

Chapter 1

Introduction

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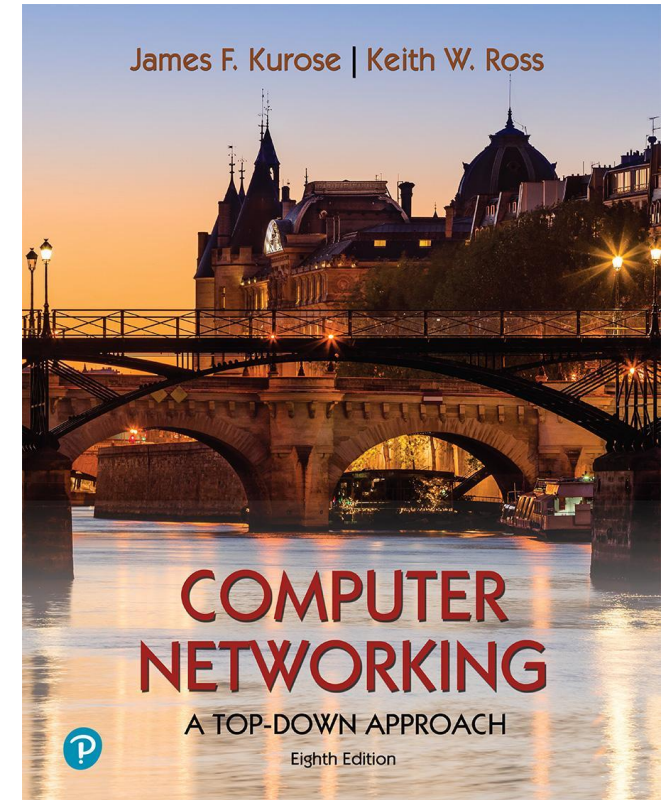
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*Computer Networking: A
Top-Down Approach*

8th edition

Jim Kurose, Keith Ross
Pearson, 2020

The Internet: a “nuts and bolts” view



End devices = Hosts

- running *network apps*



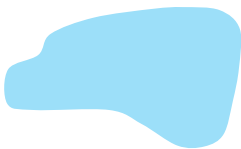
Network devices: forward packets (chunks of data)

- *routers, switches*
- *forward packets*



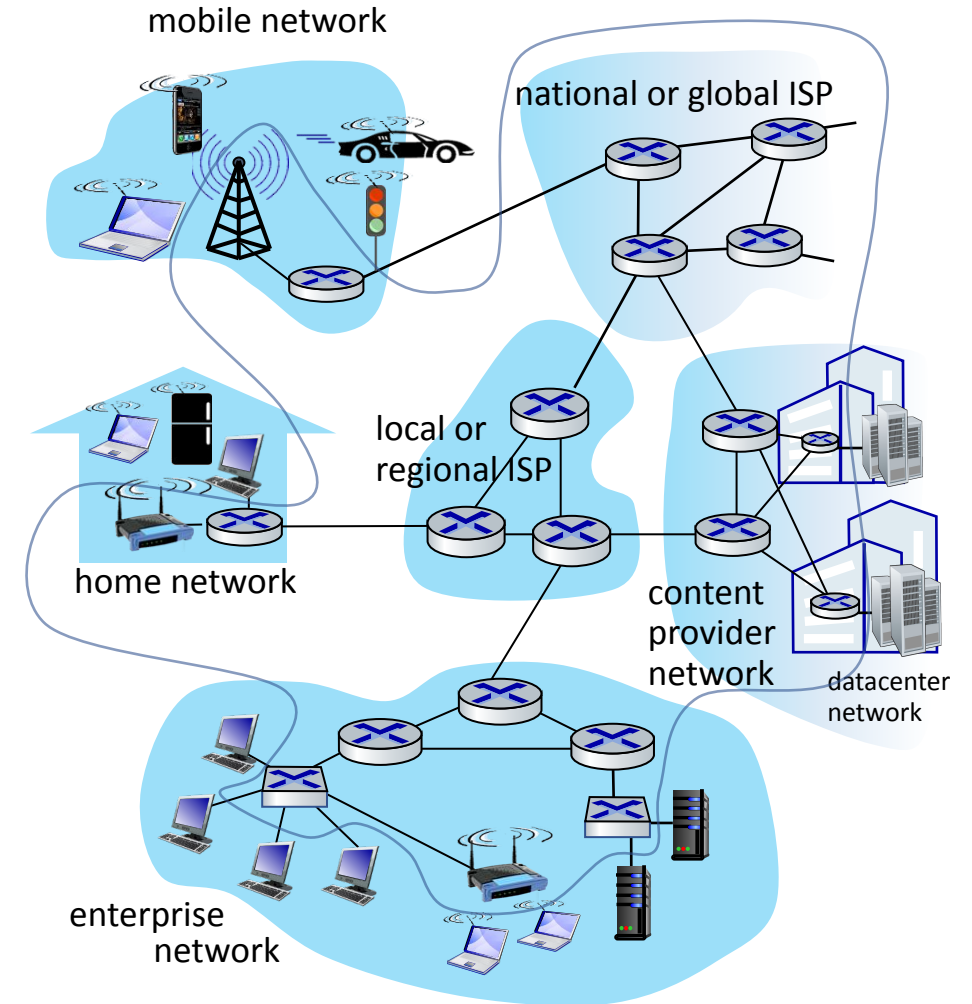
Communication links

- fiber, copper, radio, satellite



Networks

- collection of devices, routers, links



What's a protocol?

Human protocols:

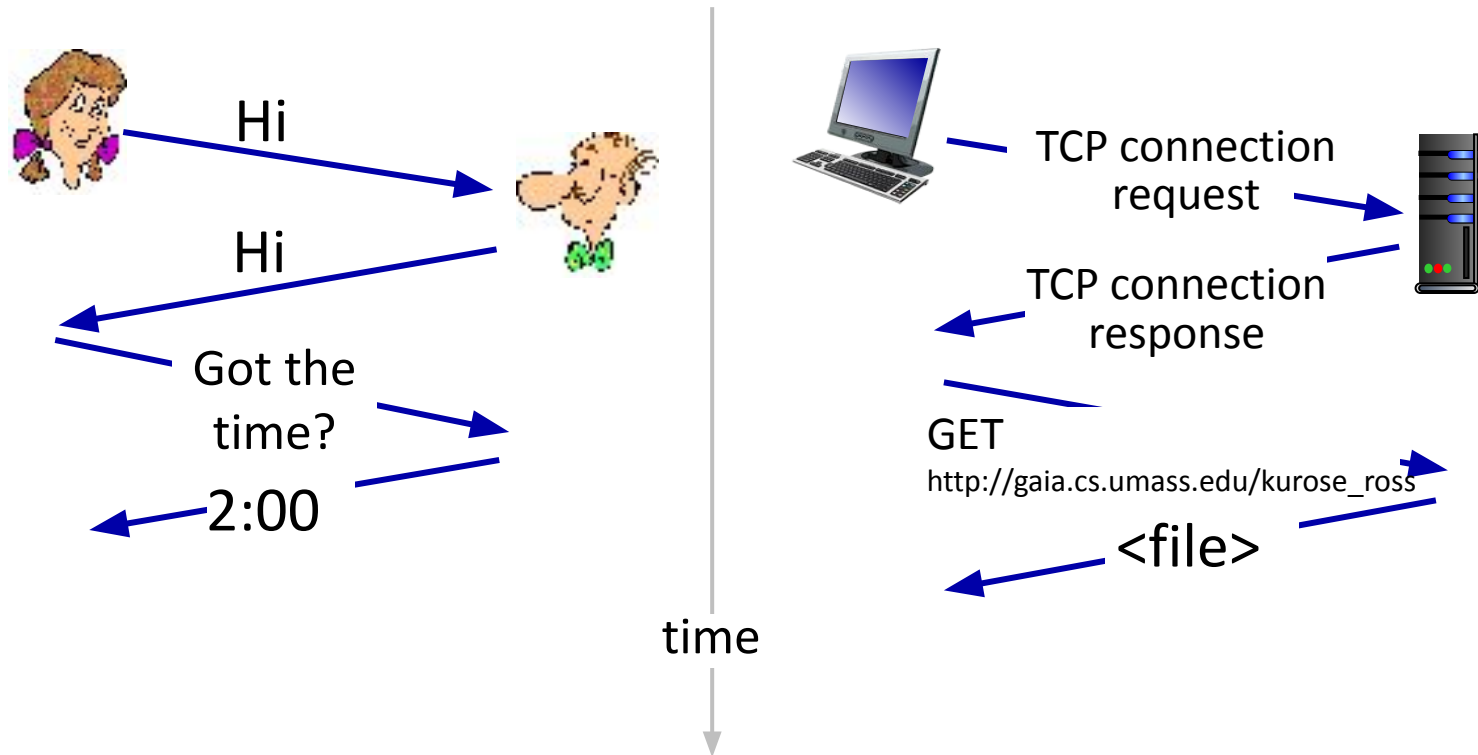
- “what’s the time?”
- “I have a question”
- natural language

Network protocols:

- the format, order of messages sent and received
- the actions taken on message transmission, receipt

What's a protocol?

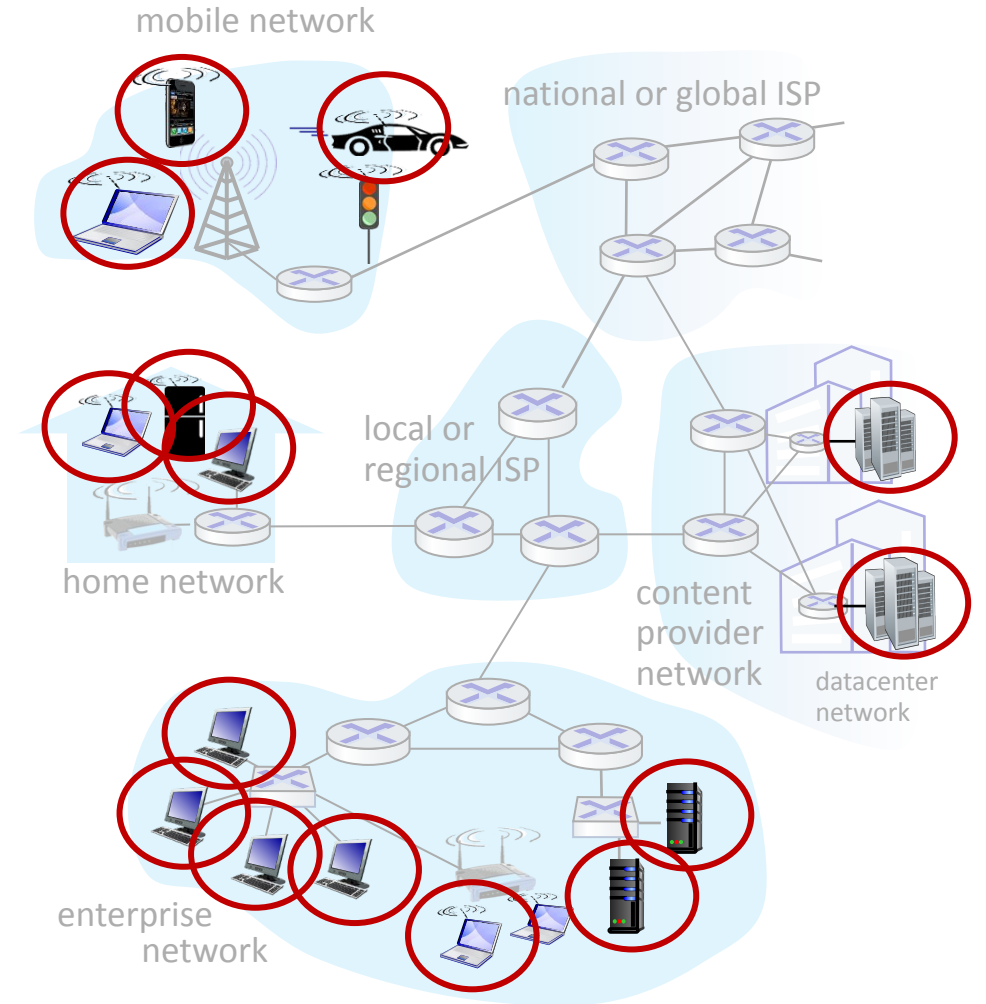
A human protocol and a computer network protocol:



A closer look at Internet structure

Network edge:

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



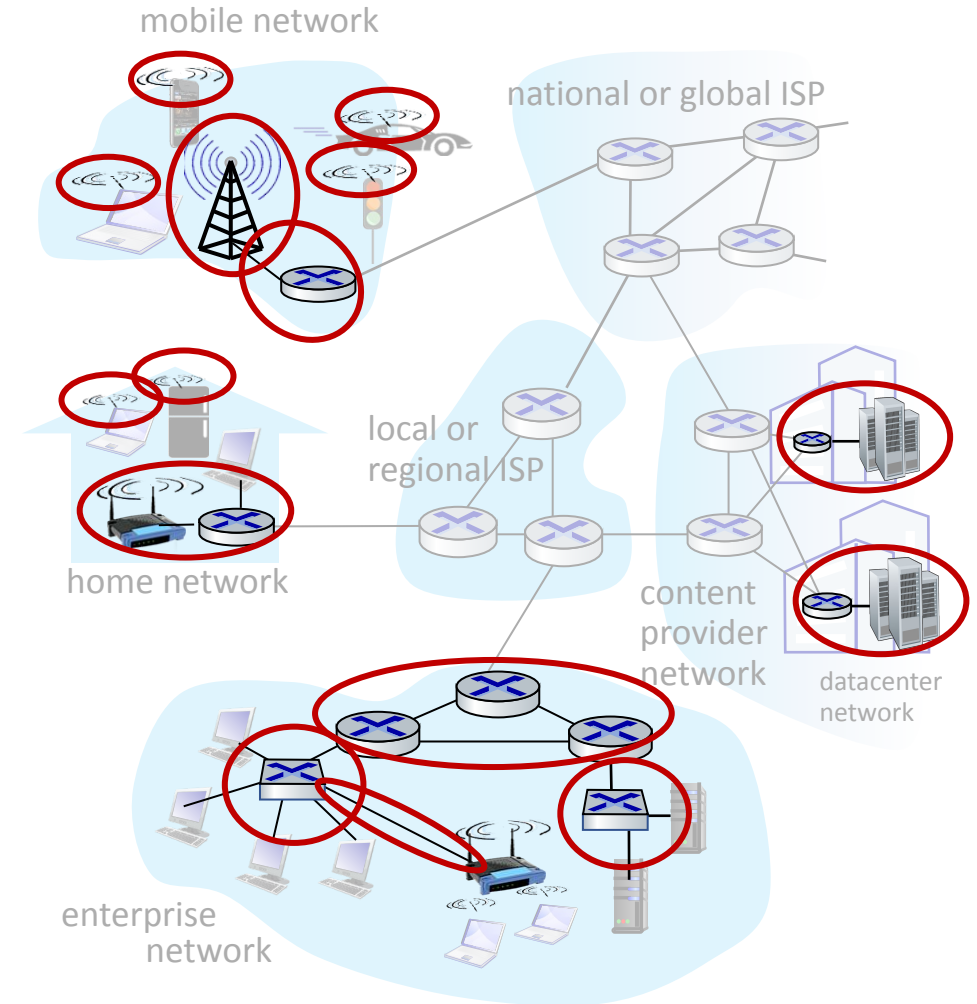
A closer look at Internet structure

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:

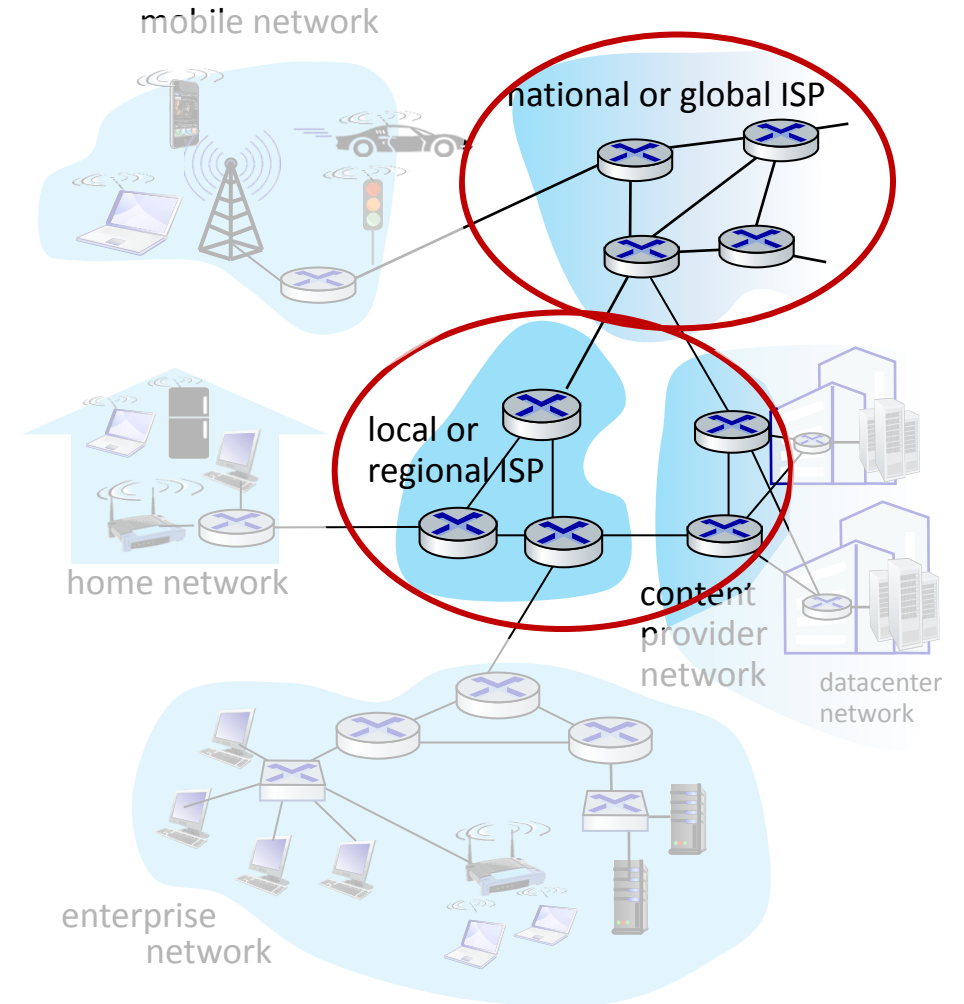
- hosts: clients and servers
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Access networks, physical media:

- wired, wireless communication links

Network core:

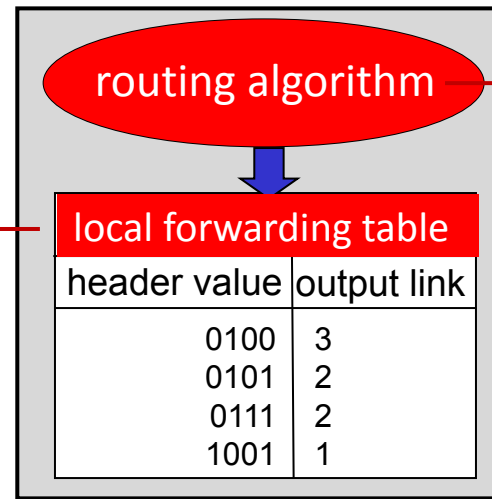
- interconnected routers
- network of networks



Two key network-core functions

Forwarding:

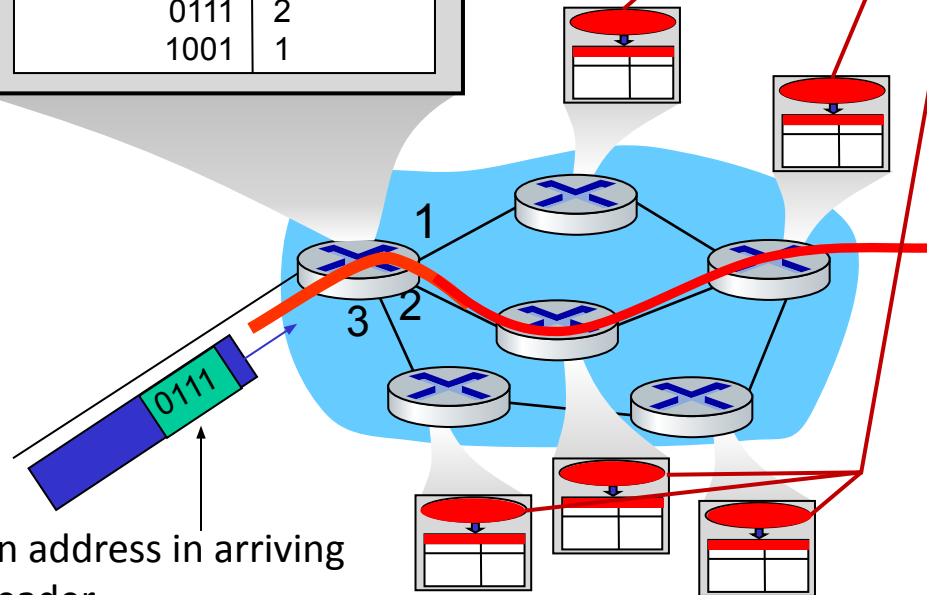
- aka “switching”
- *local* action: move arriving packets from router’s input link to appropriate router output link



destination address in arriving packet's header

Routing:

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

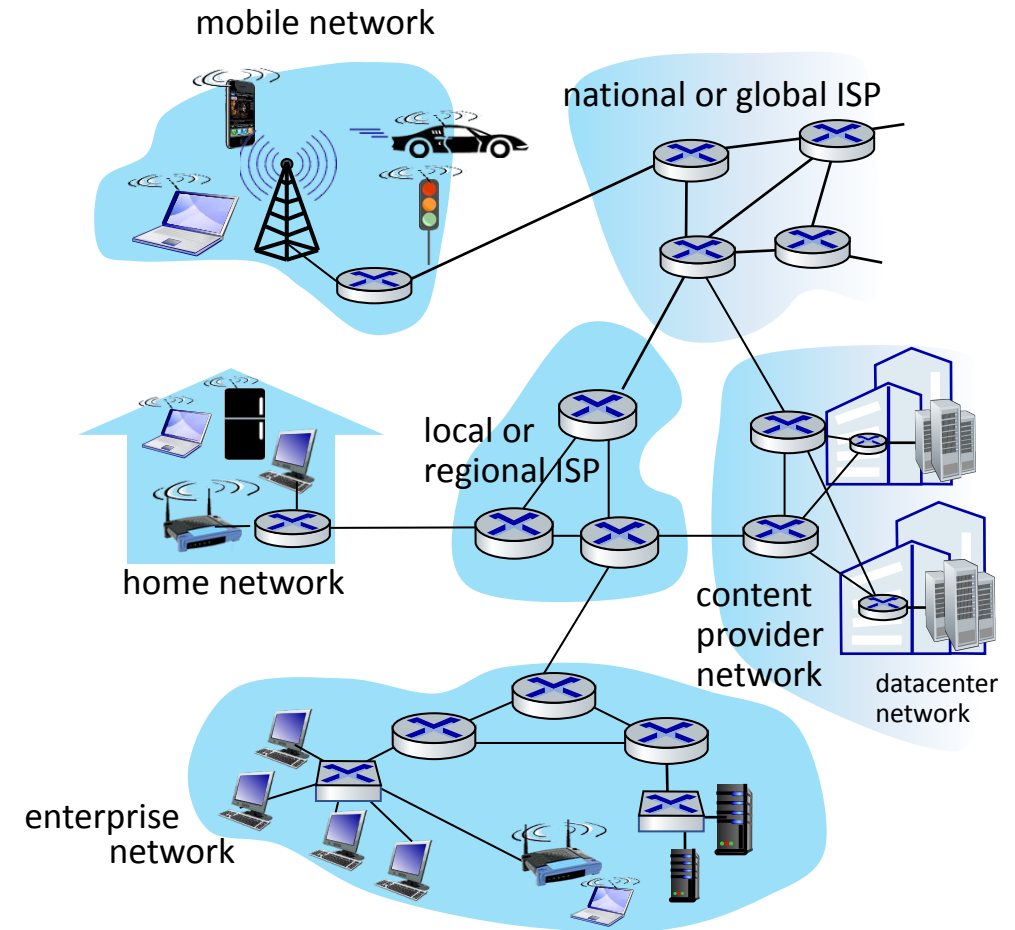






Internet structure: a “network of networks”

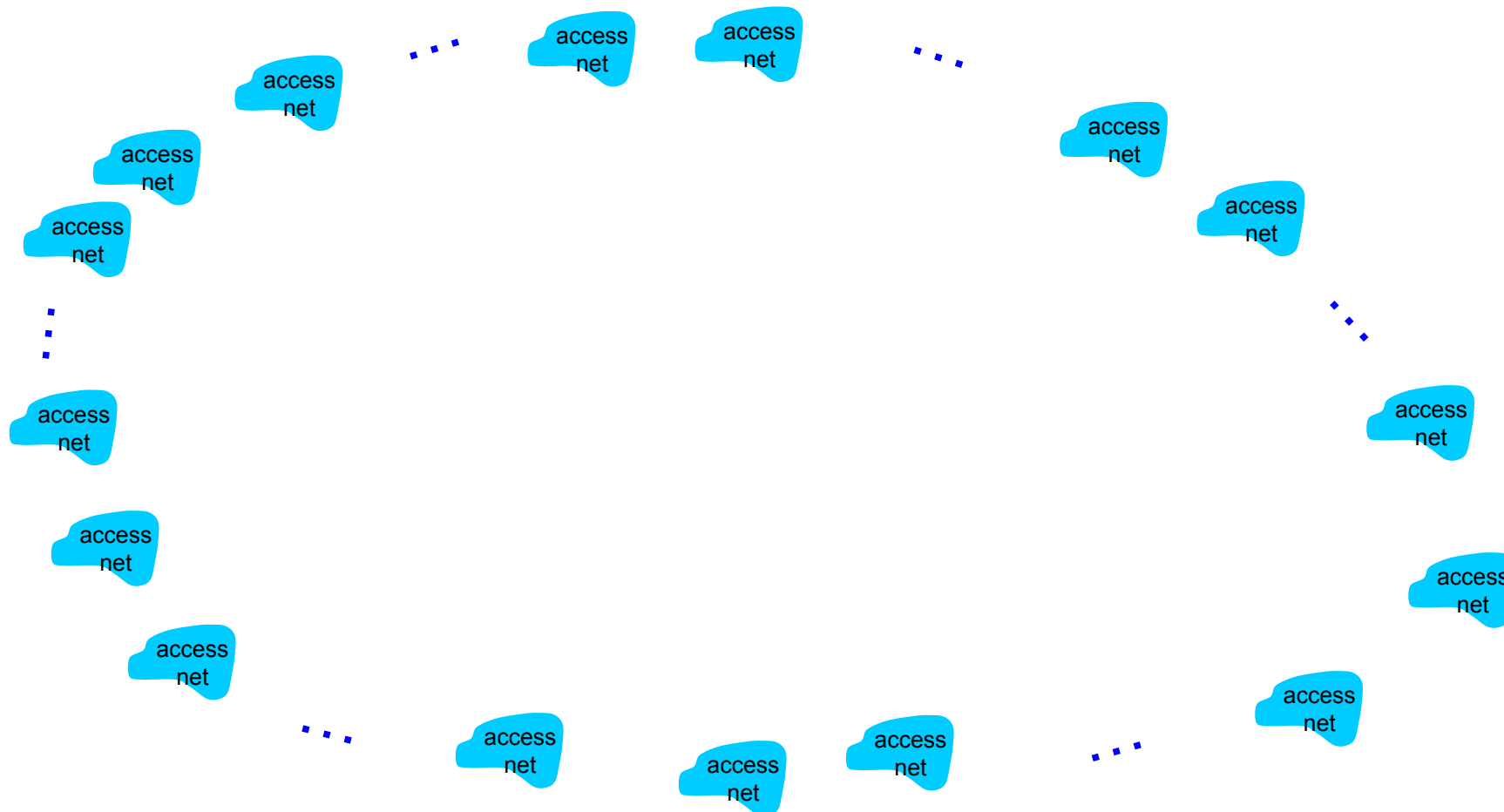
- hosts connect to Internet via **access** Internet Service Providers (ISPs)
- access ISPs in turn must be interconnected
 - so that *any* two hosts (*anywhere!*) can send packets to each other
- resulting network of networks is very complex
 - evolution driven by **economics**, **national policies**



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

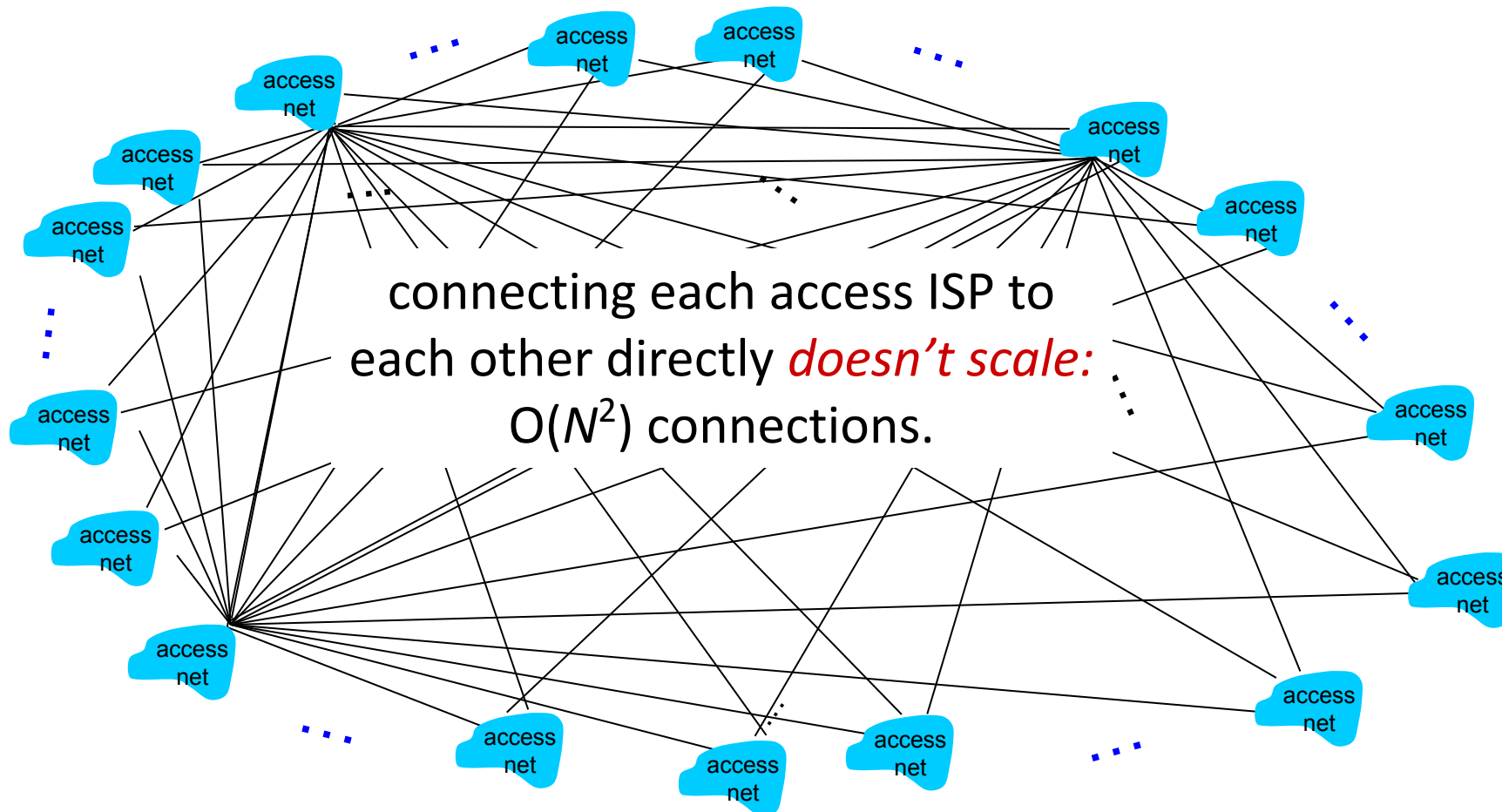
Internet structure: a “network of networks”

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



Internet structure: a “network of networks”

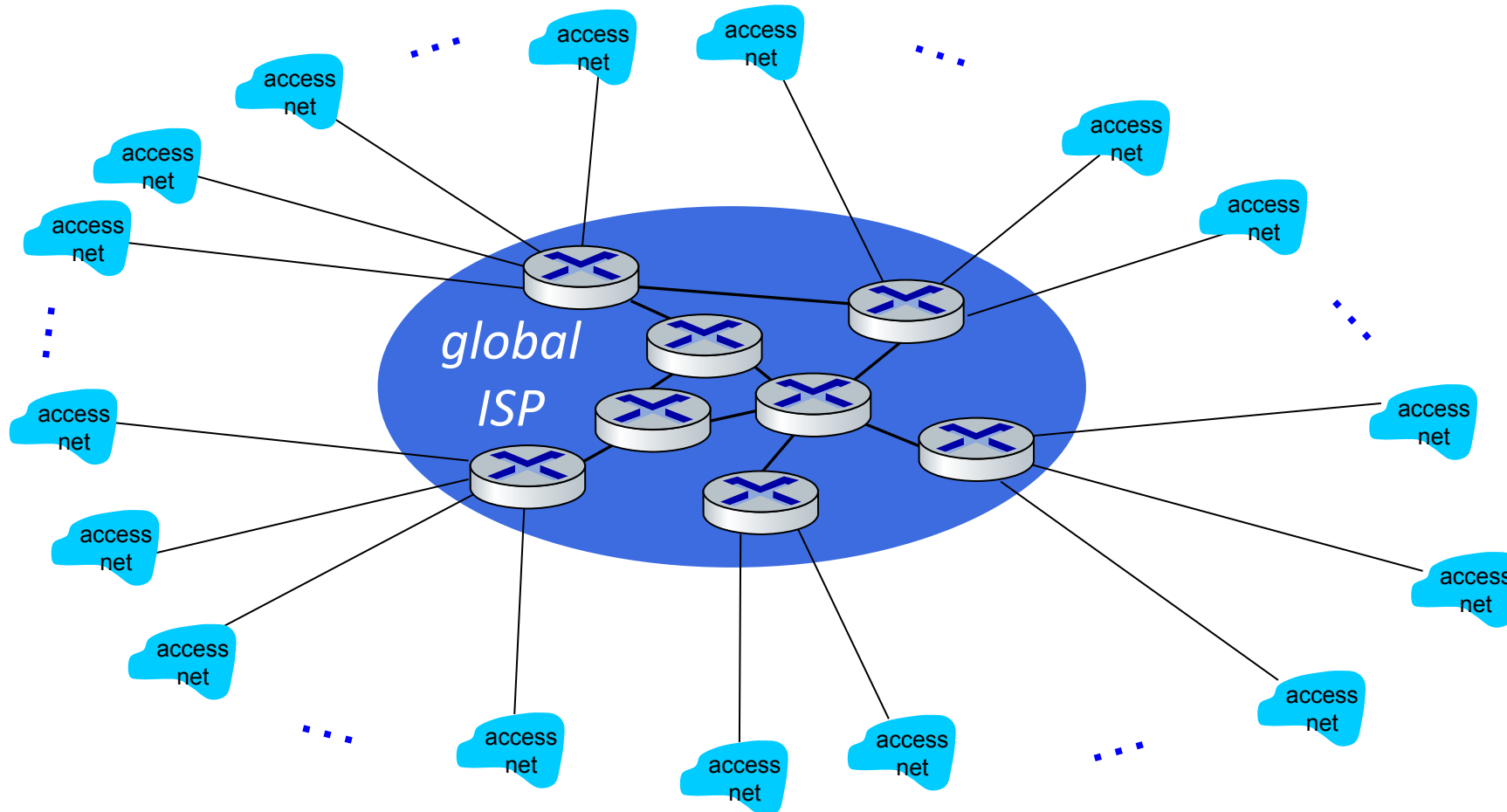
Question: given *millions* of access ISPs, how to connect them together?



Internet structure: a “network of networks”

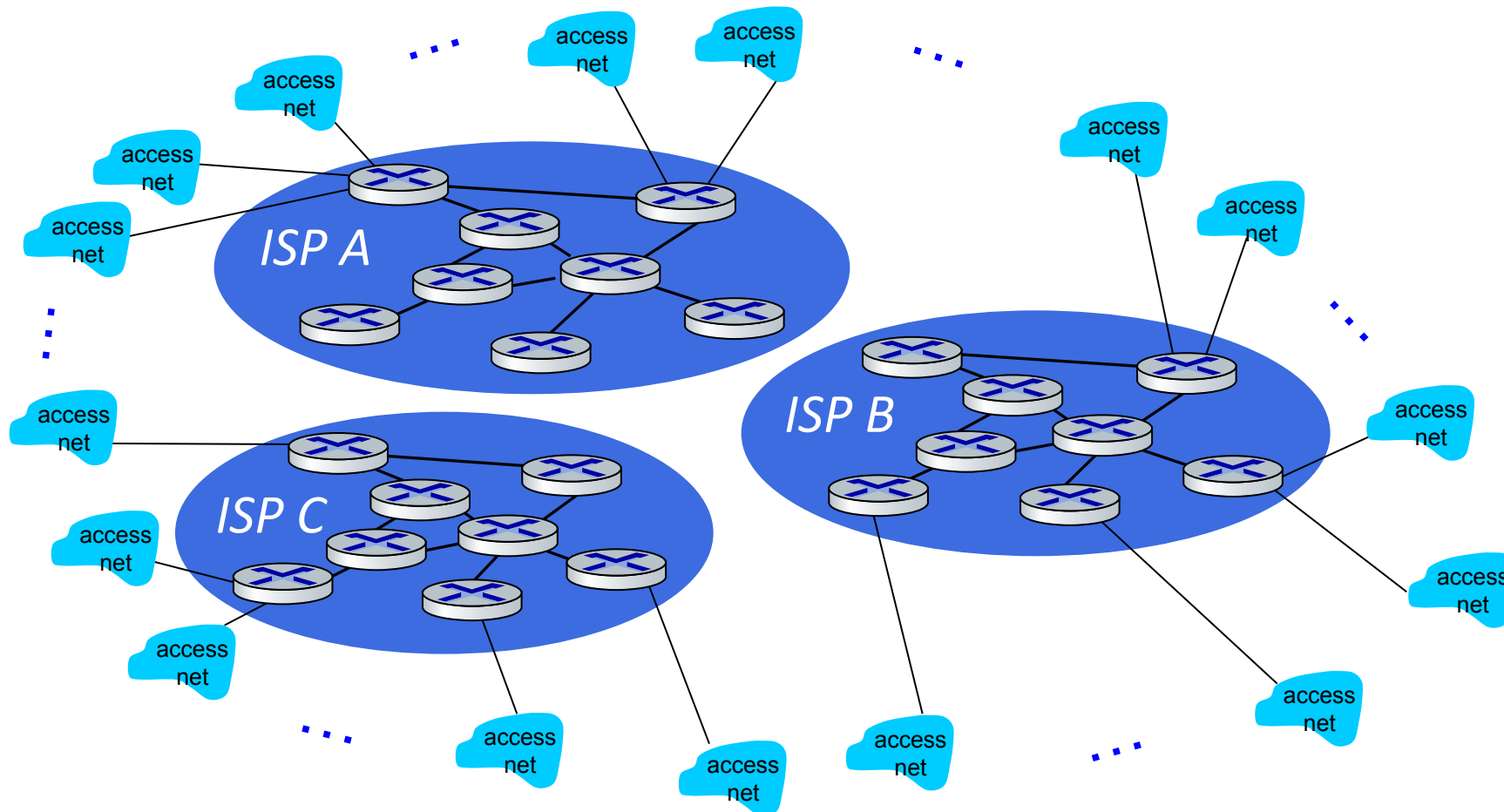
Option: connect each access ISP to one global transit ISP?

Customer and provider ISPs have economic agreement.



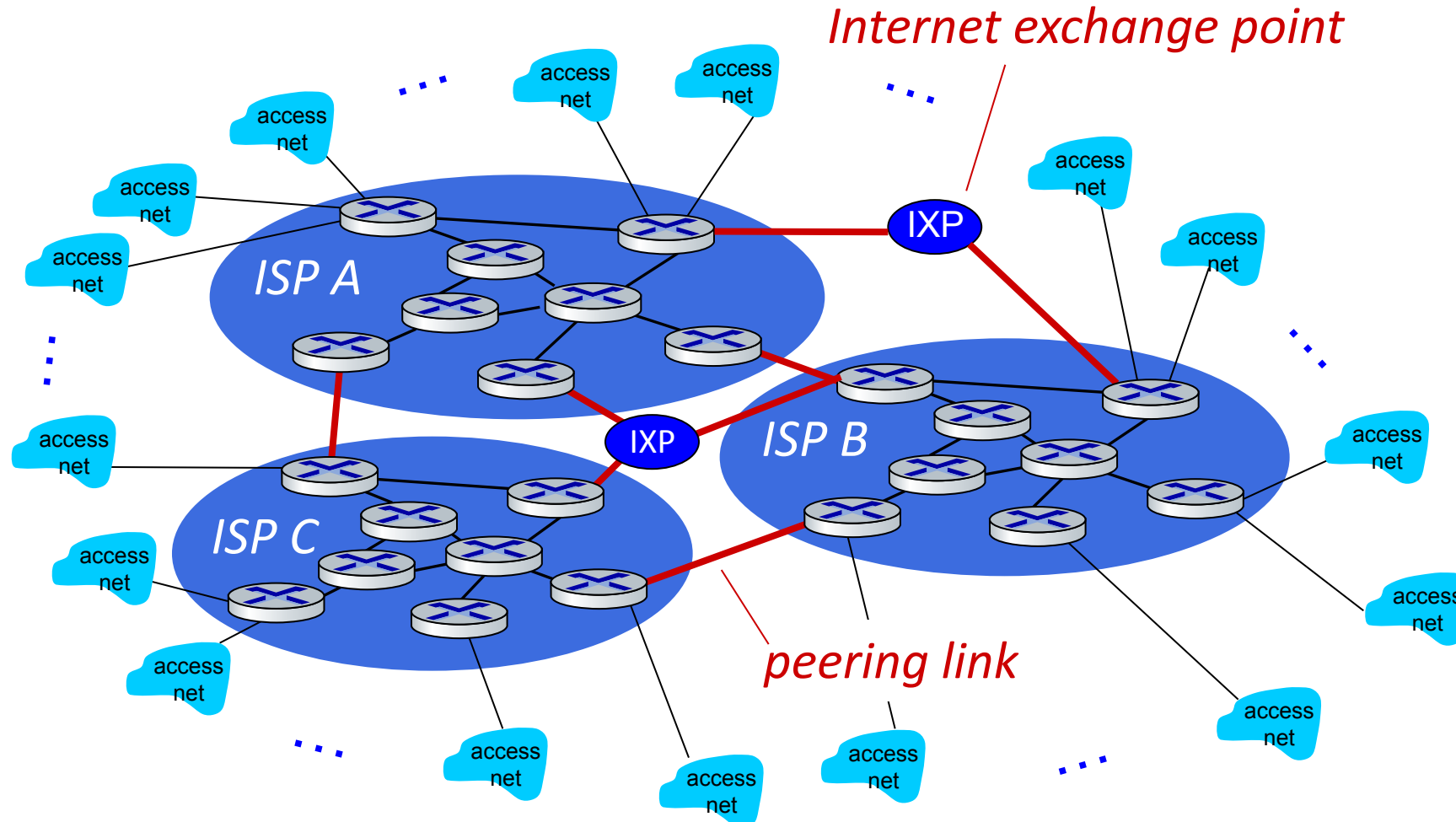
Internet structure: a “network of networks”

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



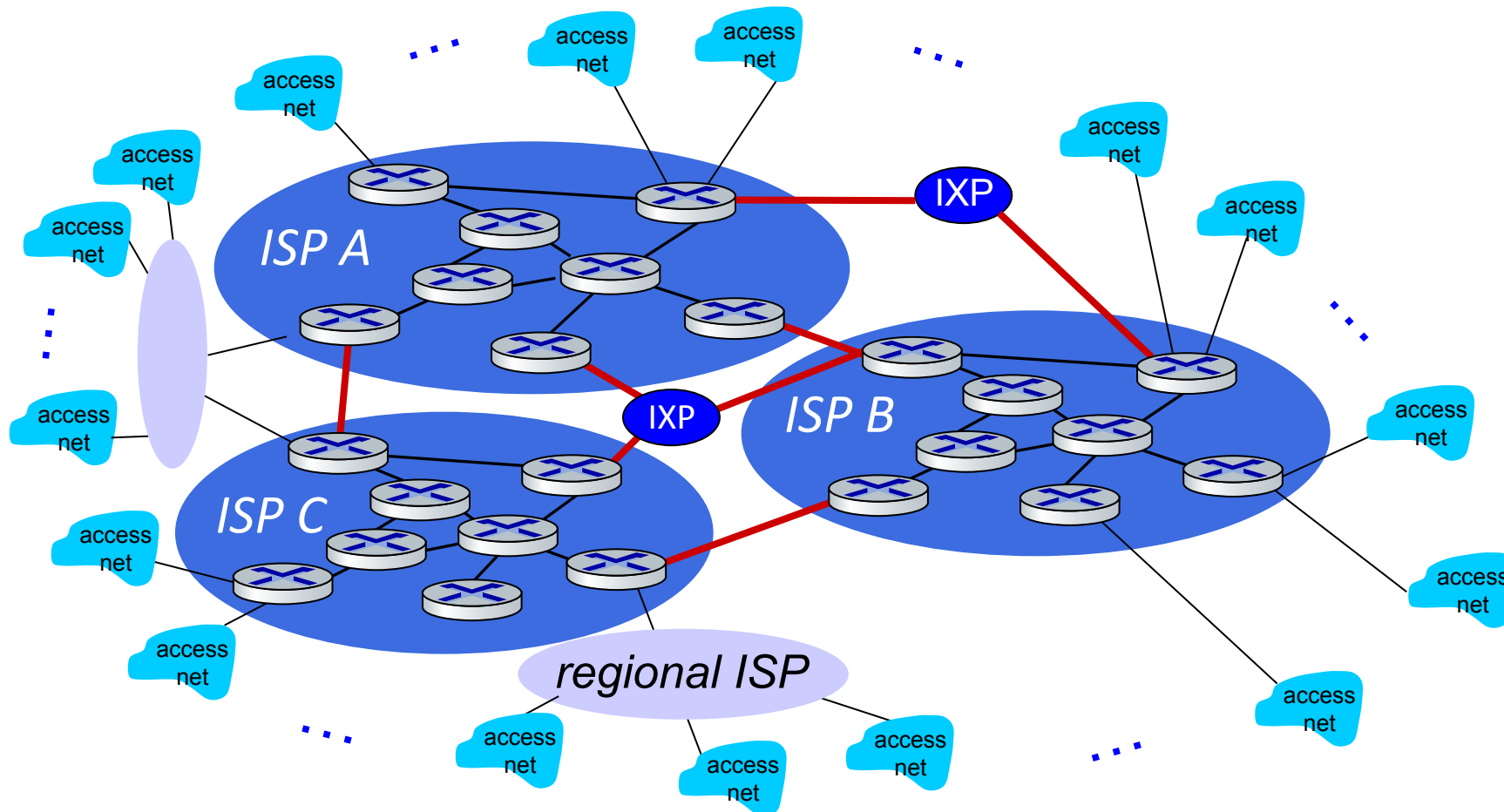
Internet structure: a “network of networks”

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



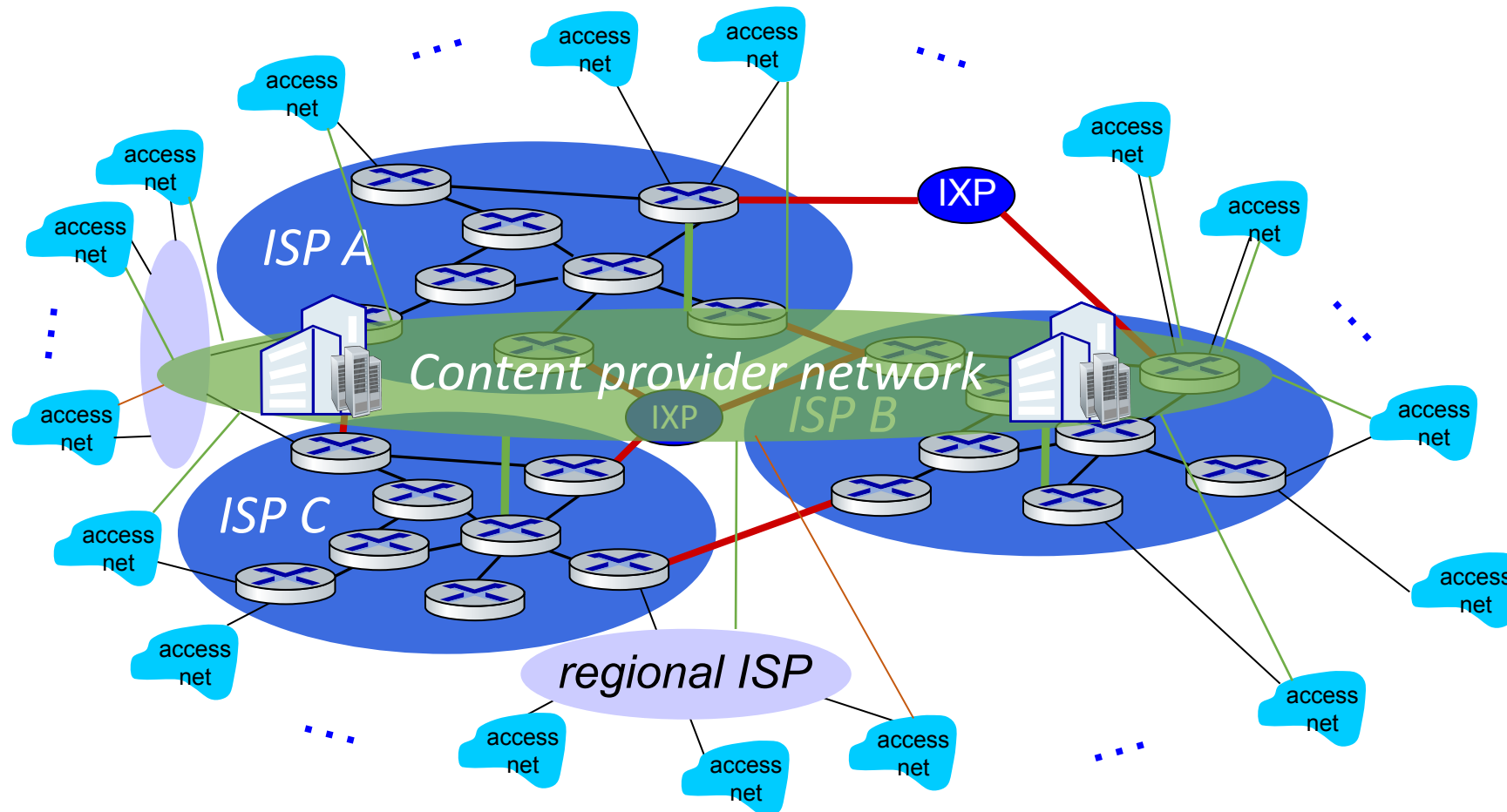
Internet structure: a “network of networks”

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

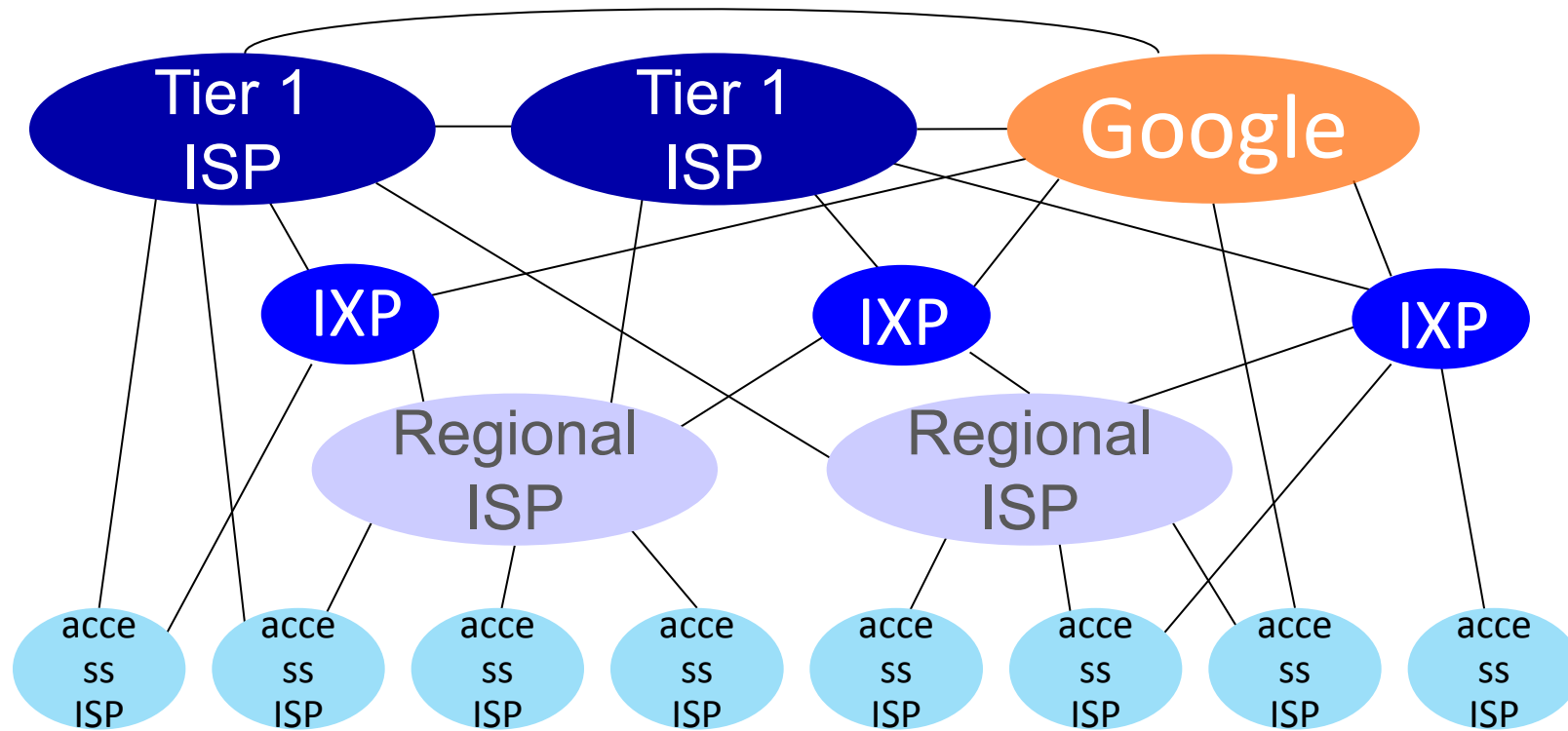


Internet structure: a “network of networks”

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



Internet structure: a “network of networks”

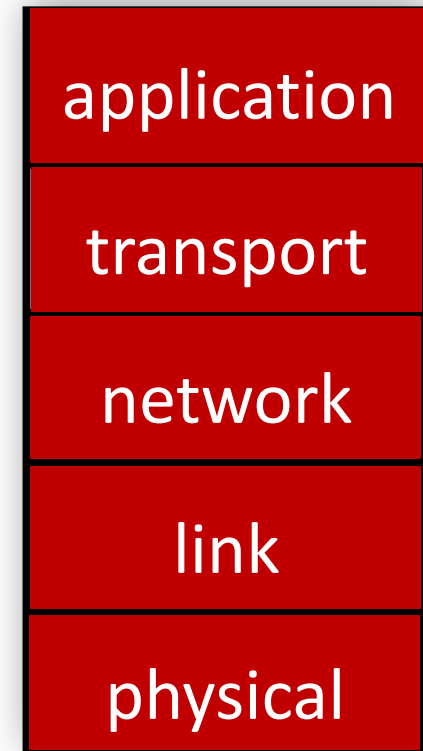


At “center”: small # of well-connected large networks

- **“tier-1” commercial ISPs** (e.g., Level 3, Sprint, AT&T, NTT), national & international coverage
- **content provider networks** (e.g., Google, Facebook): private network that connects its data centers to Internet, often bypassing tier-1, regional ISPs

Layered Internet protocol stack

- *application*: supporting network applications
 - HTTP, IMAP, SMTP, DNS
- *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, 802.11 (WiFi), PPP
- *physical*: bits “on the wire”

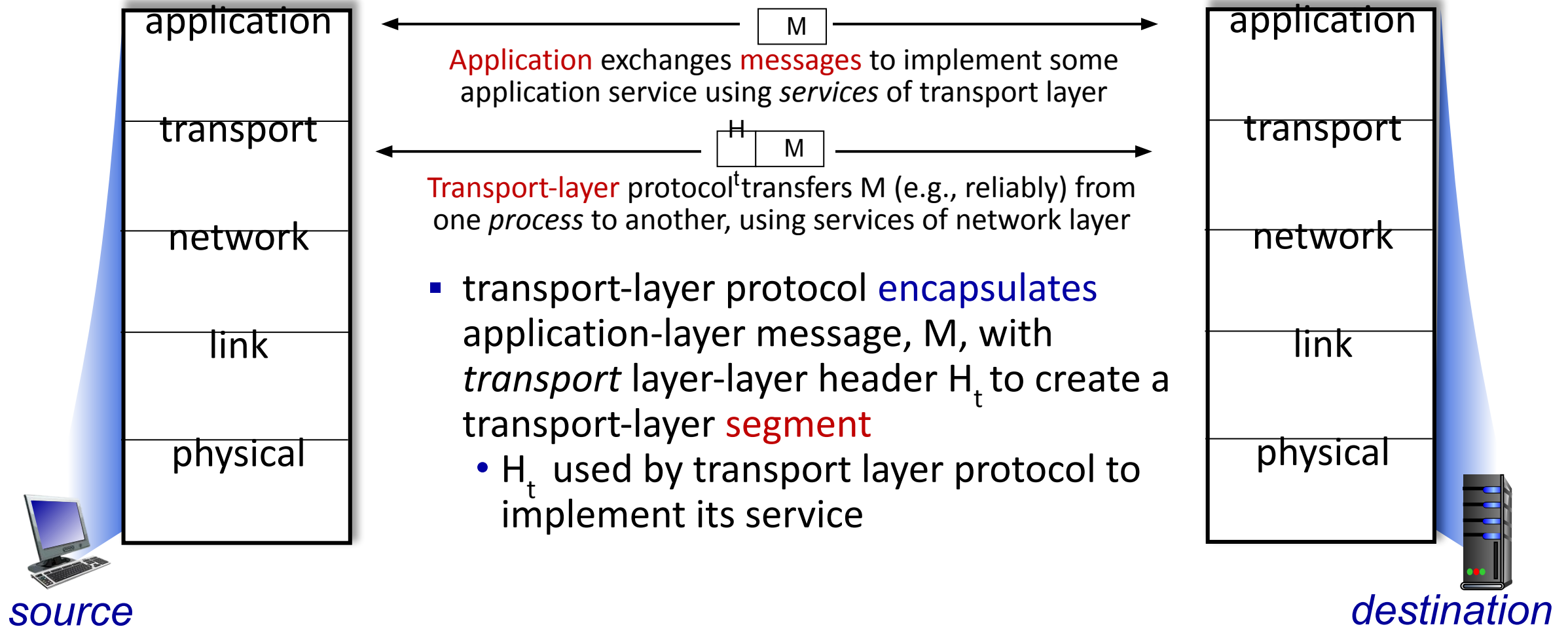


Why layering?

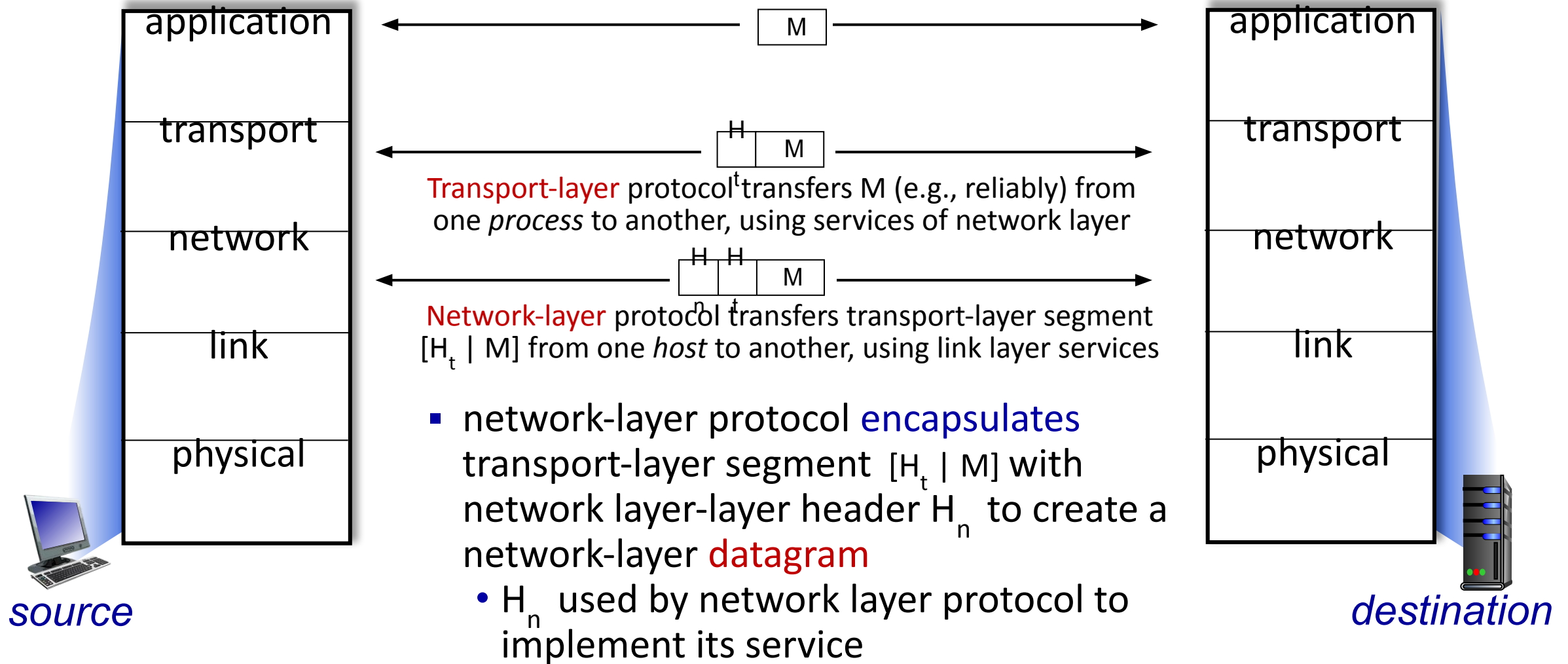
Approach to designing/discussing complex systems:

- explicit structure allows identification, relationship of system's pieces
 - layered *reference model* for discussion
- modularization eases maintenance, updating of system
 - change in layer's service *implementation*: transparent to rest of system
 - e.g., change in gate procedure doesn't affect rest of system

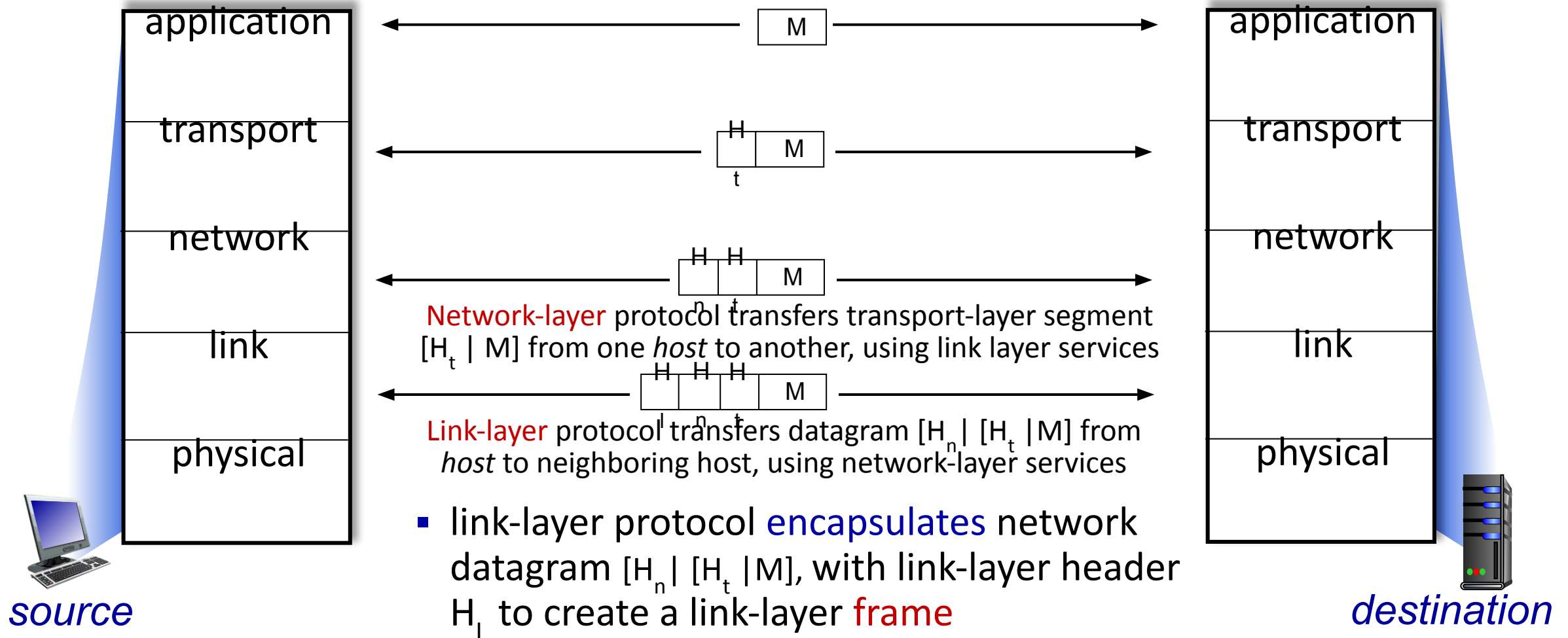
Services, Layering and Encapsulation



Services, Layering and Encapsulation

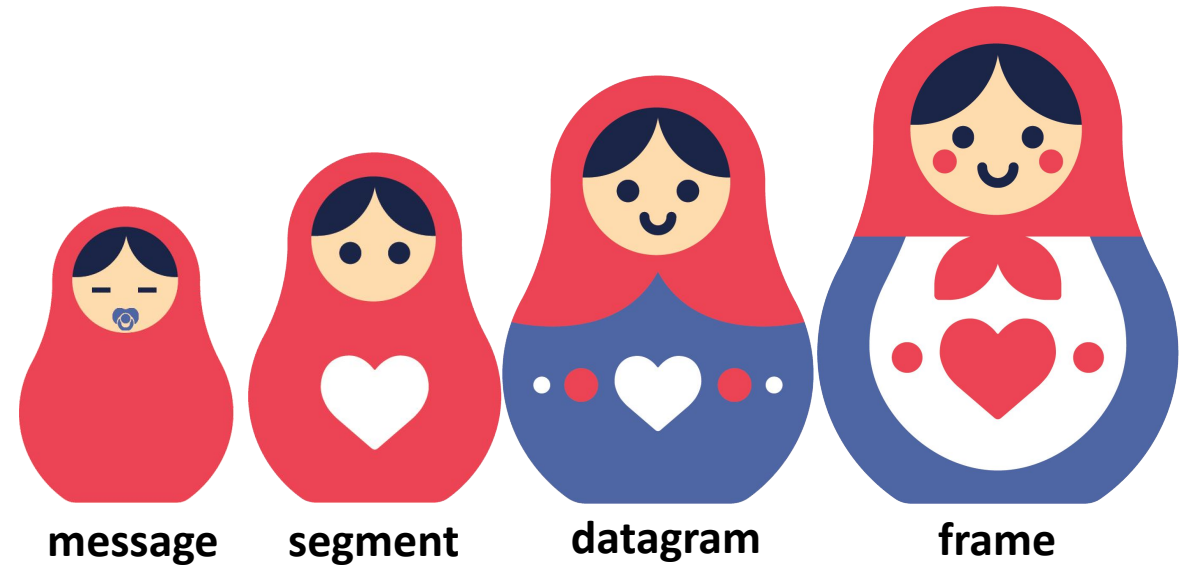


Services, Layering and Encapsulation

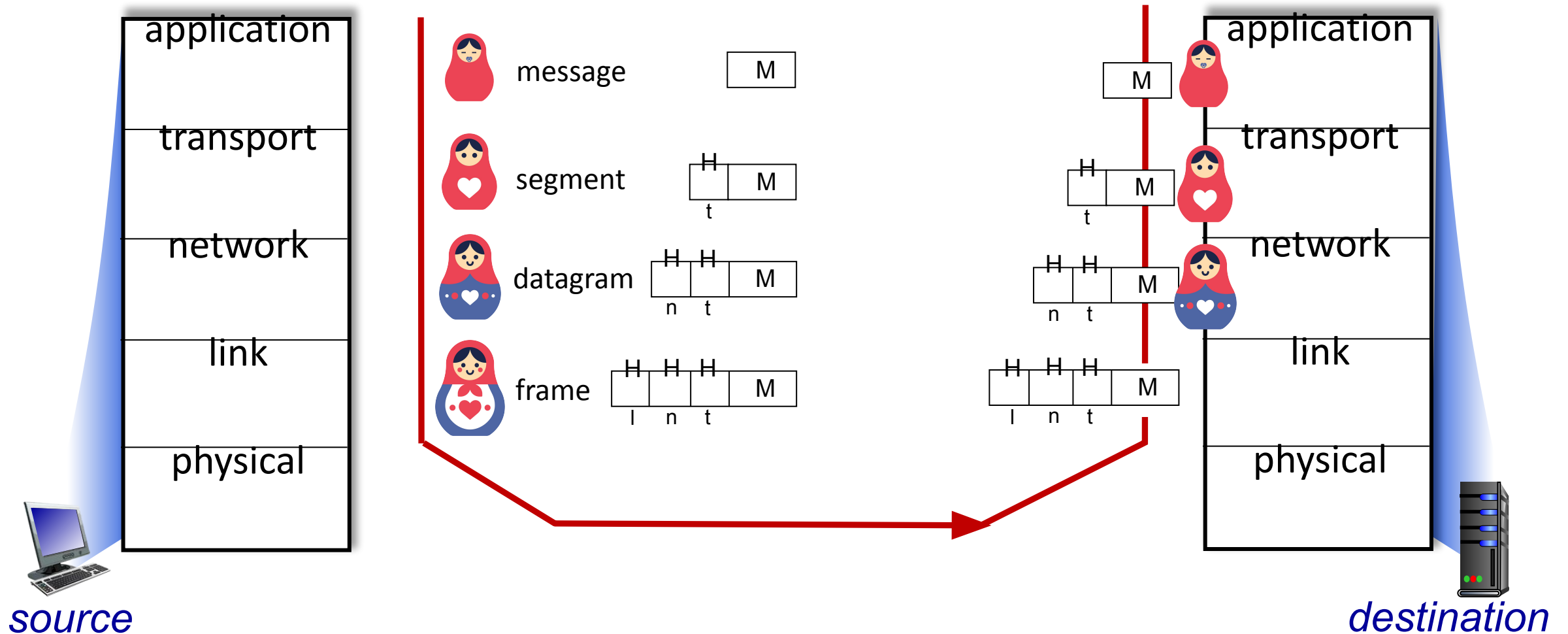


Encapsulation

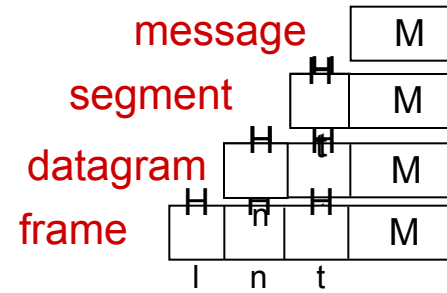
Matryoshka dolls (stacking dolls)



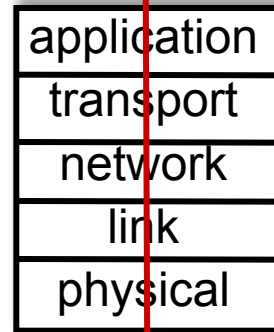
Services, Layering and Encapsulation



Encapsulation: an end-end view

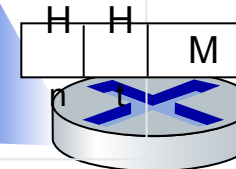
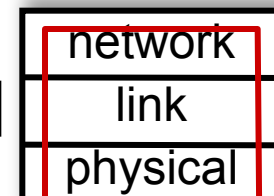
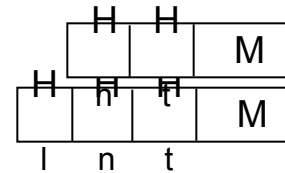
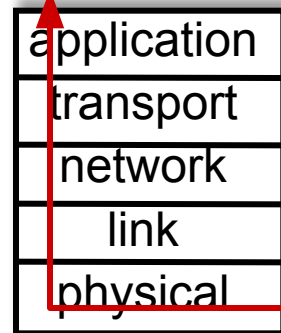
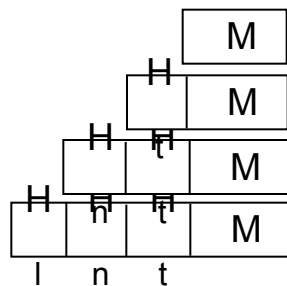


source



switch

destination

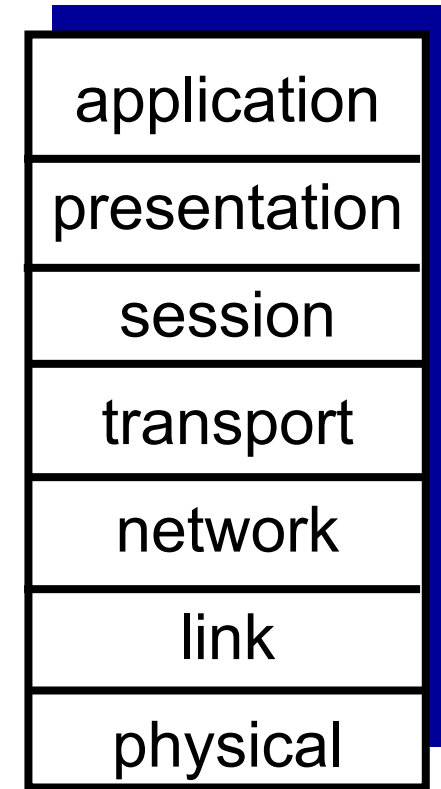


router

ISO/OSI reference model

Two layers not found in Internet protocol stack!

- *presentation*: allow applications to interpret meaning of data, e.g., encryption, compression, machine-specific conventions
- *session*: synchronization, checkpointing, recovery of data exchange
- Internet stack “missing” these layers!
 - these services, *if needed*, must be implemented in application
 - needed?



The seven layer OSI/ISO reference model

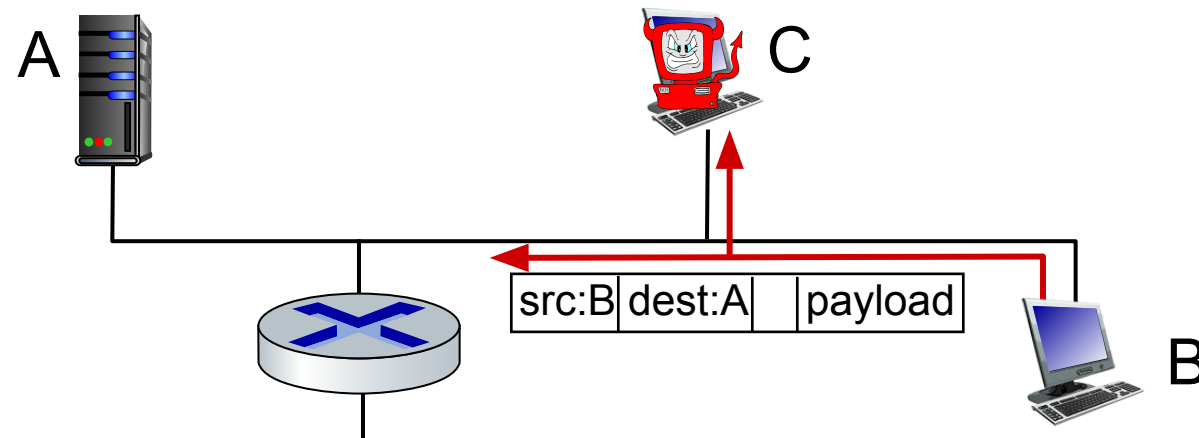
Network security

- Internet not originally designed with (much) security in mind
 - *original vision*: “a group of mutually trusting users attached to a transparent network” 😊
 - Internet protocol designers playing “catch-up”
 - security considerations in all layers!
- We now need to think about:
 - how bad guys can attack computer networks
 - how we can defend networks against attacks
 - how to design architectures that are immune to attacks

Bad guys: packet interception

packet “sniffing”:

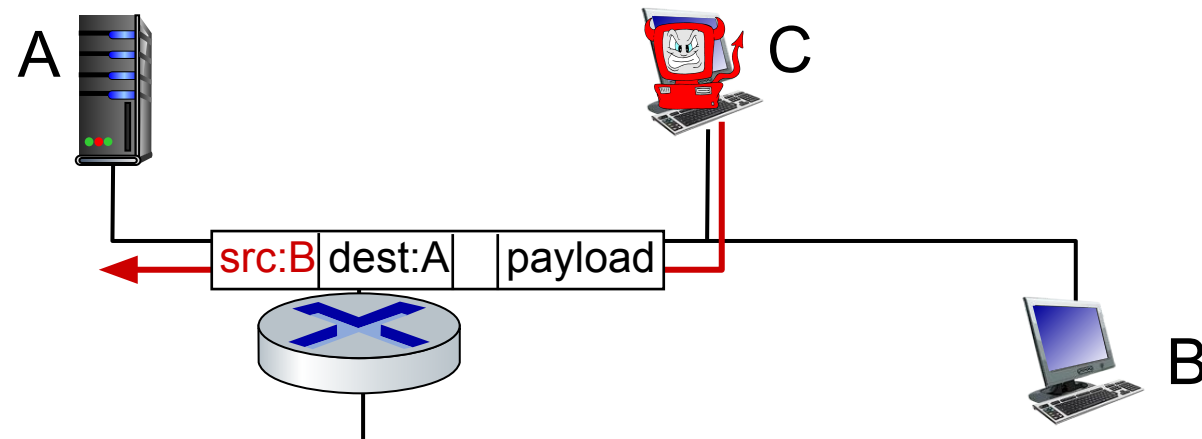
- broadcast media (shared Ethernet, wireless)
- promiscuous network interface reads/records all packets (e.g., including passwords!) passing by



Wireshark software used for our end-of-chapter labs is a (free) packet-sniffer

Bad guys: fake identity

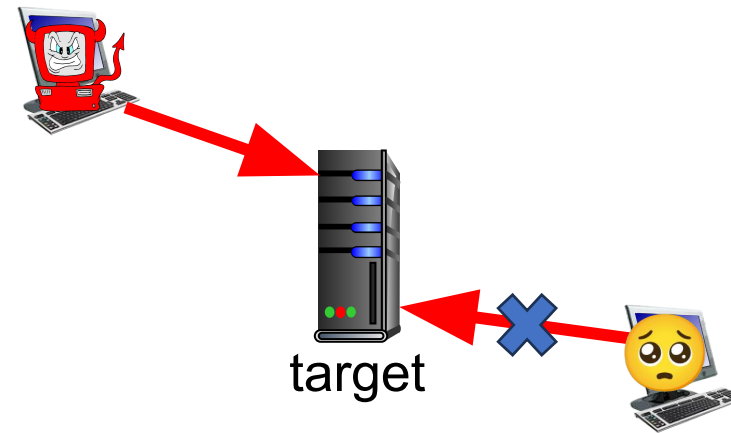
IP spoofing: injection of packet with false source address



Bad guys: denial of service

Denial of Service (DoS): attacker make resources (server, bandwidth) unavailable to legitimate traffic by overwhelming resource with bogus traffic

1. select target
2. attacker spams target with messages
3. target does not have enough resources to serve the actual user



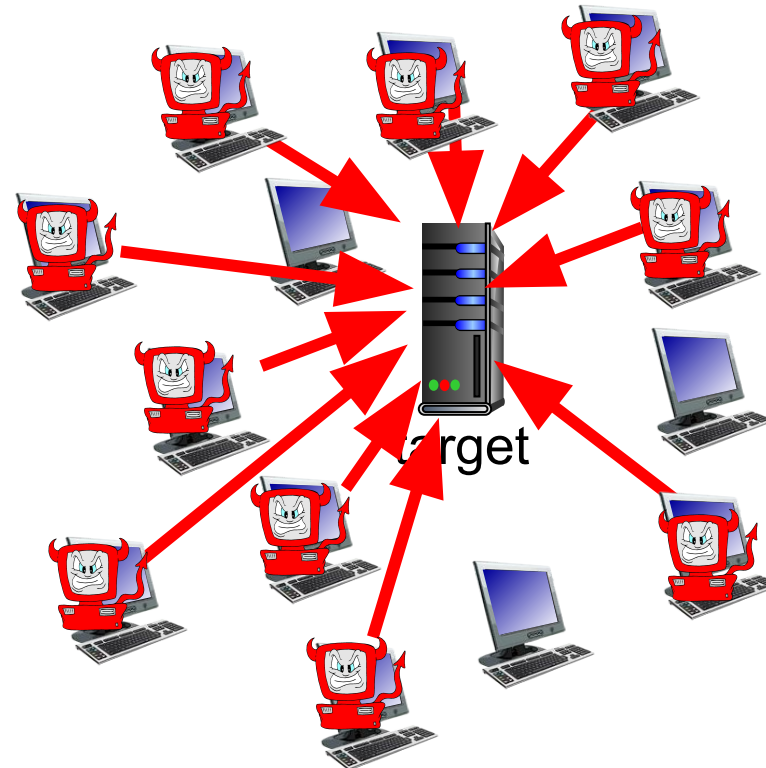
Solution: Block attacker

Bad guys: denial of service

Distributed Denial of Service (DDoS): MANY attackers make resources (server, bandwidth) unavailable to legitimate traffic by overwhelming resource with bogus traffic

1. select target
2. break into hosts around the network (see botnet)
3. send packets to target from compromised hosts

Solution: ?????? -_(\ツ)_/-



Lines of defense:

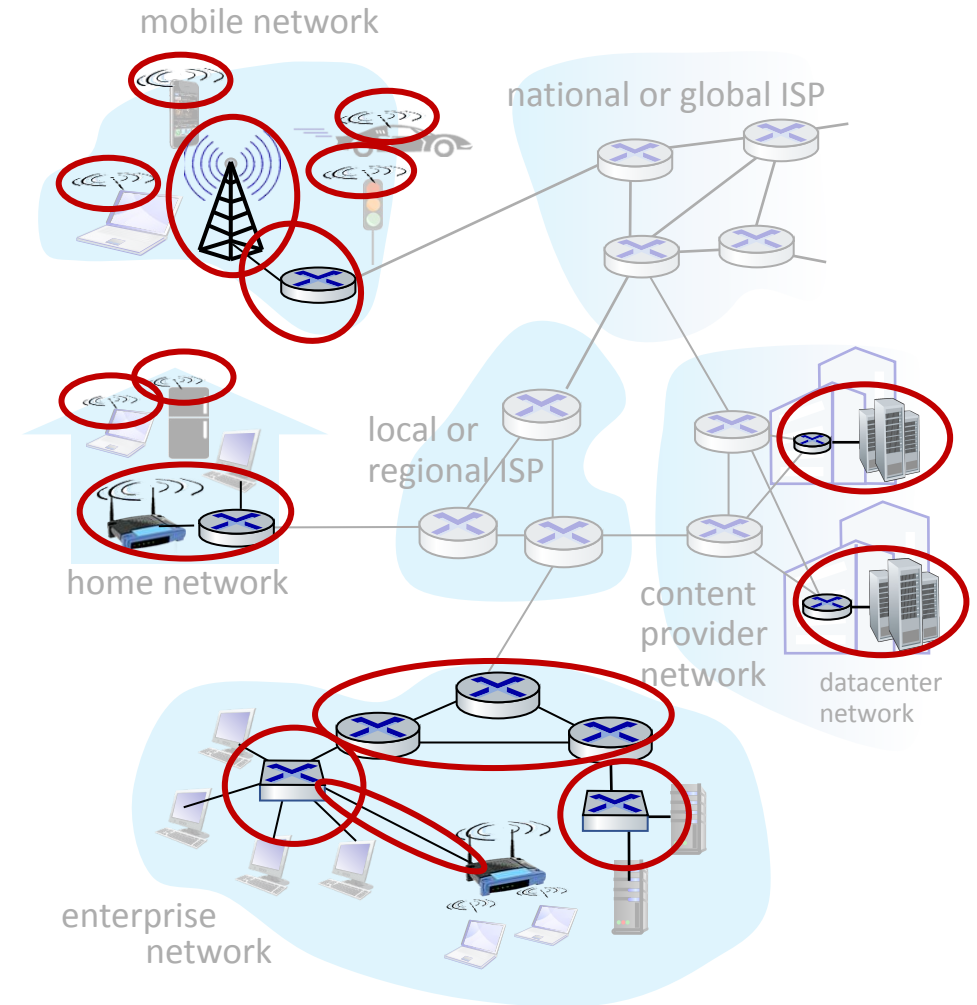
- **authentication:** proving you are who you say you are
 - cellular networks provides hardware identity via SIM card; no such hardware assist in traditional Internet
- **confidentiality:** via encryption
- **integrity checks:** digital signatures prevent/detect tampering
- **access restrictions:** password-protected VPNs
- **firewalls:** specialized “middleboxes” in access and core networks:
 - off-by-default: filter incoming packets to restrict senders, receivers, applications
 - detecting/reacting to DOS attacks

... lots more on security (throughout, Chapter 8)

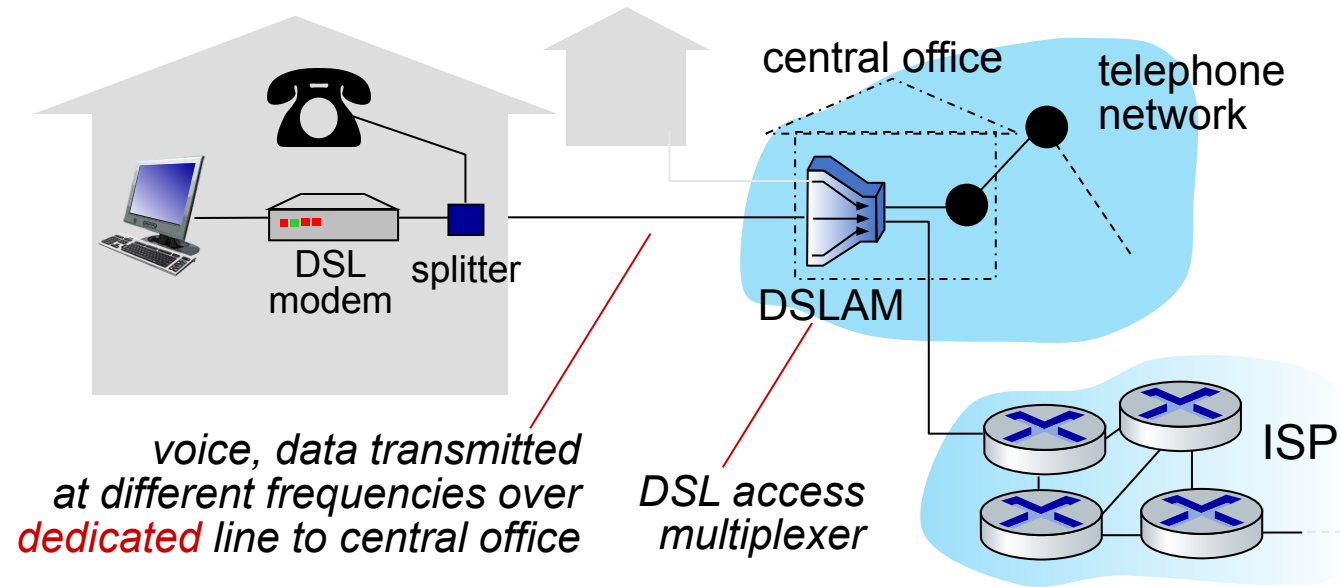
Access networks and physical media

Q: How to connect end systems to edge router?

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

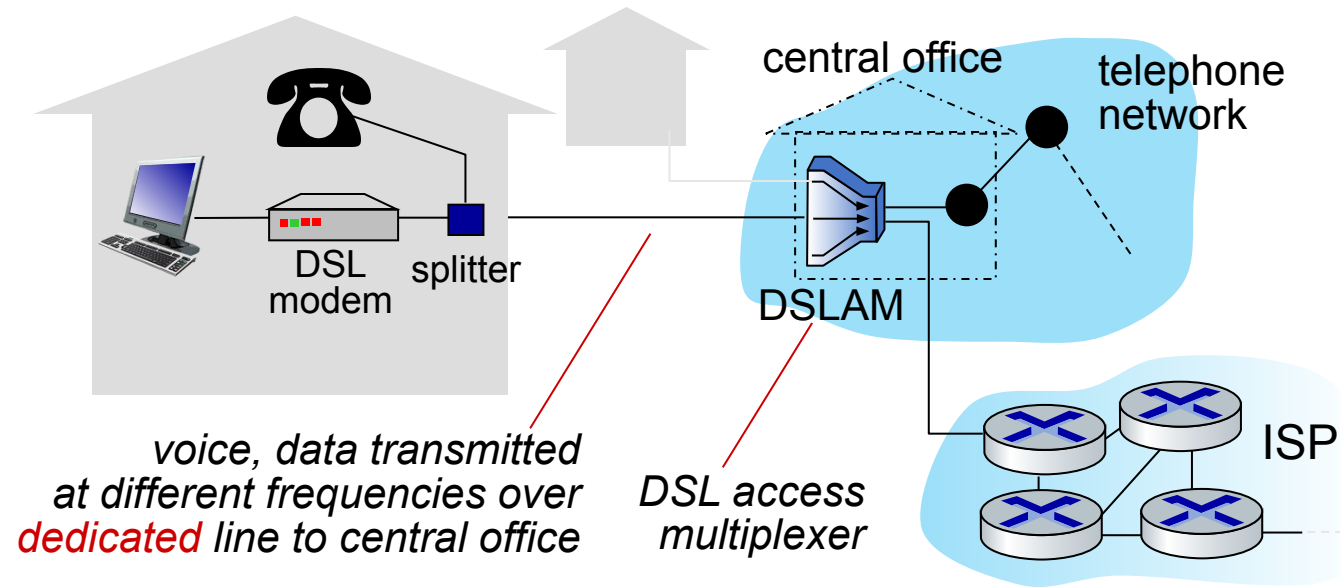


Access networks: digital subscriber line (DSL)



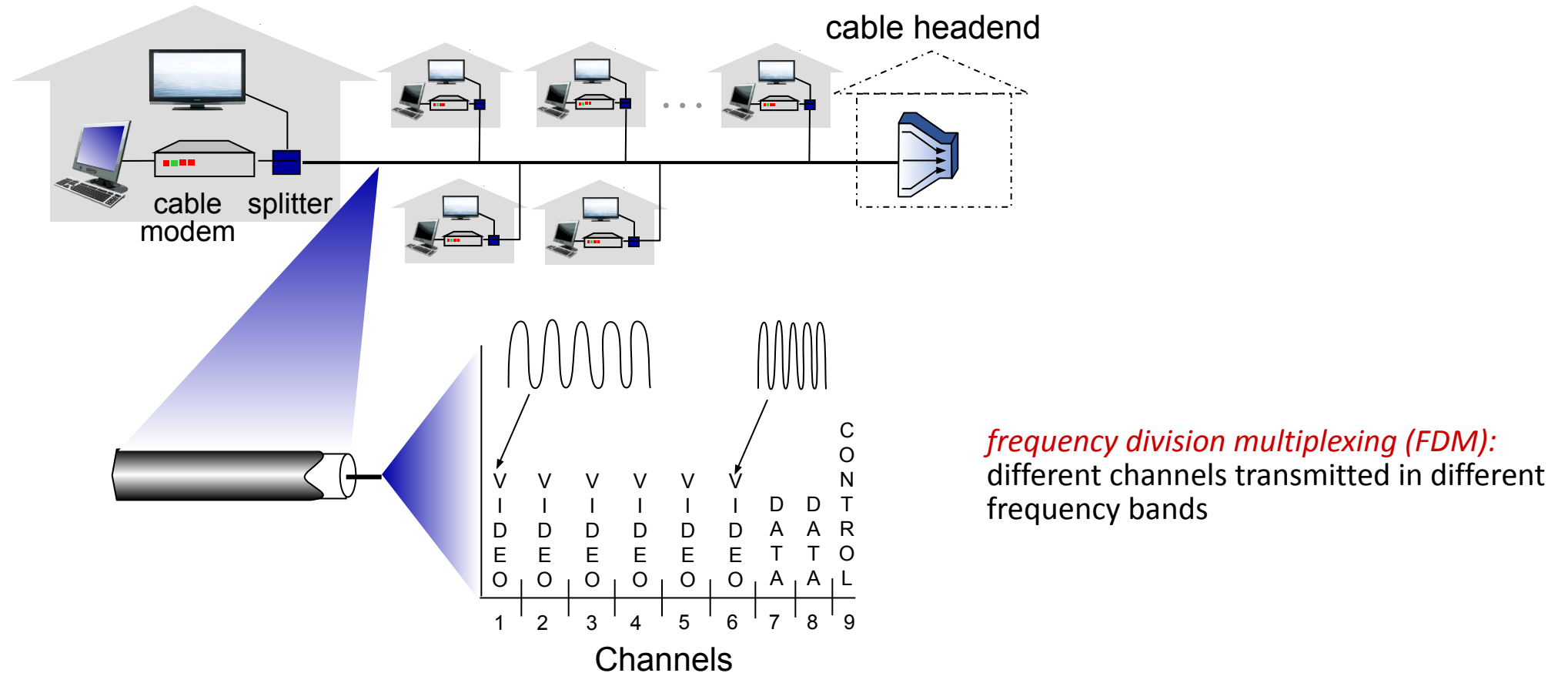
- obtains Internet access from the same telephone company that provides its phone access
 - a customer's telco is also its ISP
 - DSL modem translates digital data to analog signals
 - Splitter joins/separates the signals

Access networks: digital subscriber line (DSL)



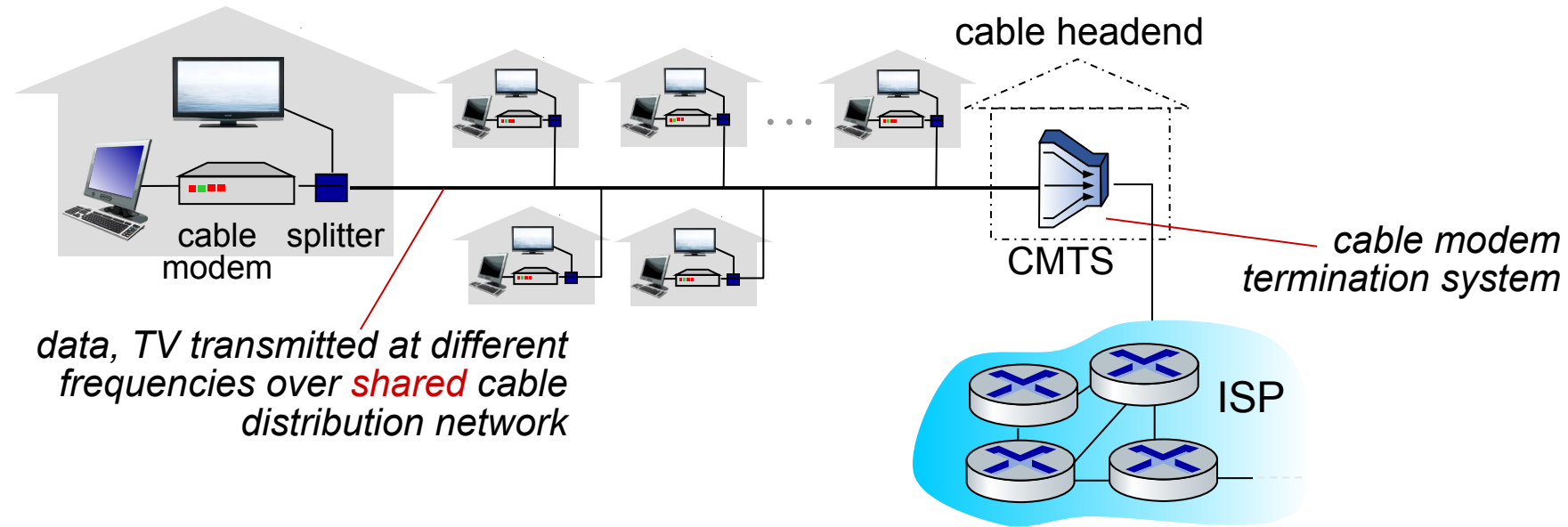
- obtains Internet access from the same telephone company that provides its phone access
 - DSLAM translates analog signals back to digital format and separates them
 - data over DSL phone line goes to Internet
 - voice over DSL phone line goes to telephone net

Access networks: cable-based access



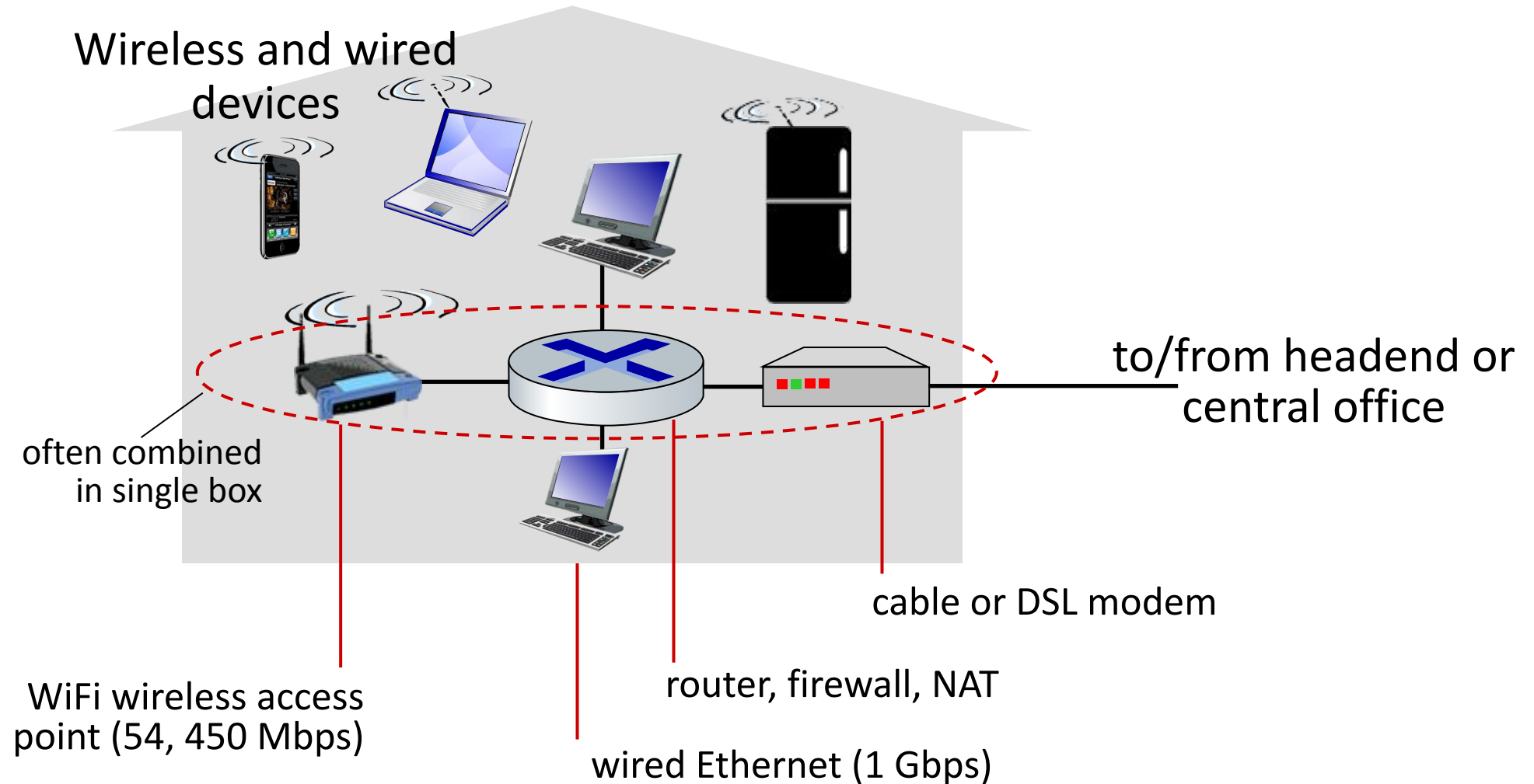
- obtains Internet access from the same telephone company that provides its *cable television*

Access networks: cable-based access



- **network** of cable, fiber attaches homes to ISP router
 - homes *share access network* to cable headend

Access networks: home networks



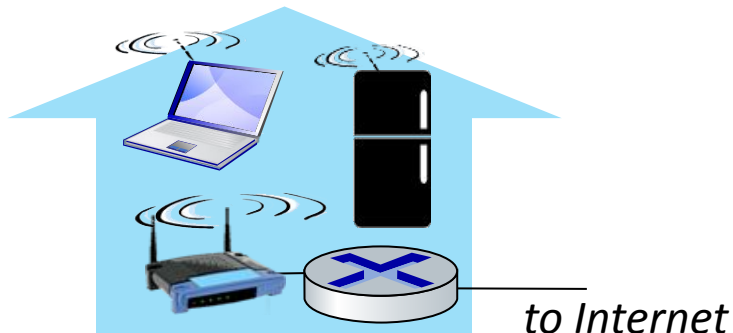
Wireless access networks

Shared *wireless* access network connects end system to router

- via base station aka “access point”

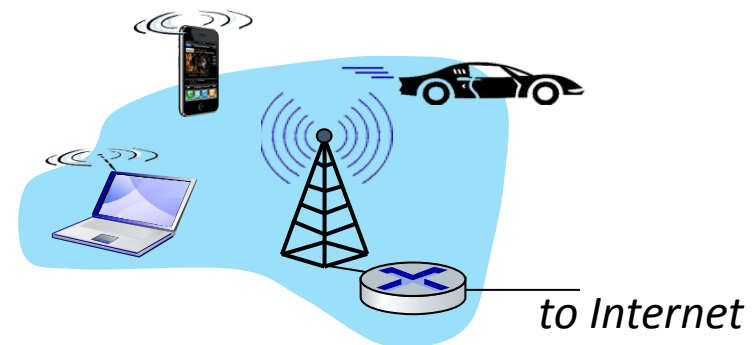
Wireless local area networks (WLANs)

- typically within or around building (~30 m.)
- 802.11b/g/n (WiFi)

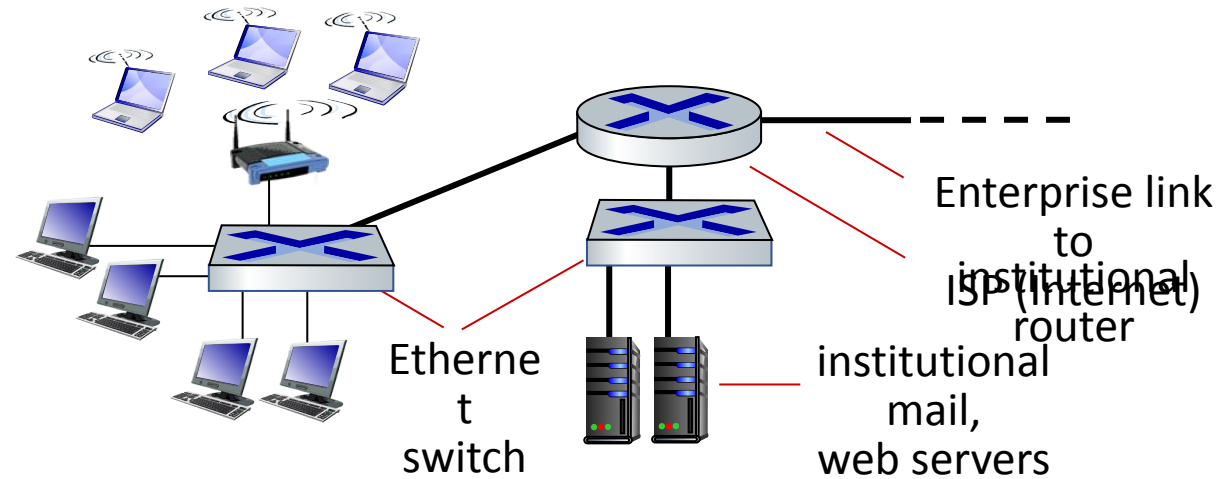


Wide-area cellular access networks

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



Access networks: Enterprise networks



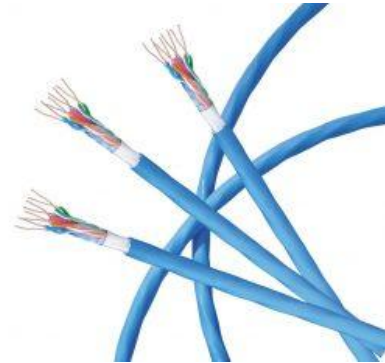
- companies, universities, etc.
- mix of wired, wireless link technologies, connecting a mix of switches and routers (we'll cover differences shortly)

Links: 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 Ethernet



Links: physical media

Fun fact: You can check what category your Ethernet cable is by just looking at the information printed on it

- **UTP:** unshielded twisted pair
- **CAT6:** category 6
- **ISO/IEC:** based on the ISO standard specifications



Links: physical media

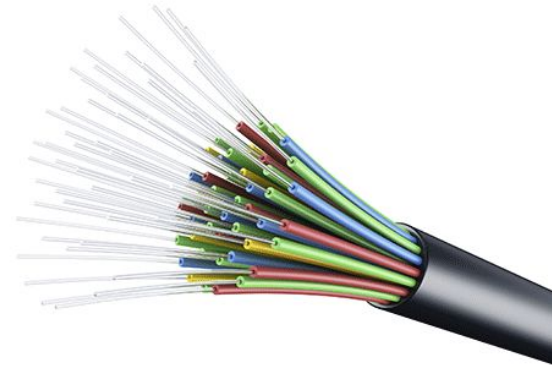
Coaxial cable:

- 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 various “bands” in electromagnetic spectrum
- no physical “wire”
- broadcast, “half-duplex” (sender to receiver)
- propagation environment effects:
 - reflection
 - obstruction by objects
 - Interference/noise

Radio link types:

- **Wireless LAN (WiFi)**
 - 10-100’s Mbps; 10’s of meters
- **wide-area** (e.g., 4G/5G cellular)
 - 10’s Mbps (4G) over ~10 Km
- **Bluetooth**: cable replacement
 - short distances, limited rates
- **terrestrial microwave**
 - point-to-point; 45 Mbps channels
- **satellite**
 - up to < 100 Mbps (Starlink) downlink
 - 270 msec end-end delay (geostationary)

QUESTIONS???

