Chapter 1: roadmap

- What *is* the Internet?
- What *is* a protocol?
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- Security
- Protocol layers, service models
- History

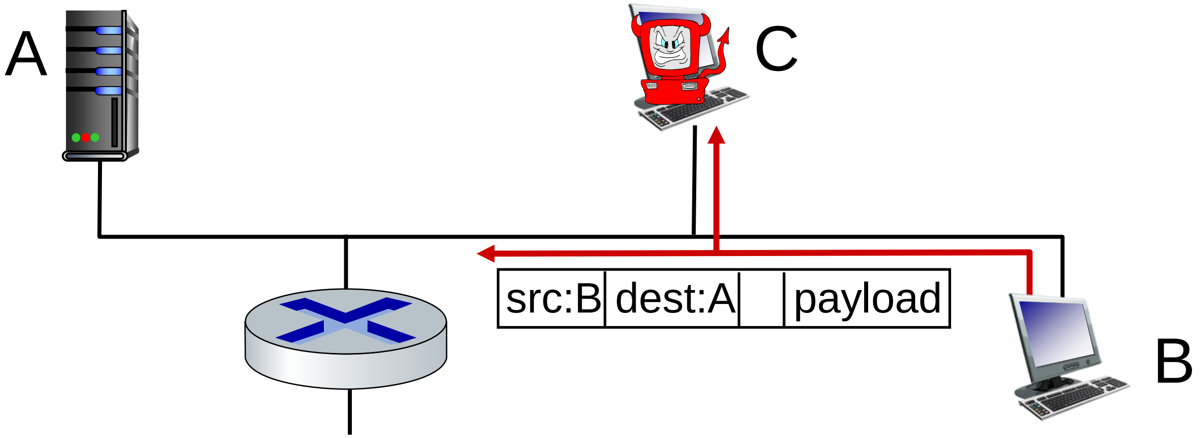
Network security

- 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

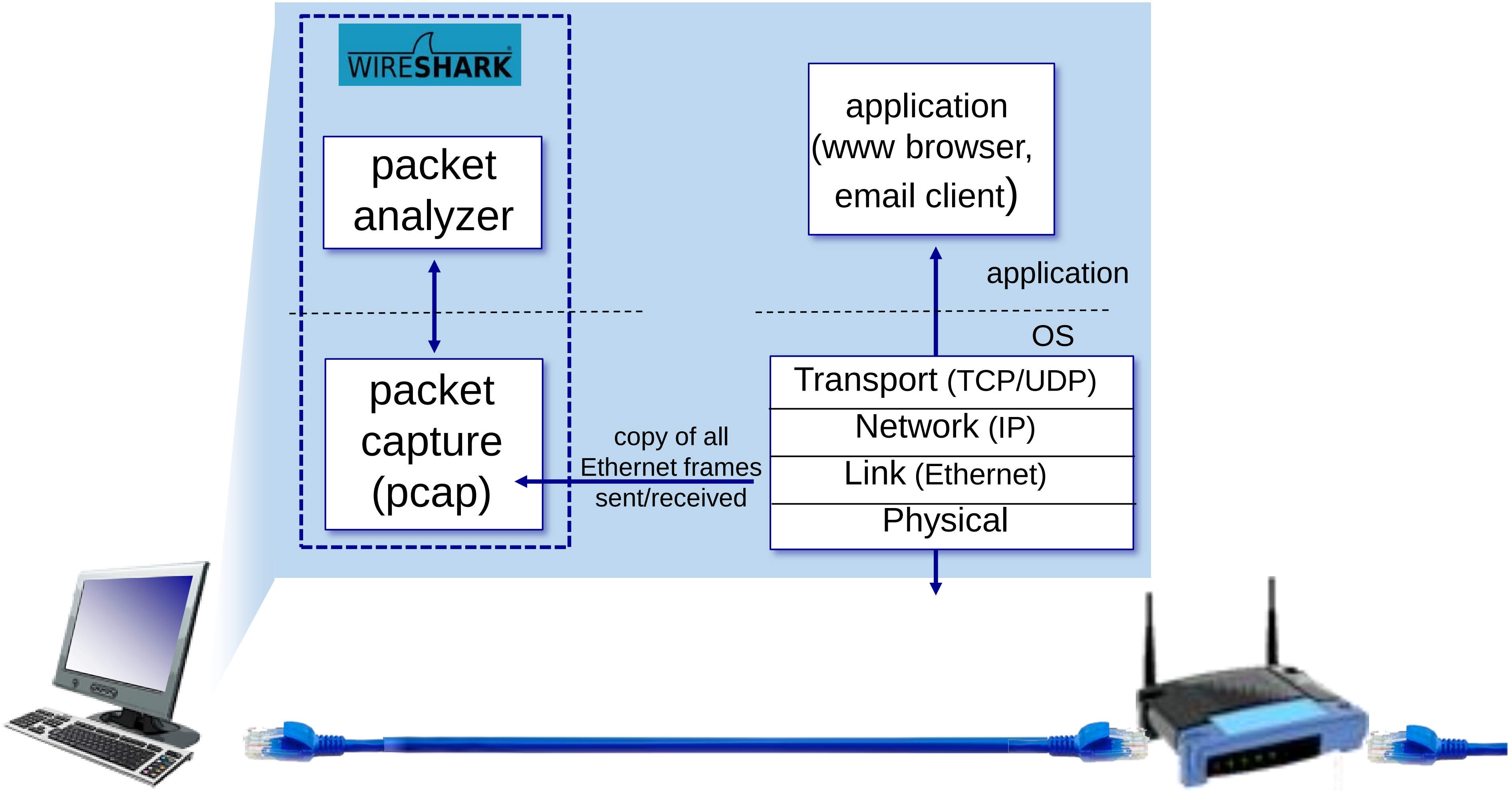
packet "sniffing":

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



Wireshark software used for a (free) packet-sniffer

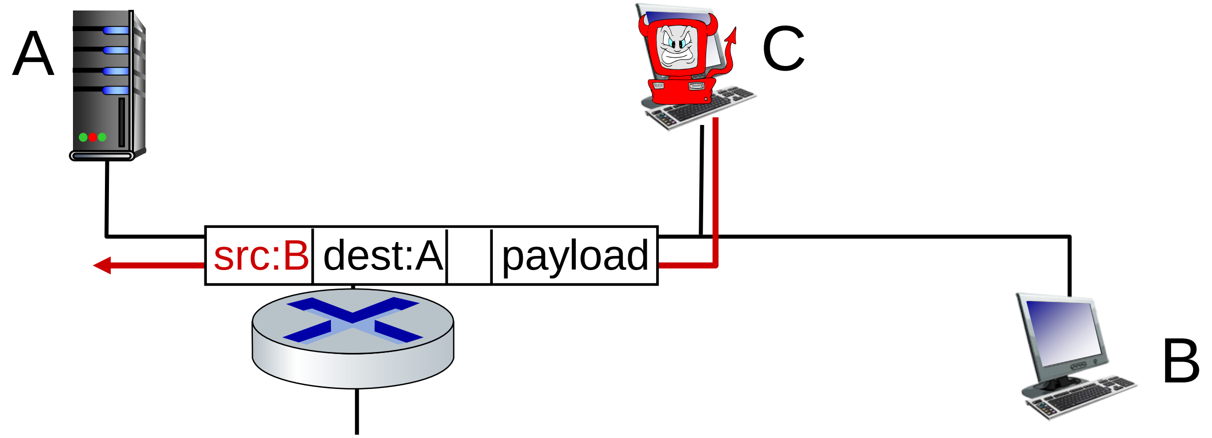
Wireshark



WIRESHARK
packet analyzer
packet capture (pcap)
copy of all Ethernet frames sent/received
application (www browser, email client)
application
OS
Transport (TCP/UDP)
Network (IP)
Link (Ethernet)
Physical

Bad guys: fake identity

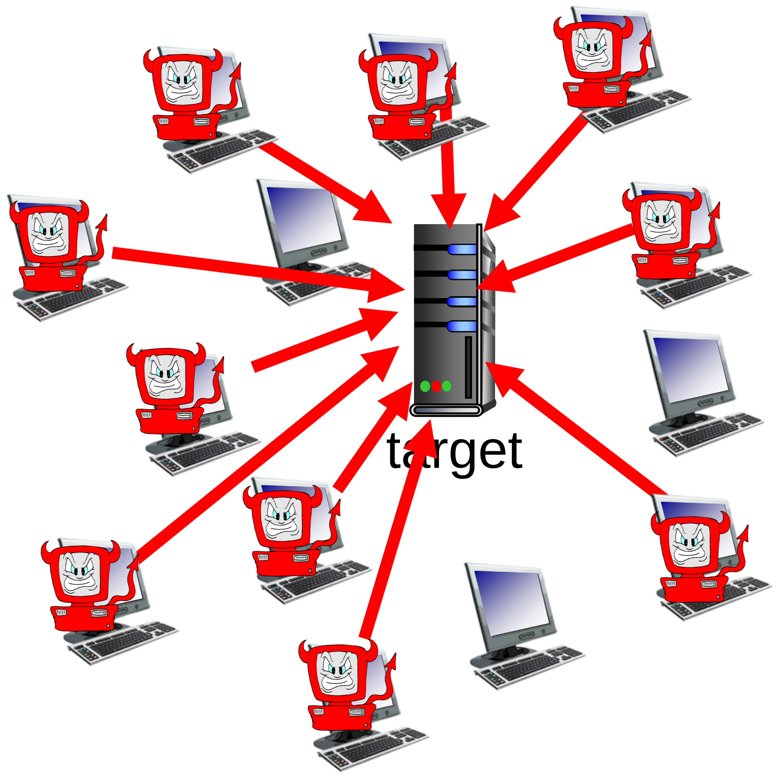
IP spoofing: injection of packet with false source address



Bad guys: denial of service

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



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)

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Protocol "layers" and reference models

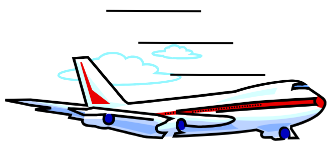
Networks are complex, with many "pieces":

- 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: organization of air travel



end-to-end transfer of person plus baggage

ticket (purchase)	ticket (complain)
baggage (check)	baggage (claim)
gates (load)	gates (unload)
runway takeoff	runway landing
airplane routing	airplane routing

airplane routing

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

- a series of steps, involving many services

Example: organization of air travel

ticket (purchase)	*ticketing service*	ticket (complain)
baggage (check)	*baggage service*	baggage (claim)
gates (load)	*gate service*	gates (unload)
runway takeoff	*runway service*	runway landing
airplane routing	*routing service*	airplane routing

layers: each layer implements a service

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

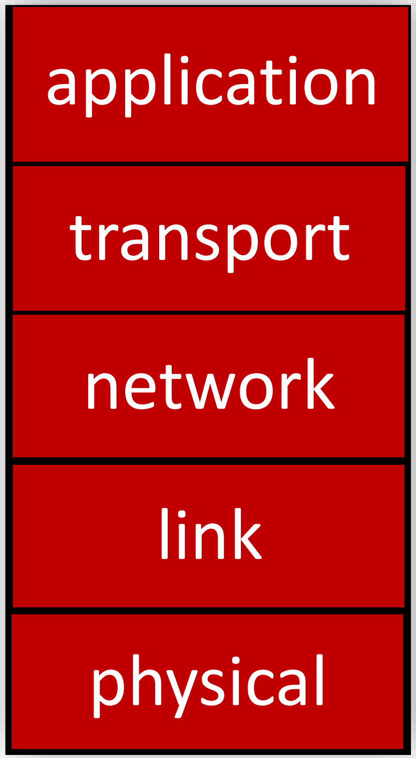
Why layering?

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

Layered Internet protocol stack

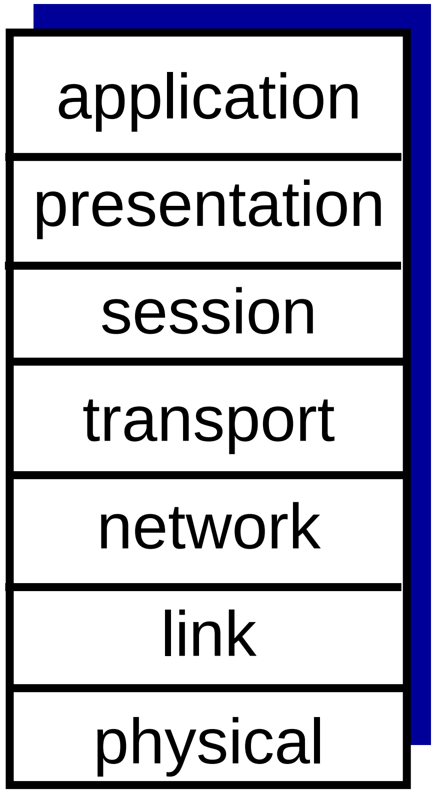
- *application:* supporting network applications
  - HTTP, IMAP, SMTP, DNS
- *transport:* process-process data transfer
  - TCP, UDP
- *network:* routing of datagrams from source to destination
  - IP, routing protocols
- *link:* data transfer between neighboring network elements
  - Ethernet, 802.11 (WiFi), PPP
- *physical:* bits “on the wire”



ISO/OSI reference model

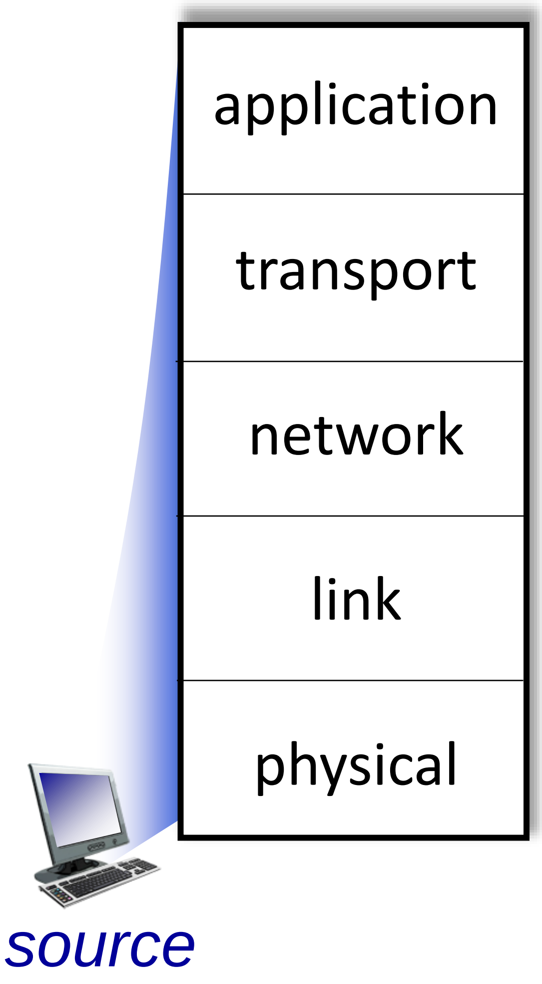
Two layers not found in Internet protocol stack!

- *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

Services, Layering and Encapsulation



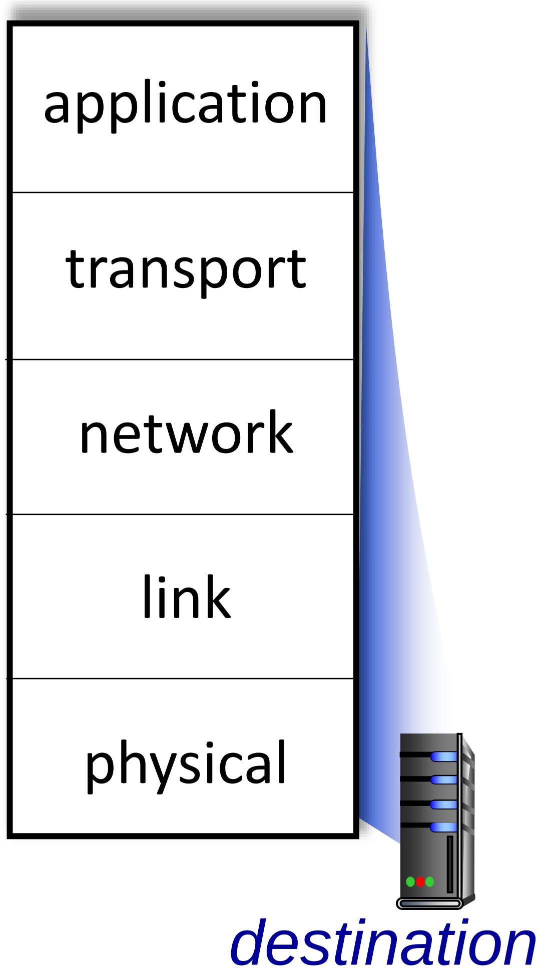
M

Application exchanges messages to implement some application service using *services* of transport layer

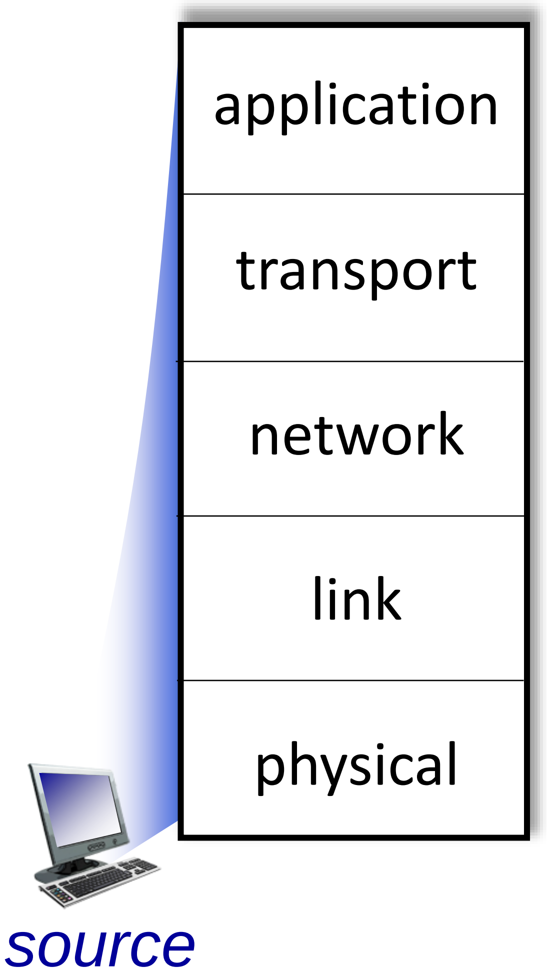
H_t M

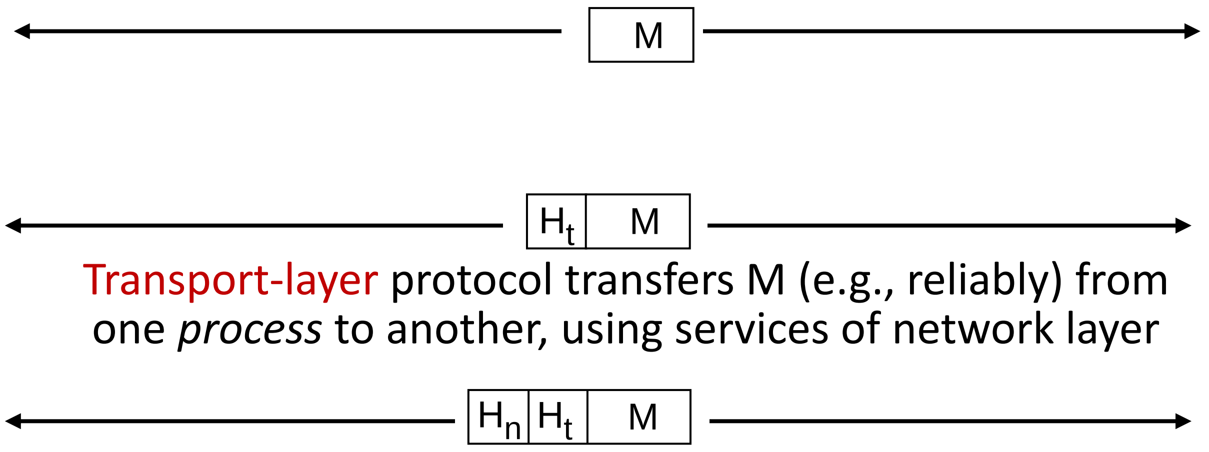
Transport-layer protocol transfers M (e.g., reliably) from one *process* to another, using services of network layer

- 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

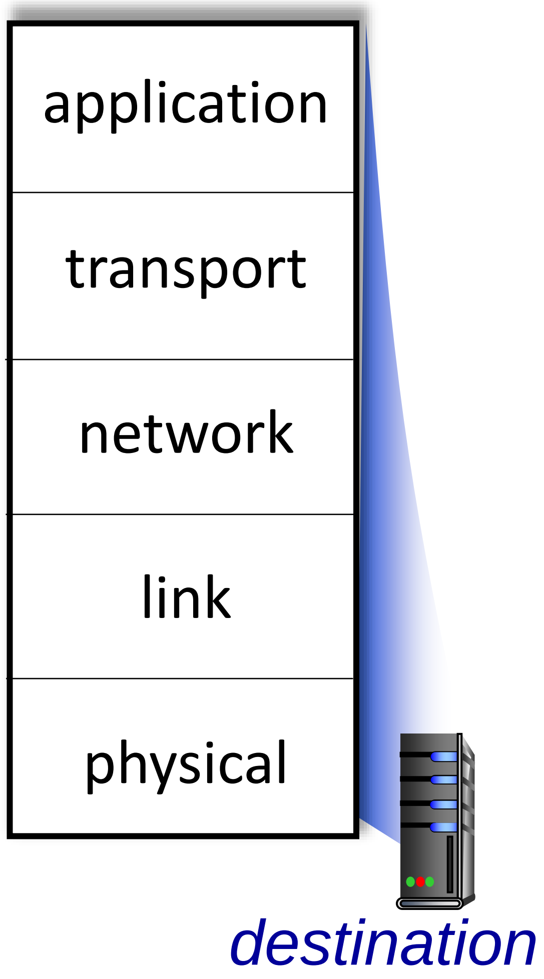




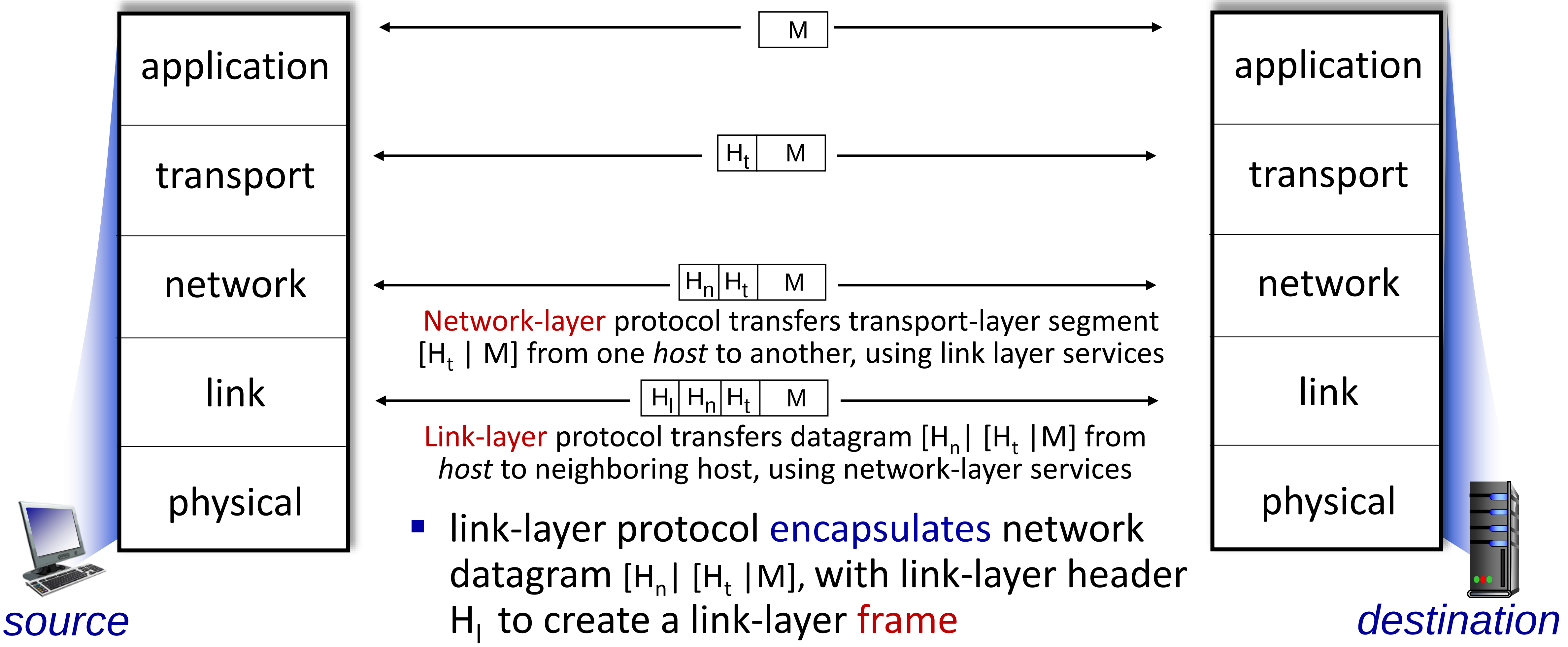
Transport-layer protocol transfers M (e.g., reliably) from one *process* to another, using services of network layer

Network-layer protocol transfers transport-layer segment [H_t | M] from one *host* to another, using link layer services

- 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



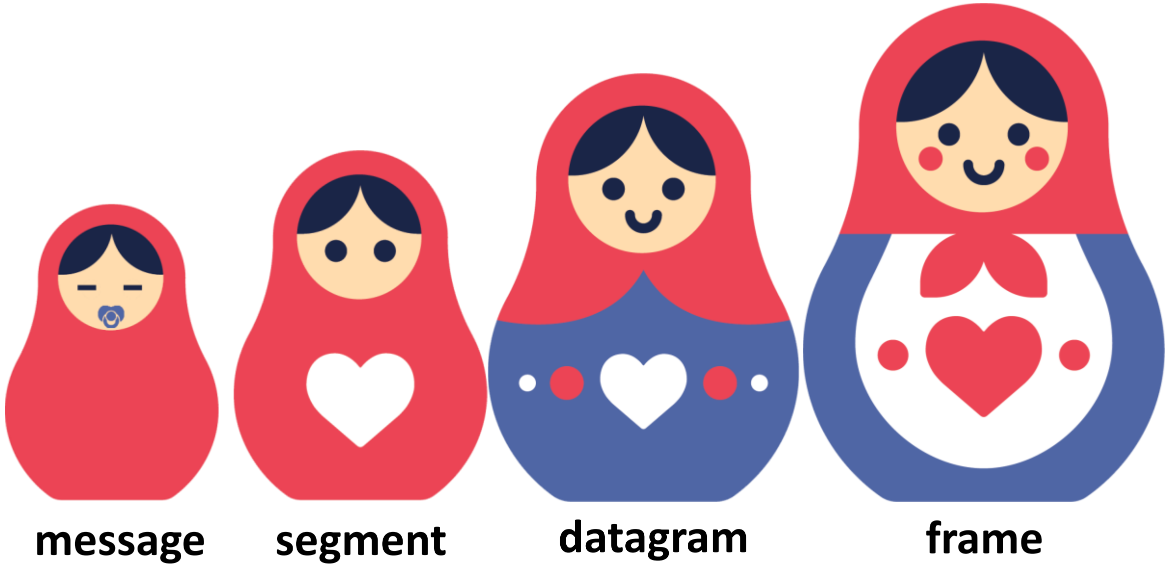
Services, Layering and Encapsulation



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

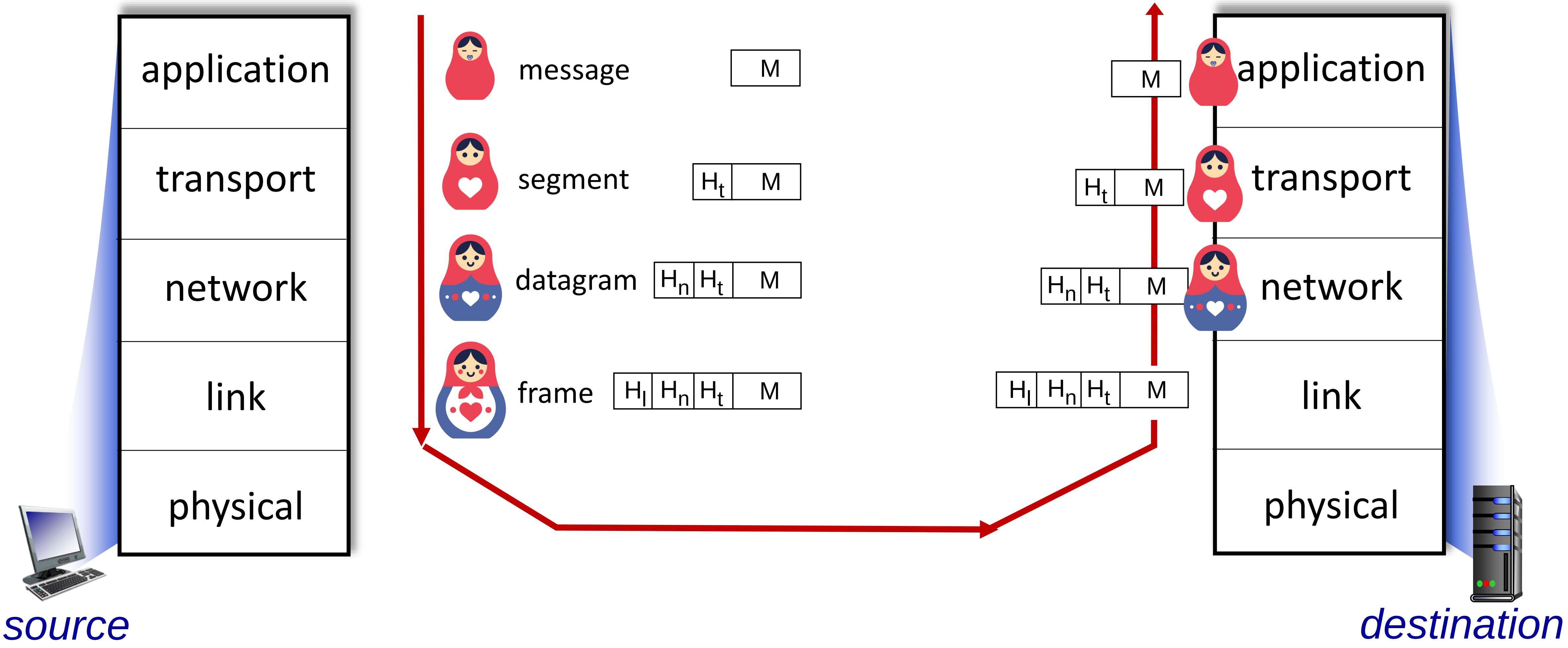
Encapsulation

Matryoshka dolls (stacking dolls)

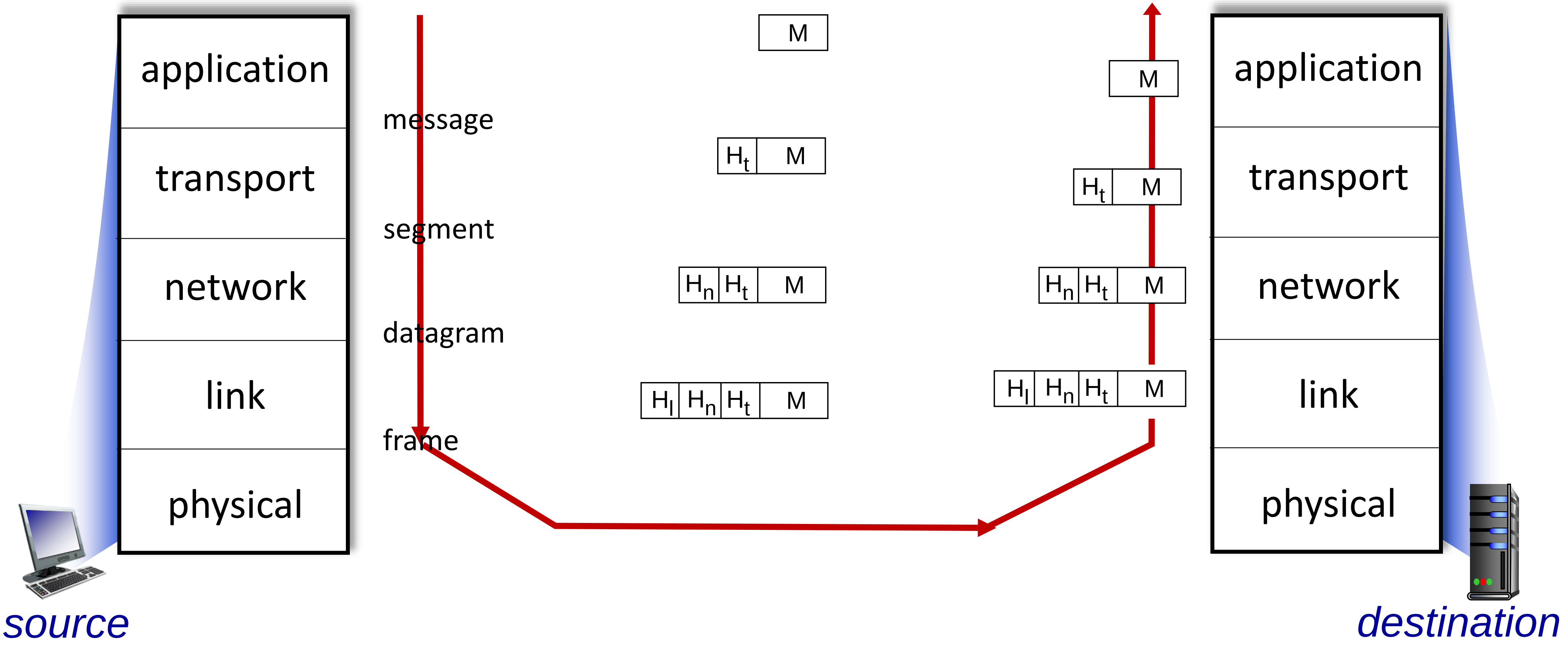


Credit: https://dribbble.com/shots/7182188-Babushka-Boi

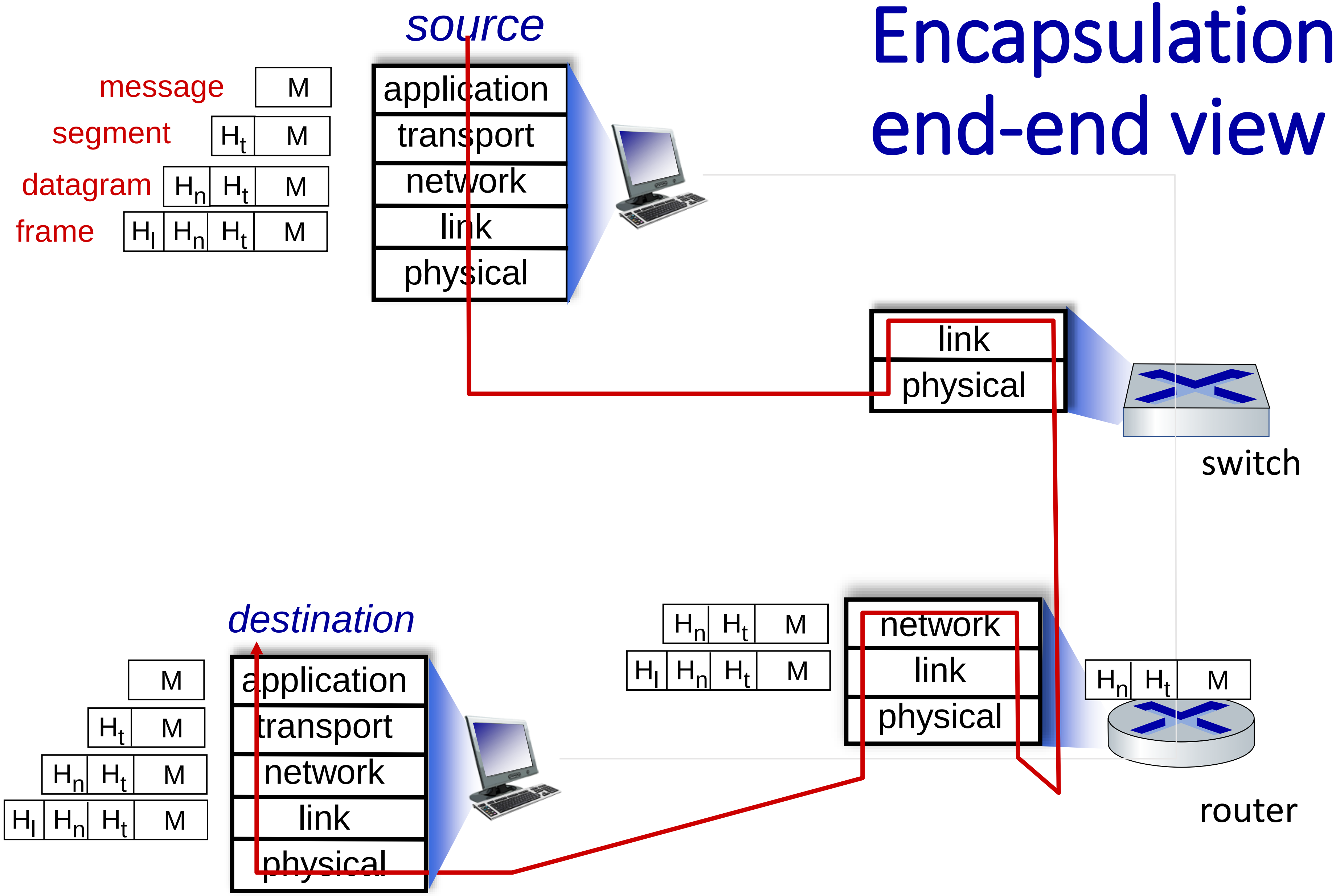
Services, Layering and Encapsulation



Services, Layering and Encapsulation



Encapsulation: an end-end view



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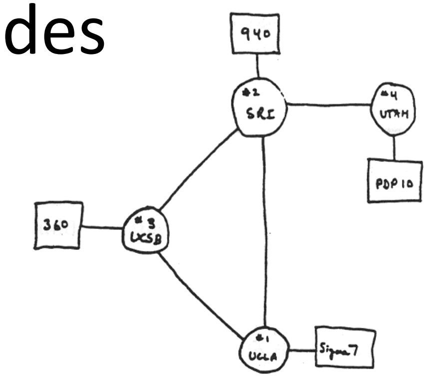
Internet history

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 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

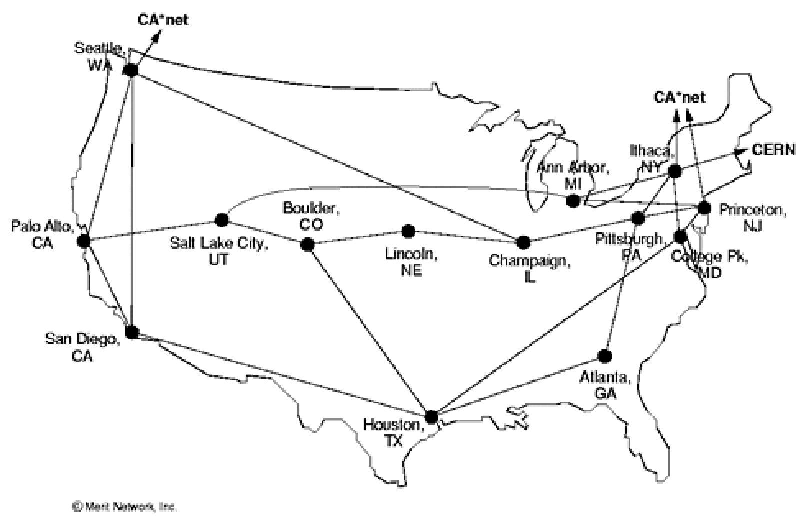
Internet history

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

NSFNET T1 Network 1991



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: 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., Amazon Web Services, Microsoft Azure)
- rise of smartphones: more mobile than fixed devices on Internet (2017)
- ~15B devices attached to Internet (2023, statista.com)

Chapter 1: summary

We’ve covered a “ton” of material!

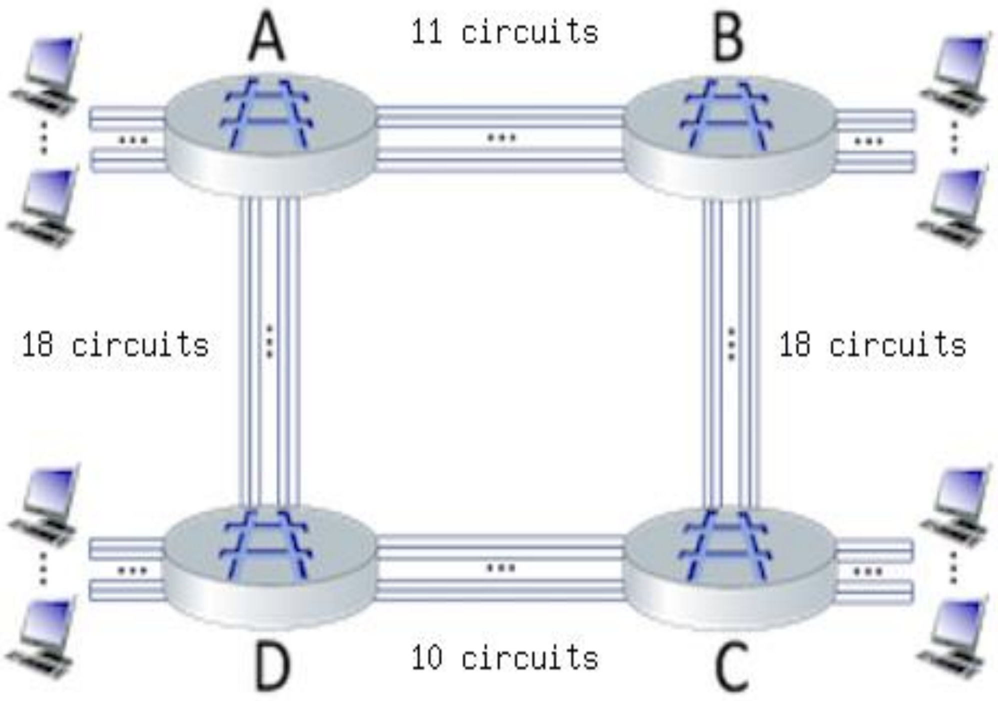
- Internet overview
- what’s a protocol?
- network edge, access network, core
  - packet-switching versus circuit-switching
  - Internet structure
- performance: loss, delay, throughput
- layering, service models
- security
- history

You now have:

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

Interactive Problem1

Consider the circuit-switched network shown in the figure below, with circuit switches A, B, C, and D. Suppose there are 11 circuits between A and B, 18 circuits between B and C, 10 circuits between C and D, and 18 circuits between D and A.

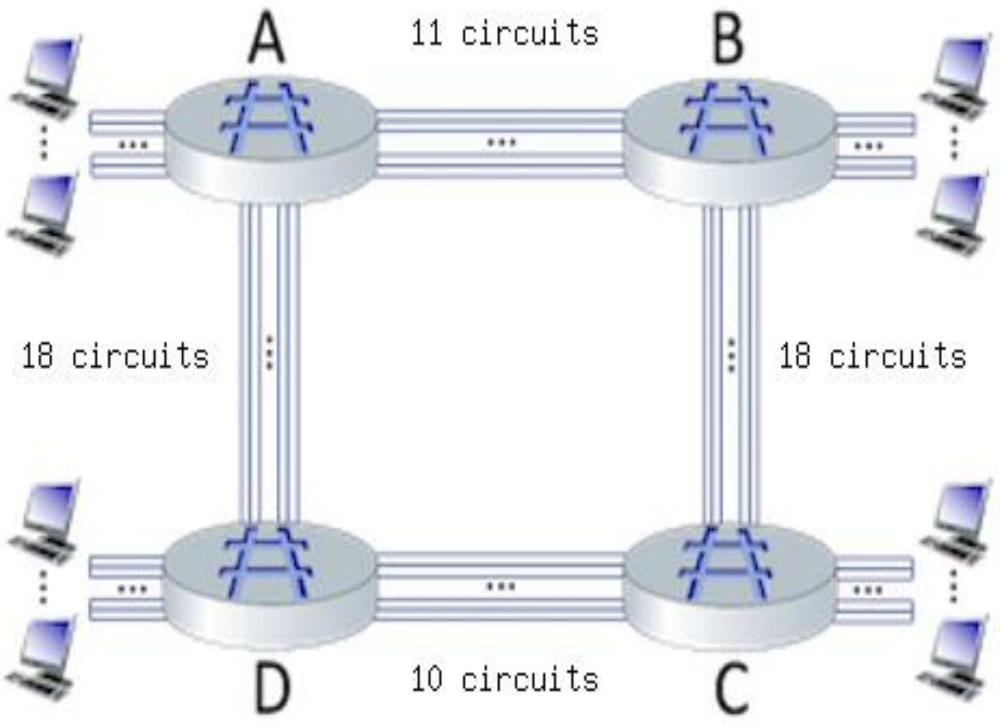


1. What is the maximum number of connections that can be ongoing in the network at any one time?

2. Suppose that these maximum number of connections are all ongoing. What happens when another call connection request arrives to the network, will it be accepted? Answer Yes or No

Interactive Problem1

Consider the circuit-switched network shown in the figure below, with circuit switches A, B, C, and D. Suppose there are 11 circuits between A and B, 18 circuits between B and C, 10 circuits between C and D, and 18 circuits between D and A.

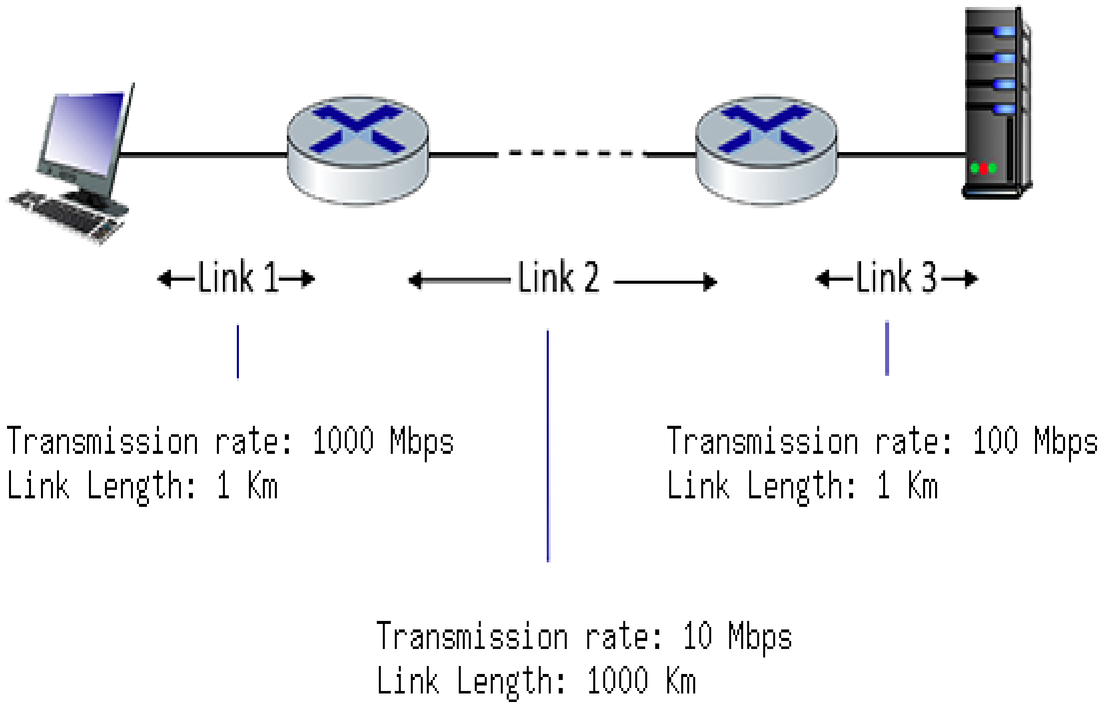


3. Suppose that every connection requires 2 consecutive hops, and calls are connected clockwise. For example, a connection can go from A to C, from B to D, from C to A, and from D to B. With these constraints, what is the is the maximum number of connections that can be ongoing in the network at any one time?

4. Suppose that 15 connections are needed from A to C, and 18 connections are needed from B to D. Can we route these calls through the four links to accommodate all 33 connections? Answer Yes or No

Interactive Problem2

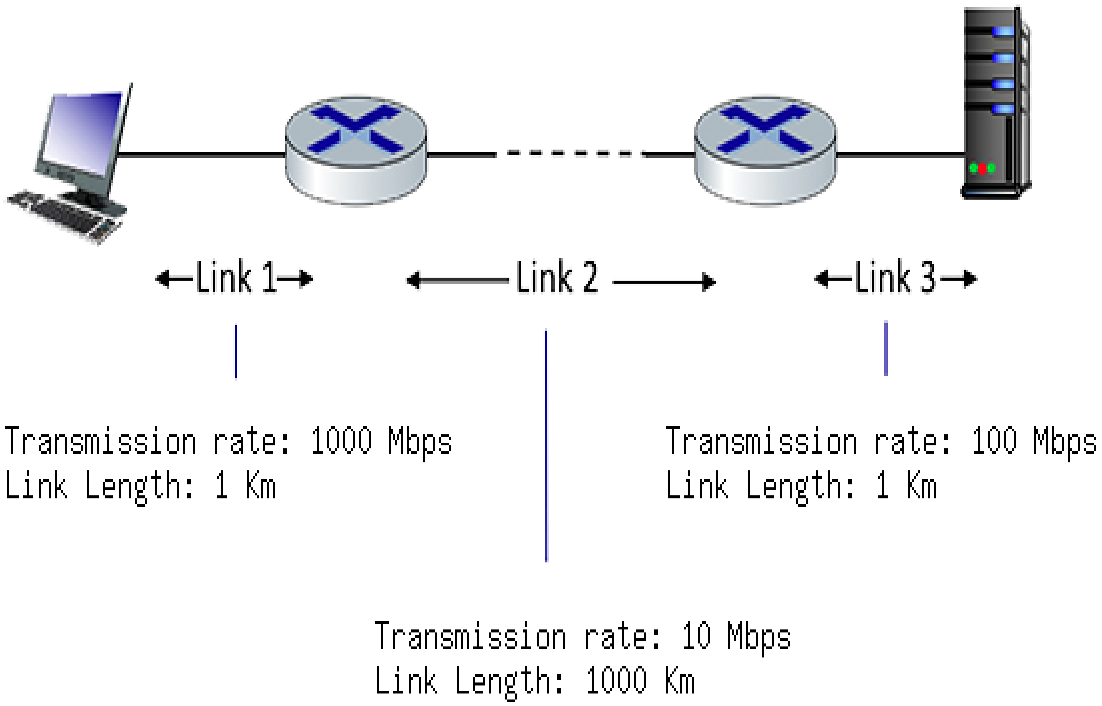
Consider the figure below, with three links, each with the specified transmission rate and link length. Assume the length of a packet is 12000 bits. The speed of light propagation delay on each link is 3x10^8 m/sec. Round your answer to two decimals after leading zeros



1. What is the transmission delay of link 1?
2. What is the propagation delay of link 1?
3. What is the total delay of link 1?
4. What is the transmission delay of link 2?
5. What is the propagation delay of link 2?
6. What is the total delay of link 2?

Interactive Problem2

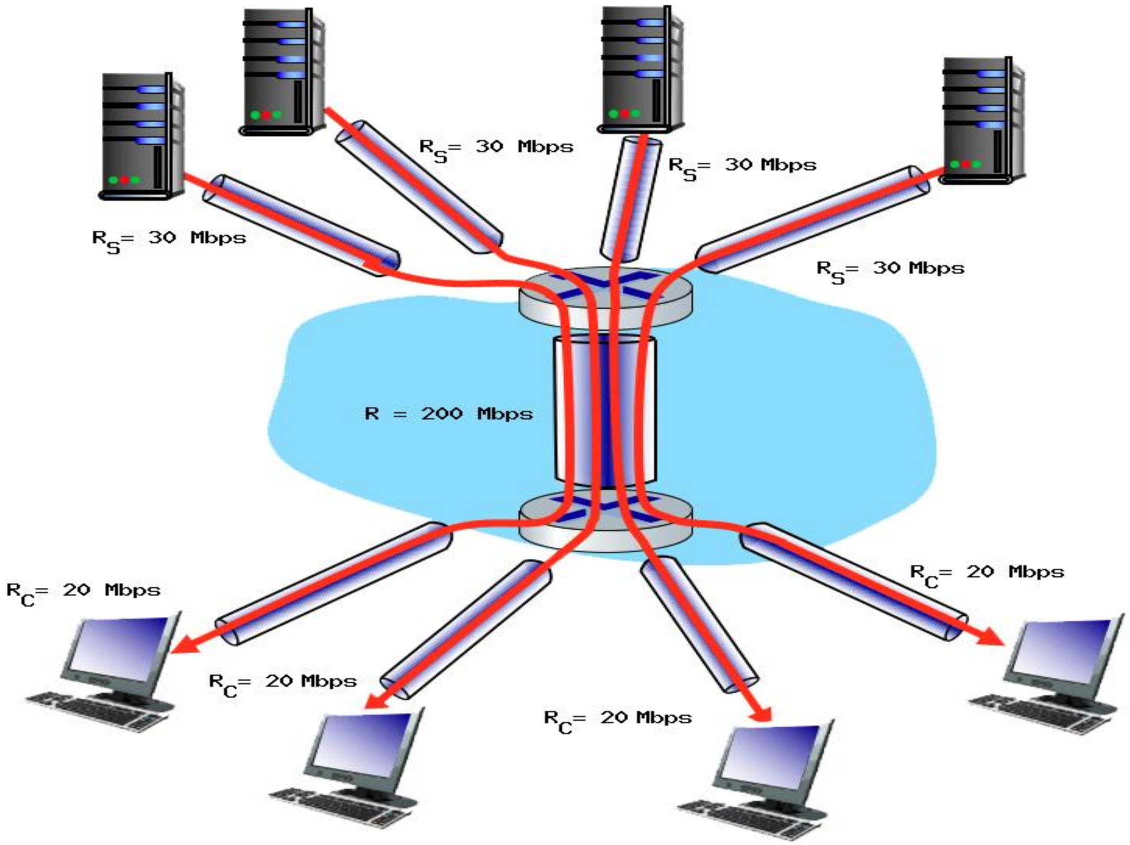
Consider the figure below, with three links, each with the specified transmission rate and link length. Assume the length of a packet is 12000 bits. The speed of light propagation delay on each link is 3x10^8 m/sec. Round your answer to two decimals after leading zeros



7. What is the transmission delay of link 3?
8. What is the propagation delay of link 3?
9. What is the total delay of link 3?
10. What is the total delay?

Interactive Problem3

Consider the scenario shown below, with four different servers connected to four different clients over four three-hop paths. The four pairs share a common middle hop with a transmission capacity of R = 200 Mbps. The four links from the servers to the shared link have a transmission capacity of R_S = 30 Mbps. Each of the four links from the shared middle link to a client has a transmission capacity of R_C = 20 Mbps.



1. What is the maximum achievable end-end throughput (in Mbps) for each of four client-to-server pairs, assuming that the middle link is fairly shared (divides its transmission rate equally)?
2. Which link is the bottleneck link? Format as Rc, Rs, or R

Interactive Problem3

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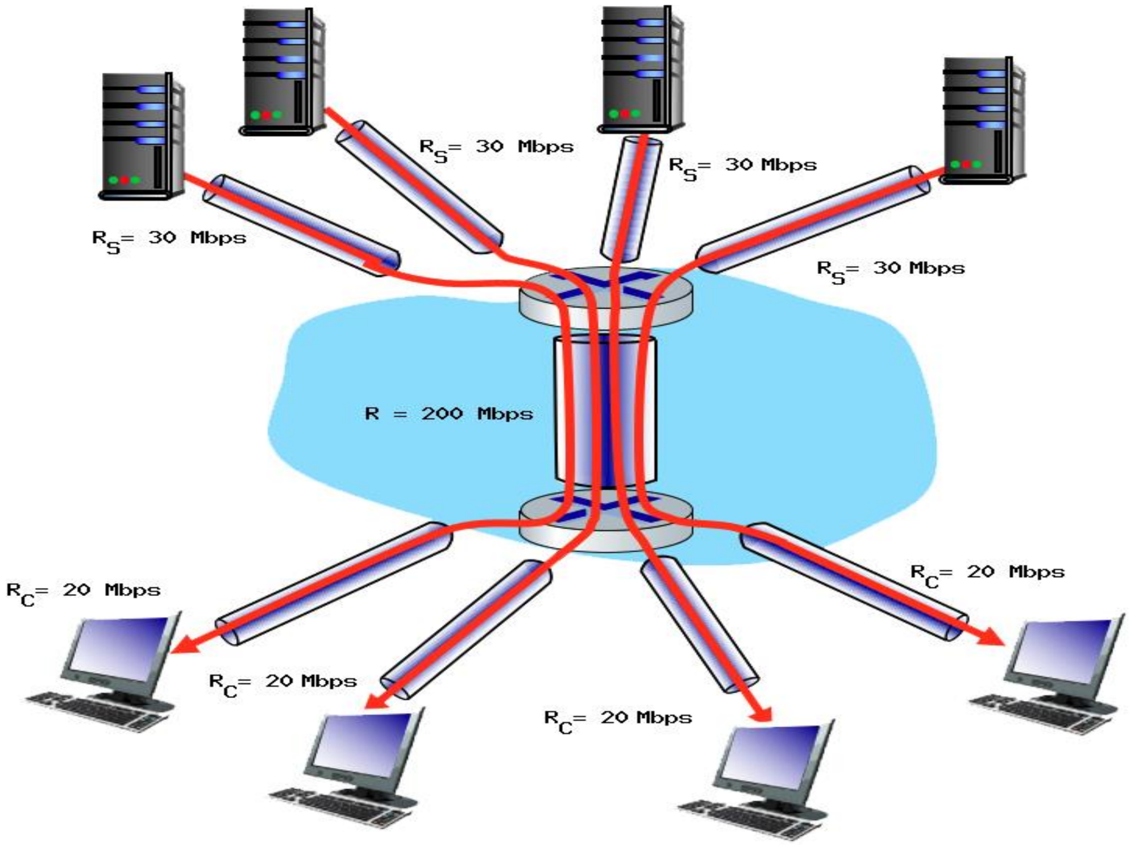

3. Assuming that the servers are sending at the maximum rate possible, what are the link utilizations for the server links (R_S)? Answer as a decimal
4. Assuming that the servers are sending at the maximum rate possible, what are the link utilizations for the client links (R_C)? Answer as a decimal
5. Assuming that the servers are sending at the maximum rate possible, what is the link utilizations for the shared link (R)? Answer as a decimal

Homework 1

6-07-2024(Friday)- Homework1 will be posted
6-14-2024(Friday), Midnight(11:59PM) -Due date

Late Assignments

All assignments are due as indicated on Blackboard. Late assignments will **NOT** be graded unless the student has prior permission from the instructor. Please send an email to the GTA and CC your instructor if you know that you are in danger of missing an assignment no later than 5pm on the day of submission. Documentation of the reason for missing may be required by the instructor.

Homework 1

Homework must be submitted on Blackboard as a single PDF file.
High Point Weightage: Homework assignments carry a significant portion of the overall grade, emphasizing their importance in the learning process. Each homework assignment will carry a weight of 5% of the overall grade.
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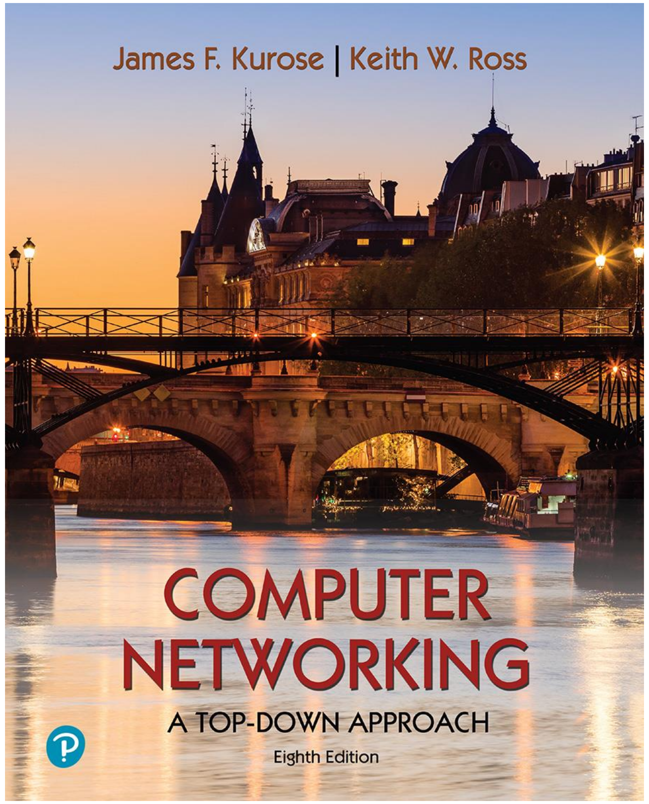

Computer Networking: A Top-Down Approach
8th edition
Jim Kurose, Keith Ross
Pearson, 2020

The Slides are adapted from,