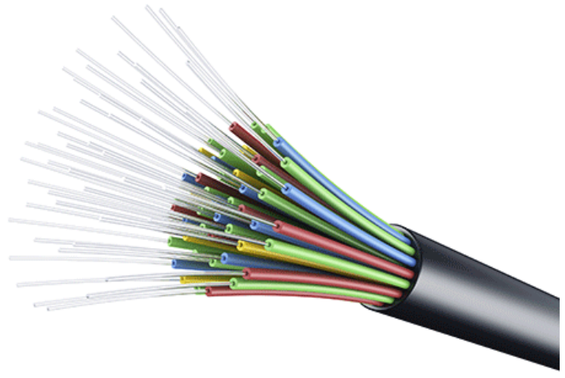
Links: physical media

Coaxial cable:

- two concentric copper conductors
- bidirectional
- broadband:
  - multiple frequency channels on cable
  - 100's Mbps per channel

Fiber optic cable:

- glass fiber carrying light pulses, each pulse a bit
- high-speed operation:
  - high-speed point-to-point transmission (10's-100's Gbps)
- low error rate:
  - repeaters spaced far apart
  - immune to electromagnetic noise



Links: physical media

Wireless radio

- signal carried in electromagnetic spectrum
- no physical "wire"
- broadcast and "half-duplex" (sender to receiver)
- propagation environment effects:
  - reflection
  - obstruction by objects
  - interference

Radio link types:

- terrestrial microwave
  - up to 45 Mbps channels
- Wireless LAN (WiFi)
  - Up to 100's Mbps
- wide-area (e.g., cellular)
  - 4G/5G cellular: ~ 10's Mbps
- satellite
  - up to 45 Mbps per channel
  - 270 msec end-end delay
  - geosynchronous versus low-earth-orbit

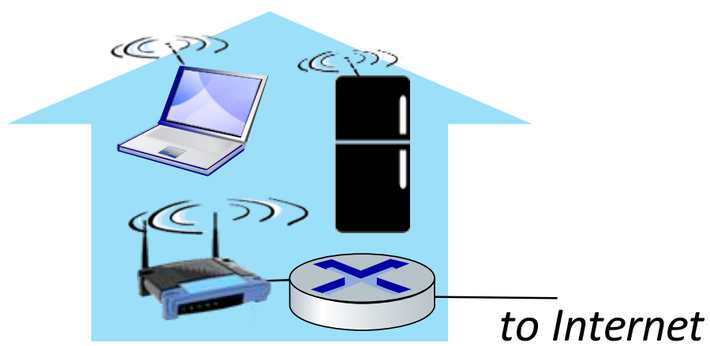
Wireless access networks

Shared *wireless* access network connects end system to router

- via base station aka “access point”

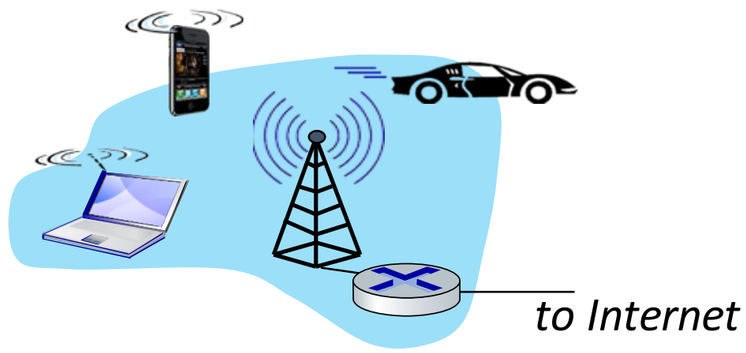
Wireless local area networks (WLANs)

- typically within or around building (~30m)
- 802.11b/g/n (WiFi): 11, 54, 450 Mbps transmission rate



Wide-area mobile access networks

- provided by mobile, cellular network operator (10’s km)
- 10’s Mbps
- 4G/5G cellular networks



Mid-break

- Q & A

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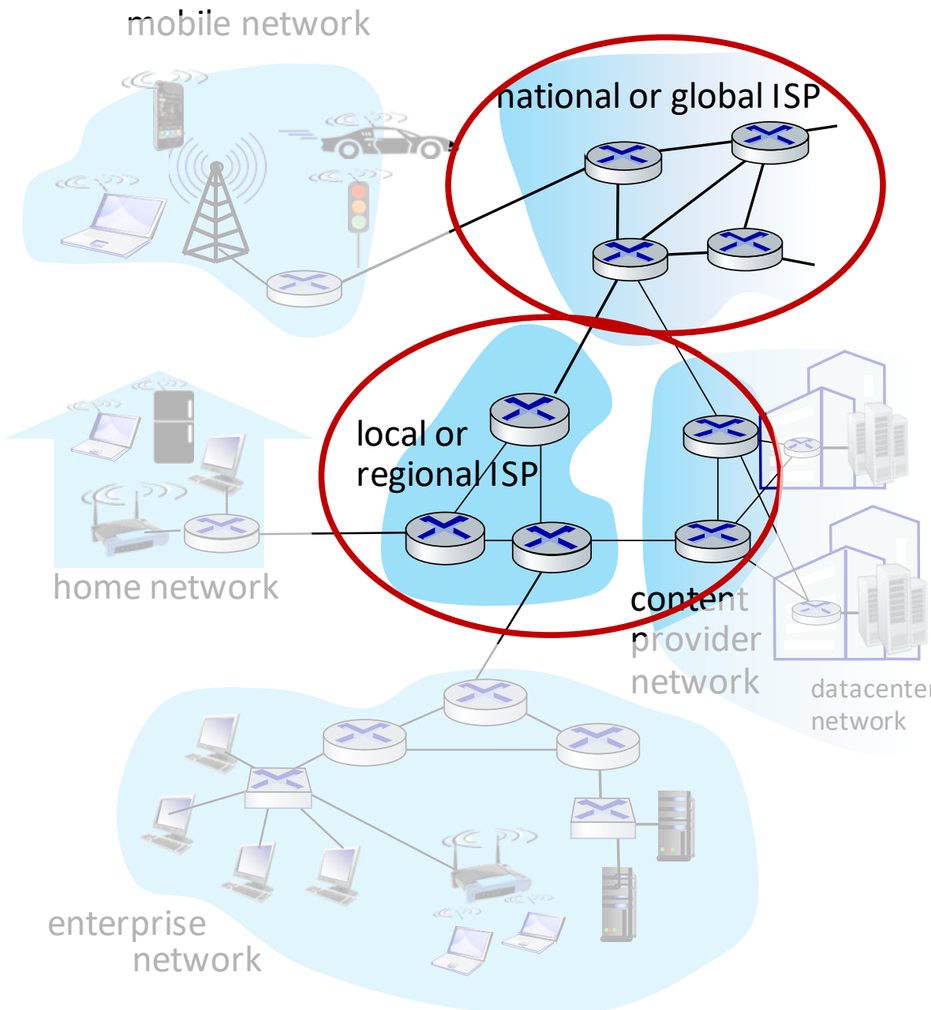
The network core

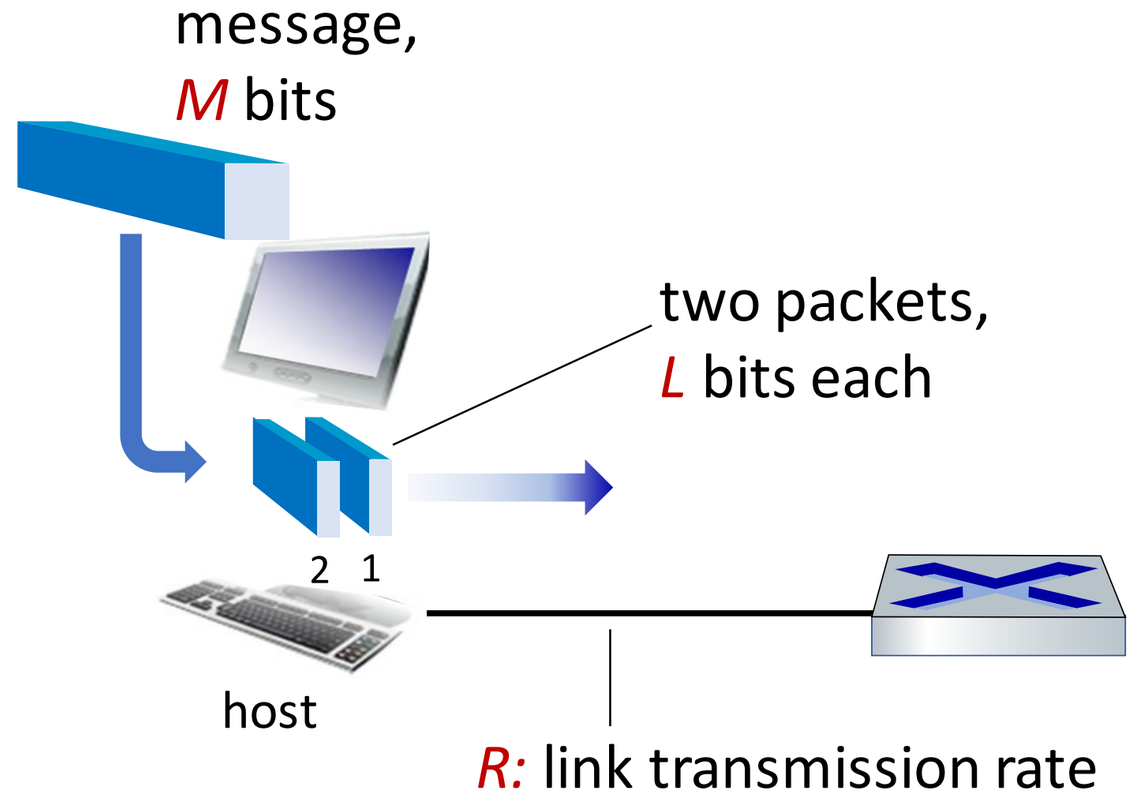
- mesh of interconnected routers
- packet-switching: hosts break application-layer messages into *packets*
  - forward packets from one router to the next, across links on path from source to destination
  - each packet transmitted at full link capacity



Host: sends *packets* of data

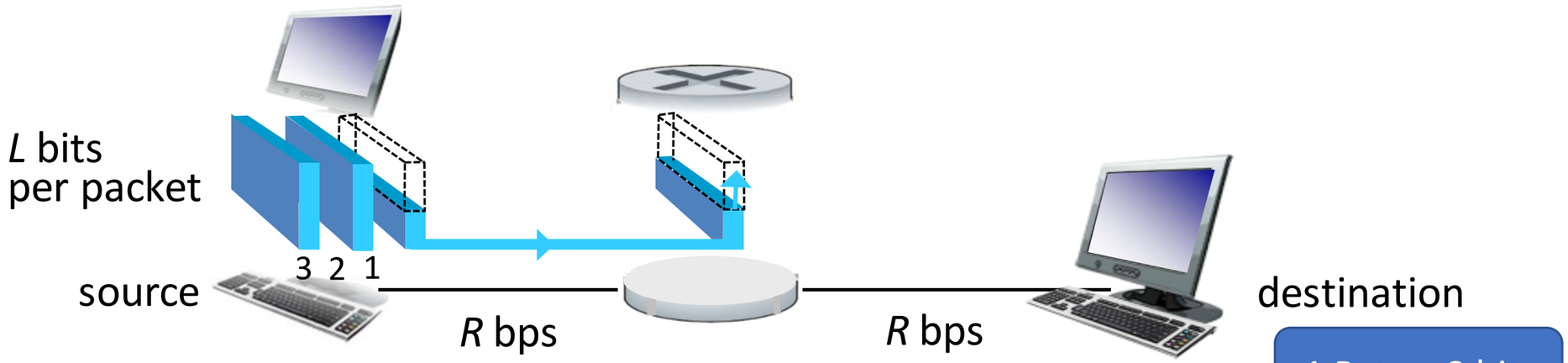
host sending function:

- 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*



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

Packet-switching: store-and-forward



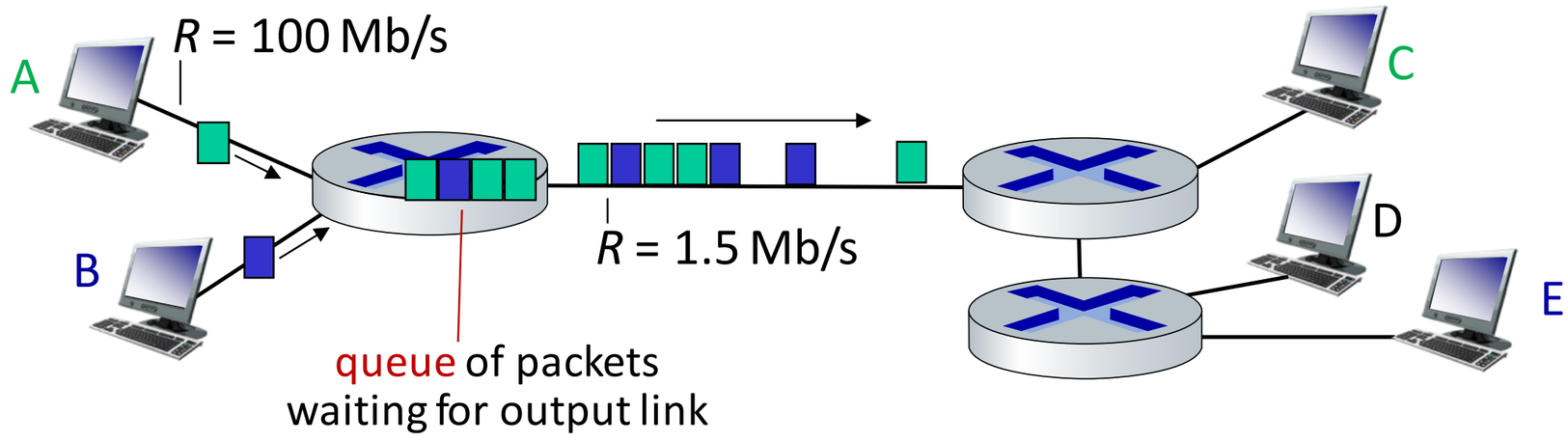
- Transmission delay: takes *L*/*R* seconds to transmit (push out) *L*-bit packet into link at *R* bps
- *Store and forward: entire* packet must arrive at router before it can be transmitted on next link
- *End-end delay:* 2*L*/*R* (above), assuming zero propagation delay (more on delay shortly)

1 Byte = 8 bits

One-hop numerical example:

- *L* = 1 KB
- *R* = 10 Mbps
- one-hop transmission delay
  $= \frac{1 \times 1000\ (B) \times 8\ (b/B)}{10 \times 1000000\ b/s}$
  = 0.0008 s = 0.8 ms

Packet-switching: queueing delay, loss



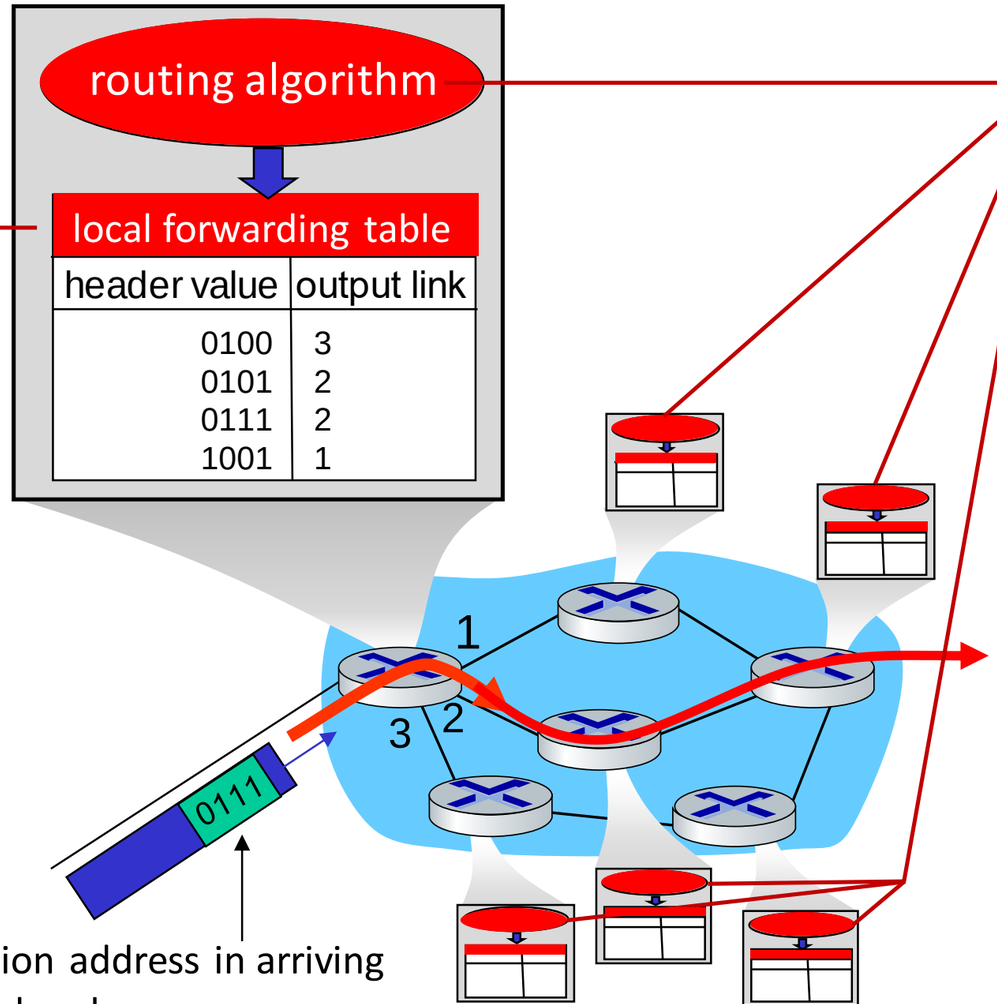
Packet queuing and loss: if arrival rate (in bps) to link exceeds transmission rate (bps) of link for a period of time:

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

Two key network-core functions

Forwarding:

- *local* action: move arriving packets from router's input link to appropriate router output link



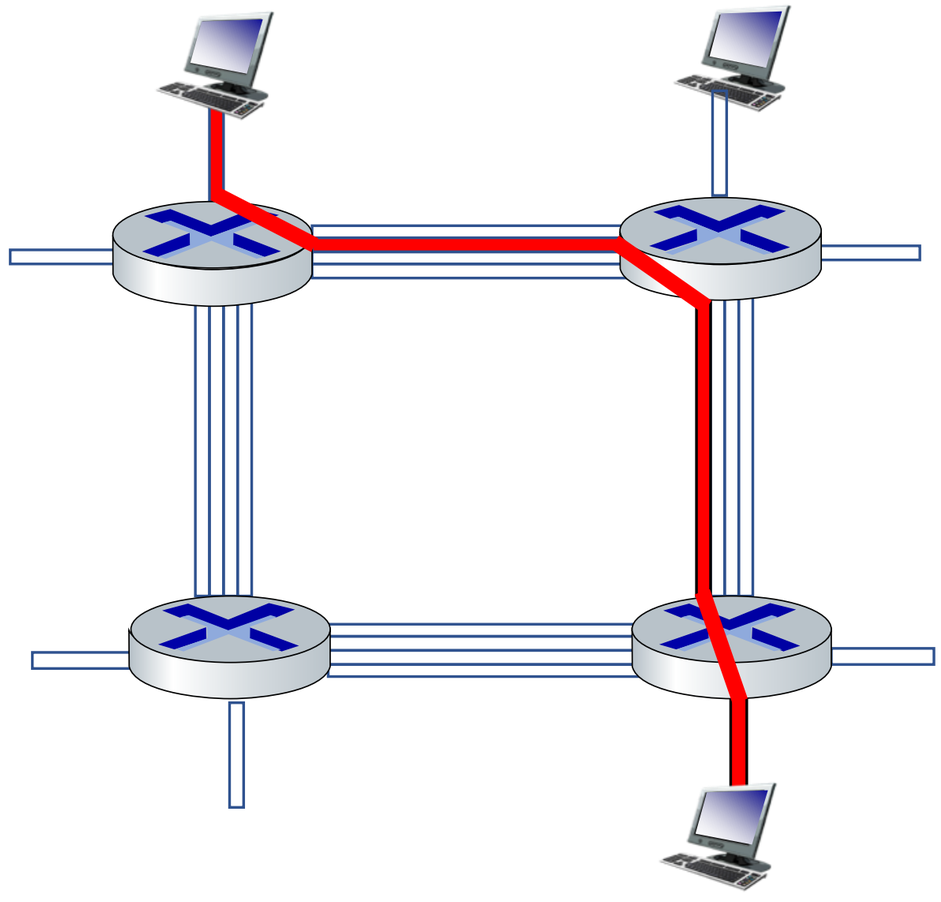
Routing:

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

Alternative to packet switching: circuit switching

end-end resources allocated to, reserved for "call" between source and destination

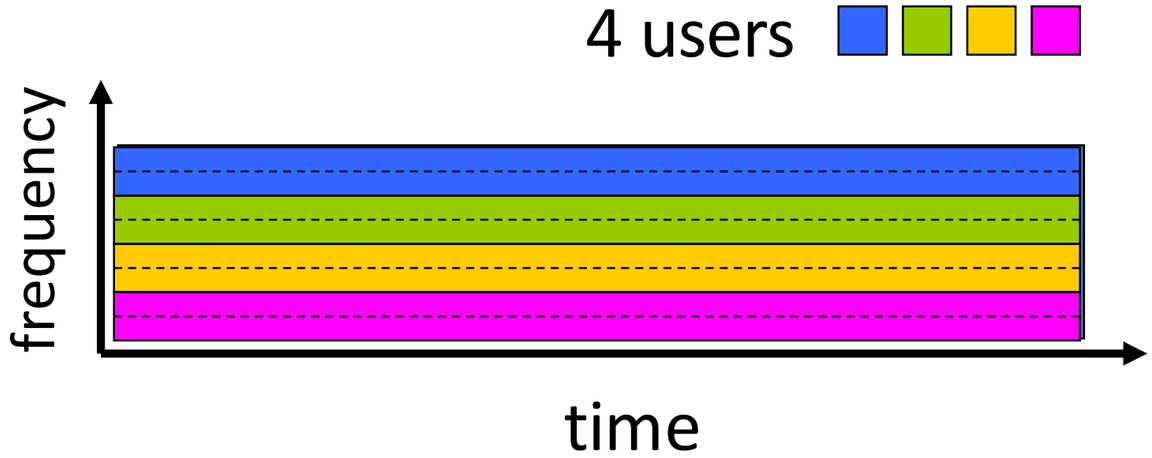
- in diagram, each link has four circuits.
  - call gets 2nd circuit in top link and 1st circuit in right link.
- dedicated resources: no sharing
  - circuit-like (guaranteed) performance
- circuit segment idle if not used by call (no sharing)
- commonly used in traditional telephone networks



Circuit switching: FDM and TDM

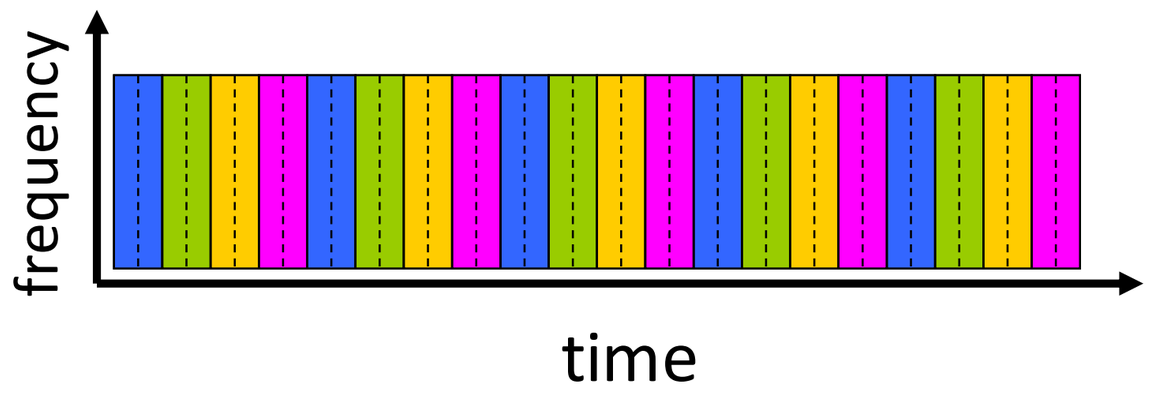
Frequency Division Multiplexing (FDM)

- optical, electromagnetic frequencies divided into (narrow) frequency bands
- each call allocated its own band, can transmit at max rate of that narrow band



Time Division Multiplexing (TDM)

- time divided into slots
- each call allocated periodic slot(s), can transmit at maximum rate of (wider) frequency band, but only during its time slot(s)

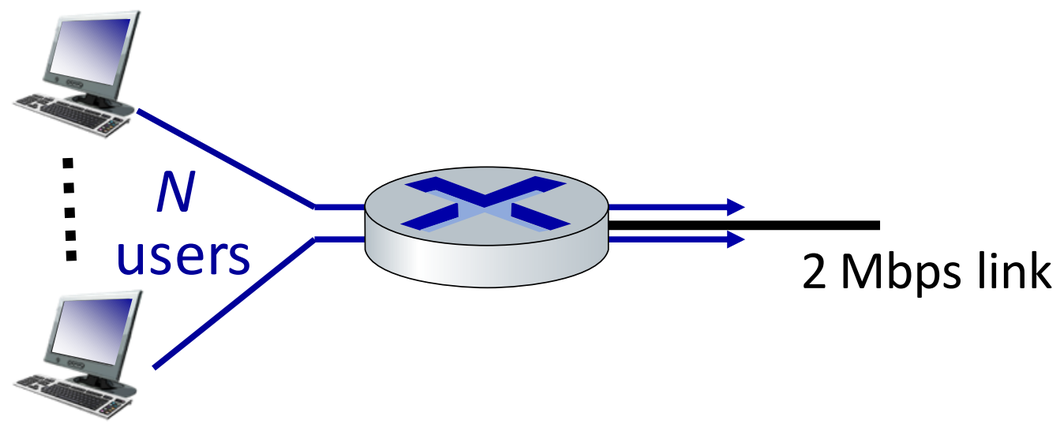


Packet switching versus circuit switching

packet switching allows more users to use network!

Example:

- 2 Mbps link
- each user:
  - 1 Mbps when "active"
  - active 20% of time, e.g. voice



- *circuit-switching:* 2 users
- *packet switching:* can handle 3 users or more …
  - with 3 users, if all 3 users are active at same time – require 3Mbps > 2Mbps (link capacity)
  - One of the 3 users has to wait – queueing delay
  - Fortunately, the probability of all 3 users are active is *small* = $C(3,3)p^3(1-p)^{3-3}=0.2^3=0.008$*

* optional - not tested

Packet switching versus circuit switching

Is packet switching a "slam dunk winner"?

- great for "bursty" data – sometimes has data to send, but at other times not
  - resource sharing
  - simpler, no call setup
- excessive congestion possible: packet delay and loss due to buffer overflow
  - protocols needed for reliable data transfer, congestion control
- *Q:* How to provide circuit-like behavior?
  - bandwidth guarantees traditionally used for audio/video applications

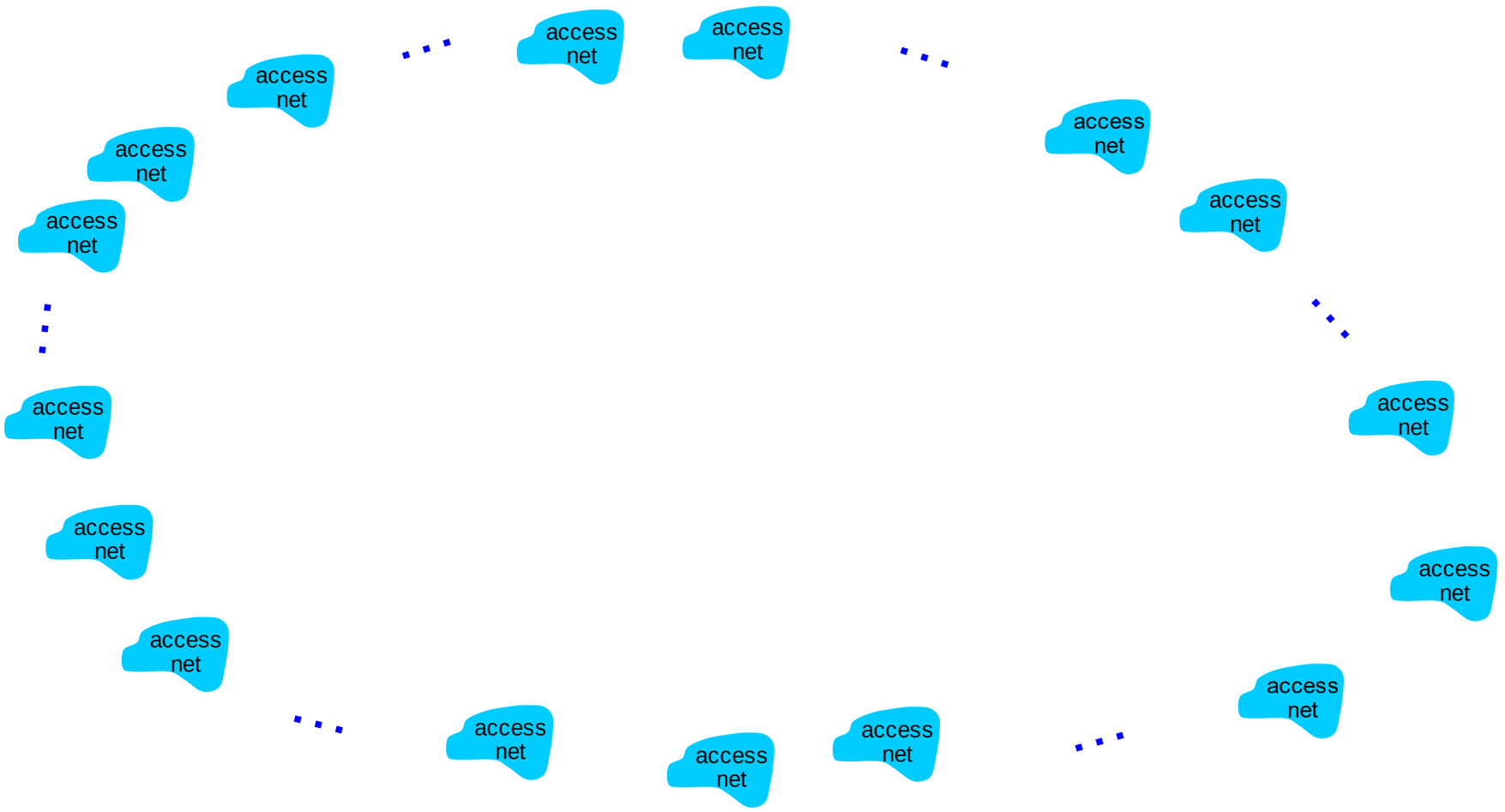
Q: human analogies of reserved resources (circuit switching) versus on-demand allocation (packet switching)?

Internet structure: a "network of networks"

- Hosts connect to Internet via access Internet Service Providers (ISPs)
  - residential, enterprise (company, university, commercial) 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

Internet structure: a "network of networks"

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



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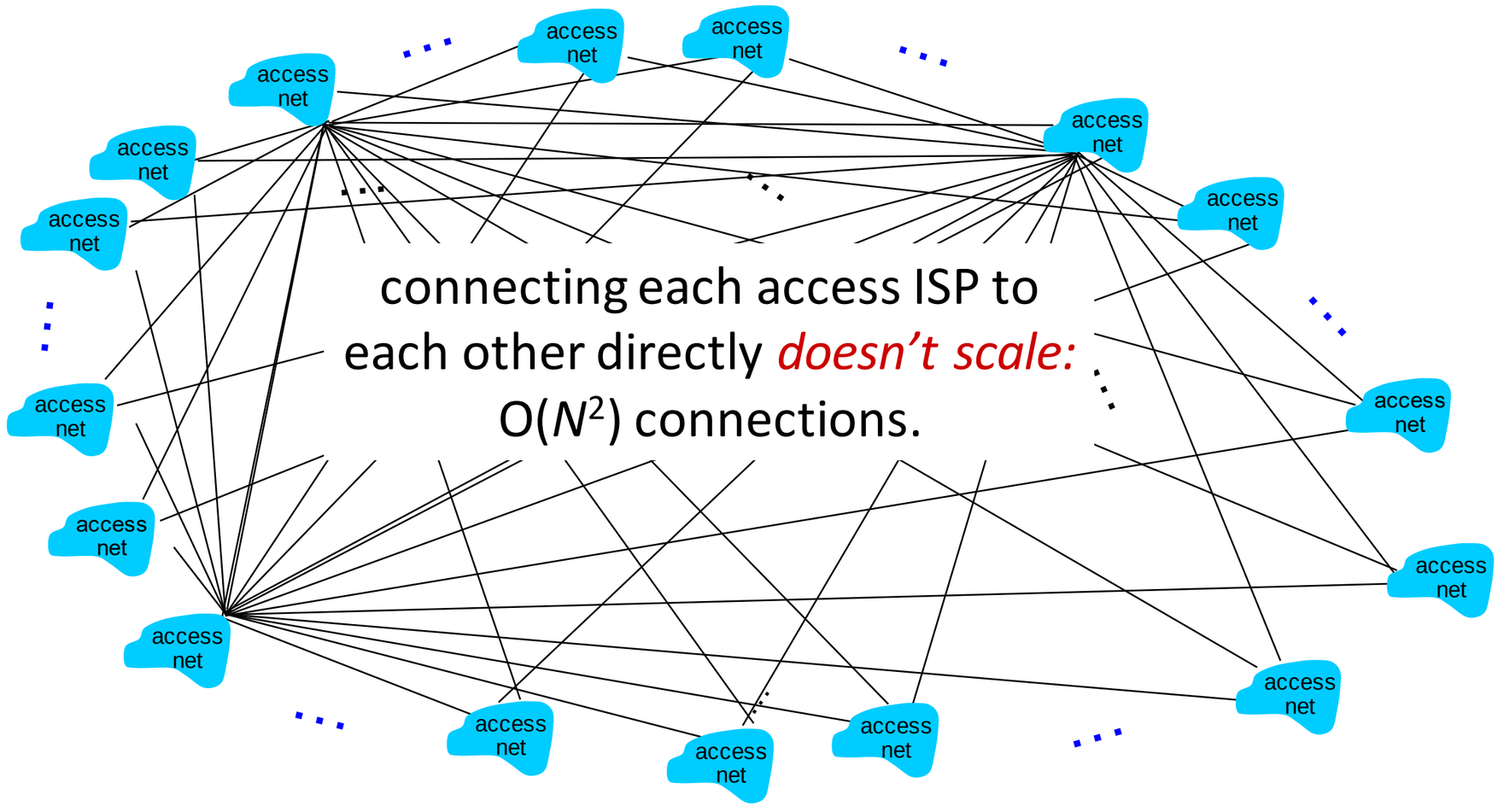
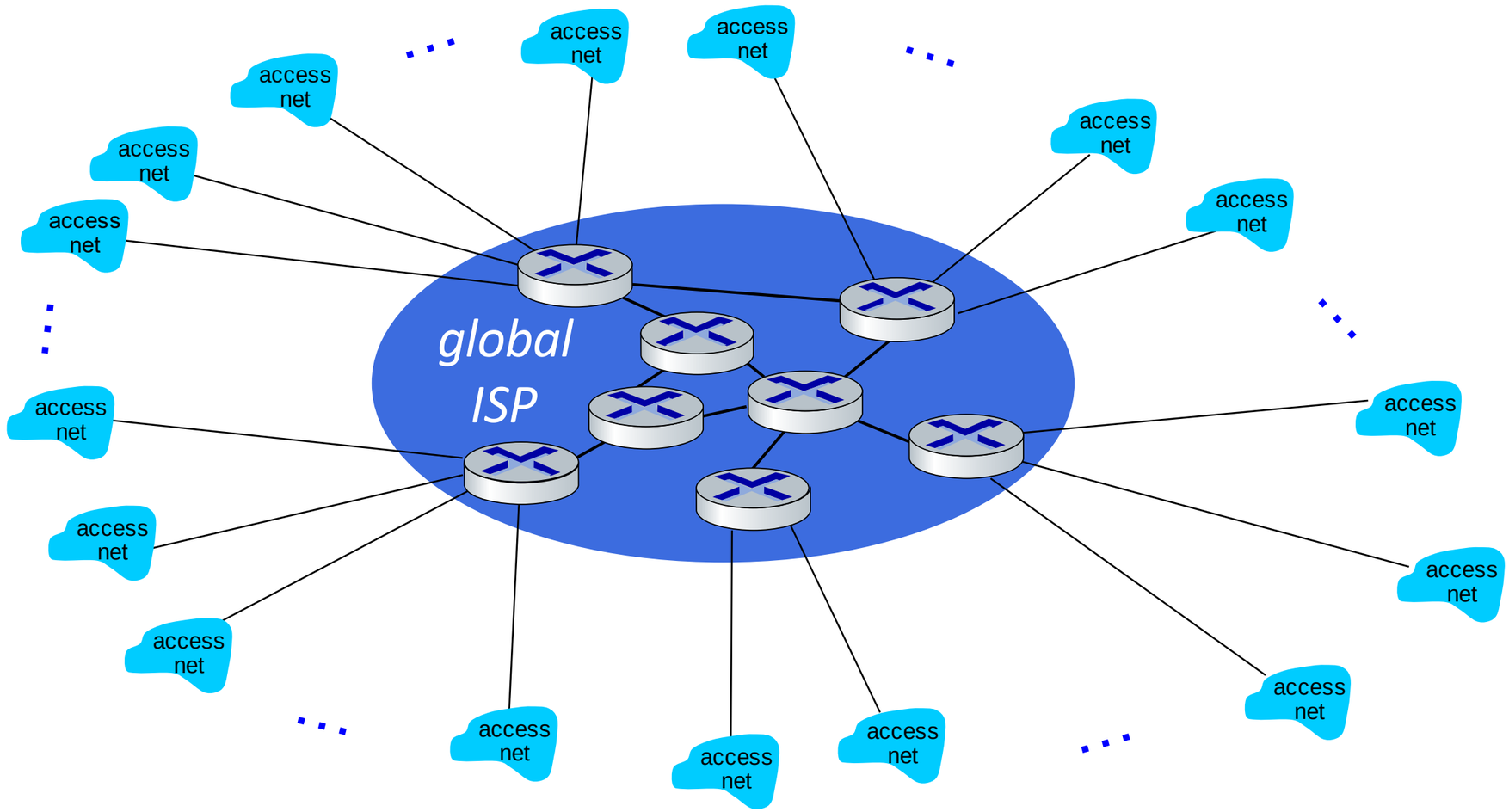


Internet structure: a "network of networks"

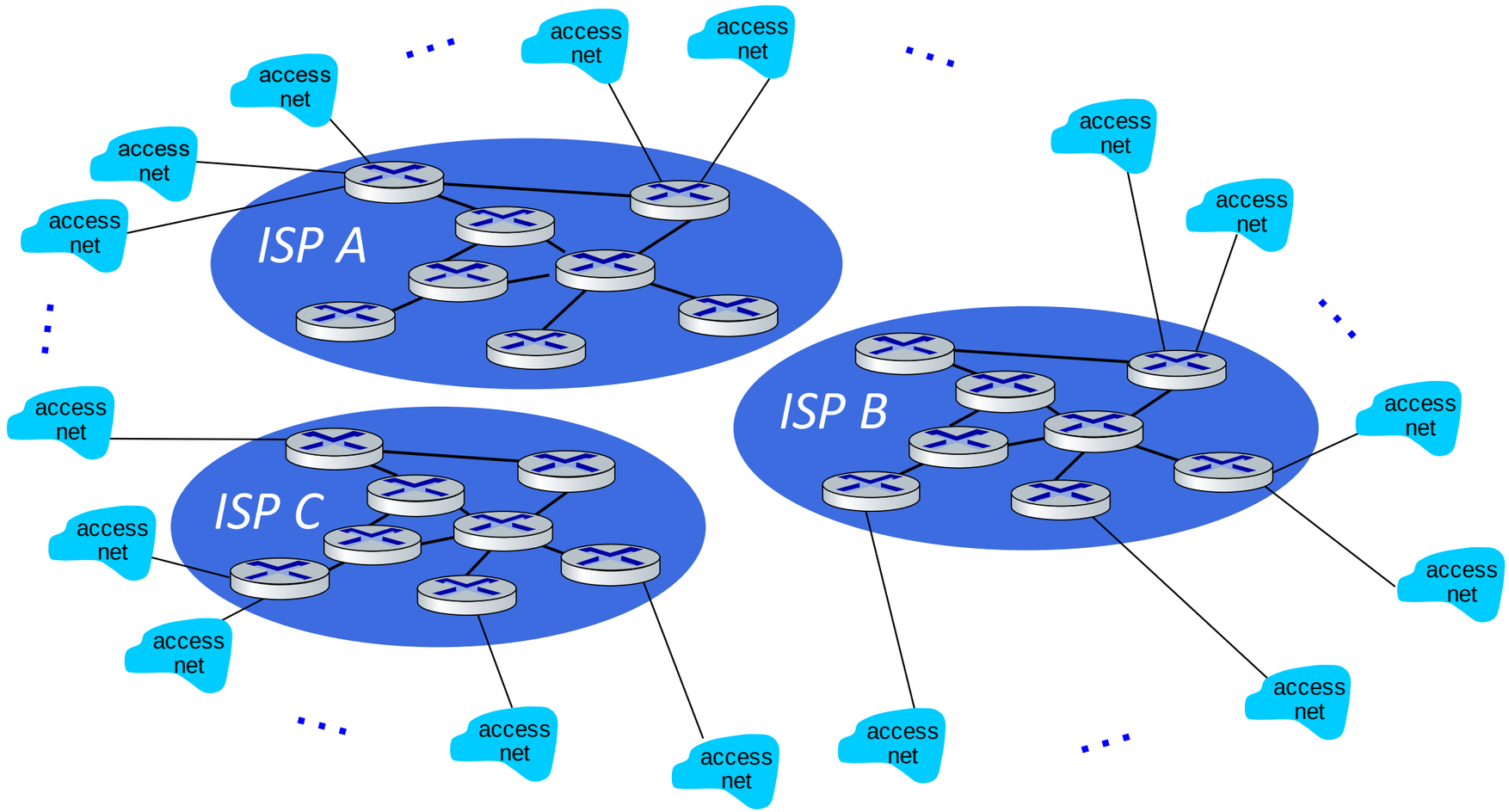
Option: connect each access ISP to one global transit ISP?

Customer and provider ISPs have economic agreement.



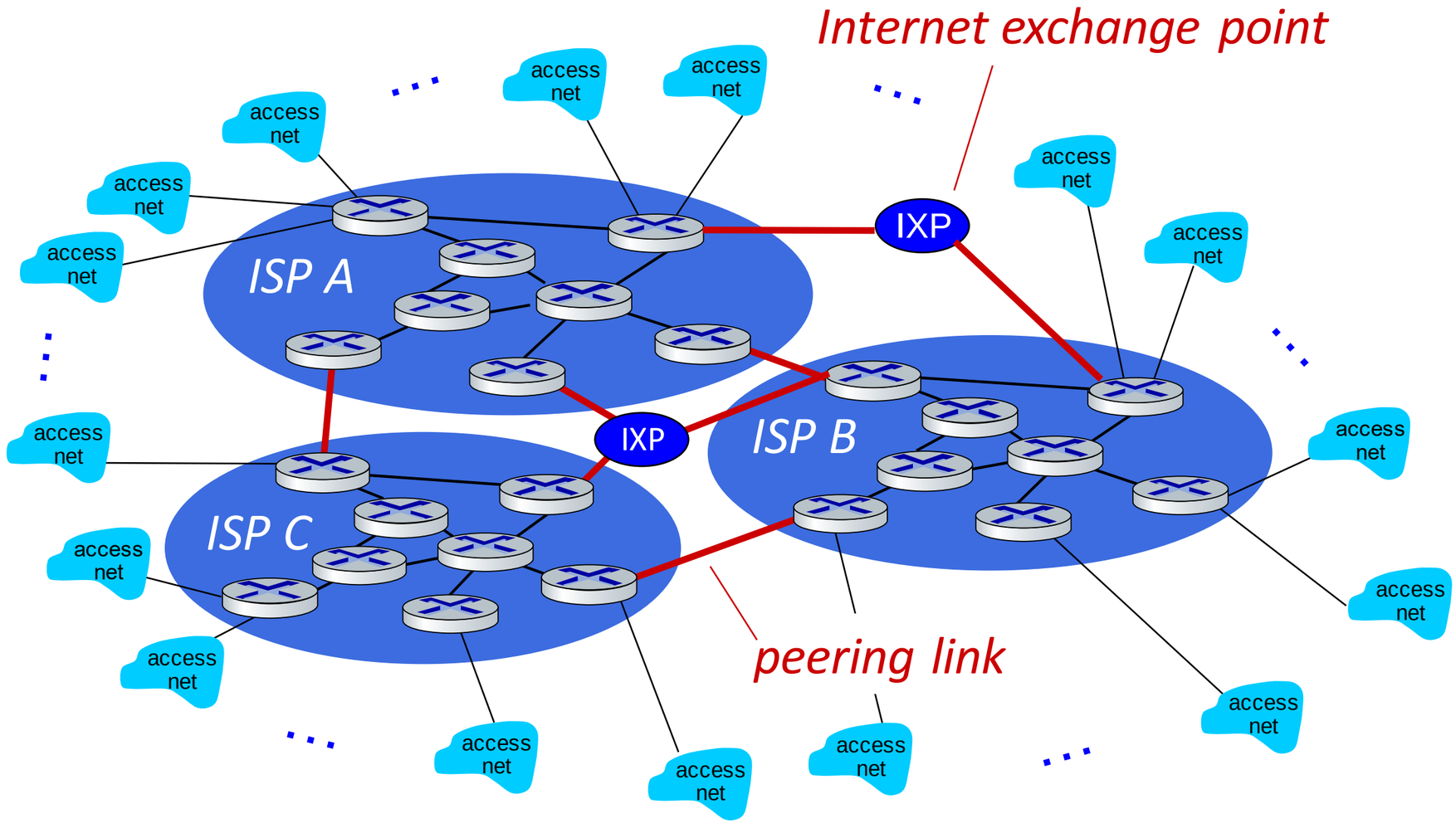
Internet structure: a "network of networks"

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



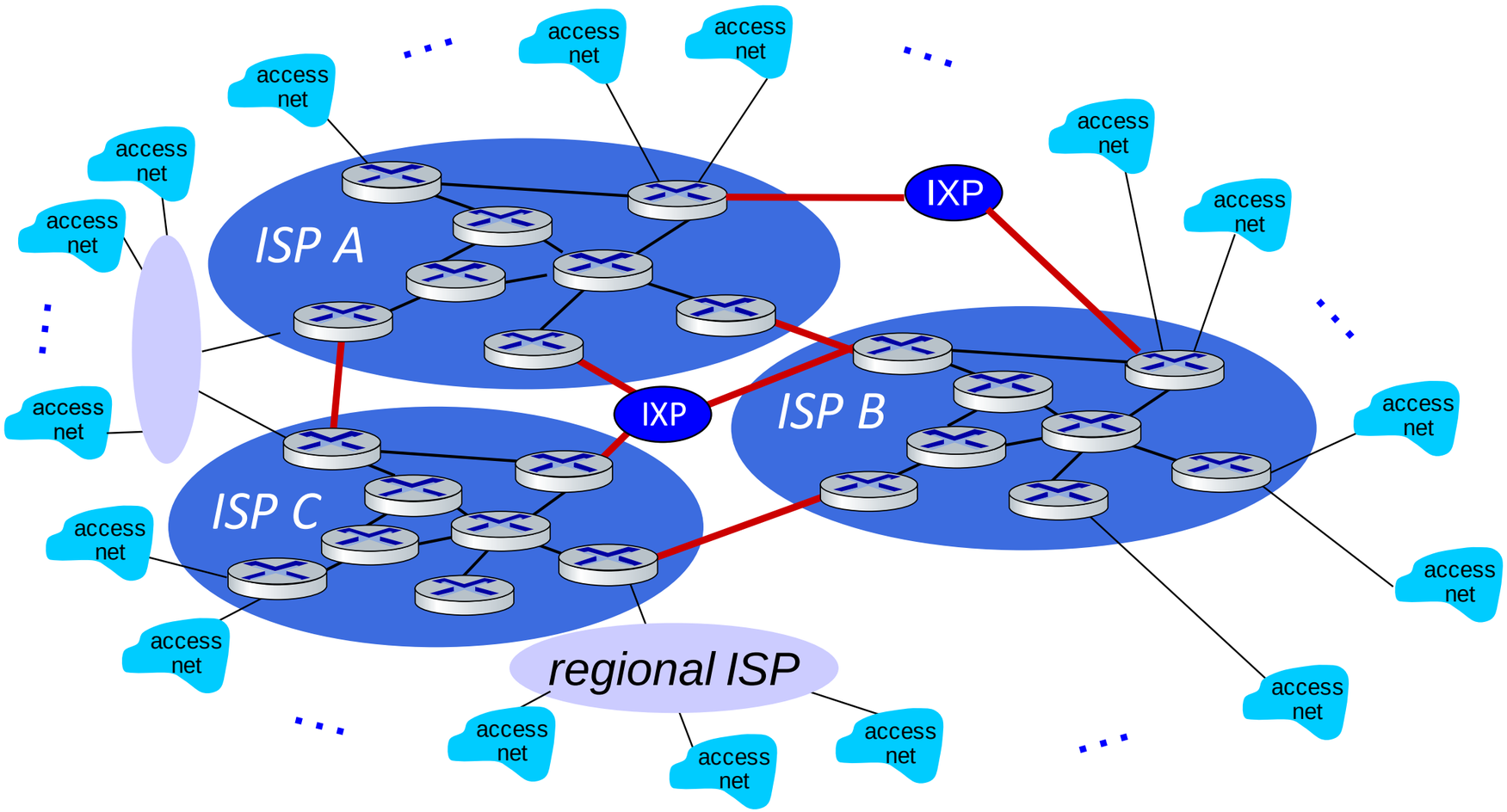
Internet structure: a "network of networks"

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



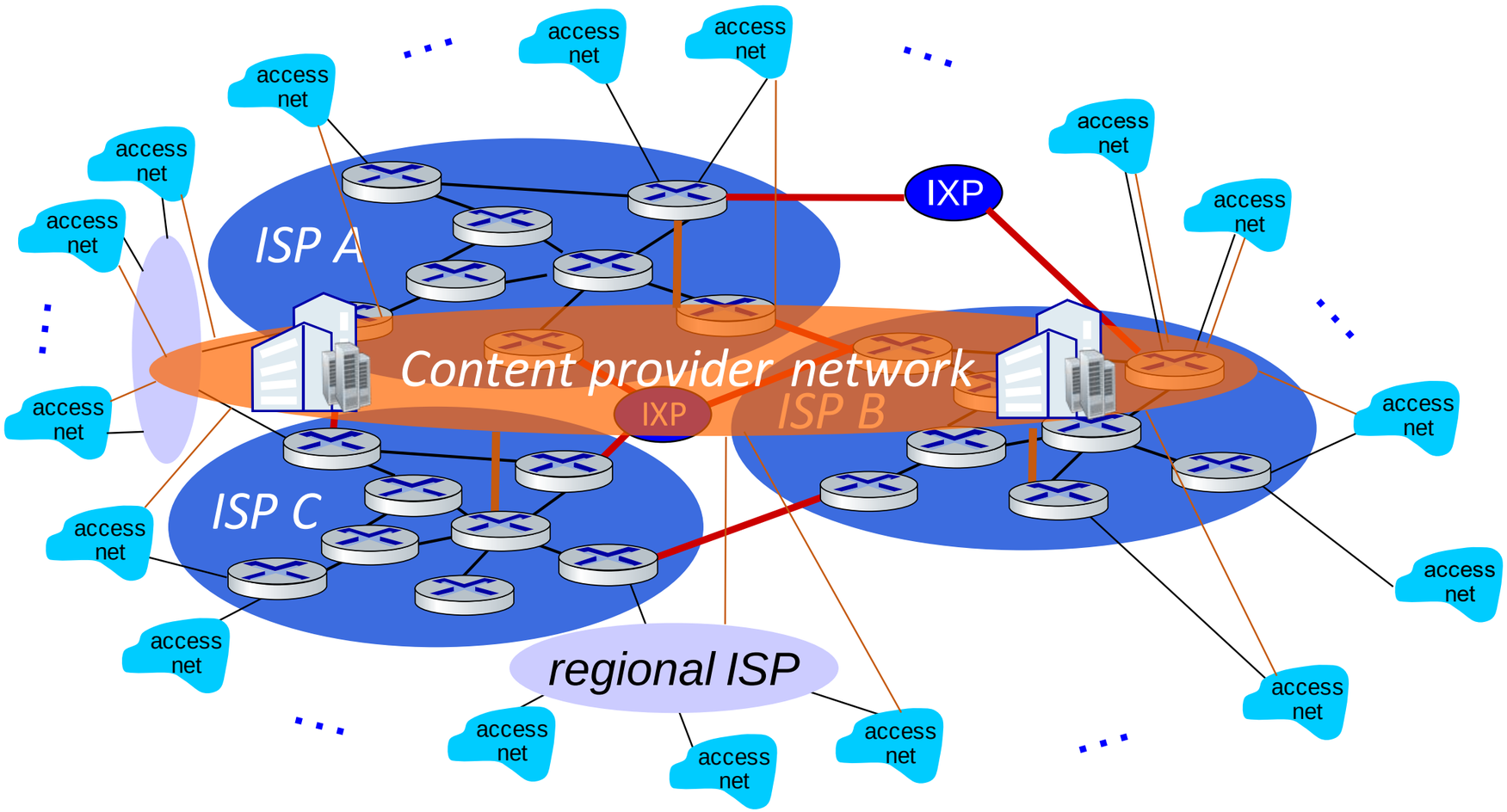
Internet structure: a "network of networks"

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



Internet structure: a "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



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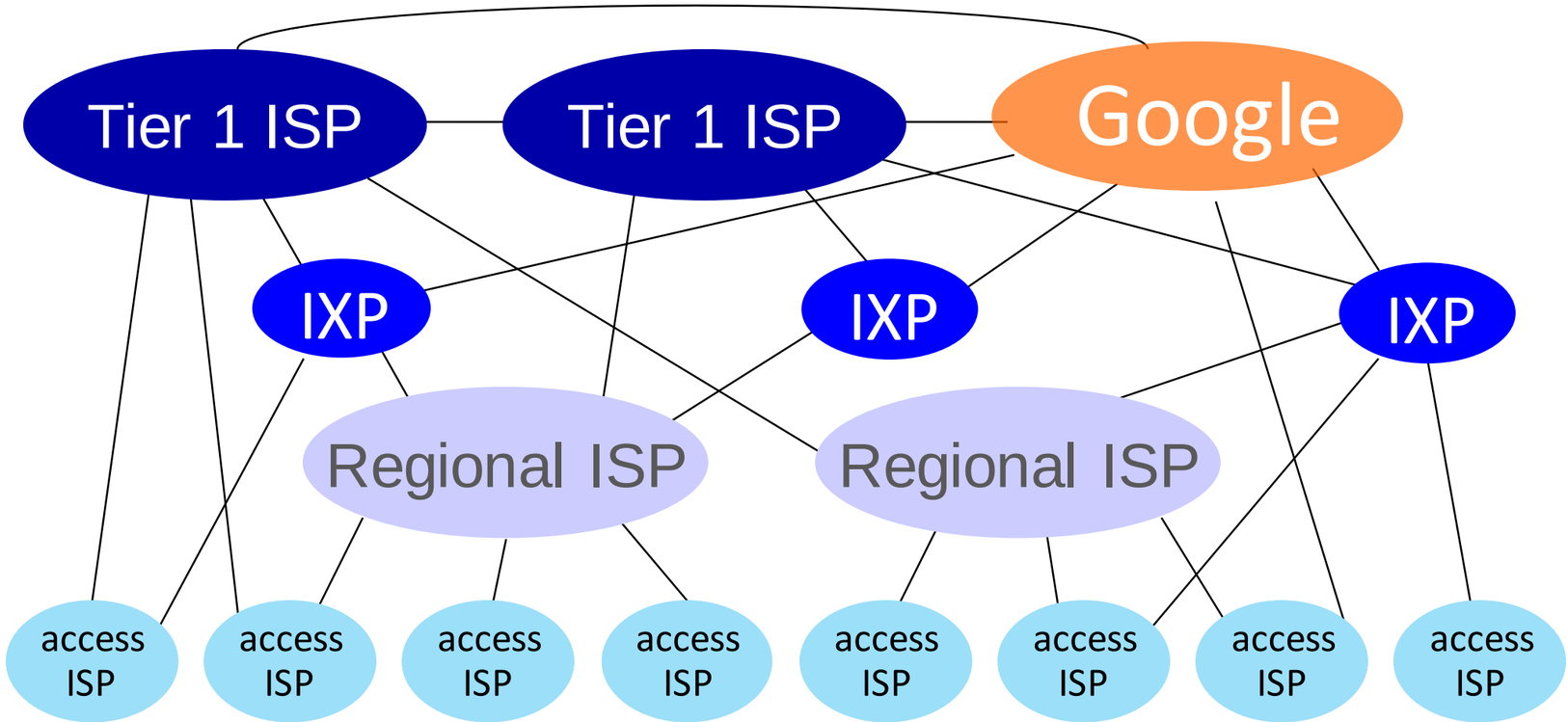
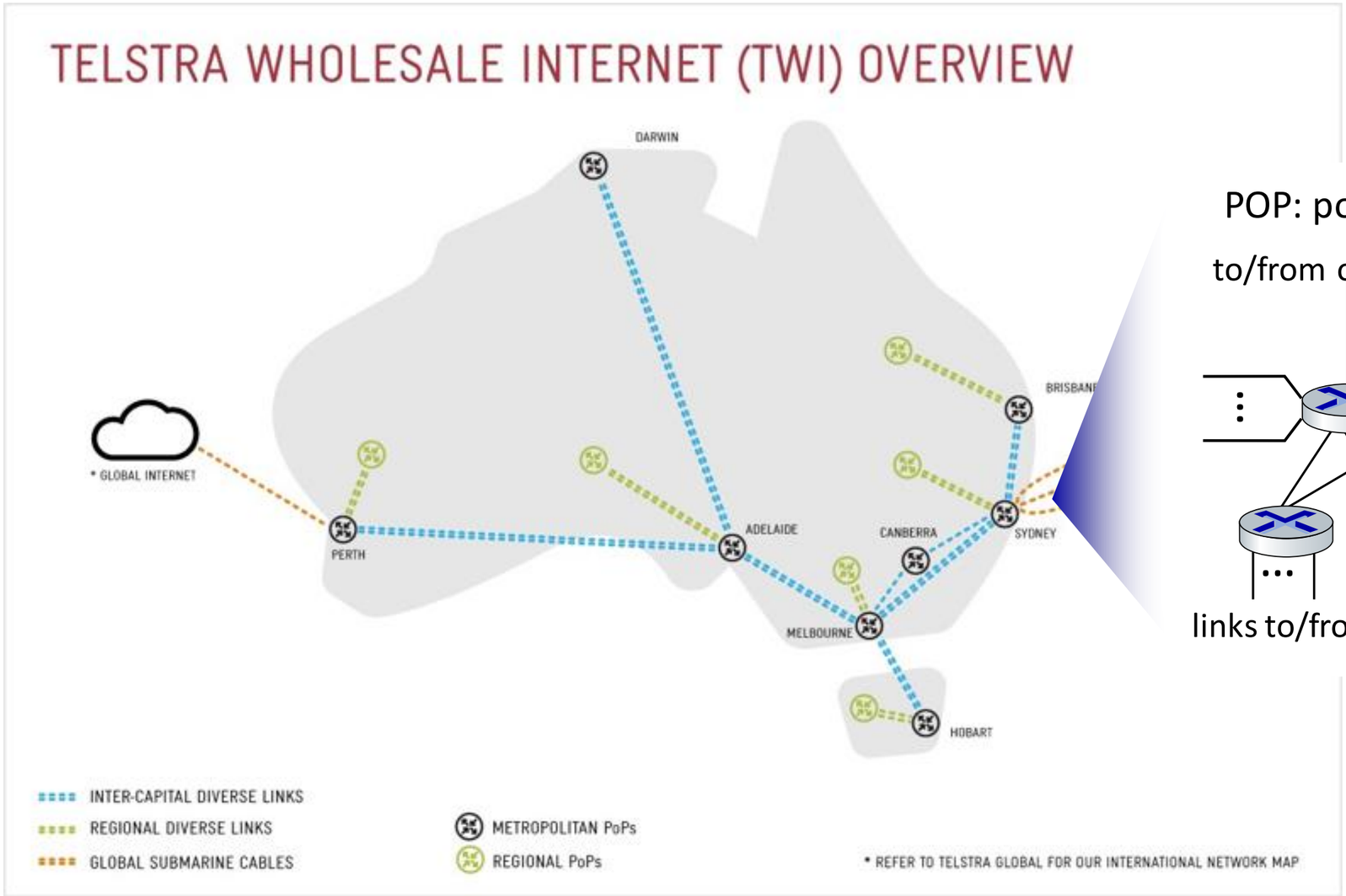
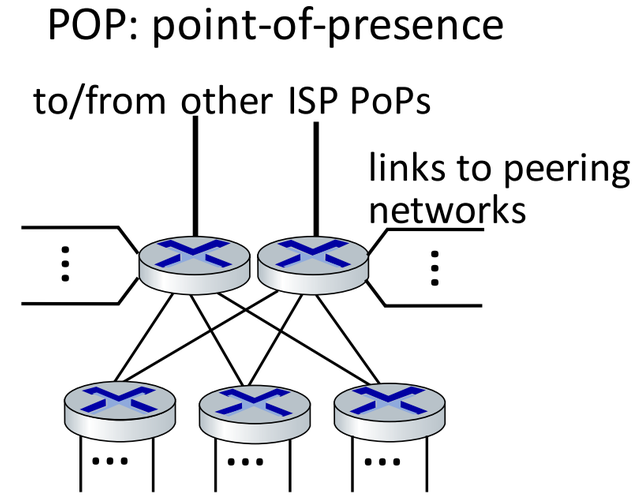


At "center": small # of well-connected large networks

- "tier-1" commercial ISPs (e.g., Sprint, AT&T, Telstra), national & international coverage
- content provider networks (e.g., Google, Facebook): private network that connects its data centers to Internet, often bypassing tier-1, regional ISPs

Tier-1 ISP Network map: Telstra





Chapter 1: summary

We've covered a "ton" of material!

- Internet overview
- what's a protocol?
- network edge, access network, core
  - packet-switching versus circuit-switching
  - Internet structure
- performance: loss, delay, throughput
- layering, service models
- security
- history

You now have:

- context, overview, vocabulary, "feel" of networking
- more depth, detail, *and fun* to follow*!*

Lecture done ✅

- Q & A