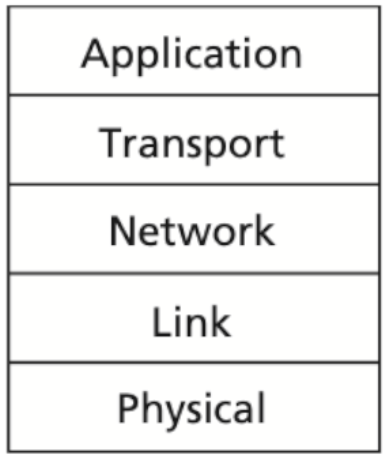
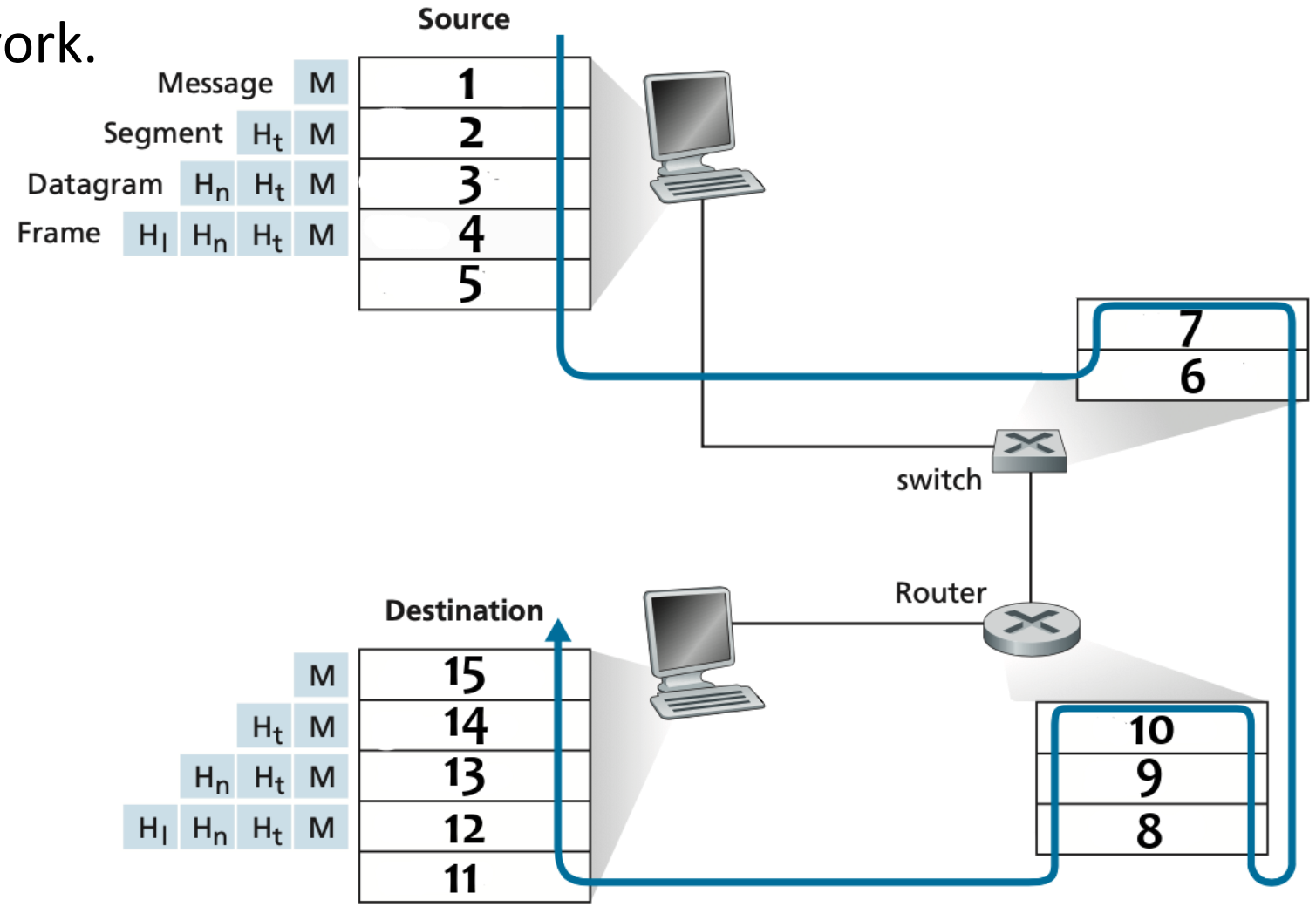
“Tell me and I forget. Show me and I remember. Involve me and I understand.”

The IP Stack and Protocol Layering

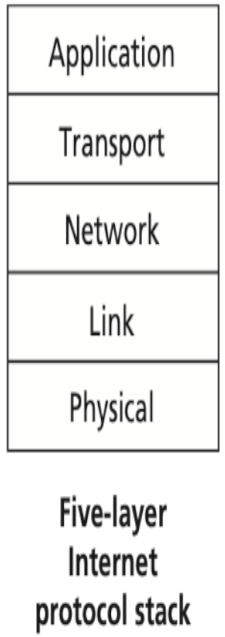
In the scenario below, imagine that you're sending an http request to another machine somewhere on the network.



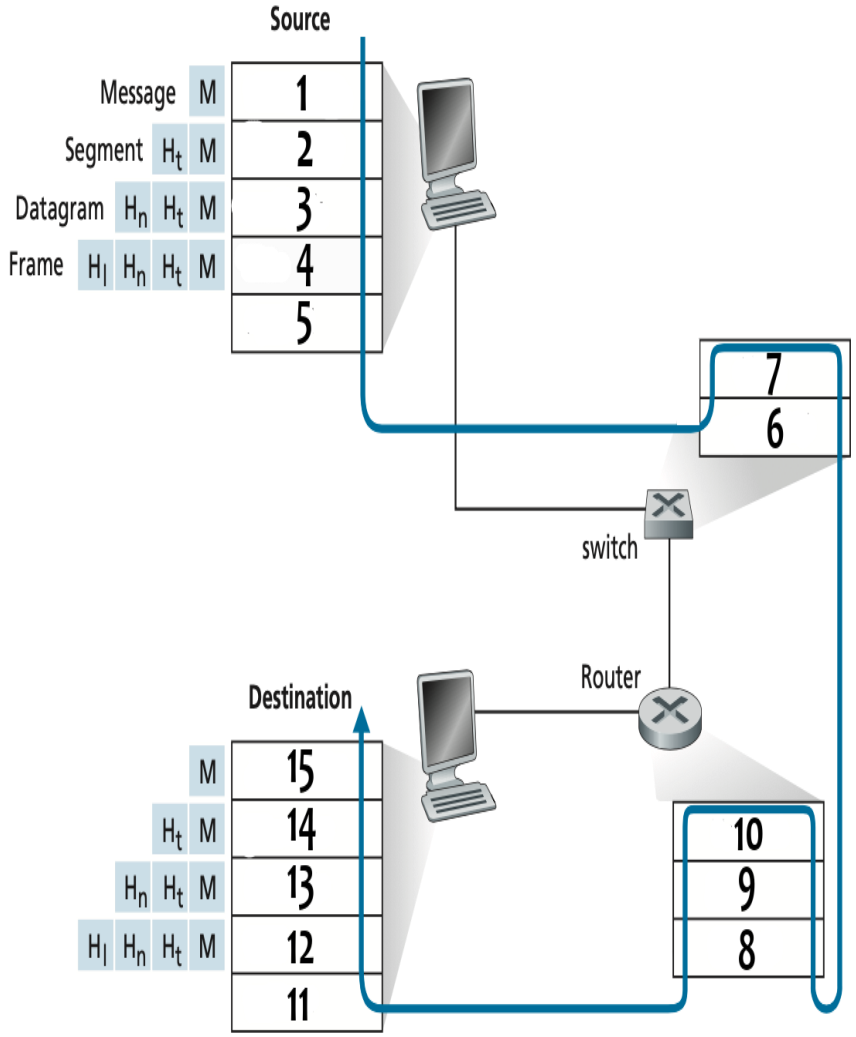
Five-layer Internet protocol stack



Question List



Five-layer Internet protocol stack



1. What layer in the IP stack best corresponds to the phrase: 'handles the delivery of segments from the application layer, may be reliable or unreliable'

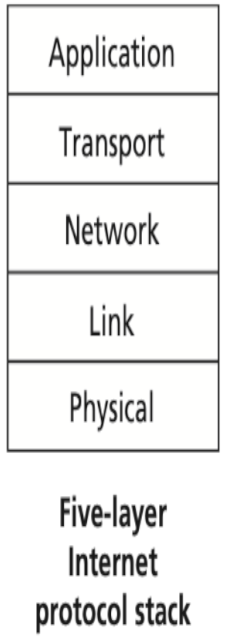
2. What layer in the IP stack best corresponds to the phrase: 'moves datagrams from the source host to the destination host'

3. What layer in the IP stack best corresponds to the phrase: 'passes frames from one node to another across some medium'

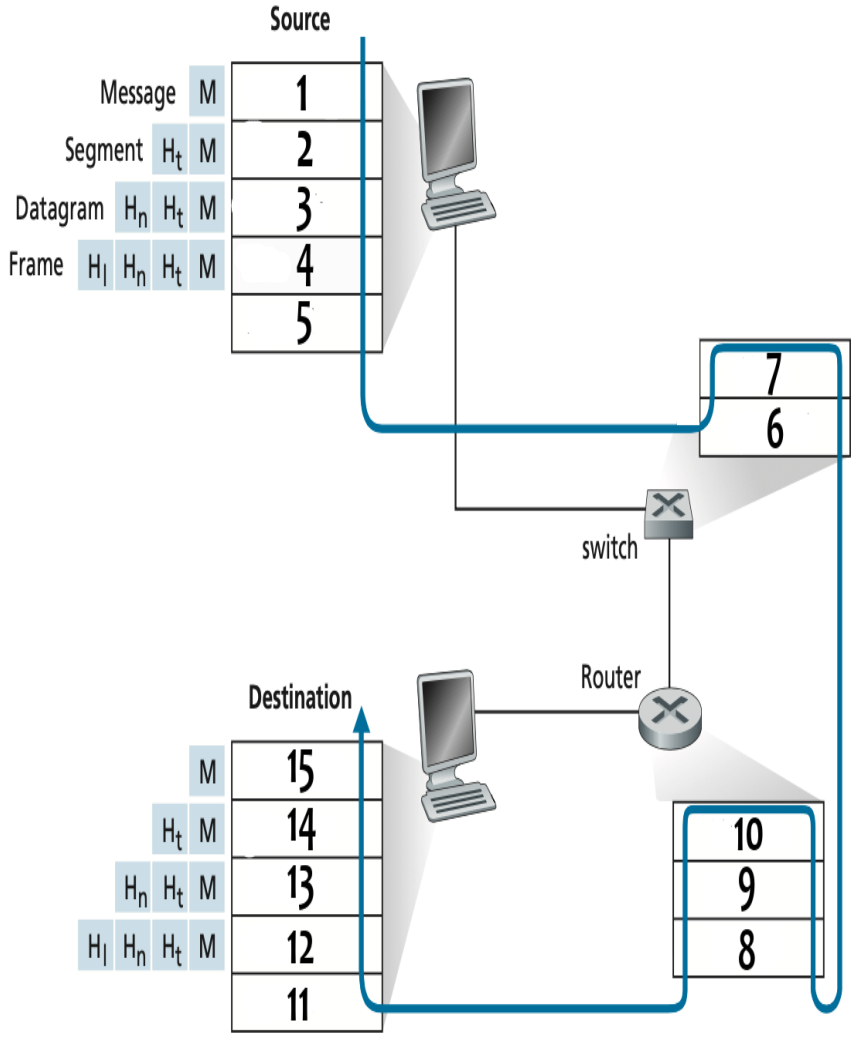
4. What layer in the IP stack best corresponds to the phrase: 'bits live on the wire'

5. What layer in the IP stack best corresponds to the phrase: 'handles messages from a variety of network applications'

Solution



Five-layer Internet protocol stack



1. What layer in the IP stack best corresponds to the phrase: 'handles the delivery of segments from the application layer, may be reliable or unreliable': Transport Layer

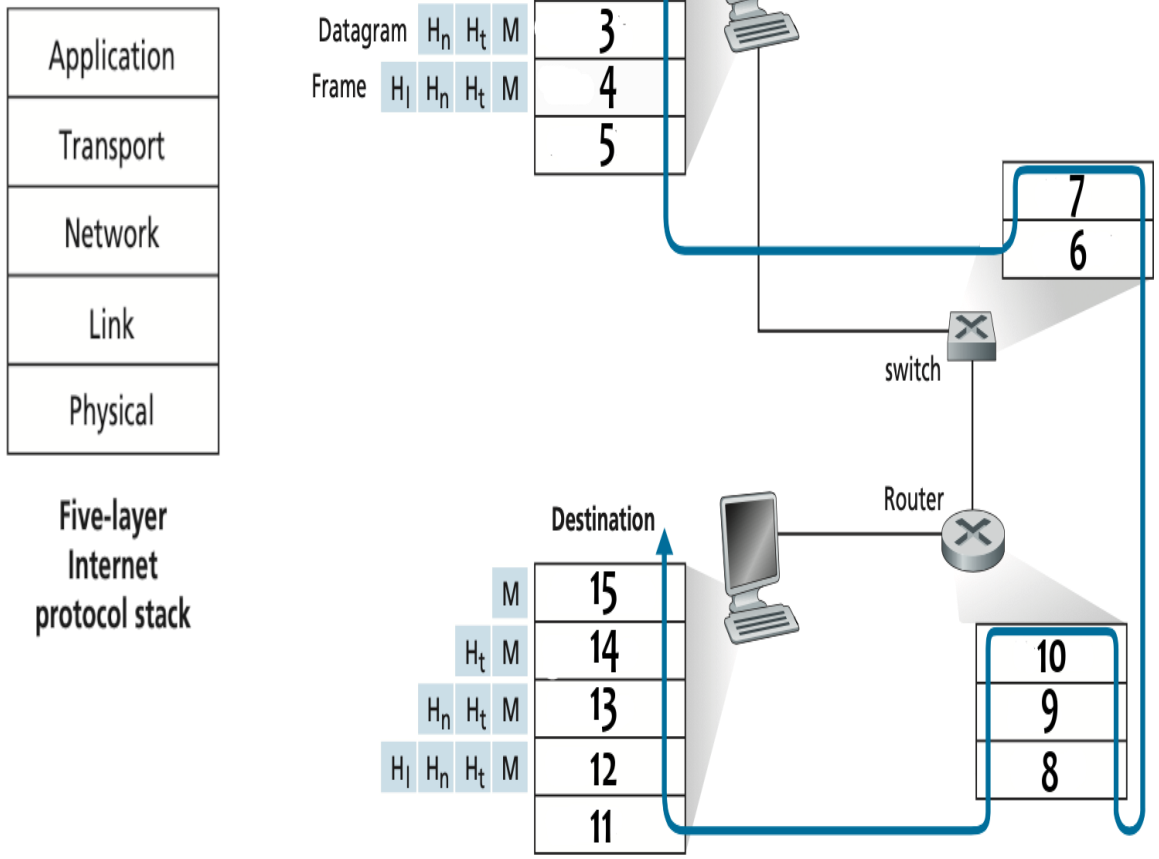
2. What layer in the IP stack best corresponds to the phrase: 'moves datagrams from the source host to the destination host': Network Layer

3. What layer in the IP stack best corresponds to the phrase: 'passes frames from one node to another across some medium': Link Layer

4. What layer in the IP stack best corresponds to the phrase: 'bits live on the wire': Physical Layer

5. What layer in the IP stack best corresponds to the phrase: 'handles messages from a variety of network applications': Application Layer.

Question List



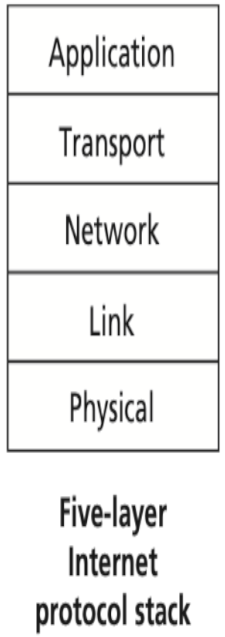
6. What layer corresponds to box 1?
7. What layer corresponds to box 2?
8. What layer corresponds to box 3?
9. What layer corresponds to box 4?

10. What layer corresponds to box 5?
11. What layer corresponds to box 6?
12. What layer corresponds to box 7?
13. What layer corresponds to box 8?

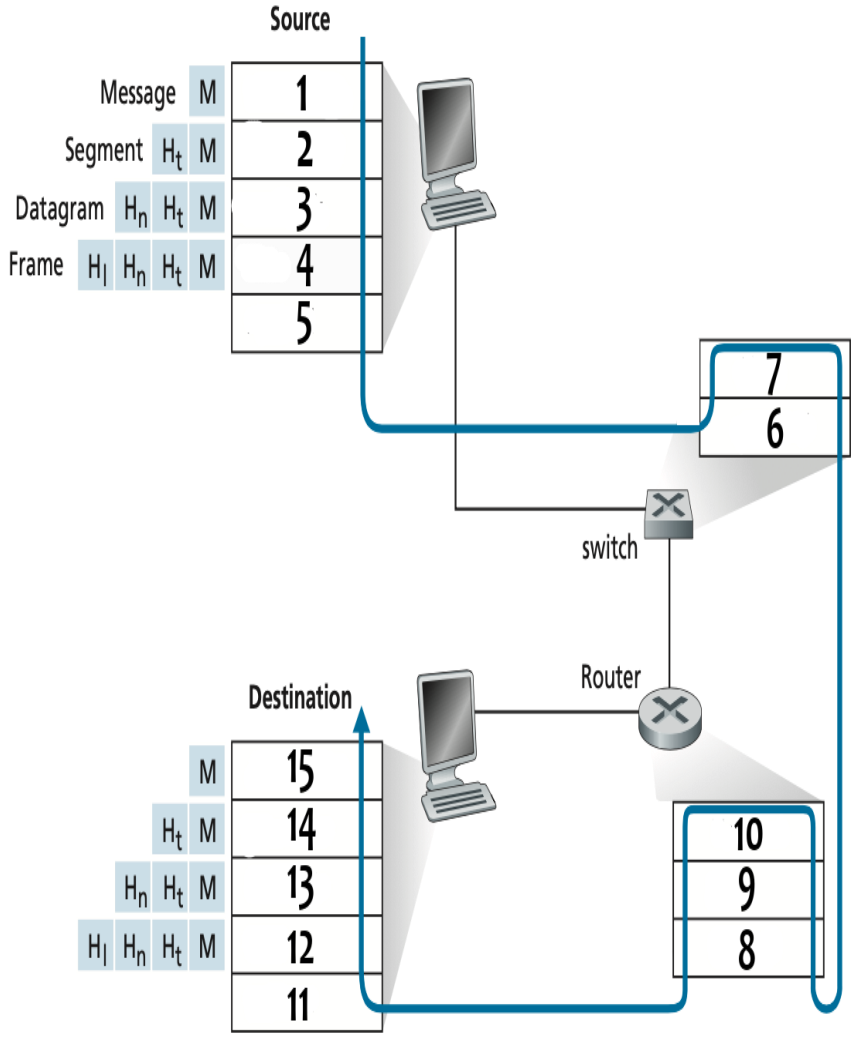
14. What layer corresponds to box 9?
15. What layer corresponds to box 10?
16. What layer corresponds to box 11?
17. What layer corresponds to box 12?

18. What layer corresponds to box 13?
19. What layer corresponds to box 14?
20. What layer corresponds to box 15?

Solution:



Five-layer Internet protocol stack



6. What layer corresponds to box 1?: Application Layer
7. What layer corresponds to box 2?: Transport Layer
8. What layer corresponds to box 3?: Network Layer
9. What layer corresponds to box 4?: Link Layer
10. What layer corresponds to box 5?: Physical Layer
11. What layer corresponds to box 6?: Physical Layer
12. What layer corresponds to box 7?: Link Layer
13. What layer corresponds to box 8?: Physical Layer
14. What layer corresponds to box 9?: Link Layer
15. What layer corresponds to box 10?: Network Layer
16. What layer corresponds to box 11?: Physical Layer
17. What layer corresponds to box 12?: Link Layer
18. What layer corresponds to box 13?: Network Layer
19. What layer corresponds to box 14?: Transport Layer
20. What layer corresponds to box 15?: Application Layer

Chapter 1: roadmap

- What *is* the Internet?
- What *is* a protocol?
- Network edge: hosts, access network, physical media
- Network core: packet/circuit switching, internet structure
- Performance: loss, delay, throughput
- Security
- Protocol layers, service models
- History

AN INTERVIEW WITH Leonard Kleinrock

Leonard Kleinrock is a professor of computer science at the University of California, Los Angeles. In 1969, his computer at UCLA became the first node of the Internet. His creation of packet-switching principles in 1961 became the technology behind the Internet. He received his B.E.E. from the City College of New York (CCNY) and his masters and PhD in electrical engineering from MIT.

What made you decide to specialize in networking/Internet technology?

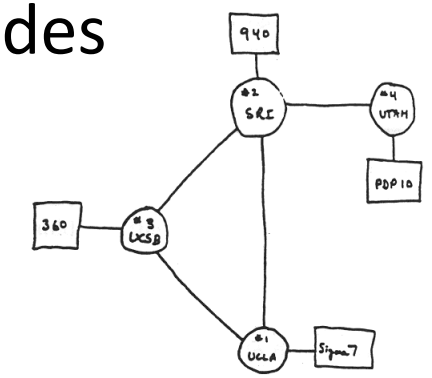
As a PhD student at MIT in 1959, I looked around and found that most of my classmates were doing research in the area of information theory and coding theory. At MIT, there was the great researcher, Claude Shannon, who had launched these fields and had solved most of the important problems already. The research problems that were left were hard and of lesser consequence. So I decided to launch out in a new area that no one else had yet conceived of. Remember that at MIT I was surrounded by lots of computers, and it was clear to me that soon these machines would need to communicate with each other. At the time, there was no effective way for them to do so, so I decided to develop the technology that would permit efficient and reliable data networks to be created.

Internet 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

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



THE ARPA NETWORK

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
- late70's: proprietary architectures: DECnet, SNA, XNA
- late 70's: switching fixed length packets (ATM precursor)
- 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

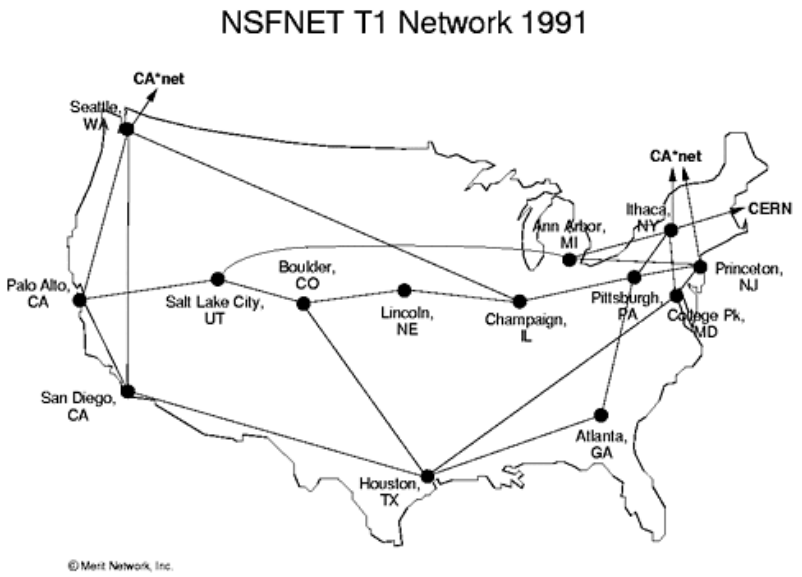
define today's Internet architecture

Internet 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



Internet 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

Internet history

2005-present: more new applications, Internet is "everywhere"

- ~50B devices attached to Internet (2025)
  - rise of smartphones (iPhone: 2007)
- aggressive deployment of broadband access
- increasing ubiquity of high-speed wireless access: 4G/5G, WiFi
- emergence of online social networks:
- Facebook: ~ 2.5 billion users
- service providers (Google, FB, Microsoft) create their own networks
  - bypass commercial Internet to connect "close" to end user, providing "instantaneous" access to search, video content, …
- enterprises run their services in "cloud" (e.g., Amazon Web Services, Microsoft Azure)

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:

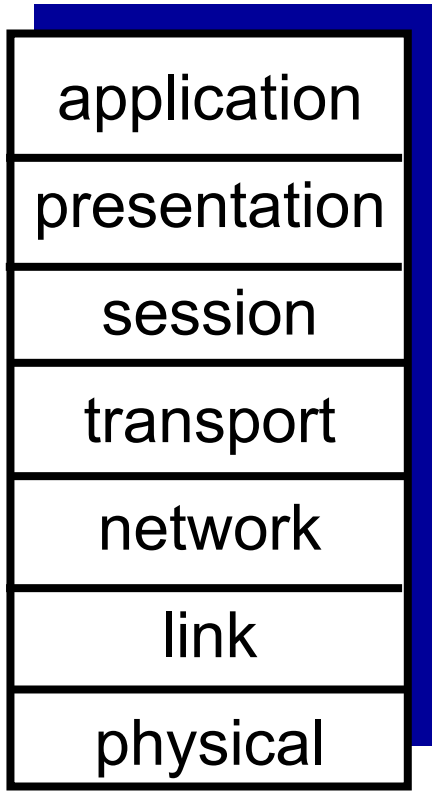
- context, overview, vocabulary, "feel" of networking
- more depth, detail, *and fun* to follow*!*

ISO/OSI reference model

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

Chapter 2
Application Layer

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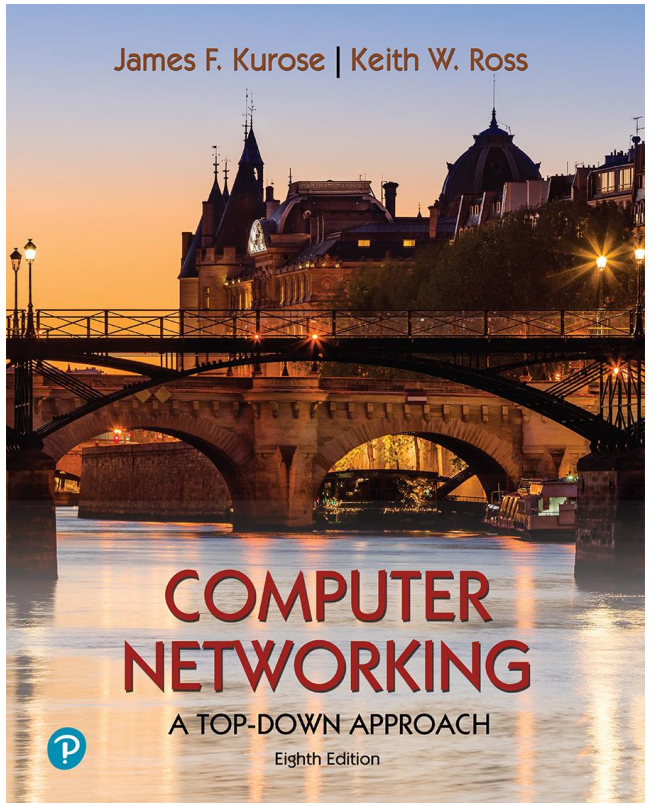
- If you use these slides (e.g., in a class) that you mention their source (after all, we'd like people to use our book!)
- If you post any slides on a www site, that you note that they are adapted from (or perhaps identical to) our slides, and note our copyright of this material.

For a revision history, see the slide note for this page.

Thanks and enjoy! JFK/KWR



Computer Networking: A Top-Down Approach

8th edition n
Jim Kurose, Keith Ross
Pearson, 2020

Application layer: overview

- Principles of network applications
- Web and HTTP
- E-mail, SMTP, IMAP
- The Domain Name System DNS

- P2P applications
- video streaming and content distribution networks
- socket programming with UDP and TCP

Application layer: overview

Our goals:

- conceptual *and* implementation aspects of application-layer protocols
  - transport-layer service models
  - client-server paradigm
  - peer-to-peer paradigm
- learn about protocols by examining popular application-layer protocols
  - HTTP
  - SMTP, IMAP
  - DNS
- programming network applications
  - socket API

Some network apps

- social networking
- Web
- text messaging
- e-mail
- multi-user network games
- streaming stored video (YouTube, Hulu, Netflix)
- P2P file sharing
- voice over IP (e.g., Skype)
- real-time video conferencing
- Internet search
- remote login
- …

Q: your favorites?