National University of Computer & Emerging Sciences

CS 3001 – COMPUTER NETWORKS

Lecture 04

Chapter 1

30th January, 2025

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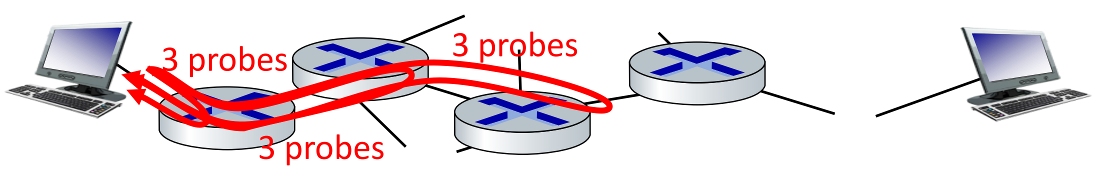
Office Hours: 11:30 am till 01:00 pm (Every Tuesday & Thursday)

"Real" Internet delays and routes

- what do "real" Internet delay & loss look like?
- **traceroute** (tracert in windows) program: provides delay measurement from source to router along end-end Internet path towards destination. For all *i:*
  - sends three packets that will reach router *i* on path towards destination (with time-to-live field value of *i*)
  - router *i* will return packets to sender
  - sender measures time interval between transmission and reply



Real Internet delays and routes

traceroute: gaia.cs.umass.edu to www.eurecom.fr

3 delay measurements from gaia.cs.umass.edu to cs-gw.cs.umass.edu (All delays; includes all the delay components, i.e. processing, queuing, transmission & propagation delays)

1 cs-gw (128.119.240.254) 1 ms 1 ms 2 ms
2 border1-rt-fa5-1-0.gw.umass.edu (128.119.3.145) 1 ms 1 ms 2 ms
3 cht-vbns.gw.umass.edu (128.119.3.130) 6 ms 5 ms 5 ms
4 jn1-at1-0-0-19.wor.vbns.net (204.147.132.129) 16 ms 11 ms 13 ms
5 jn1-so7-0-0-0.wae.vbns.net (204.147.136.136) 21 ms 18 ms 18 ms
6 abilene-vbns.abilene.ucaid.edu (198.32.11.9) 22 ms 18 ms 22 ms
7 nycm-wash.abilene.ucaid.edu (198.32.8.46) 22 ms 22 ms 22 ms
8 62.40.103.253 (62.40.103.253) 104 ms 109 ms 106 ms
9 de2-1.de1.de.geant.net (62.40.96.129) 109 ms 102 ms 104 ms
10 de.fr1.fr.geant.net (62.40.96.50) 113 ms 121 ms 114 ms
11 renater-gw.fr1.fr.geant.net (62.40.103.54) 112 ms 114 ms 112 ms
12 nio-n2.cssi.renater.fr (193.51.206.13) 111 ms 114 ms 116 ms
13 nice.cssi.renater.fr (195.220.98.102) 123 ms 125 ms 124 ms
14 r3t2-nice.cssi.renater.fr (195.220.98.110) 126 ms 126 ms 124 ms
15 eurecom-valbonne.r3t2.ft.net (193.48.50.54) 135 ms 128 ms 133 ms
16 194.214.211.25 (194.214.211.25) 126 ms 128 ms 126 ms
17 * * *
18 * * *
19 fantasia.eurecom.fr (193.55.113.142) 132 ms 128 ms 136 ms

3 delay measurements to border1-rt-fa5-1-0.gw.umass.edu

trans-oceanic link (meaning large propagation delay)

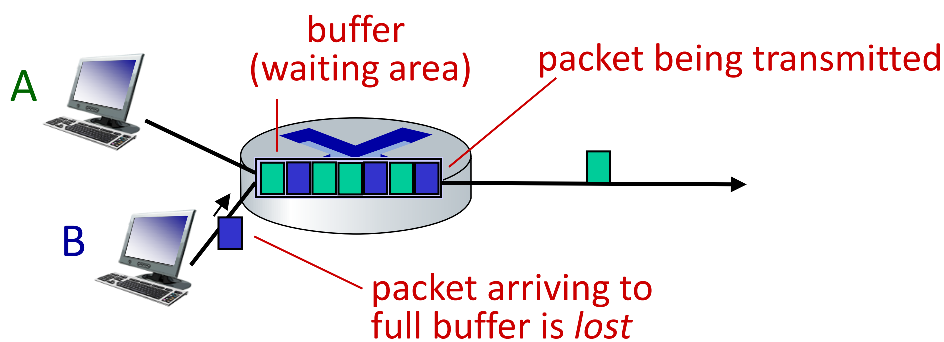
looks like delays *decrease*! Why? (Queuing delay at Router 11 may be greater than at Router 12)

* means no response (probe lost, router not replying)

- Do some traceroutes from exotic countries at www.traceroute.org
- Free software programs providing a graphical interface to Traceroutes (for example PingPlotter)

Packet loss

- queue (aka buffer) preceding link in buffer has finite capacity
- packet arriving to full queue dropped (aka lost)
- lost packet may be retransmitted by previous node, by source end system, or not at all



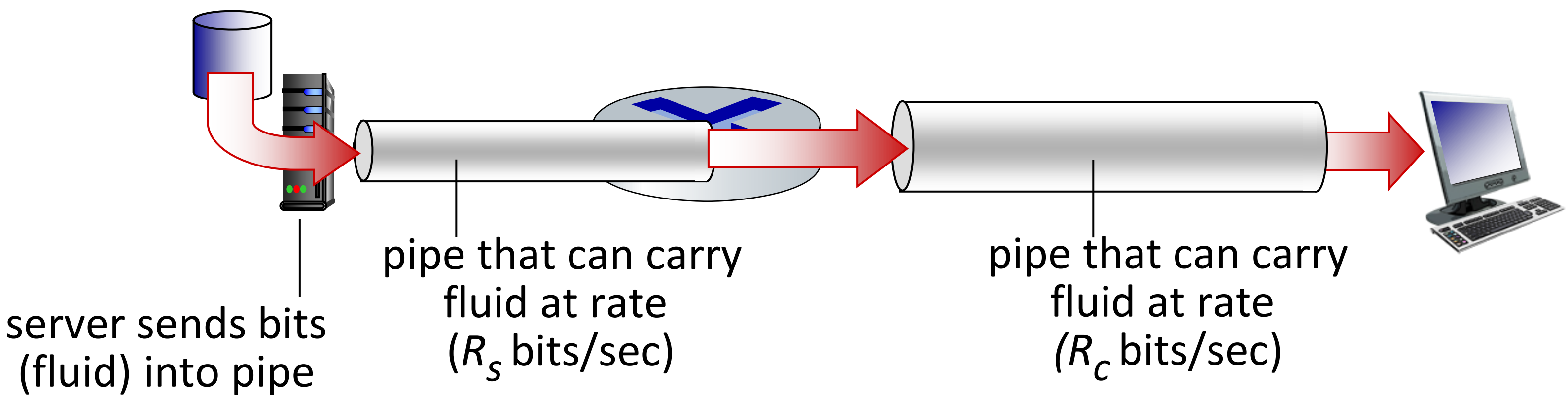
* Check out the Java applet for an interactive animation (on publisher's website) of queuing and loss

Throughput

- At what rate is the destination receiving data from the source?

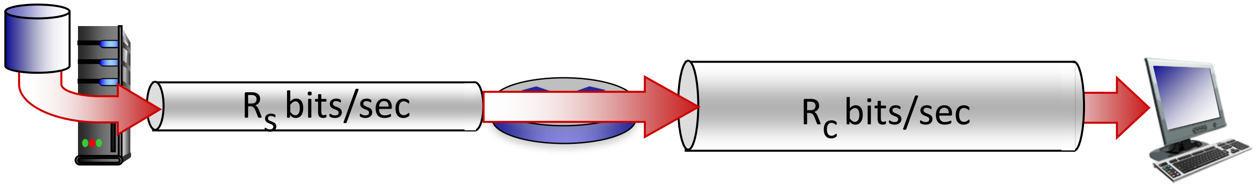
Throughput

- *throughput:* rate (bits/time unit) at which bits are being sent from sender to receiver
  - *instantaneous:* rate at given point in time
  - *average:* rate over longer period of time



Throughput

$R_s < R_c$ What is average end-end throughput?



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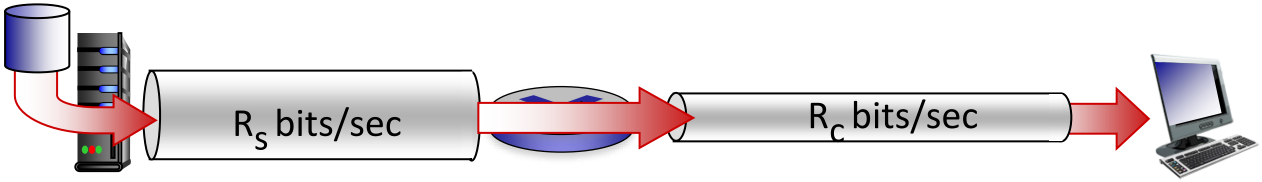
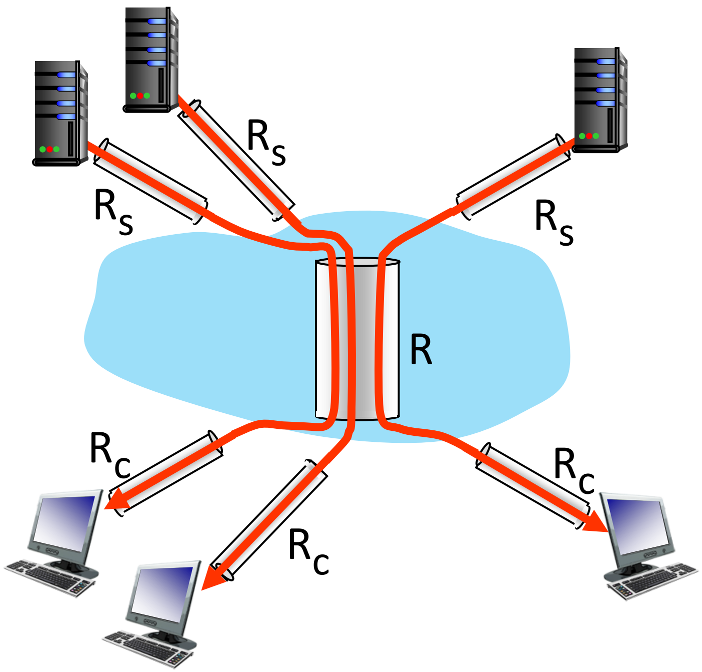


bottleneck link

link on end-end path that constrains end-end throughput

Throughput: network scenario



10 connections (fairly) share backbone bottleneck link *R* bits/sec

- per-connection end-end throughput: $min(R_c, R_s, R/10)$
- in practice: R_c or R_s is often bottleneck

* Check out the online interactive exercises for more examples: http://gaia.cs.umass.edu/kurose_ross/

Bandwidth Delay Product

- The bandwidth-delay product is the product of a link's rate / capacity (in bits per second) and its round-trip delay time (in seconds)

- The result, an amount of data measured in bits (or bytes), is equivalent to the maximum amount of data on the network circuit at any given time

- i.e., data that has been transmitted but not yet acknowledged. (Maximum number of bits that can be inserted into the pipe (link) in a given interval of time.)

- The bandwidth-delay product was originally proposed as a rule of thumb for sizing router buffers in conjunction with congestion avoidance algorithm Random Early Detection (RED).

Examples

- Moderate speed satellite network: 512 kbit/s, 900 ms round-trip time (RTT)
  $B \times D = (512 \times 10^3 \text{ bits/s}) \times (900 \times 10^{-3} \text{ s}) = 460{,}800 \text{ bits} = 460.8 \text{ kbit} = 57.6\text{kB}$

- Residential DSL: 2 Mbit/s, 50 ms round-trip time (RTT)
  $B \times D = (2 \times 10^6 \text{bits/s}) \times (50 \times 10^{-3} \text{ s}) = 100 \times 10^3 \text{ bits} = 100 \text{ kbit} = 12.5\text{kB}$

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

Protocol "layers" and reference models

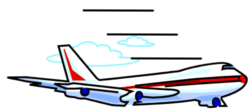
Networks are complex, with many "pieces":

- 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

layers: each layer implements a service

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

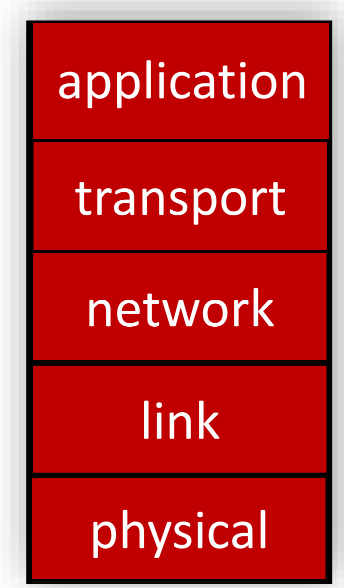
Why layering?

Approach to designing/discussing complex systems:

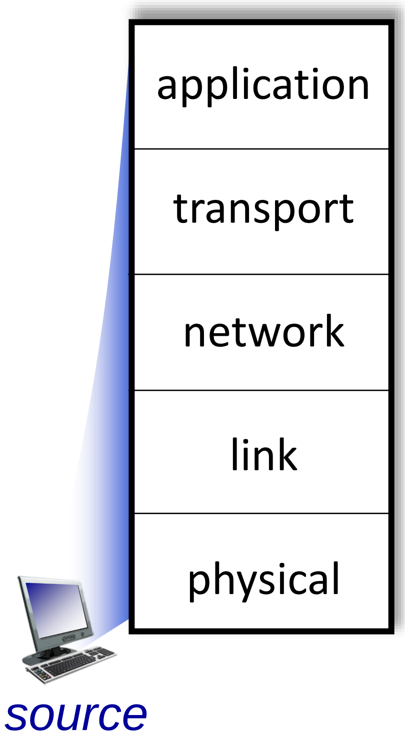
- explicit structure allows identification, relationship of system's pieces
  - layered *reference model* for discussion
- modularization eases maintenance, updating of system
  - change in layer's service *implementation*: transparent to rest of system
  - e.g., change in gate procedure doesn't affect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



Services, Layering and Encapsulation



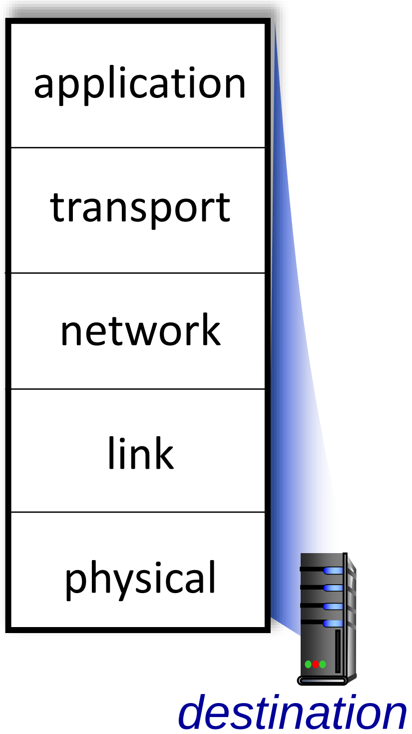
M

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

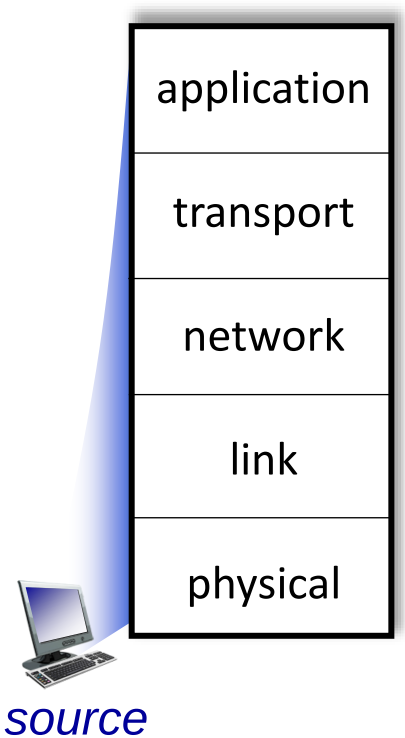
H_t M

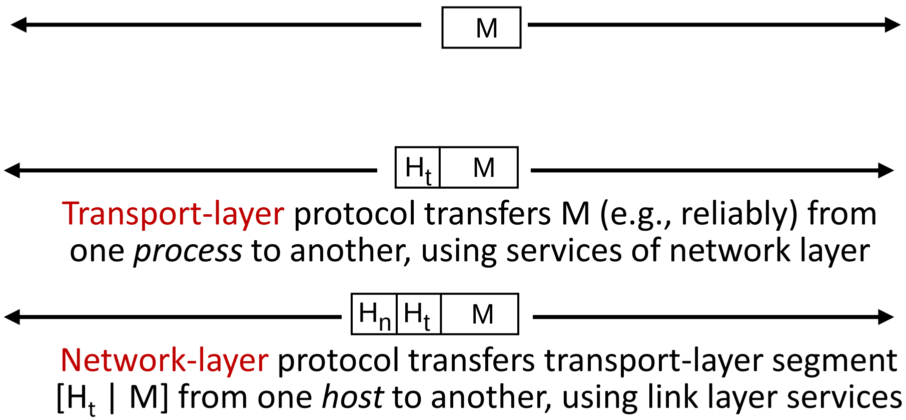
Transport-layer protocol transfers M (e.g., reliably) from one *process* to another, using services of network layer

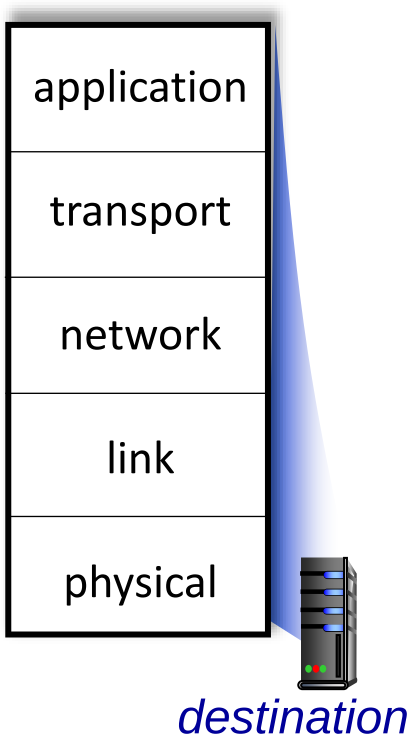
- transport-layer protocol encapsulates application-layer message, M, with *transport* layer-layer header H_t to create a transport-layer segment
  - H_t used by transport layer protocol to implement its service



Services, Layering and Encapsulation

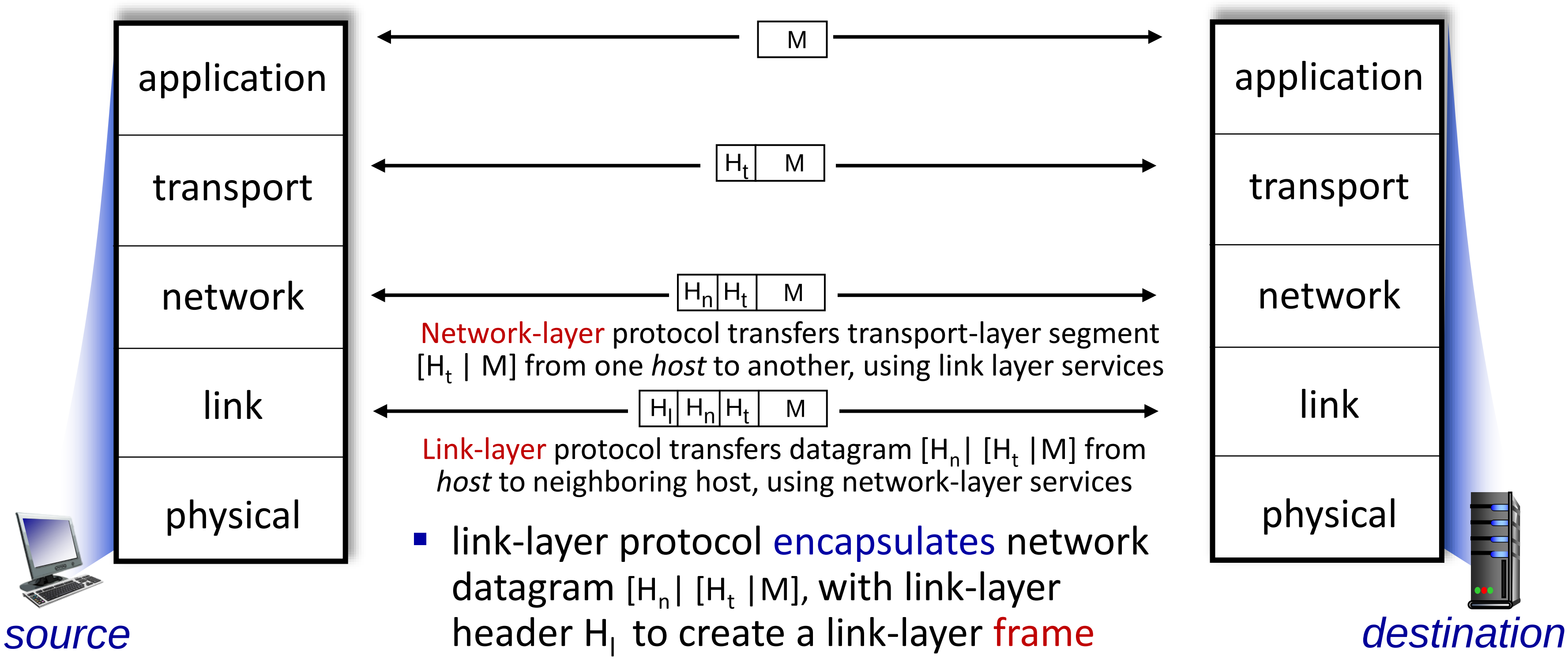






- network-layer protocol encapsulates transport-layer segment [H_t | M] with network layer-layer header H_n to create a network-layer datagram
  - H_n used by network layer protocol to implement its service

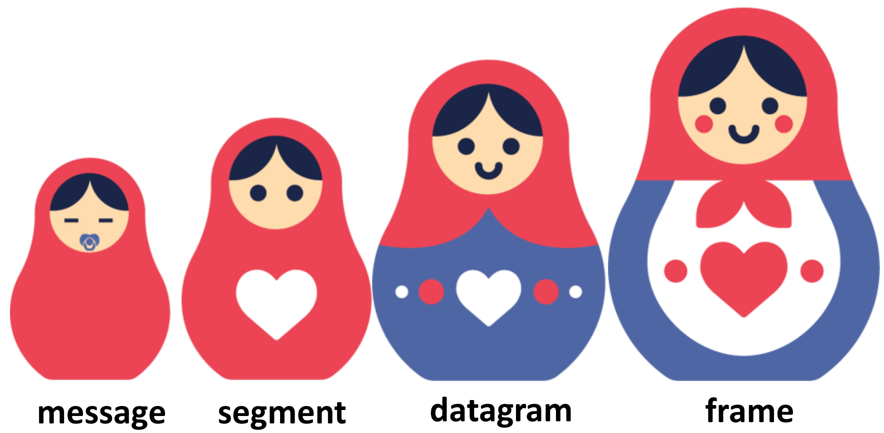
Services, Layering and Encapsulation



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

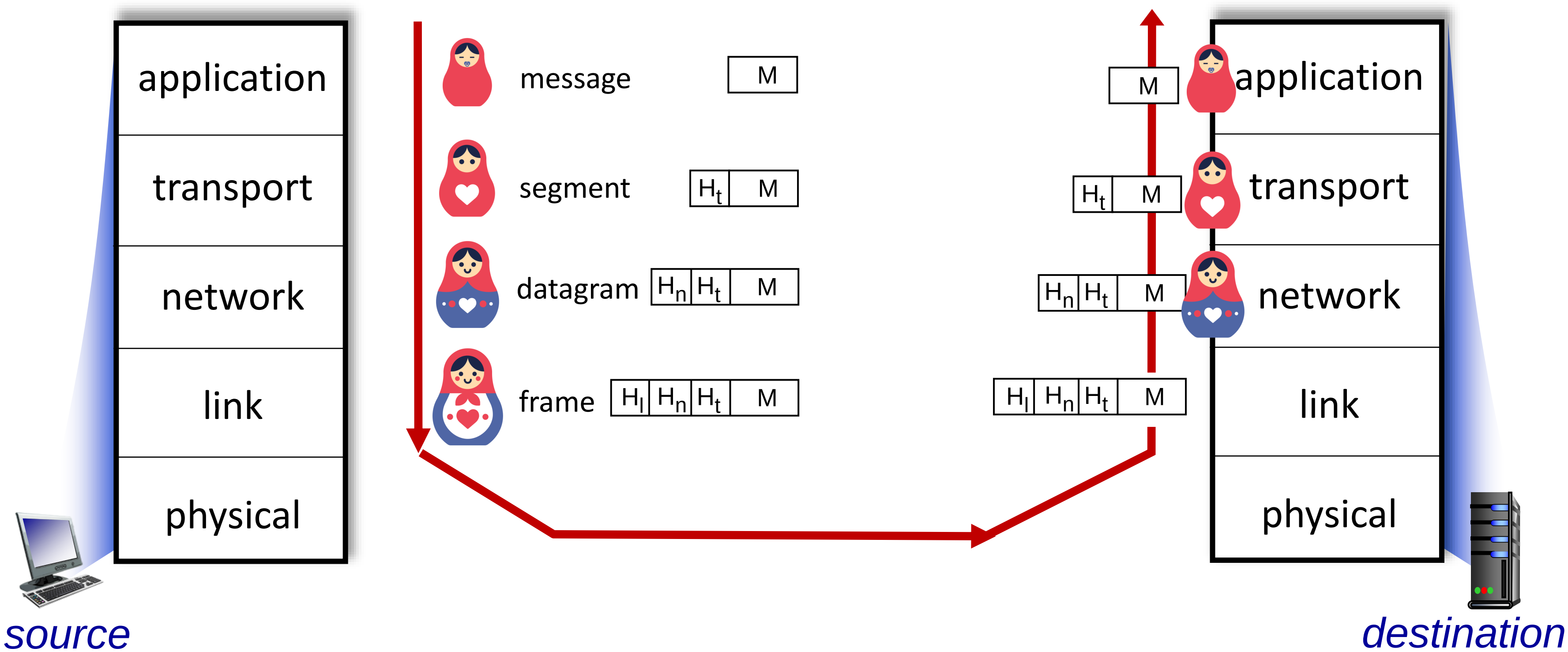
Encapsulation

Matryoshka dolls (stacking dolls / babushka dolls / Russian dolls)



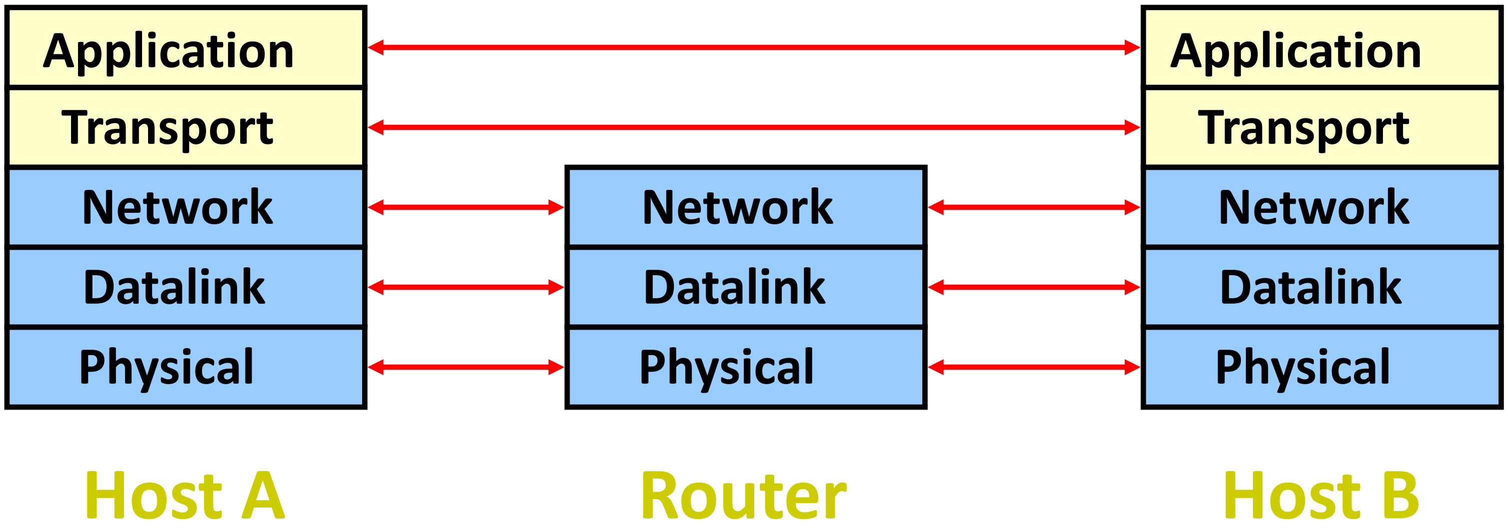
Credit: https://dribbble.com/shots/7182188-Babushka-Boi

Services, Layering and Encapsulation



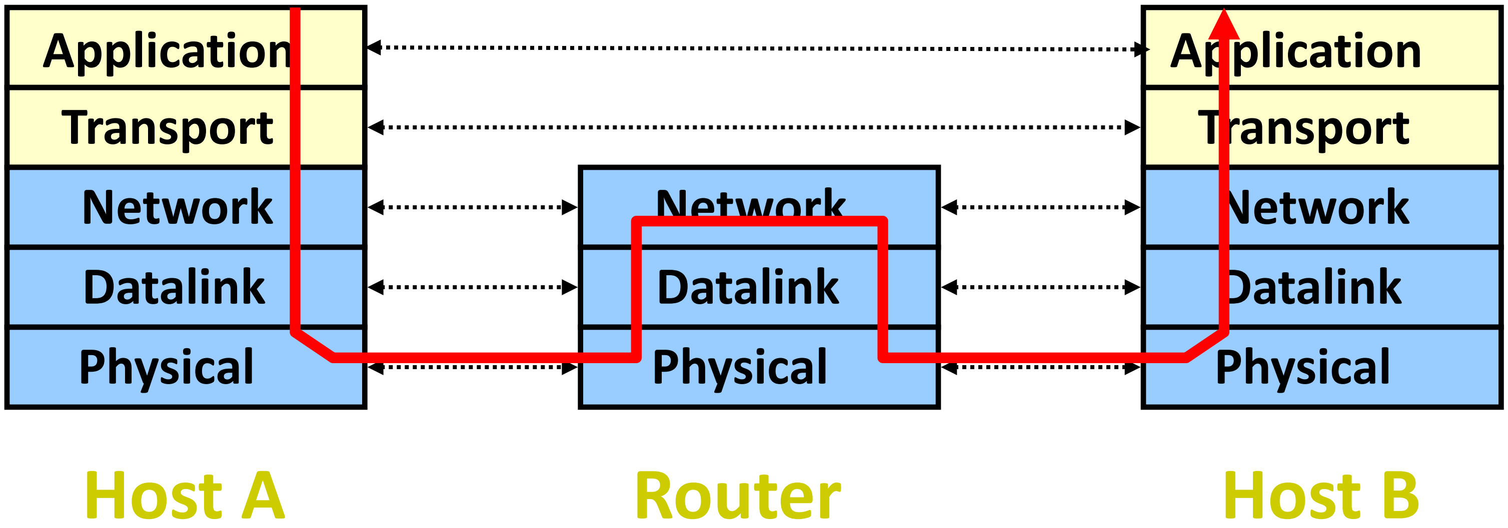
Logical Communication

- Layers interacts with peer's corresponding layer

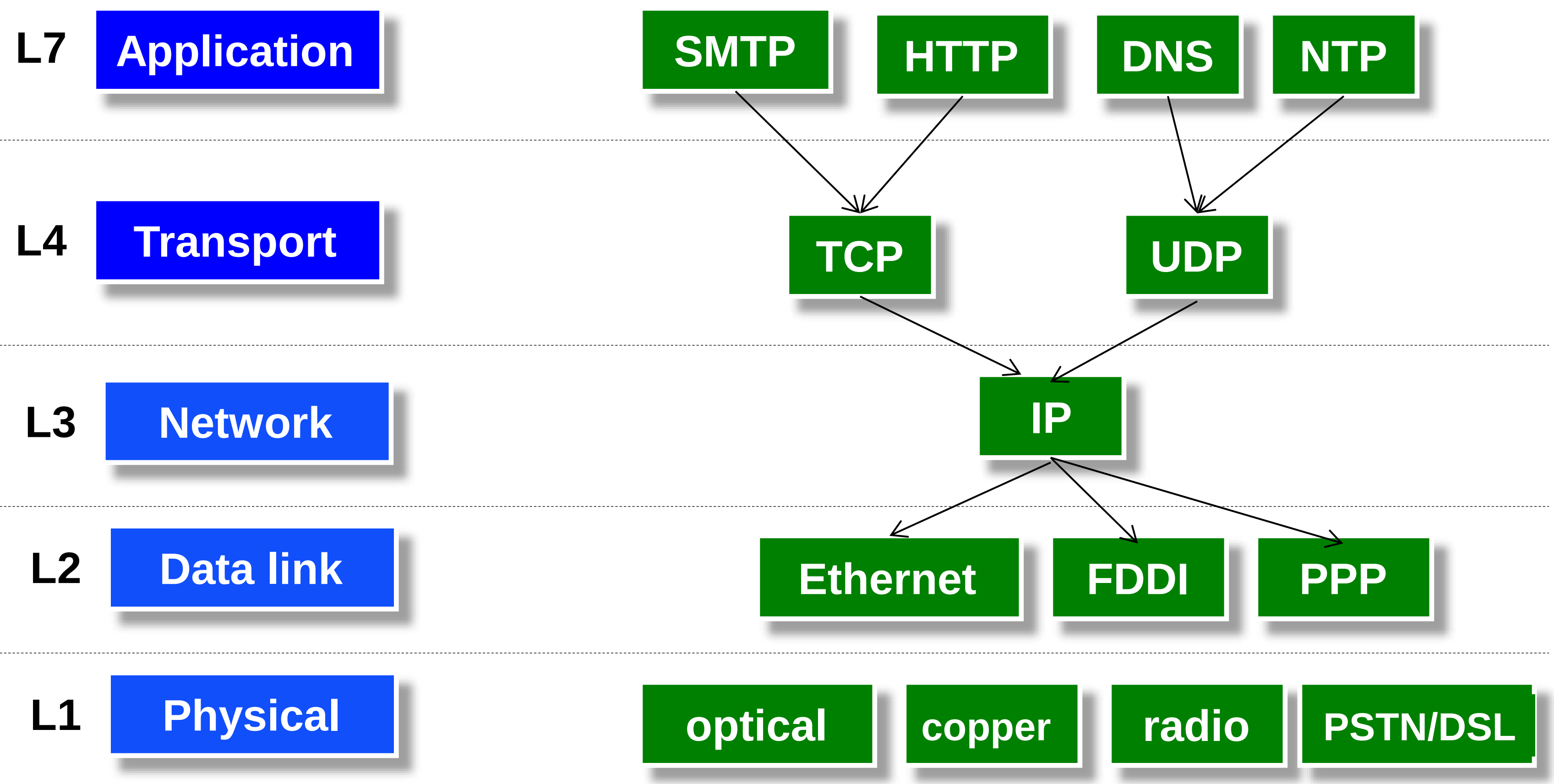


Physical Communication

- Communication goes down to physical network
- Then up to relevant layer

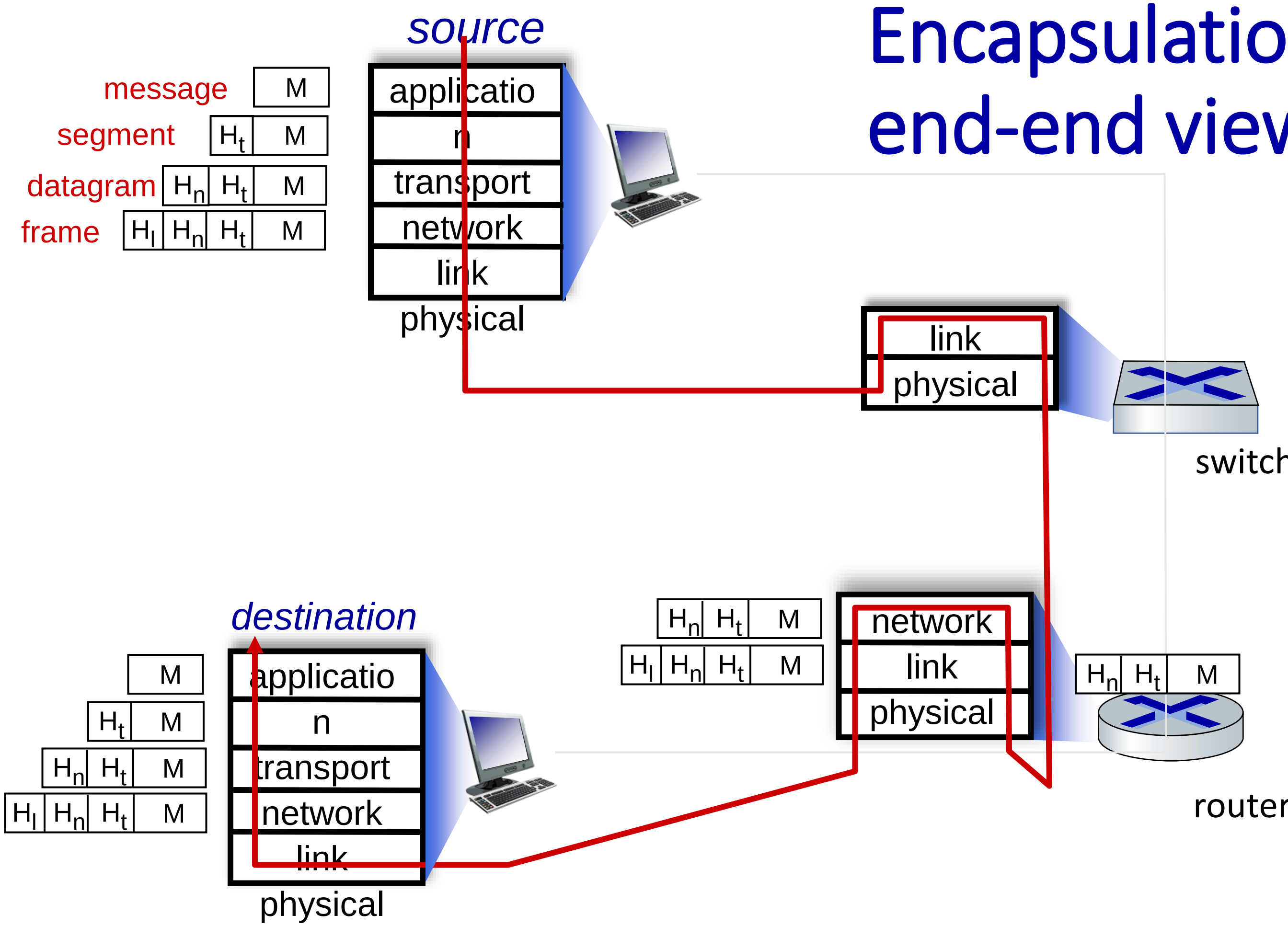


Protocols at different layers



There is just one network-layer protocol!

Encapsulation: an end-end view



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:

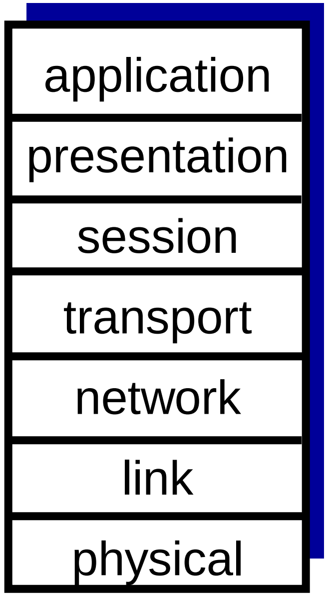
- context, overview, vocabulary, "feel" of networking
- more depth, detail, *and fun* to follow*!*

Additional Chapter 1 slides

ISO/OSI reference model

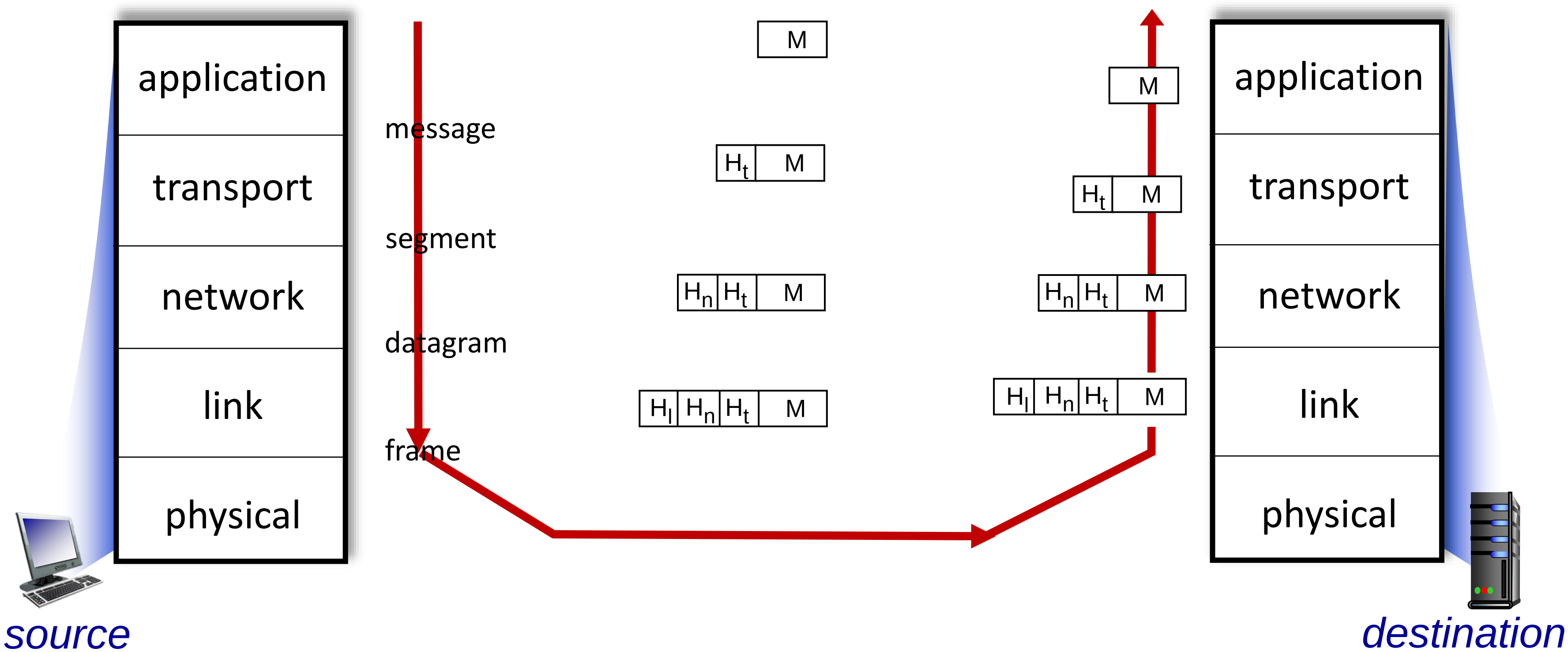
Two layers not found in Internet protocol stack!

- *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?

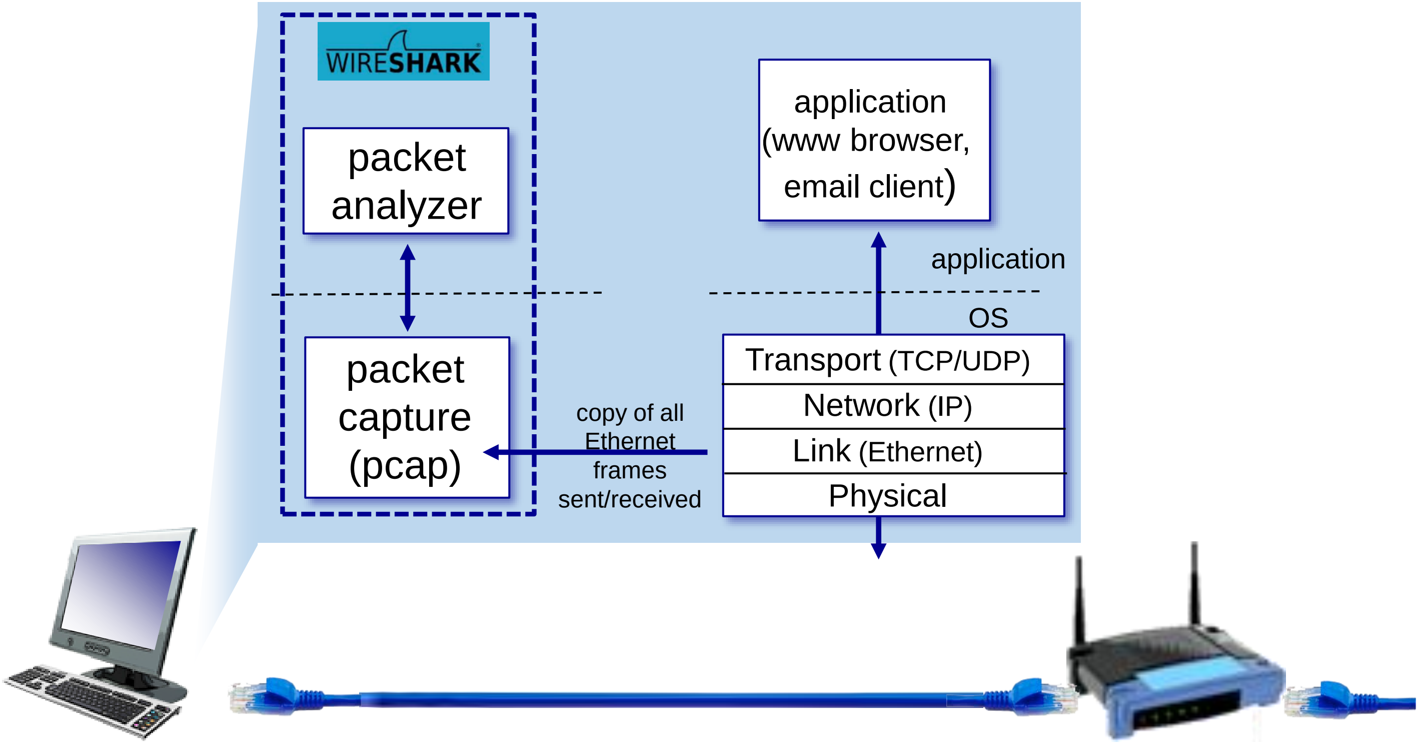


The seven layer OSI/ISO reference model

Services, Layering and Encapsulation



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

Assignement # 1 (Chapter – 1)

- ***1st Assignment will be uploaded on Google Classroom after the lecture in the Stream Section, on Thursday 30th January, 2025***

- ***Due Date: Thursday, 6th February, 2025 (During the lecture)***

- ***Hard copy of the handwritten assignment to be submitted directly to the Instructor during the lecture.***

- ***Please read all the instructions carefully in the uploaded Assignment document, follow & submit accordingly***

Quiz # 1 (Chapter – 1)

- *Quiz # 1 for Chapter 1 to be taken in the class on Thursday, 6th February, 2025 during the lecture time (or in the next class in case of a public holiday.)*

No Retake

Be on time