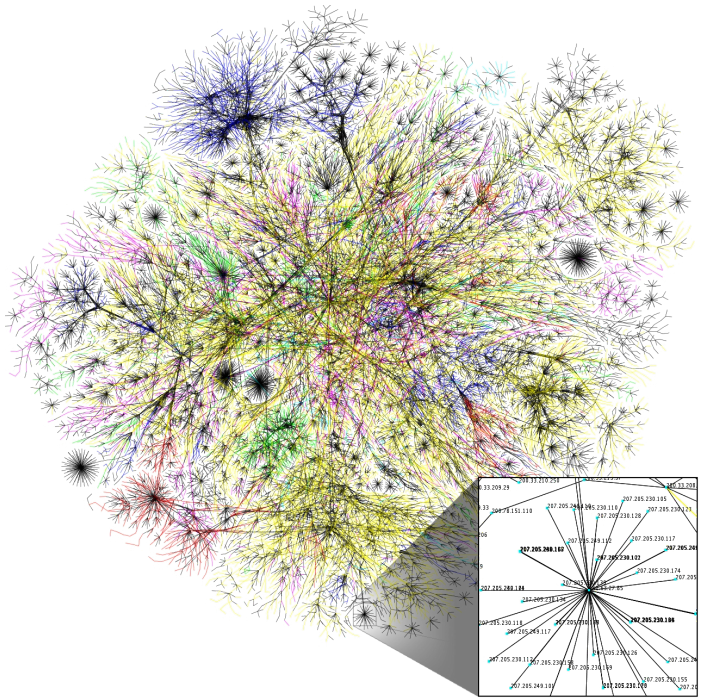
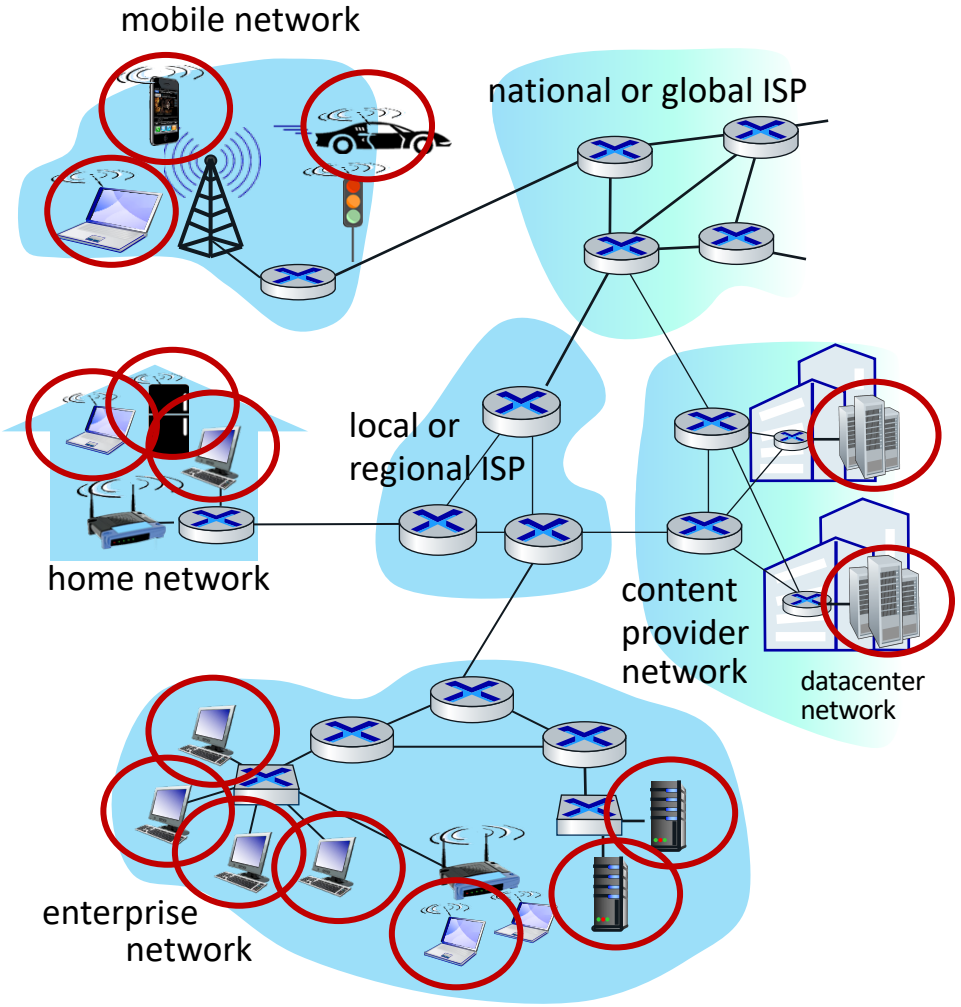
Introduction to Networking Technologies

Fundamentals of Network Communication

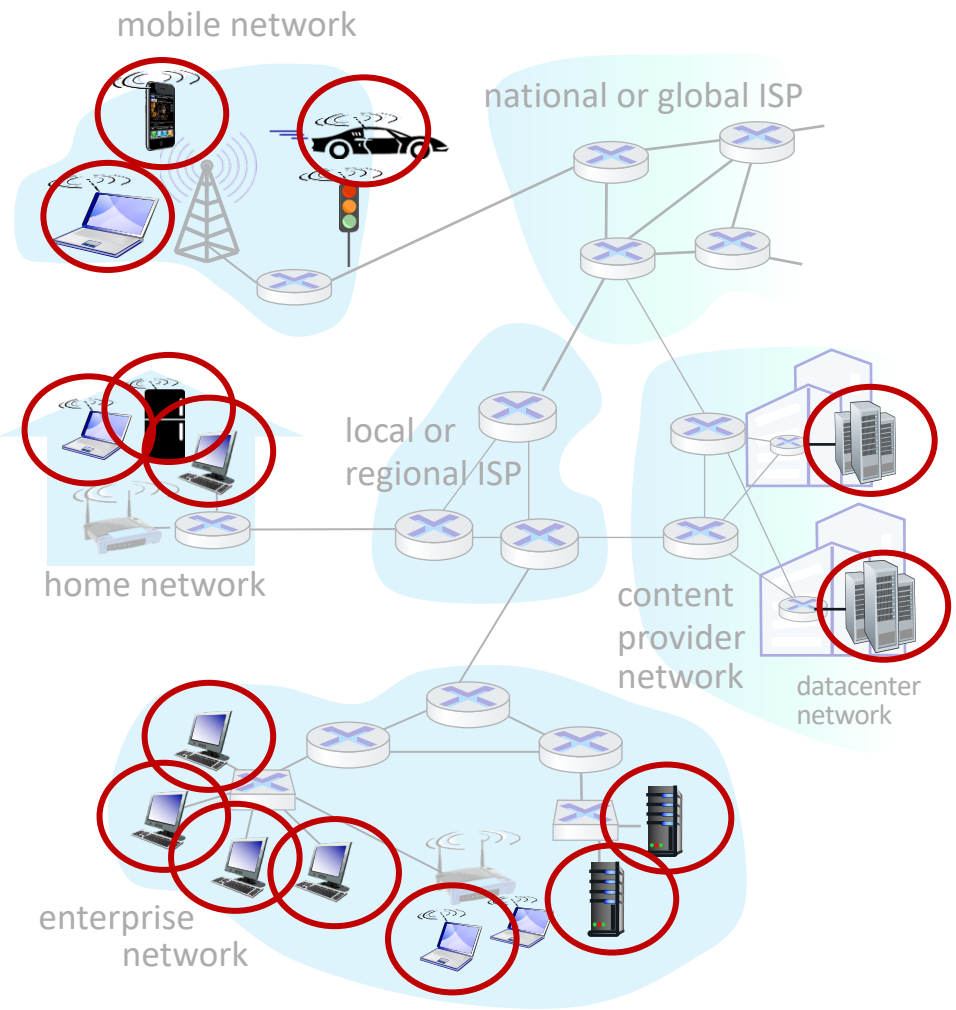
- What is Internet?
- What is a protocol?
- Home Internet connections?
- Internet topology?





What is Internet?

The Internet is the global system of interconnected computer networks that uses the Internet protocol suite (TCP/IP) to communicate between networks and devices (Wikipedia).



Network edge:

hosts: clients and servers

servers often in data centers

What is Internet?

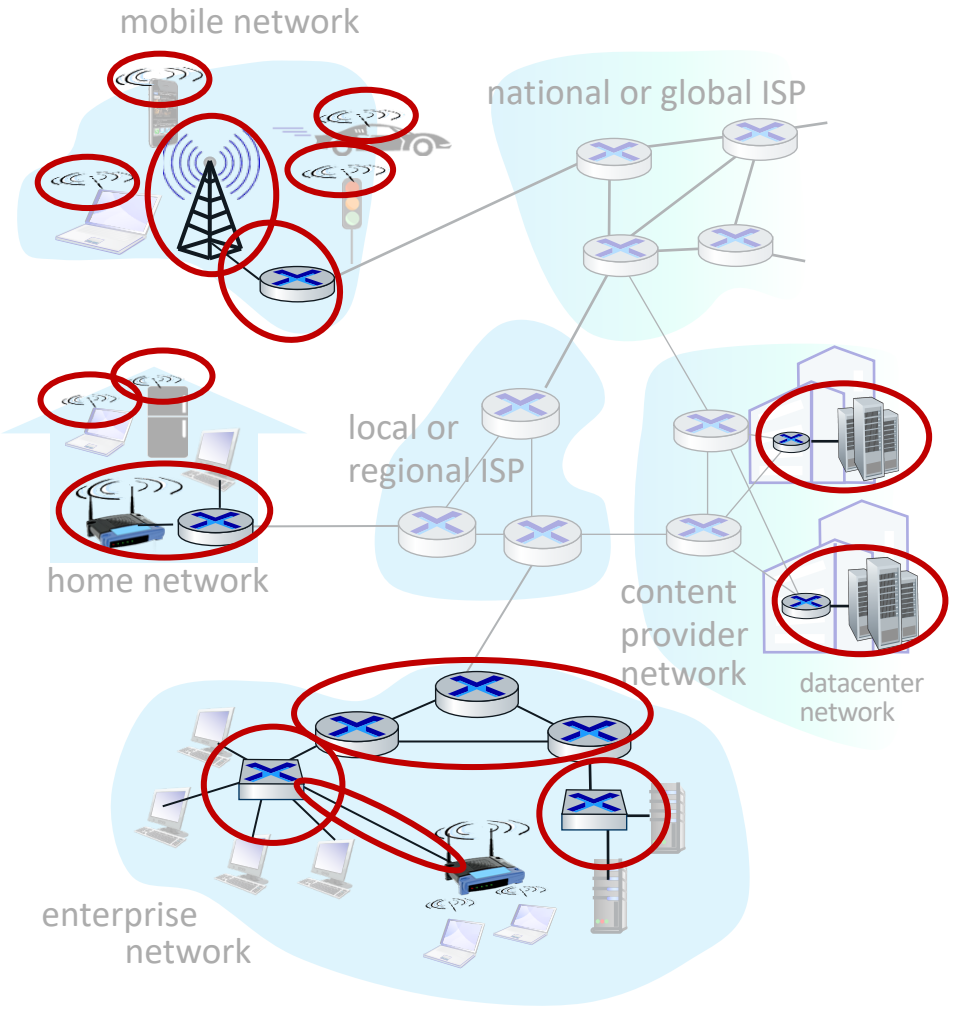
Network edge:

hosts: clients and servers

servers often in data centers

Access networks, physical media:

wired, wireless communication links



What is Internet?

Network edge:

hosts: clients and servers

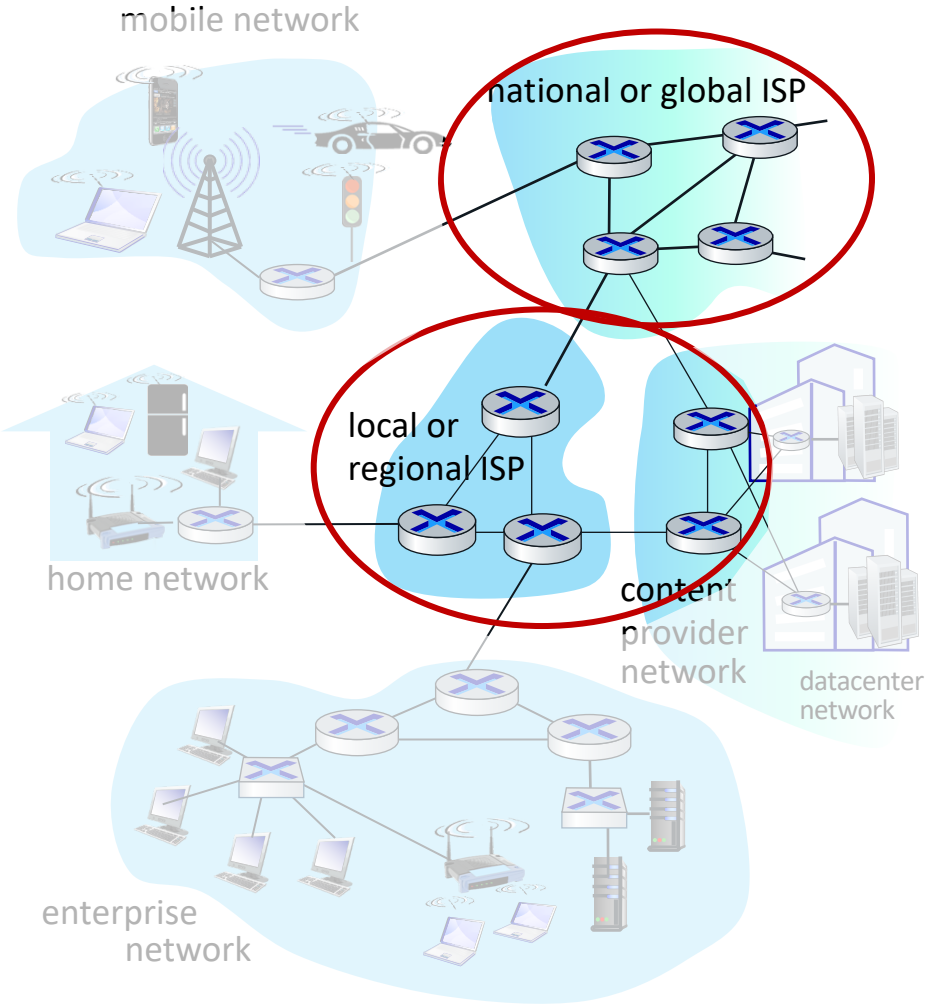
servers often in data centers

Access networks, physical media:

wired, wireless communication links

Network core:

- interconnected routers
- network of networks



What is a protocol?

Human protocols:

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

Rules for:

… specific messages sent

… specific actions taken when message received, or other events

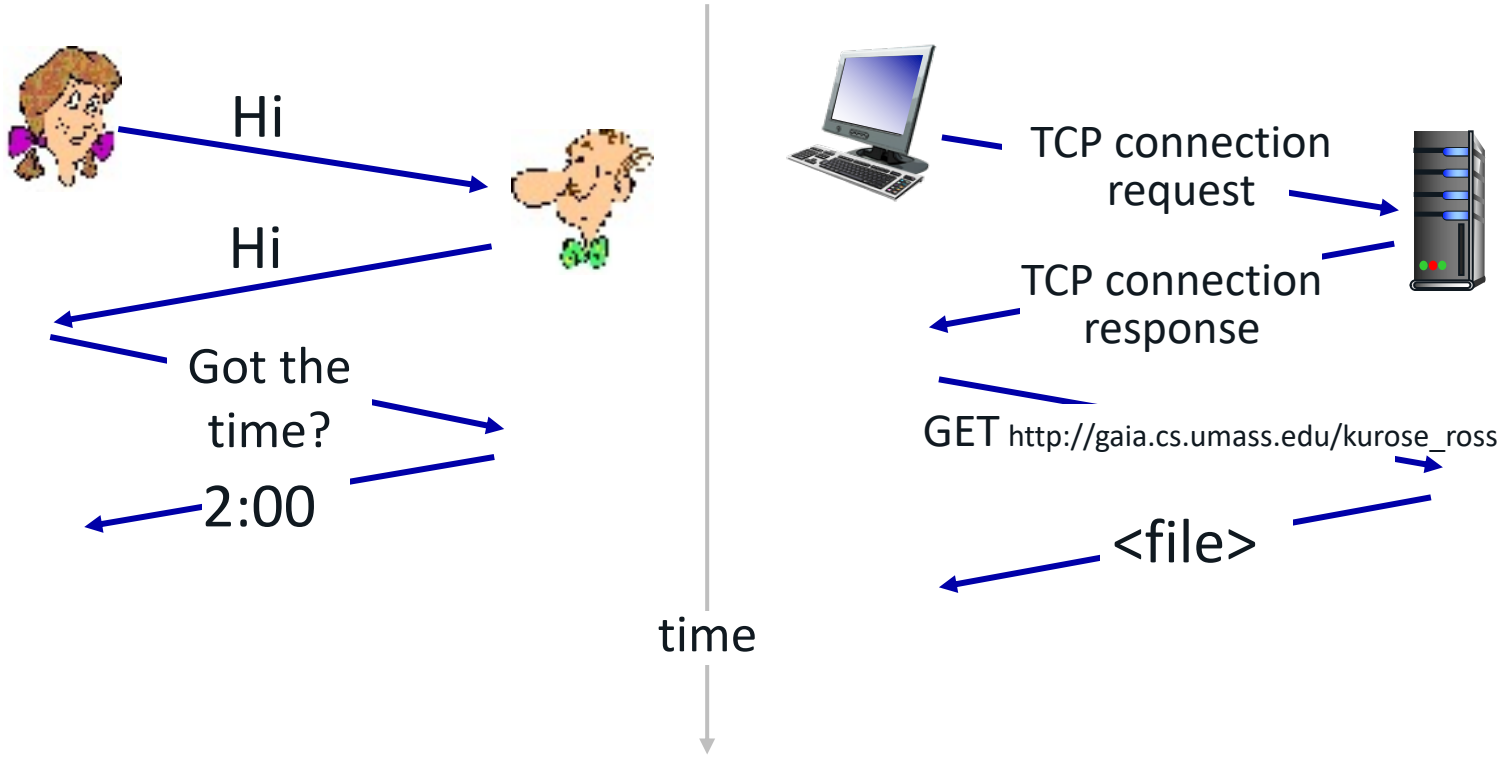
Network protocols:

- computers (devices) rather than humans
- all communication activity in Internet governed by protocols

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

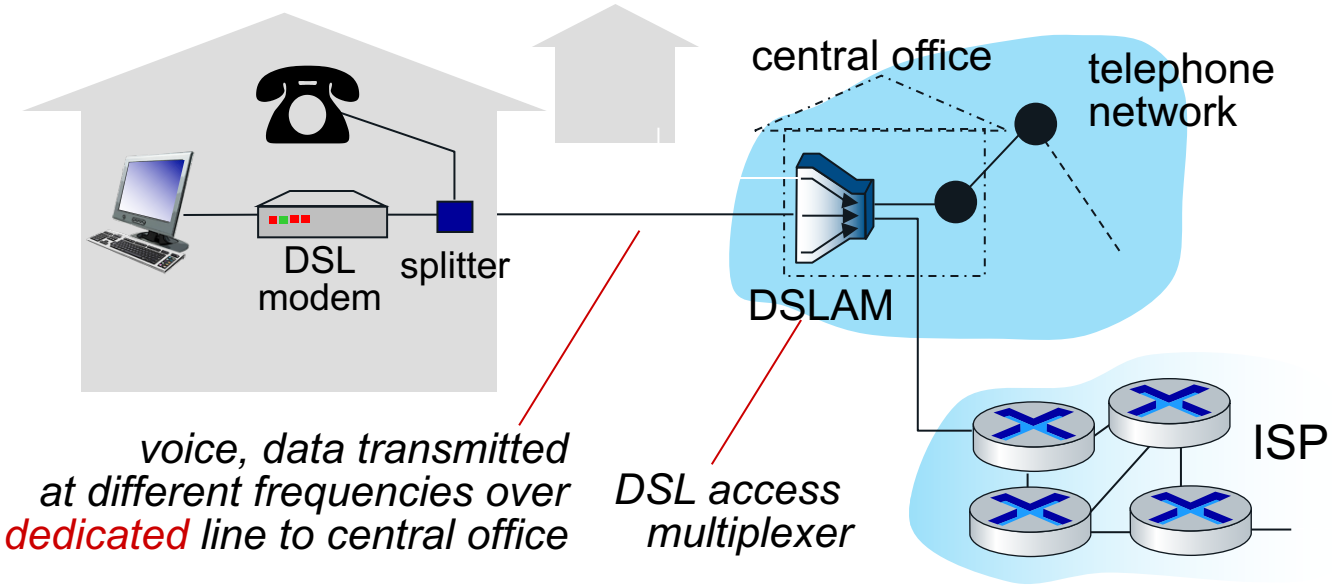
What is a protocol?

A human protocol and a computer network protocol:



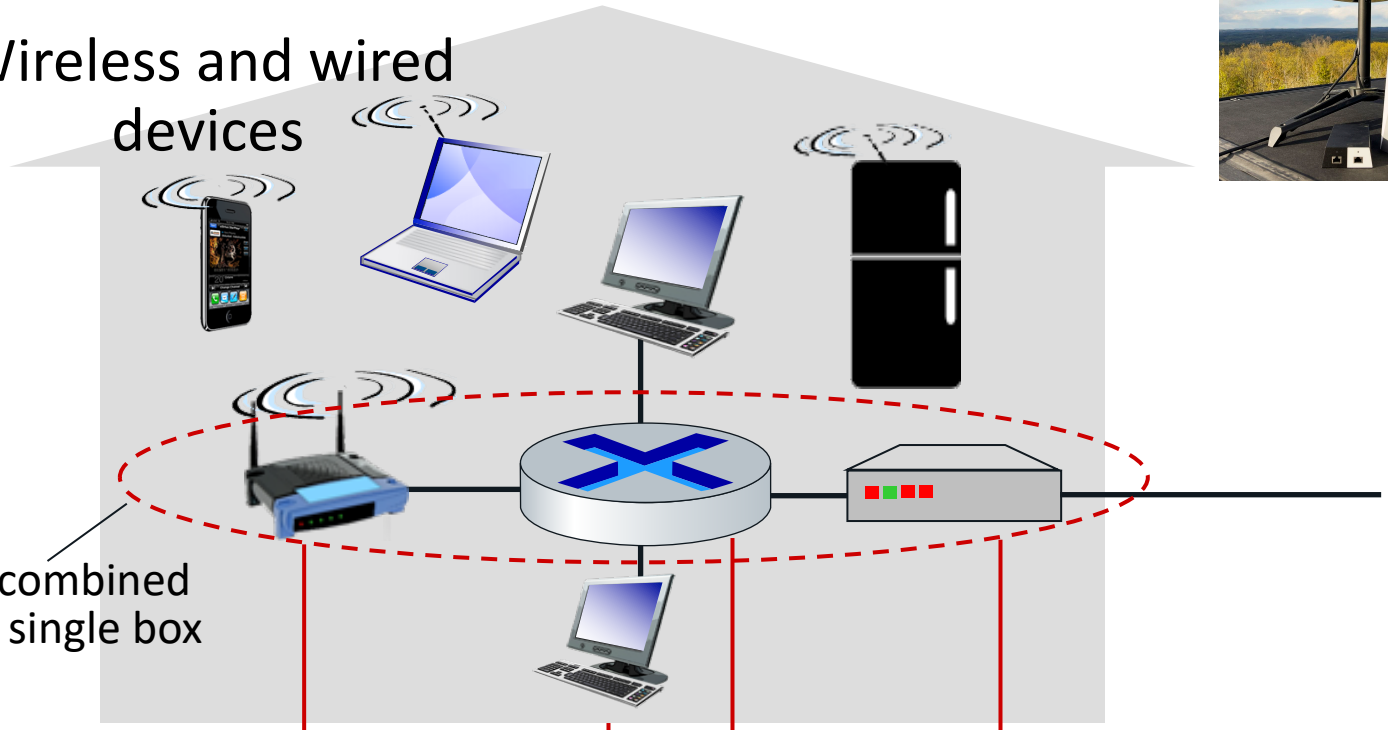
Question: Other human protocols?

Home Internet Connections?



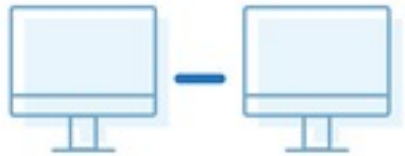
- use *existing* telephone line to central office
  - data over digital subscriber line (DSL) phone line goes to Internet
  - voice over DSL phone line goes to telephone net

Home Internet Connections?

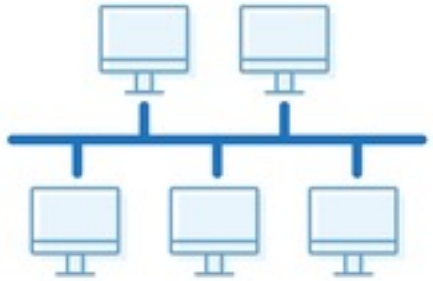


Internet Topology?

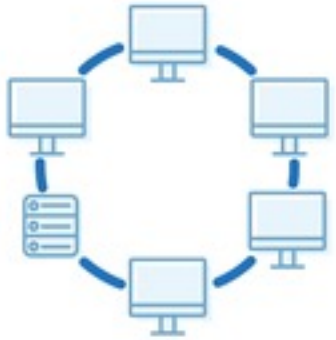
1 Point to point



2 Bus

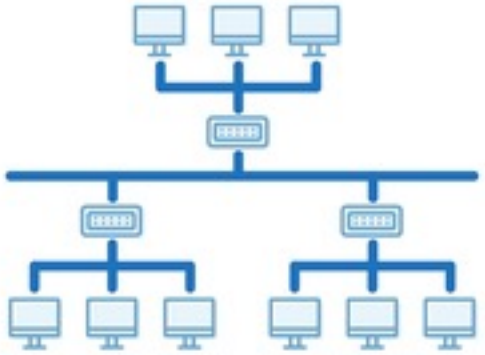


3 Ring



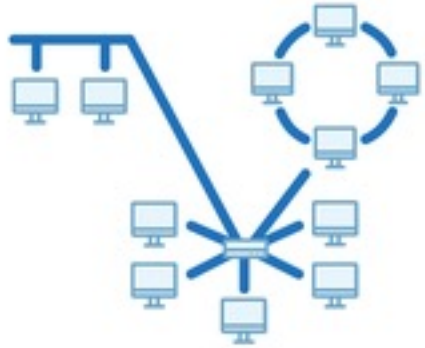
4 Star

5 Tree

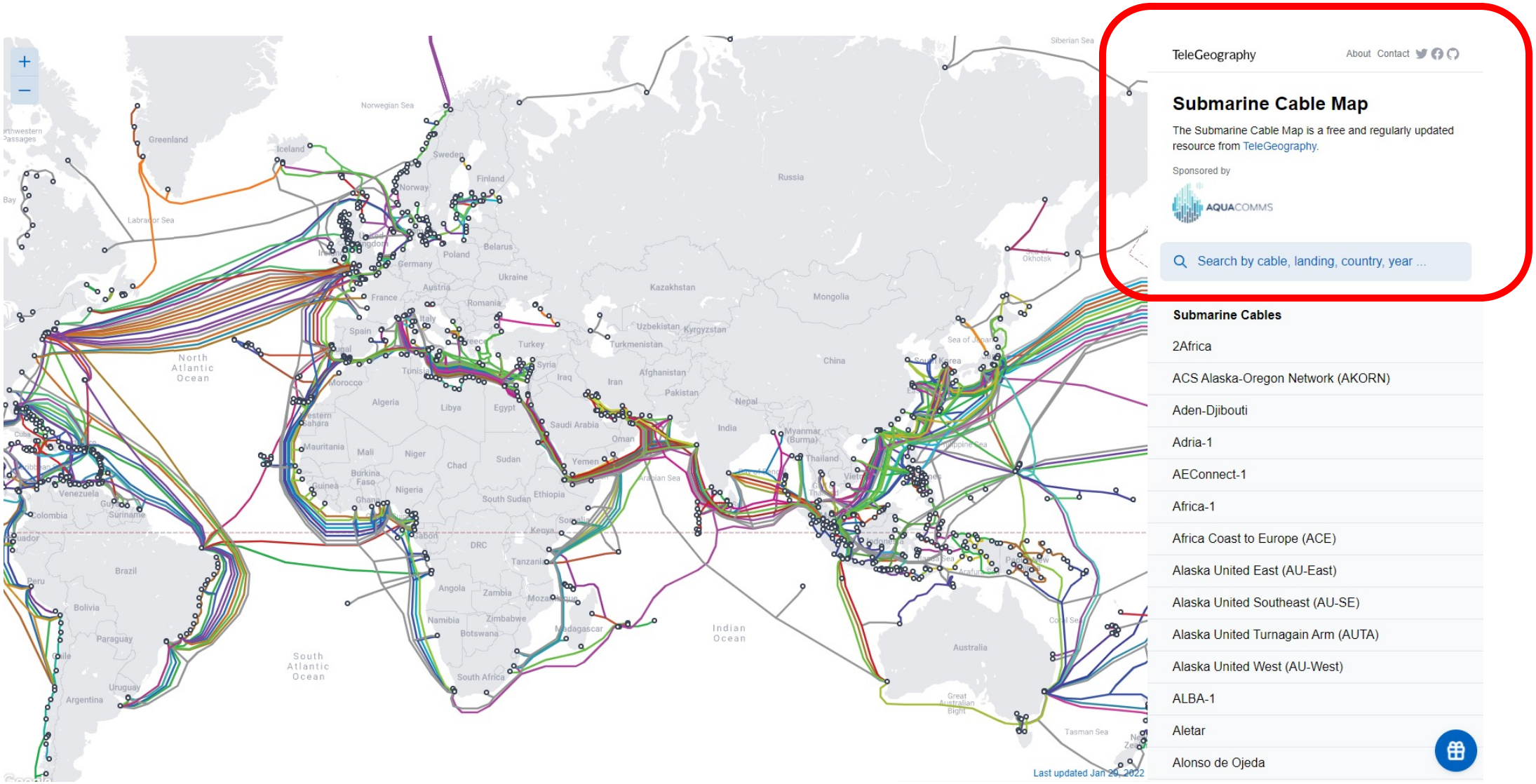


6 Mesh

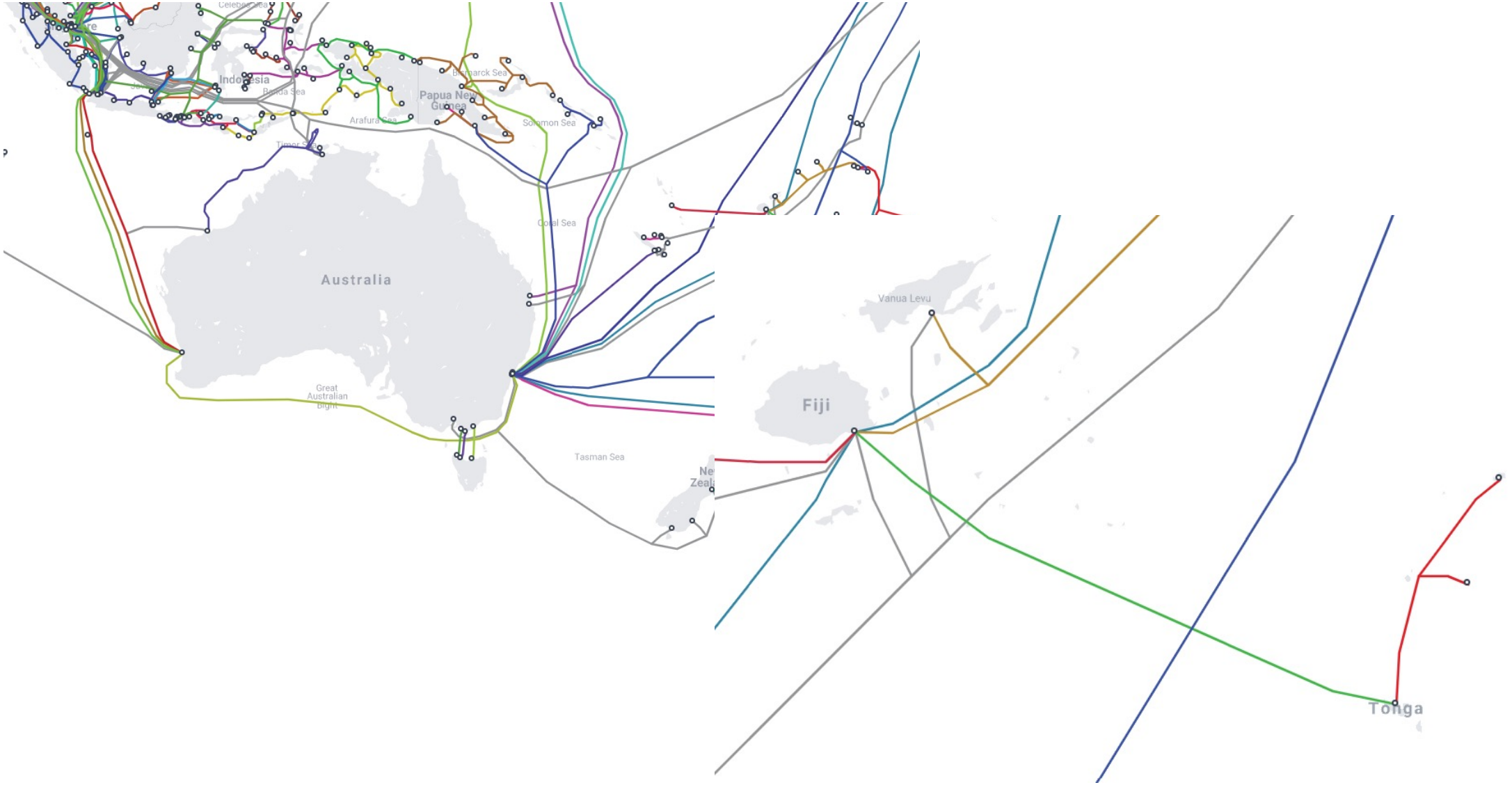
7 Hybrid



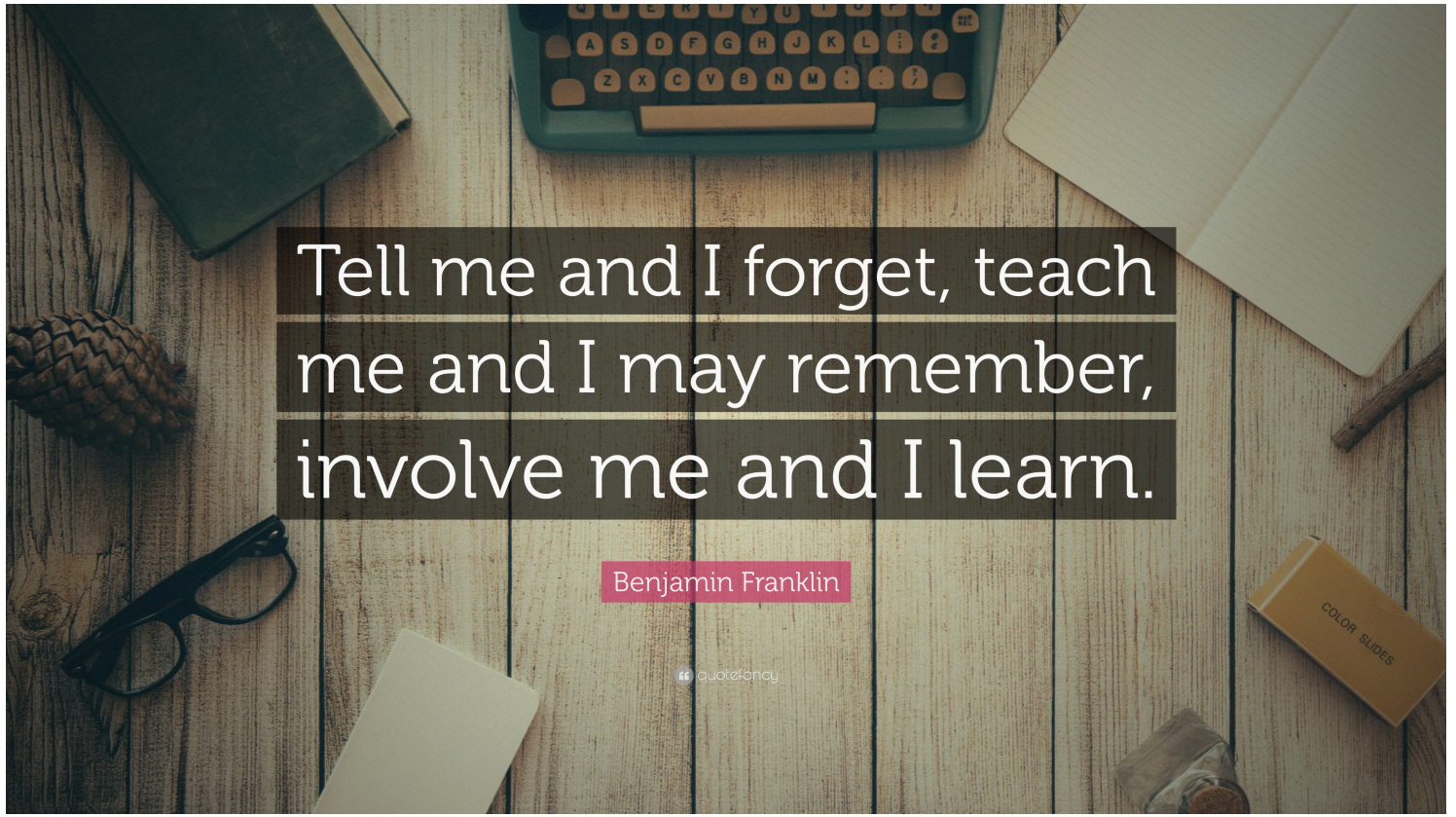
Internet Topology?



Internet Topology?



Thank You!


Tell me and I forget, teach me and I may remember, involve me and I learn.
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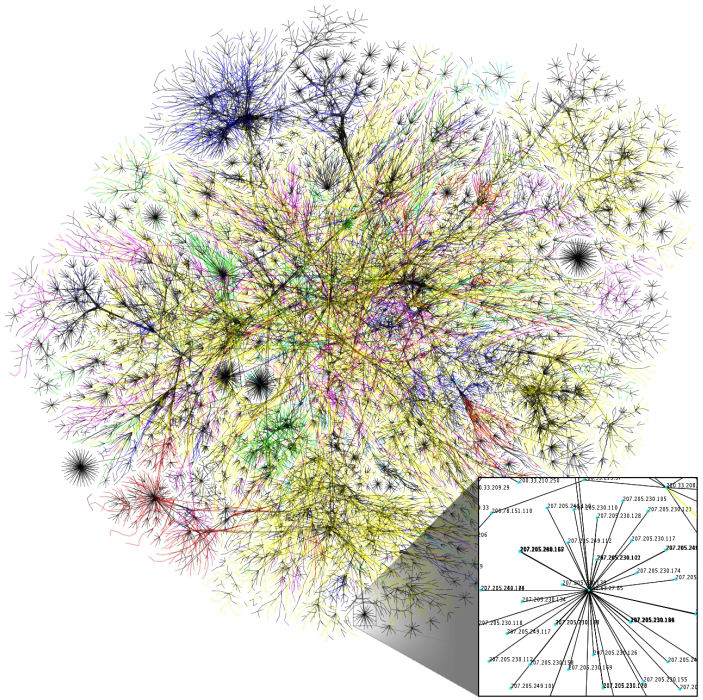
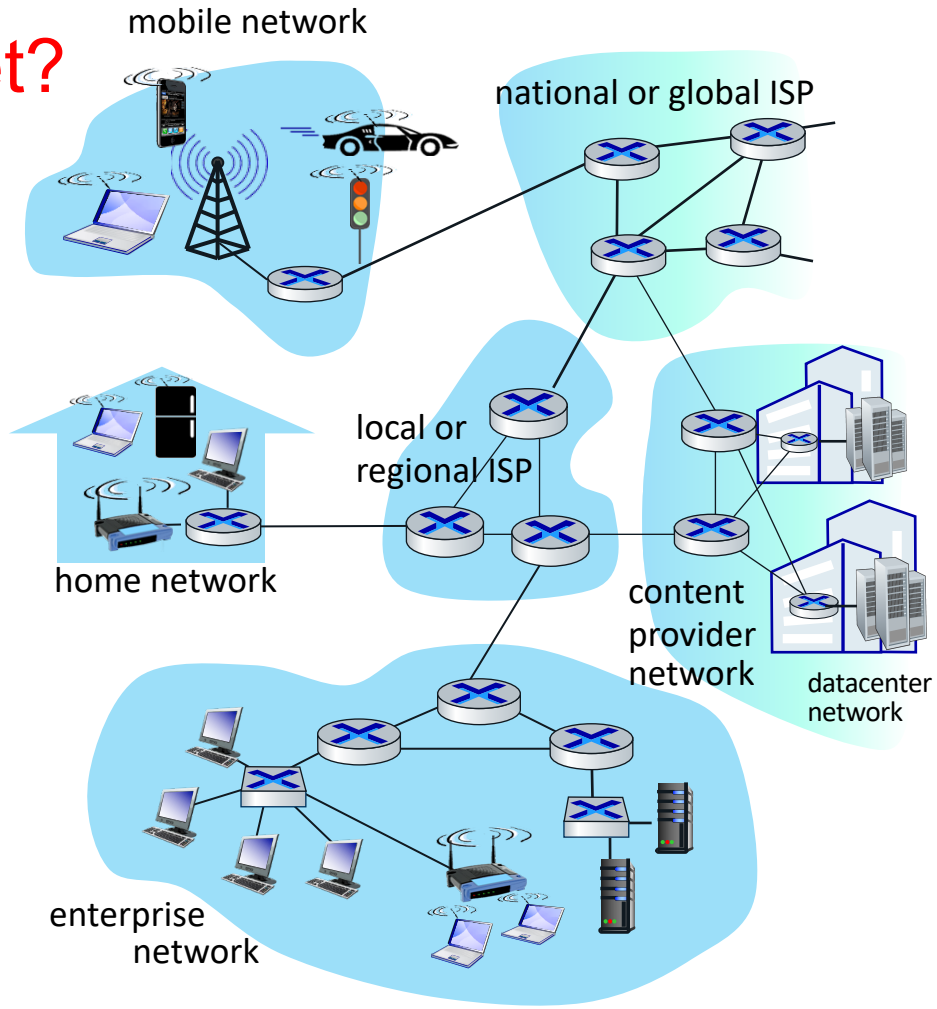
Introduction to Networking Technologies

Fundamentals of Network Communication

- What are the components of Internet?

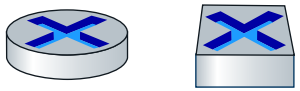




What are the components of Internet?

Billions of connected computing *devices*:

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



Packet switches: forward packets (chunks of data)

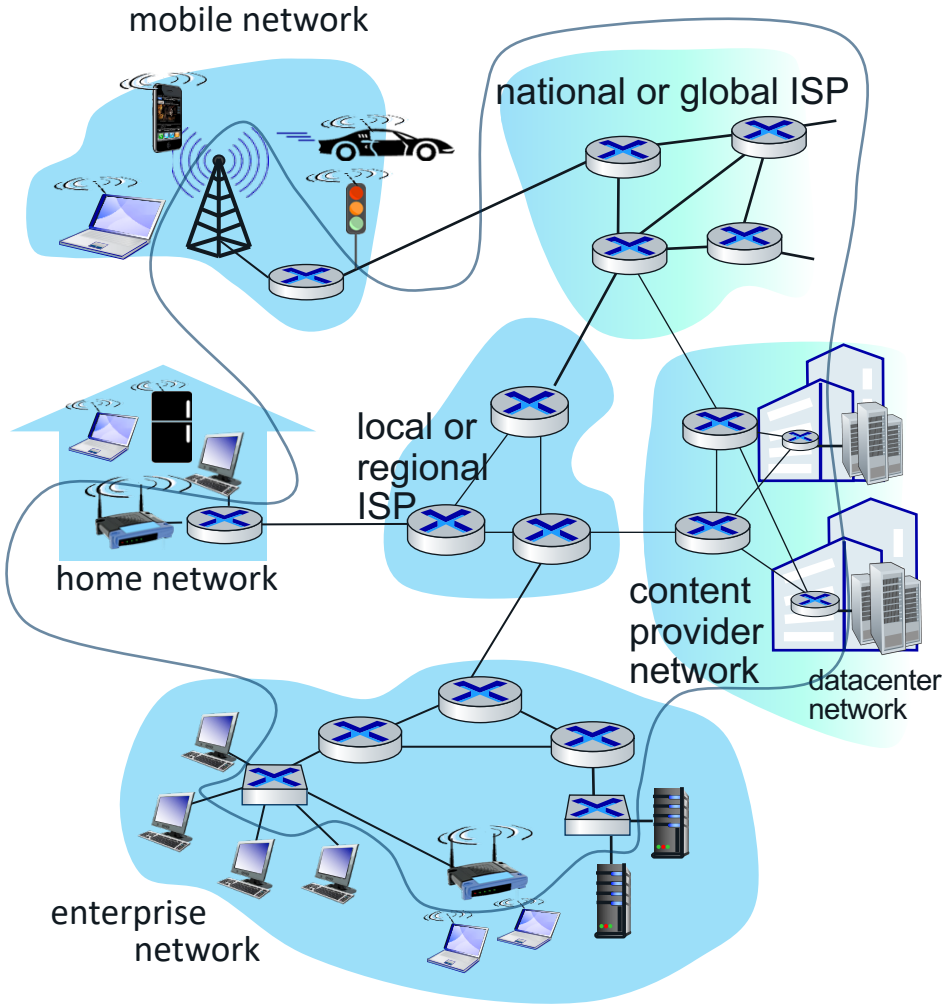
- *routers, switches*

Communication links

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

Networks

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



What are the components of Internet? (Devices)

Amazon Echo

Internet refrigerator

IP picture frame

Pacemaker & Monitor

Tweet-a-watt: monitor energy use

bikes

cars

scooters

Security Camera

Slingbox: remote control cable TV

Web-enabled toaster + weather forecaster

AR devices

Internet phones

Gaming devices

sensorized, bed mattress

Fitbit

Others?

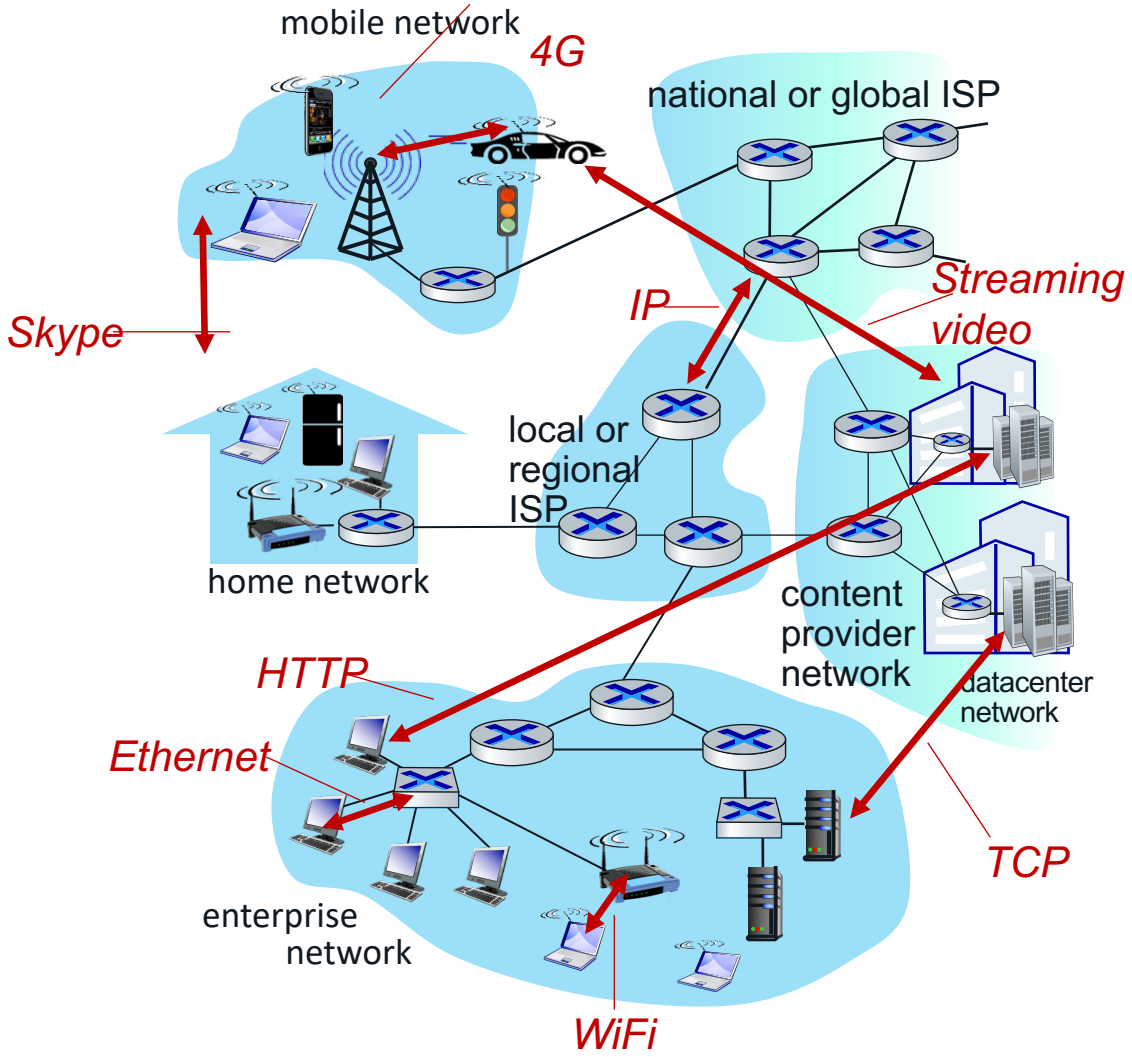
What are the components of Internet? (Protocols)

Internet: "network of networks"

- Interconnected ISPs

- *protocols* are *everywhere*
  - control sending, receiving of messages
  - e.g., HTTP (Web), streaming video, Skype, TCP, IP, WiFi, 4G, Ethernet

- *Internet standards*
  - RFC: Request for Comments
  - IETF: Internet Engineering Task Force

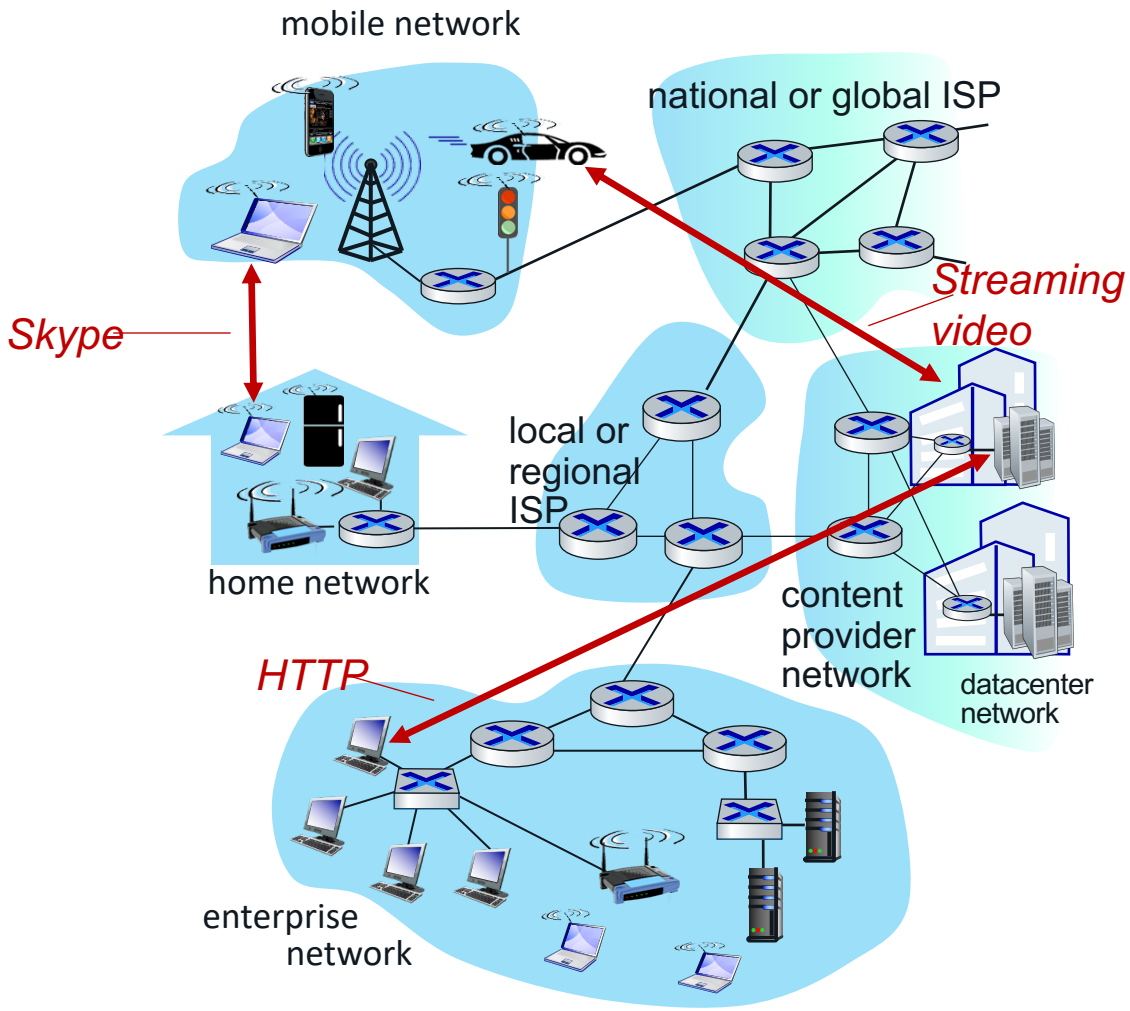


What are the components of Internet? (Services)

Infrastructure that provides services to applications:

- Web, streaming video, multimedia teleconferencing, email, games, e-commerce, social media, inter-connected appliances, …

- provides *programming interface* to distributed applications:
  - "hooks" allowing sending/receiving apps to "connect" to, use Internet transport service
  - provides service options, analogous to postal service

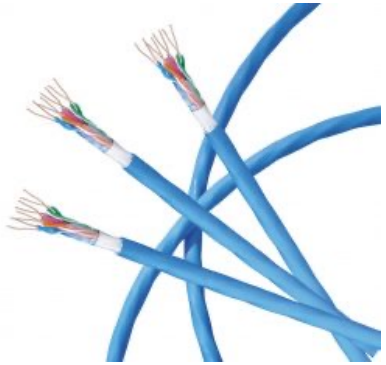


What are the components? (Physical Media)

- 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



What are the components? (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

What are the components? (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 cellular)
  - 10's Mbps over ~10 Km
- Bluetooth: cable replacement
  - short distances, limited rates
- terrestrial microwave
  - point-to-point; 45 Mbps channels
- satellite
  - up to 45 Mbps per channel
- Visible light (LIFI)?
- Quantum?

Thank You!


Tell me and I
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Involve me and I
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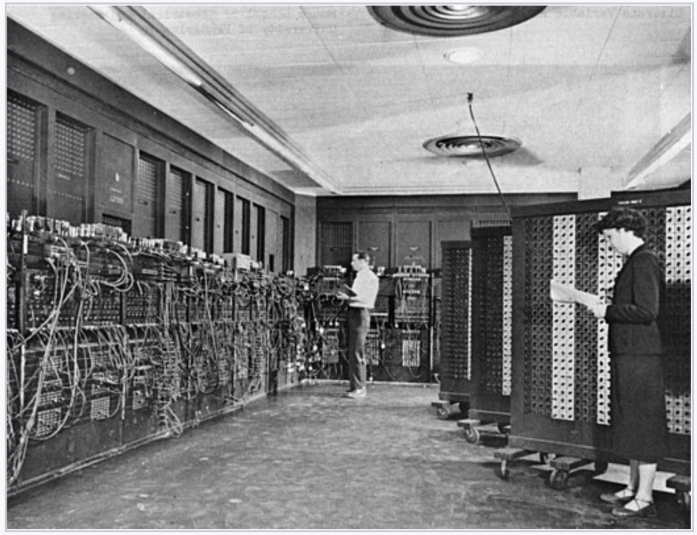
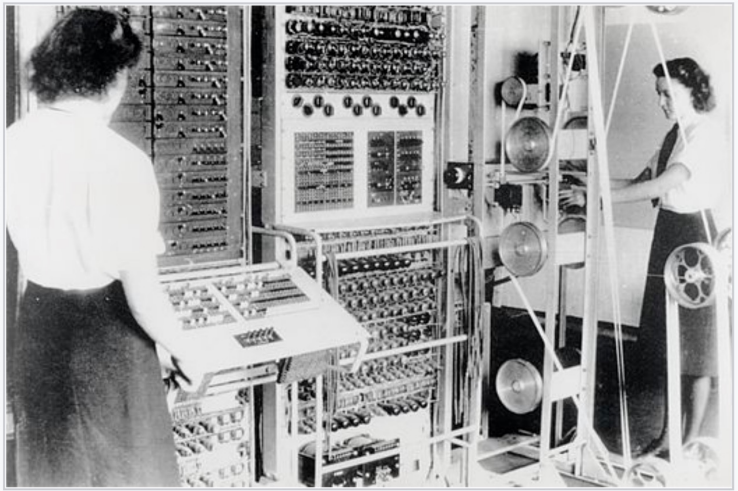
Computer Network History

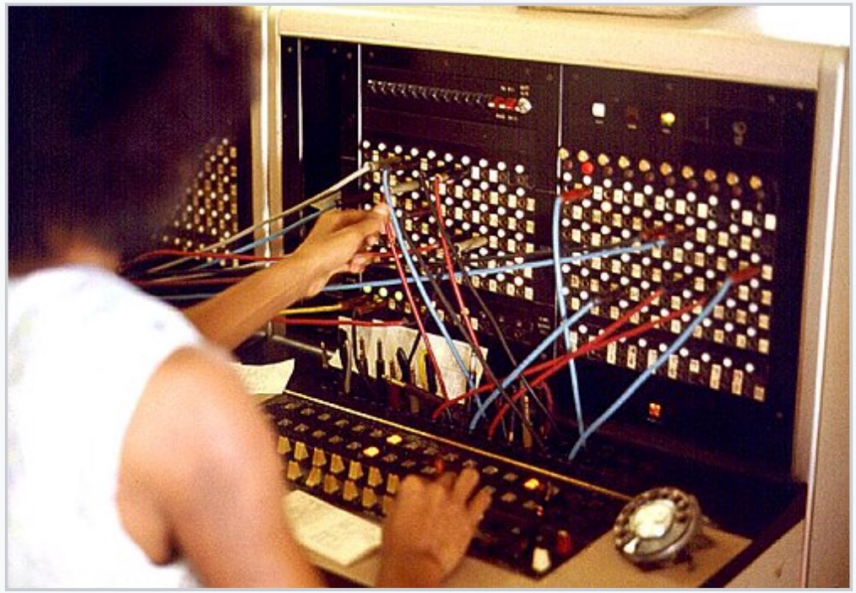
Early Computers in the World



ENIAC was the first electronic, Turing-complete device, and performed ballistics trajectory calculations for the United States Army.



Colossus, the first electronic digital programmable computing device, was used to break German ciphers during World War II. It is seen here in use at Bletchley Park in 1943.



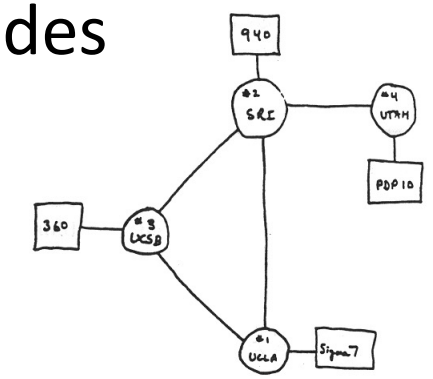
A telephone operator manually connecting calls with cord pairs at a telephone switchboard

World Network History

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 (3 nodes)

- 1972:
  - ARPAnet public demo
  - NCP (Network Control Protocol) first host-host protocol
  - first e-mail program
  - ARPAnet has 15 nodes



THE ARPA NETWORK

World Network History

1972-1980: Internetworking, new and proprietary networks

- 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
- 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 routing
- decentralized control

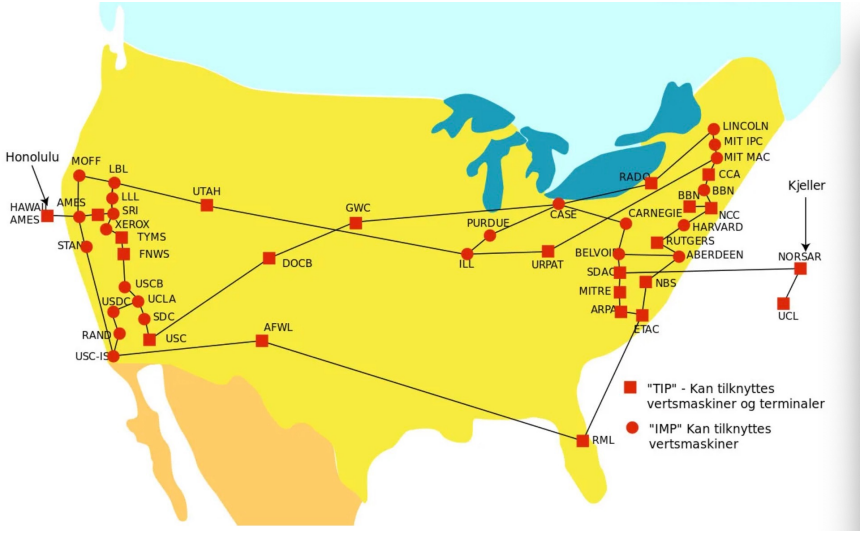
define today's Internet architecture

World Network 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



World Network History

1990, 2000s: commercialization, the Web, new applications

- early 1990s: 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 1990s: commercialization of the Web

late 1990s – 2000s:

- more killer apps: instant messaging, P2P file sharing
- network security to forefront
- est. 50 million host, 100 million+ users
- backbone links running at Gbps

World Network History

2005-present: scale, SDN, mobility, cloud

- aggressive deployment of broadband home access (10-100's Mbps)
- 2008: software-defined networking (SDN)
- increasing ubiquity of high-speed wireless access: 4G/5G, WiFi
- service providers (Google, FB, Microsoft) create their own networks
  - bypass commercial Internet to connect "close" to end user, providing "instantaneous" access to social media, search, video content, …
- enterprises run their services in "cloud" (e.g., Google Drive, Microsoft Onedrive)
- rise of smartphones: more mobile than fixed devices on Internet (2017)
- ~22B devices attached to Internet (2018). Could be 38.6B in 2025.

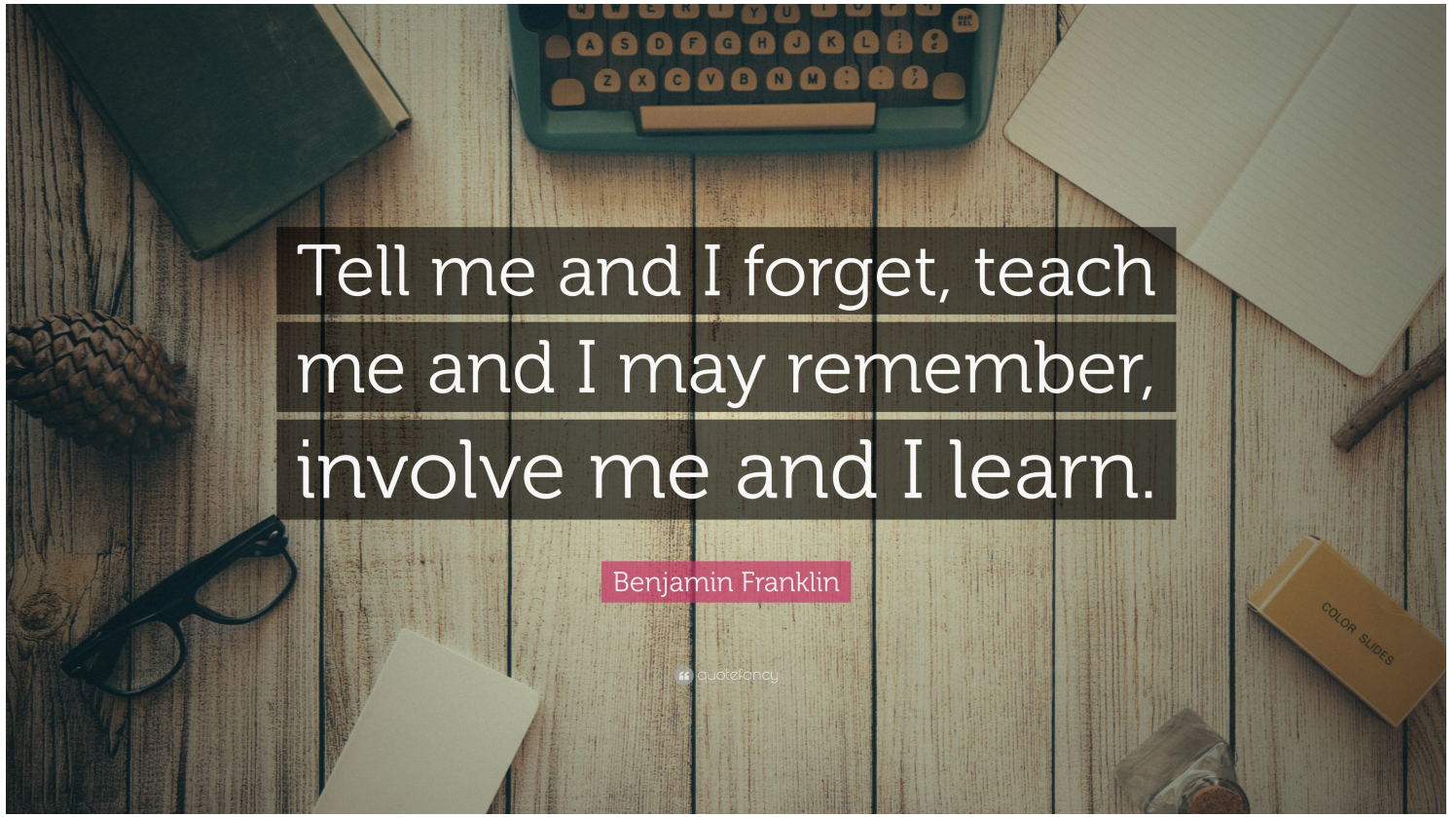
Australia Network History

- Internet in Australia first became available on a permanent basis to universities in Australia in May 1989, via AARNet.
- It linked the University of Melbourne with the University of Hawaii via a 2400 bit/s (bits per second) satellite connection.
- Pegasus Networks was Australia's first public Internet provider in June 1989.
- DIALix provided services to Perth in 1992.
- In the late 1990s, Telstra and Optus rolled-out separate cable Internet services.
- In 2000, the first consumer ADSL services were made available via Telstra Bigpond.

Top 10 Internet Usage Statistics in Australia

- 86.5% of Australia's population is online
- 21.93-million active Australian internet users each month
- 45.2% of all internet traffic comes from mobile devices
- Telstra is Australia's leading ISP with a market share of 6.35-million users
- The most popular online internet activity is email
- Australia has one of the fastest mobile internet speeds in the developed world
- 41% of Australian's access news from mobile devices
- There are 15.9-million smart home devices such as Amazon Echo, Google Home, and Apple HomePod installed in Australia
- Australia has 16.19-million active Facebook users
- 59% of Australian's say that social media is the first thing they look at each morning

Thank You!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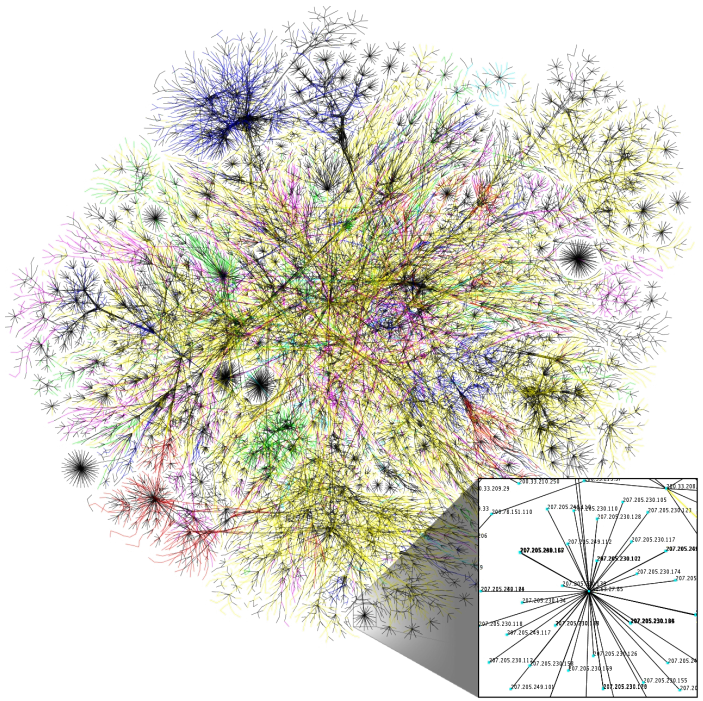
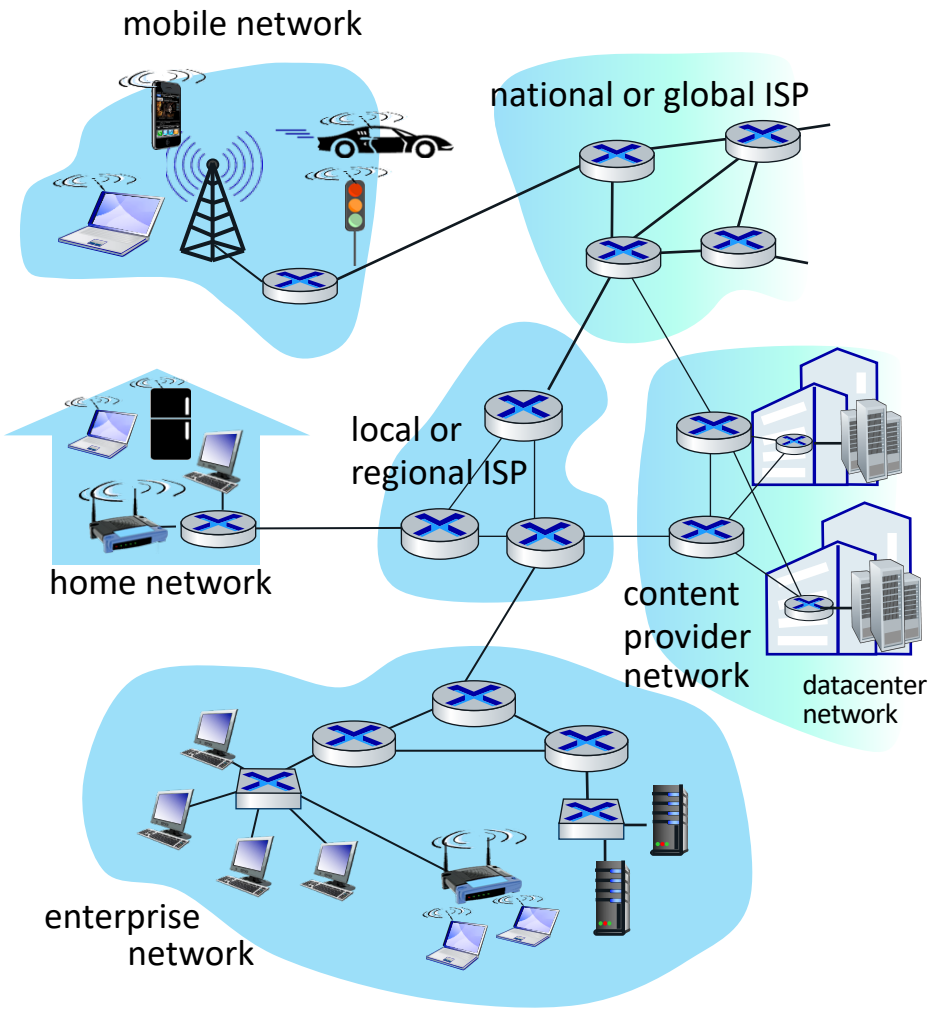
Fundamentals of Network Communication

- Network layering?





Why layering networks?

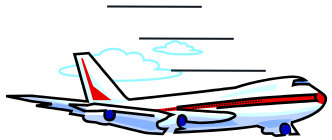
Networks are complex, with many "pieces":

- hosts
- routers
- links of various media
- applications
- protocols
- hardware, software

Question: is there any hope of *organizing* structure of network?

- and/or our *discussion* of networks?

Example: Air travel



end-to-end transfer of person plus baggage

ticket (purchase)

baggage (check)

gates (load)

runway takeoff

airplane routing

ticket (complain)

baggage (claim)

gates (unload)

runway landing

airplane routing

airplane routing

How would you *define/discuss* the *system* of airline travel?

- a series of steps, involving many services

Example: Air travel

layers: each layer implements a service

- via its own internal-layer actions
- relying on services provided by layer below

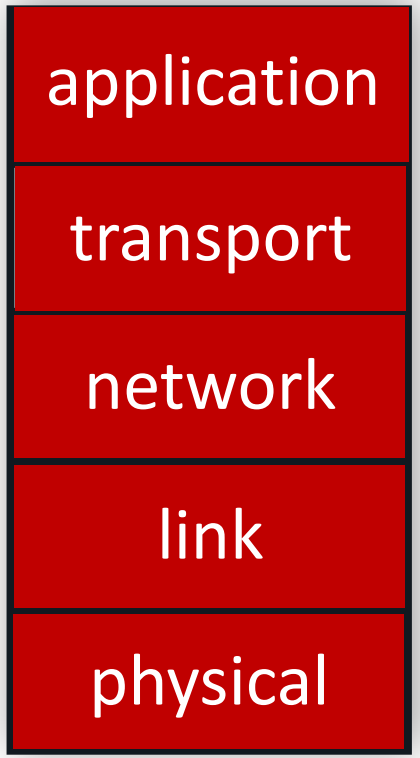
Why layering networks?

Approach to designing/discussing complex systems:

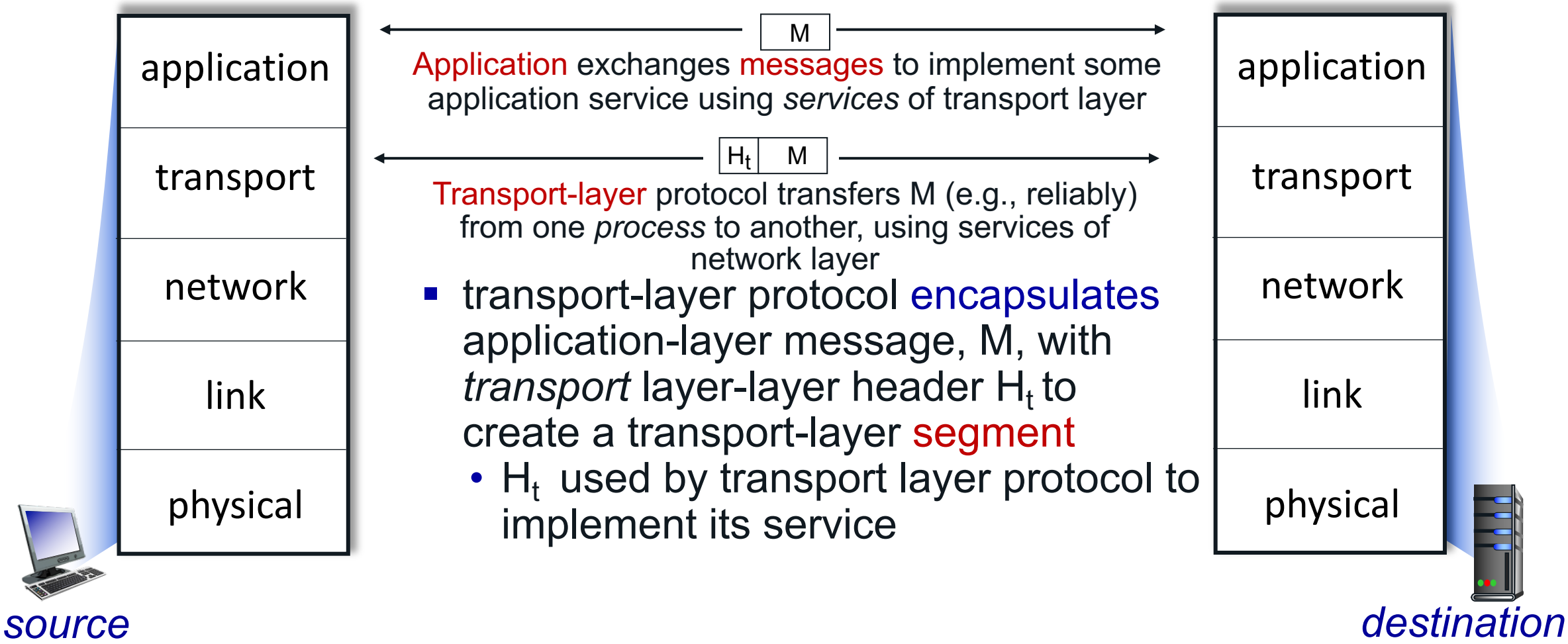
- explicit structure allows identification, relationship of system's pieces
  - layered *reference model* for discussion
- modularization eases maintenance, updating of system
  - change in layer's service *implementation*: transparent to rest of system
  - e.g., change in gate procedure doesn't affect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

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”

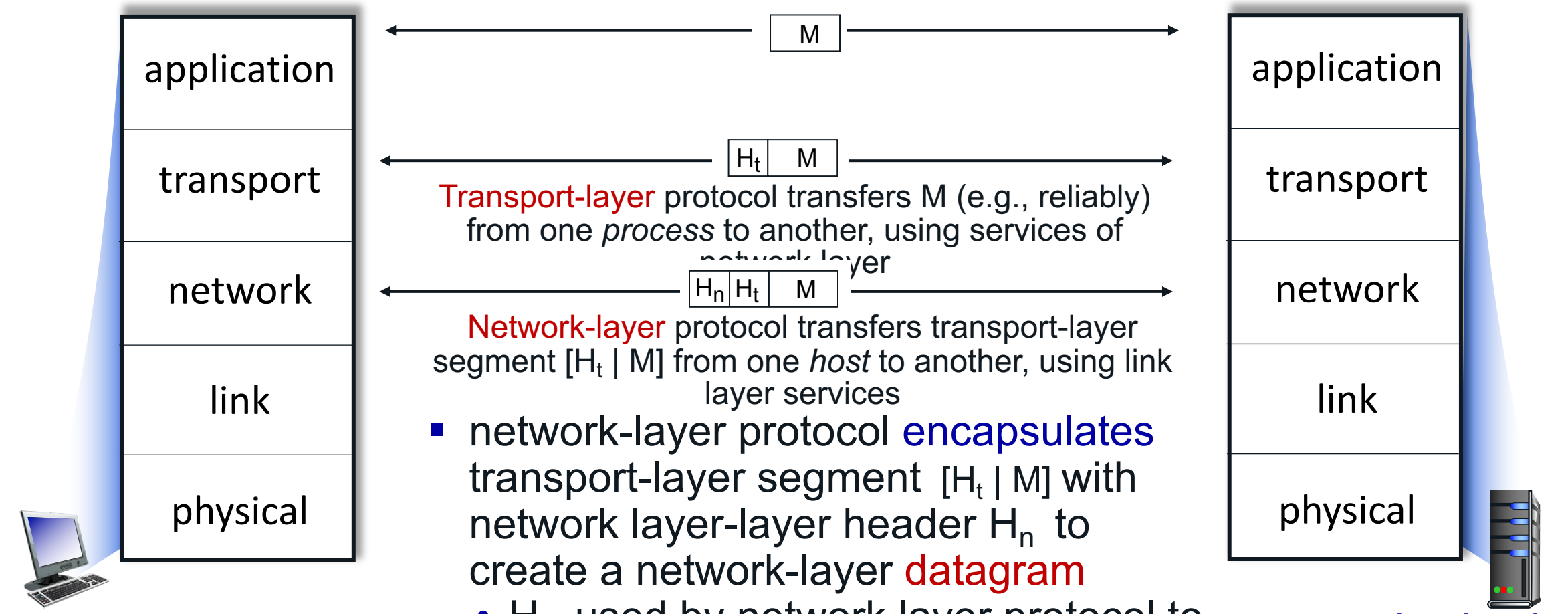


Services, Layering and Encapsulation



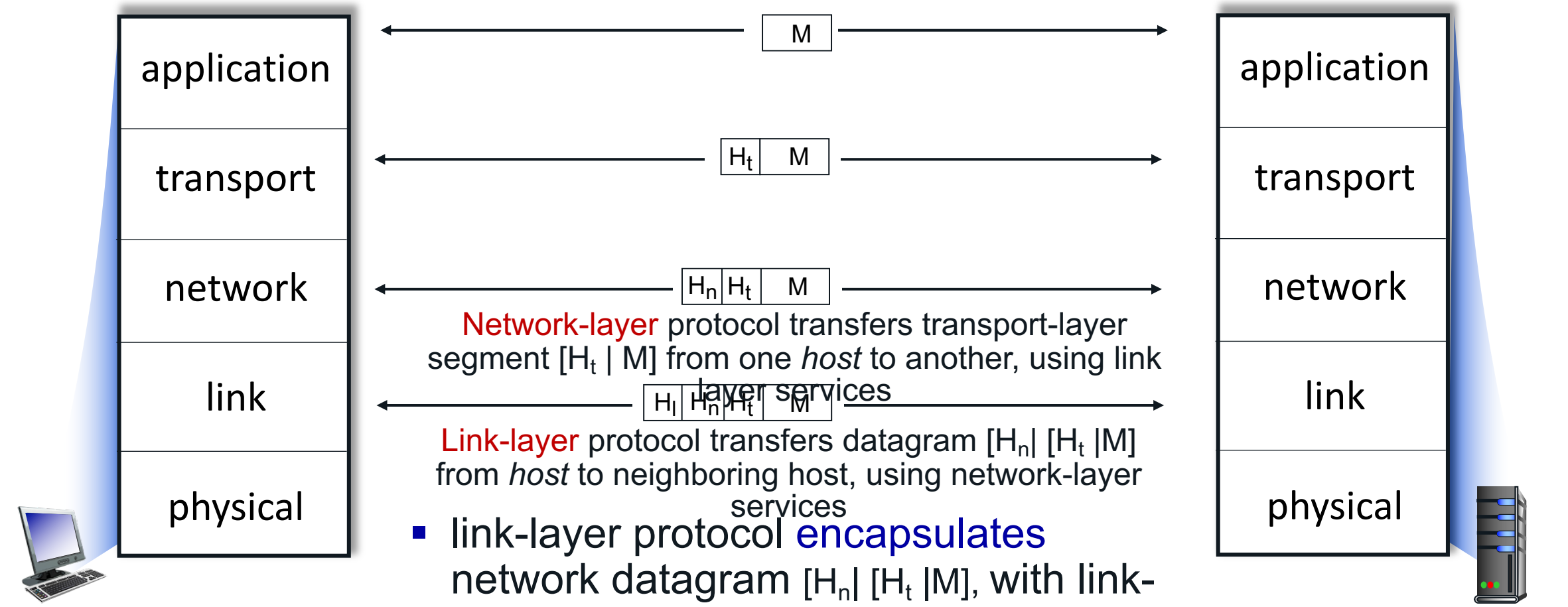
- transport-layer protocol encapsulates application-layer message, M, with *transport* layer-layer header H_t to create a transport-layer segment
  - H_t used by transport layer protocol to implement its service

Services, Layering and Encapsulation



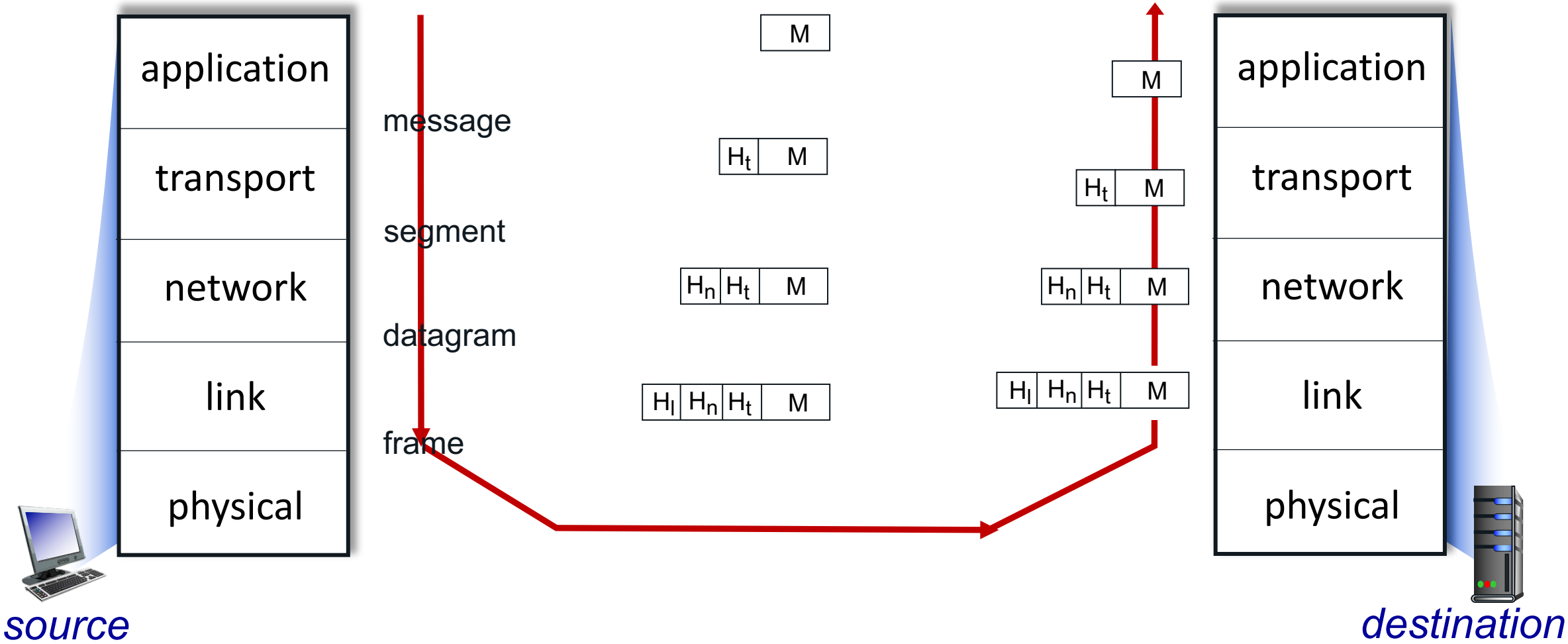
- network-layer protocol encapsulates transport-layer segment [H_t | M] with network layer-layer header H_n to create a network-layer datagram
  - H_n used by network layer protocol to implement its service

Services, Layering and Encapsulation

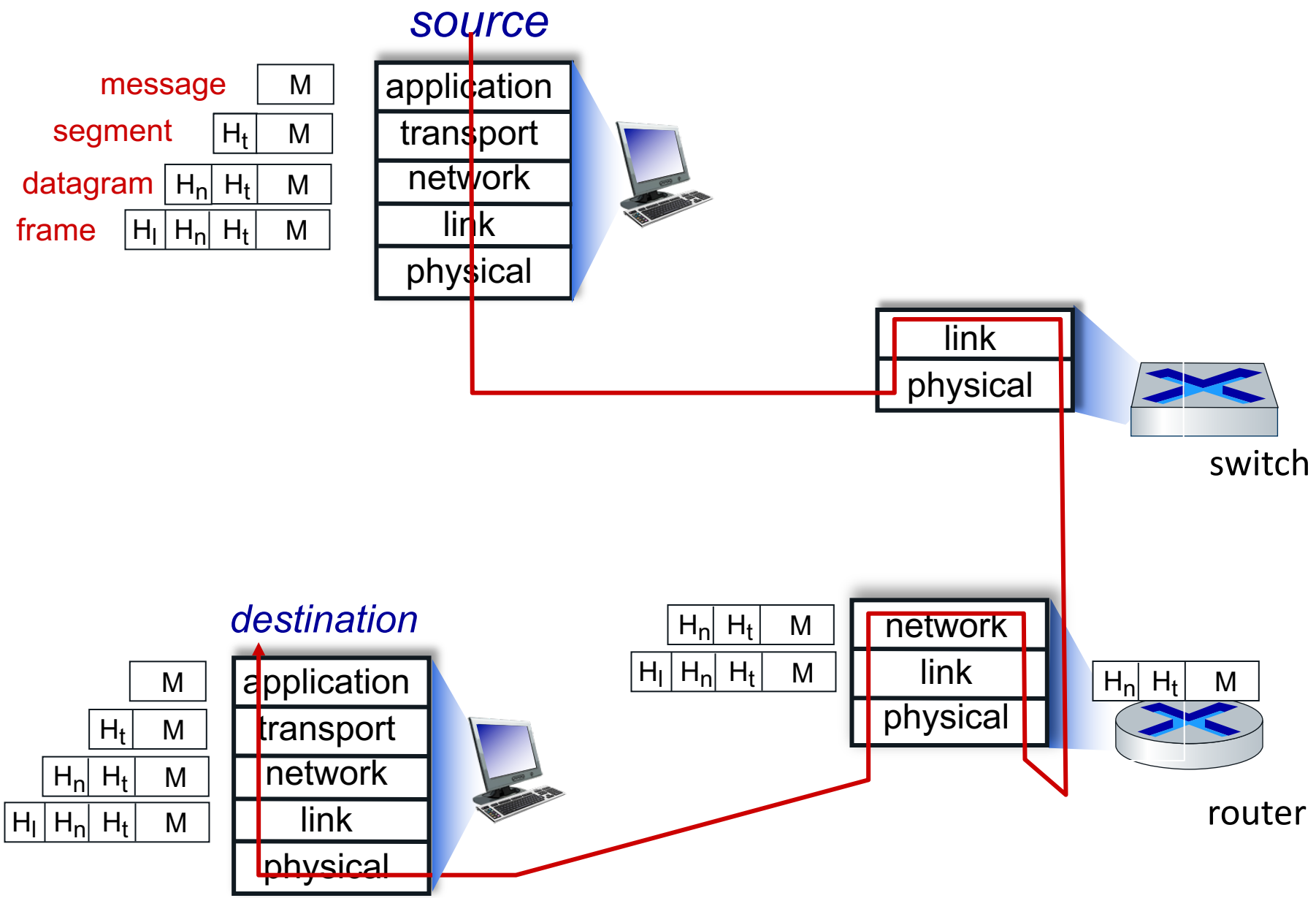


- link-layer protocol encapsulates network datagram [H_n| [H_t |M], with link-layer header H_l to create a link-layer frame

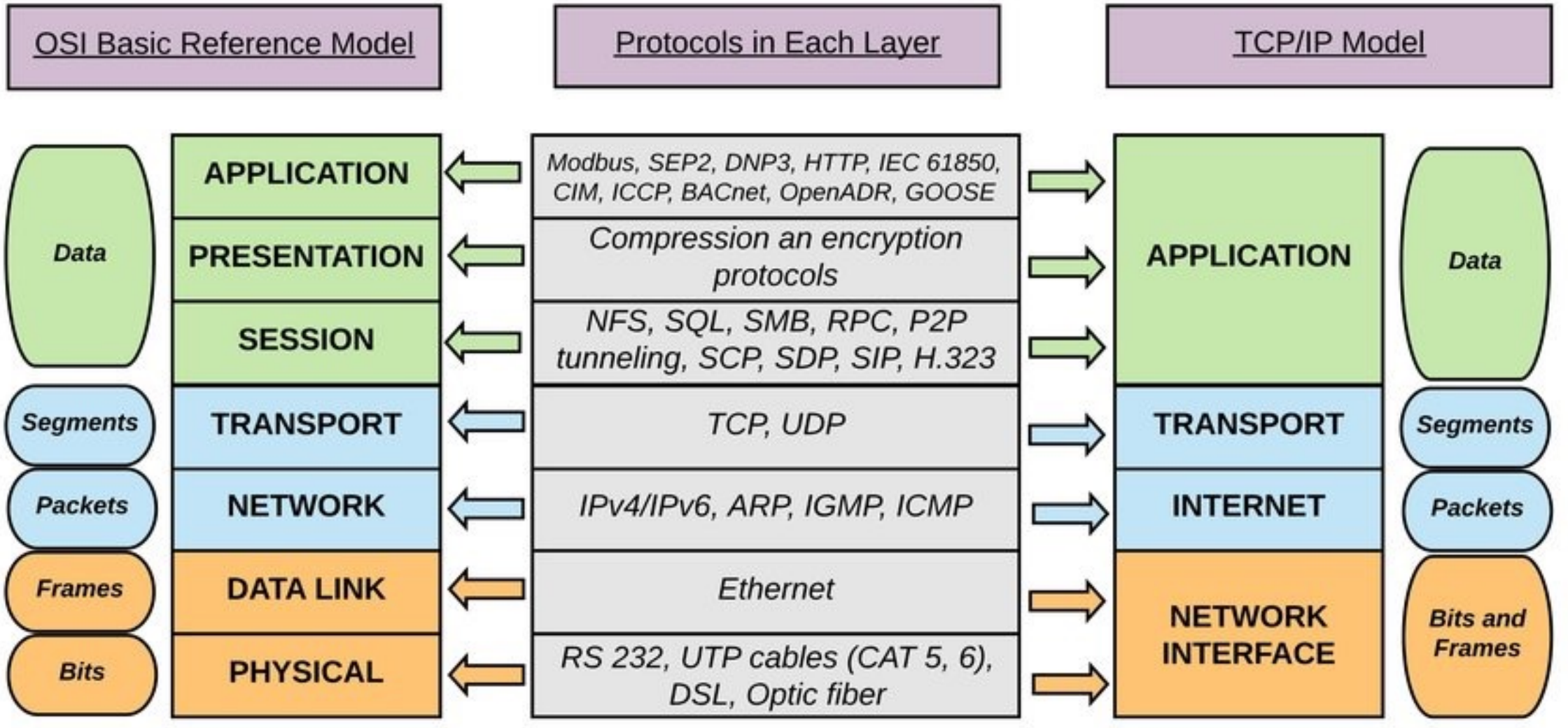
Services, Layering and Encapsulation



Services, Layering and Encapsulation



Comparison of OSI & TCP/IP suite



https://www.researchgate.net/figure/The-logical-mapping-between-OSI-basic-reference-model-and-the-TCP-IP-stack_fig2_327483011

OSI and TCP/IP Reference Model

Similarities:

- Both have layered architecture.
- Layers provide similar functionalities.
- Both are protocol stack.
- Both are reference models.

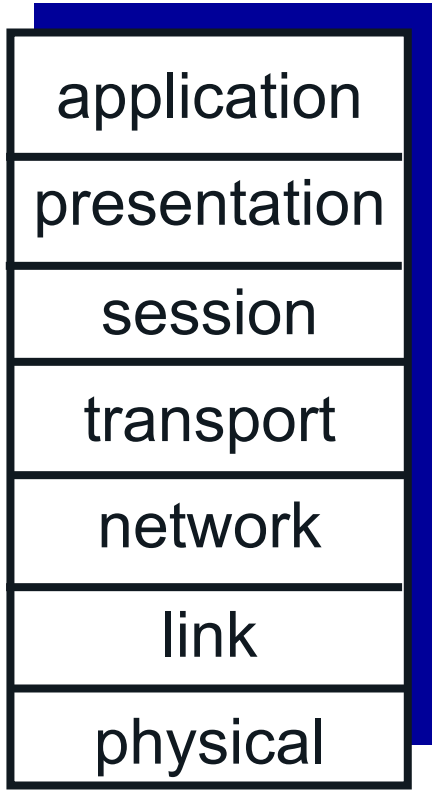
Differences:

- OSI model defines services, interfaces and protocols very clearly and makes clear distinction between them. It is protocol independent, however in TCP/IP, services, interfaces and protocols are not clearly separated. It is also protocol dependent.
- OSI has 7 layers, TCP/IP suite has 4 layers.
- TCP/IP follows Horizontal approach. On the other hand, the OSI Model supports Vertical approach.

OSI and TCP/IP 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

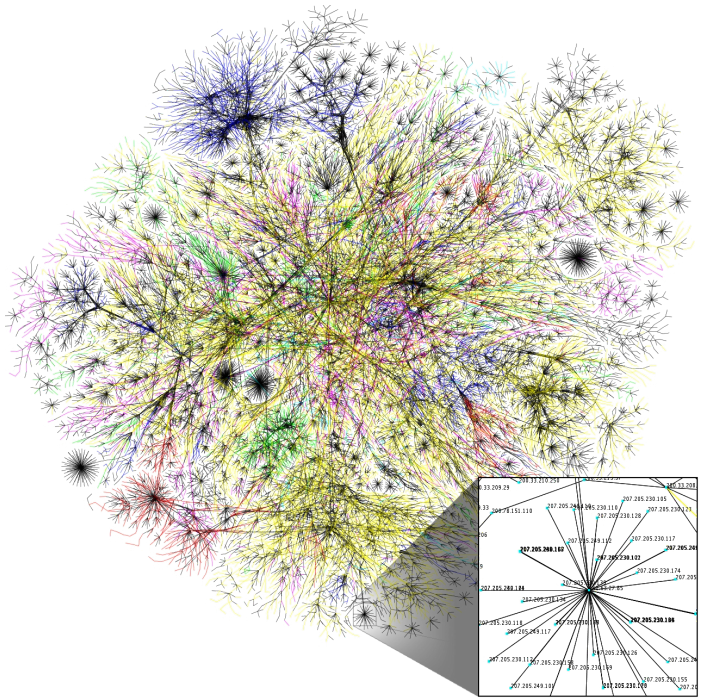
Thank You!

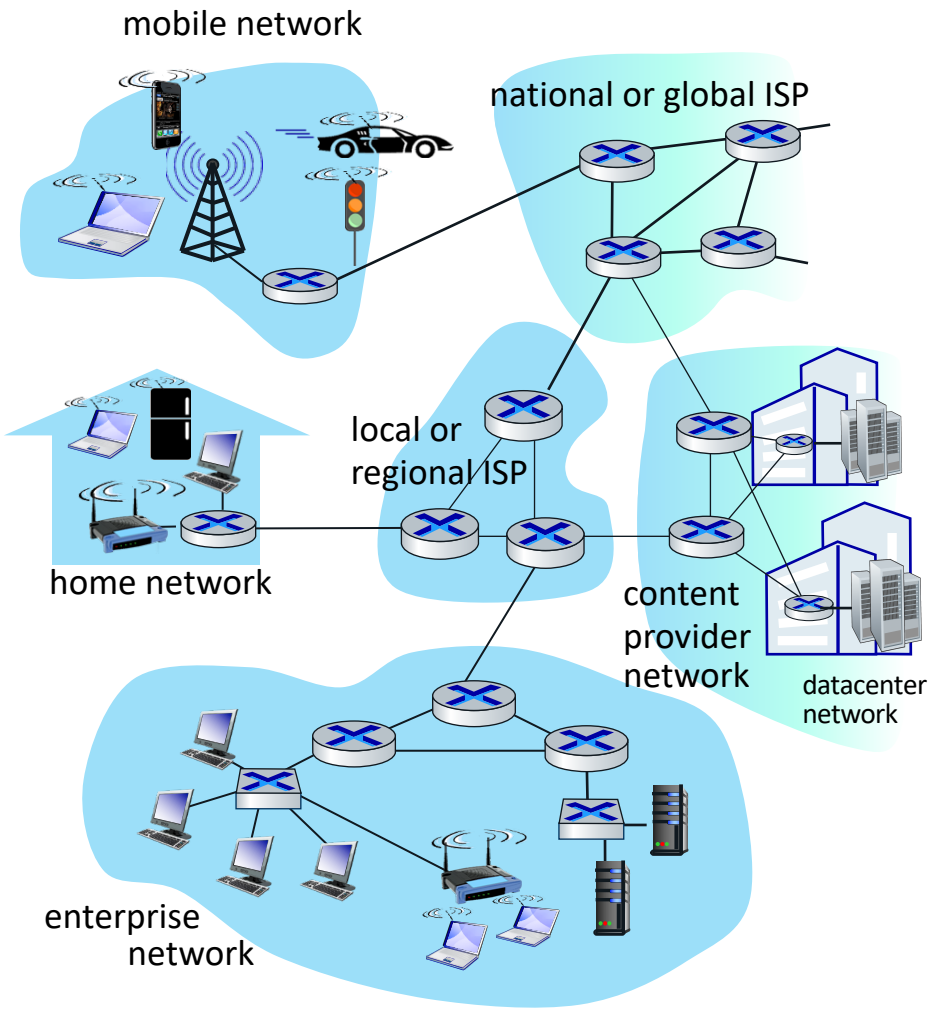

Tell me and I forget.
Teach me and I remember.
Involve me and I learn.
-Benjamin Franklin

Introduction to Networking Technologies

Fundamentals of Network Communication

- Network under attacks!





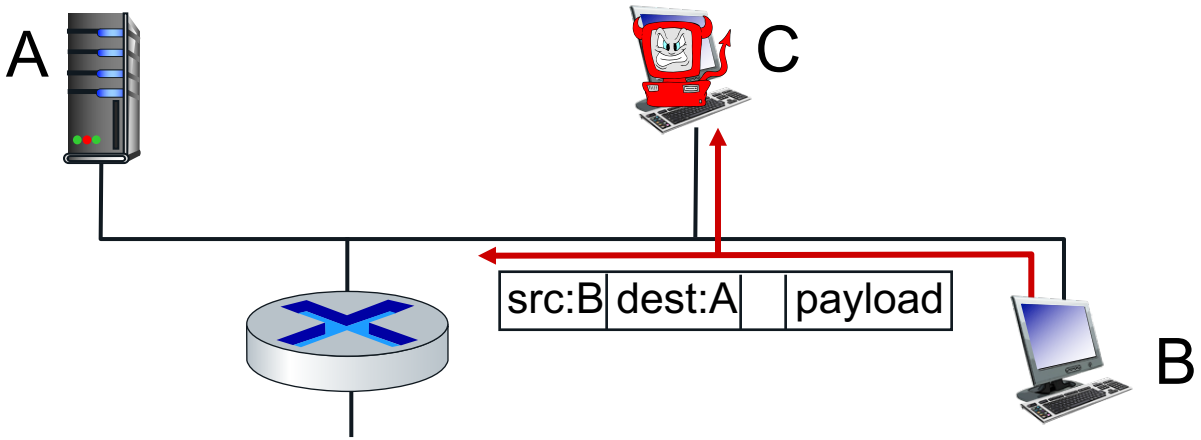
Network Security

- 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

Packet interception

packet "sniffing":

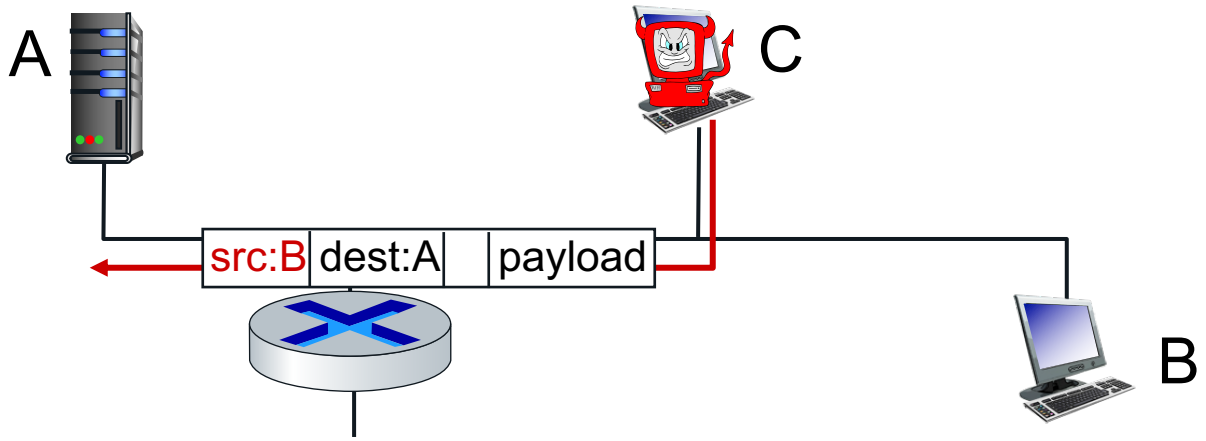
- broadcast media (shared Ethernet, wireless)
- promiscuous network interface reads/records all packets (e.g., including passwords!) passing by



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

Fake identity

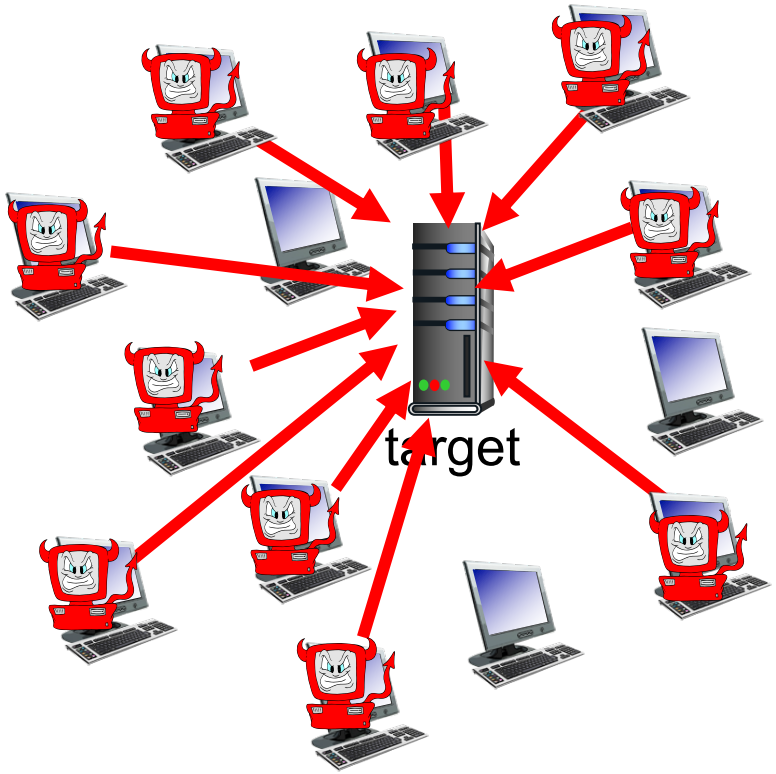
IP spoofing: injection of packet with false source address



Denial of Service (DoS)

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

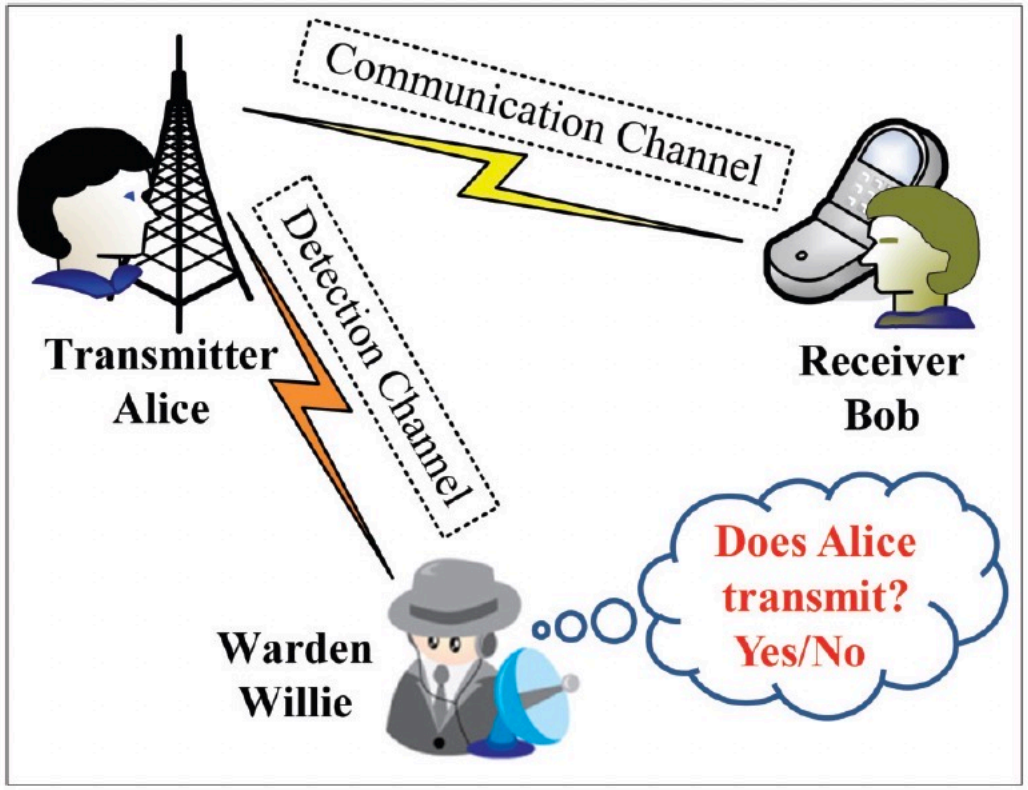
1. select target
2. break into hosts around the network (see botnet)
3. send packets to target from compromised hosts



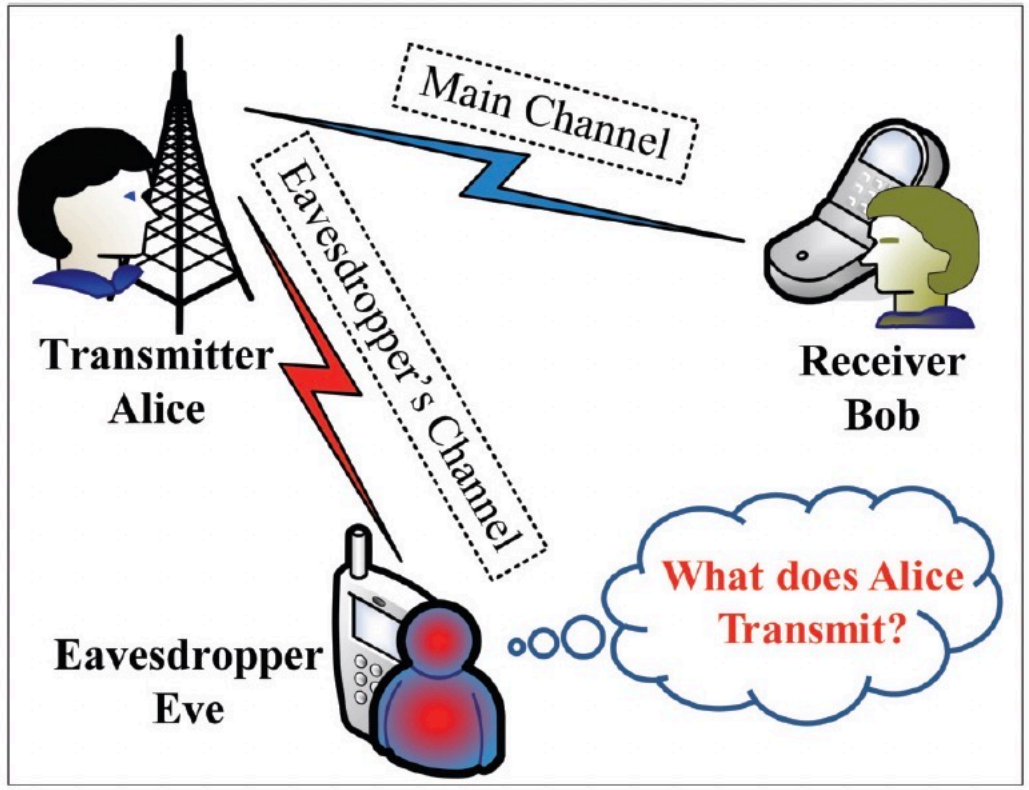
Defenses

- 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

Covert Communication and Physical Layer Security

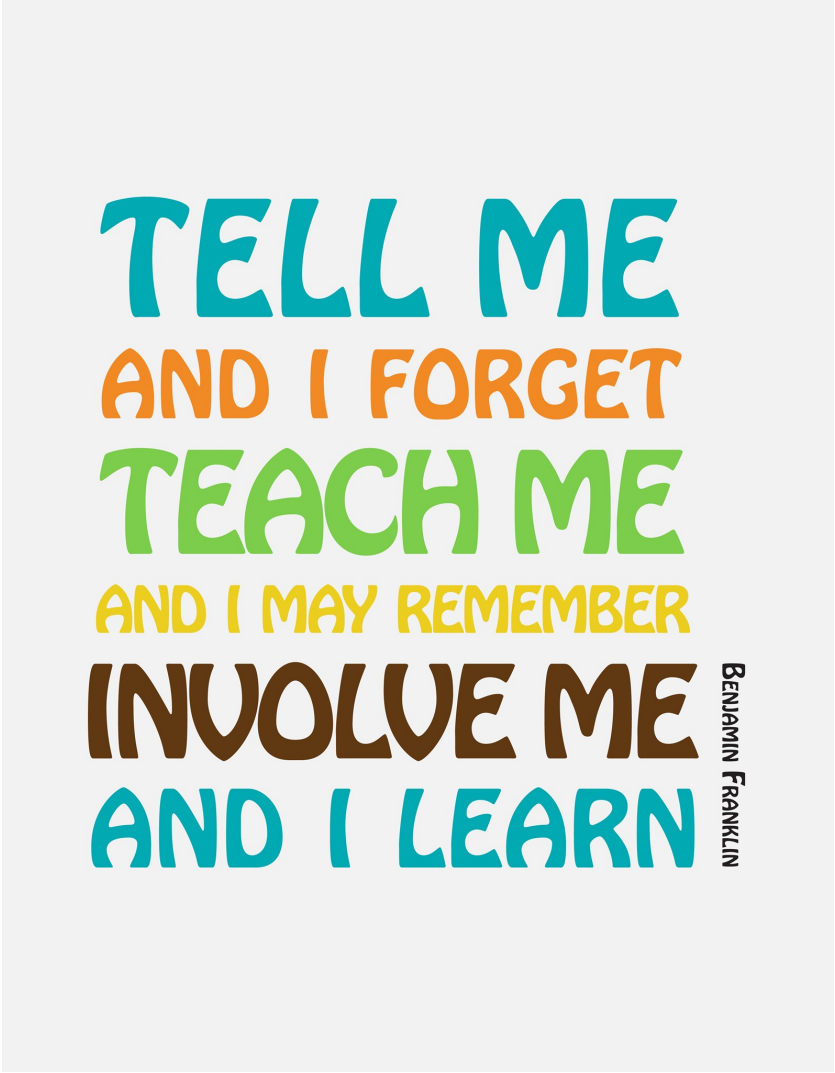


Covert communication



Physical layer security

Thank You!


TELL ME
AND I FORGET
TEACH ME
AND I MAY REMEMBER
INVOLVE ME
AND I LEARN
BENJAMIN FRANKLIN