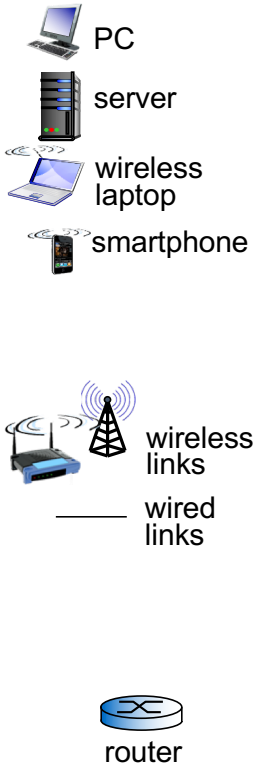
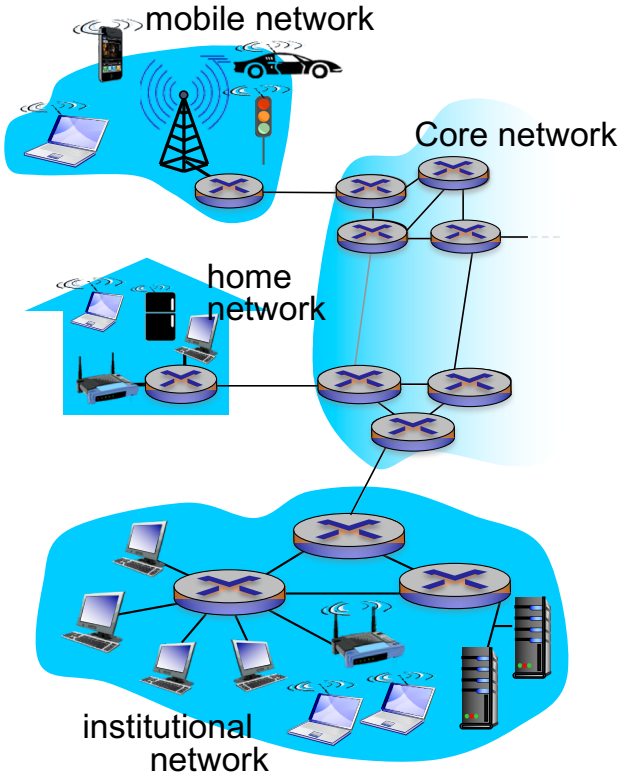
CSE 534: Fundamentals of Computer Networks

Slides adapted from *Computer Networking: A Top Down Approach*

What's the Internet: "nuts and bolts" view



- billions of connected computing devices:
  - *Hosts/clients*
  - running *network apps*
- *communication links*
  - fiber, copper, radio, satellite
- *Core network*
  - Carries traffic from one end to another
- *server*
  - Usually one of the end points with "information"



What's the Internet: "nuts and bolts" view

- *Internet:* "network of networks"
  - Interconnected Internet server providers (or core network) connecting edge nodes (servers and clients)
  - Access network is used to connect the subscriber (client/server) to the server provider (the core)
- *protocols* tells you what a message means
  - e.g., TCP, IP, HTTP, Skype, 802.11
- *Internet standards*
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force

What's a protocol?

human protocols:

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

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

Goal of this class

Learn how the Internet (and any network) works

What are the core principles?

- Abstraction and layering to reduce the complexity of the architecture
- Design principles often used: hierarchy, state, complexity vs performance, indirection, caching, etc

How to design a protocol?

- What assumptions are made, what are the design space
- The nitty gritty of some protcols

How does the (Internet) world look today?

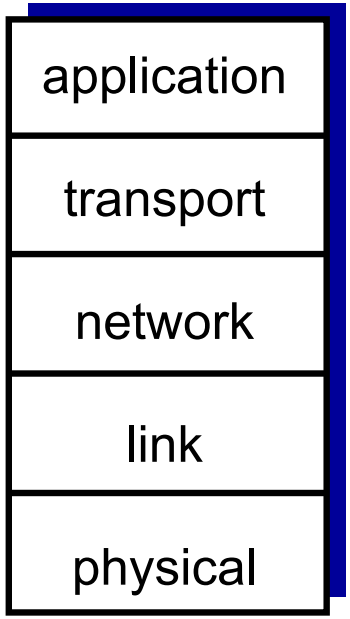
Why layering?

dealing with complex systems:

- explicit structure allows identification, relationship of complex system's pieces
- modularization eases maintenance, updating of system
  - change of implementation of layer's service transparent to rest of system

Internet protocol stack (or OSI stack)

- *application:* support applications
  - FTP, SMTP, HTTP
- *transport:* end-to-end data transfer
  - TCP, UDP
- *network:* routing from source to destination
  - IP, routing protocols
- *link:* data transfer between one-hop neighbors
- *physical:* sending bits "on the wire"



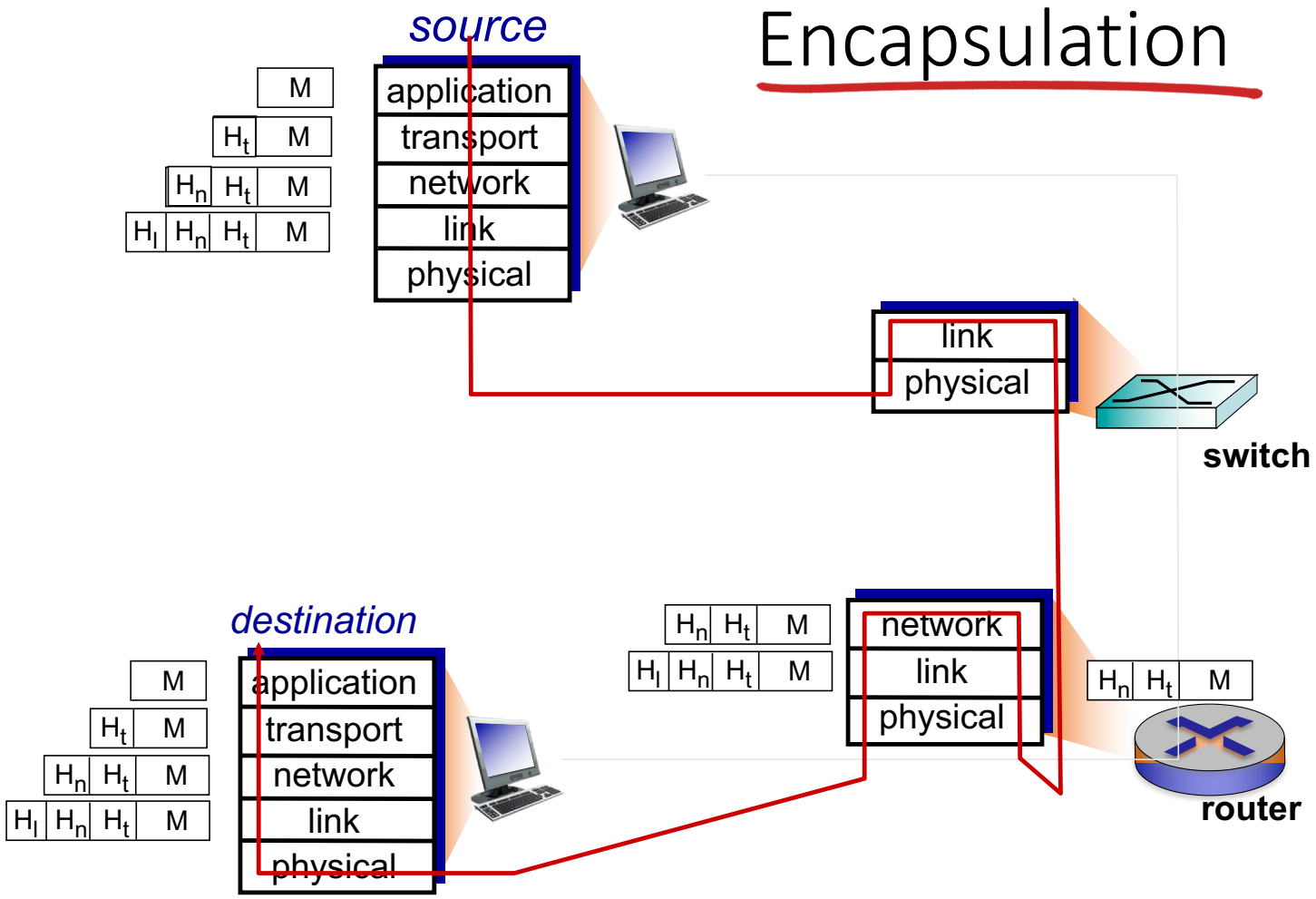
Lets look at it the other way (1 of 2)

- Physical Layer Abstraction: send bits from one computer to the next
  - The computers are either directly connected so the bits are on the wire or are sent over the wireless signal
  - Most innovation in this space today are in the areas of signal processing (and 5G)
- Link layer Abstraction: Check correctness of received bytes and perform access control
  - Link layer is between nodes within one hop, communication among one-hop nodes is through a shared medium
  - Medium access control decides who can send data, and then ensures correctness

Lets look at it the other way (1 of 2)

- Network Layer Abstraction: find route from source to destination and forward data
  - Takes care of addressing and routing
- Transport layer abstraction: End-to-end connectivity
  - Makes it look like the source and destination are connected through a pipe.
  - Often determines data rates; i.e., how much data can be sent from the source to destination
- Application layer abstraction: Supports applications
  - No longer data but rather objects with semantic meaning
  - Objects are fetched according to the application specification

Encapsulation



What information is being encapsulated?

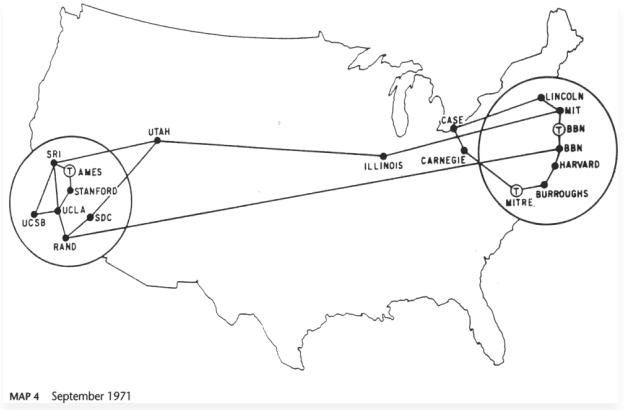
- Each layer adds a header to the packet
- The header has information required by the protocol that the other end needs
  - For example, in the case of Transport or application layer, the headers exchange information between the end source and destination
  - In the case of link layer, the headers exchange information between neighboring nodes

Internet history

1961-1972: Early packet-switching principles

- 1961: Kleinrock - queueing theory shows effectiveness of packet-switching
- 1964: Baran - packet-switching in military nets
- 1969: first ARPAnet node operational

- 1972:
  - ARPAnet public demo
  - 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
- 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

defines today's Internet architecture

1980-1990: new protocols, a proliferation 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
  - HTML, HTTP: Berners-Lee
  - 1994: Mosaic, later Netscape
  - late 1990's: commercialization of the Web

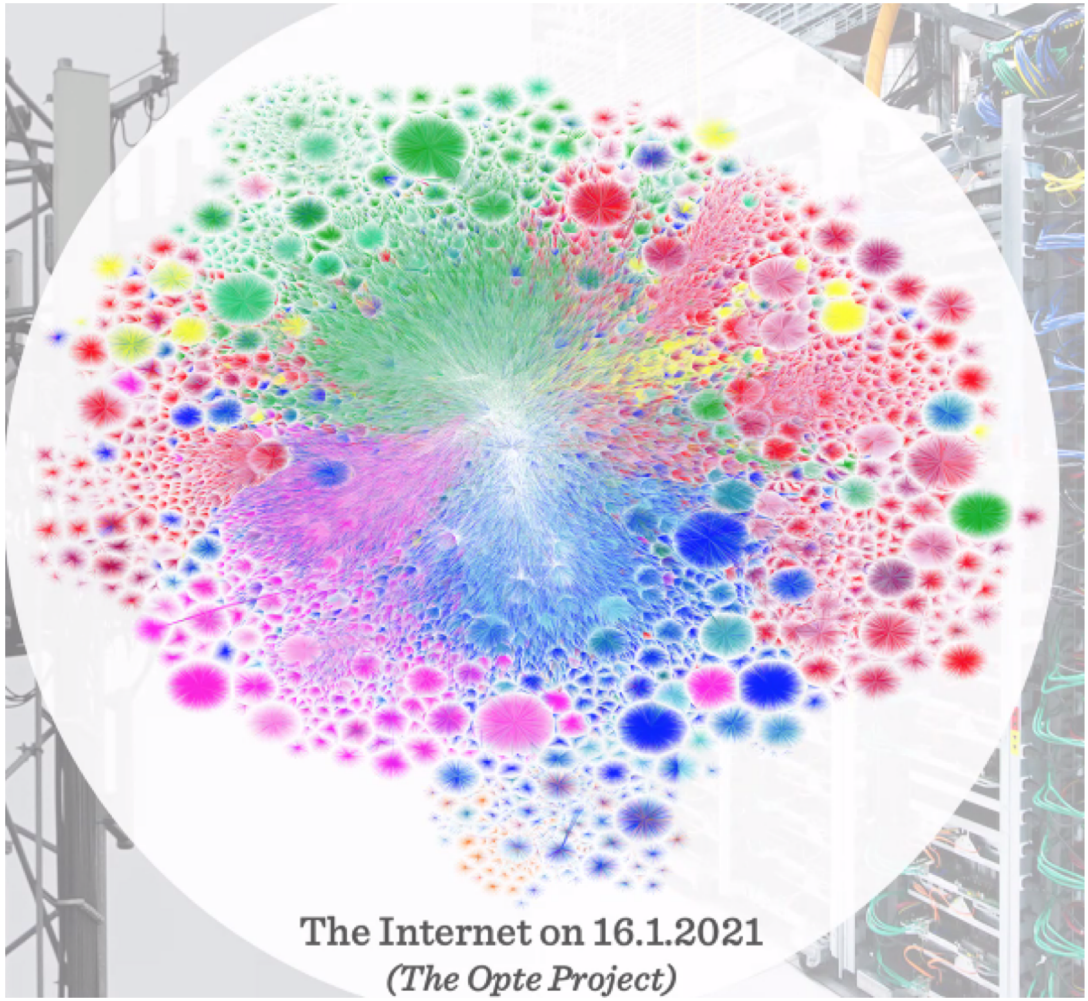
late 1990's – 2000's:

- 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

2005-2015

- ~5B devices attached to Internet (2016)
  - smartphones and tablets
- aggressive deployment of broadband access
- increasing ubiquity of high-speed wireless access
- emergence of online social networks:
  - Facebook: ~ one billion users
- e-commerce, universities, enterprises running their services in "cloud" (e.g., Amazon EC2)


The Internet on 16.1.2021
(The Opte Project)