

# I. Introduction: roadmap

I.1 what is the Internet?

I.2 network edge

- end systems, access networks, links

I.3 network core

- packet switching, circuit switching, network structure

I.4 delay, loss, throughput in networks

I.5 protocol layers, service models

I.6 networks under attack: security

I.7 history



Self study



## Quiz: Circuit Switching

Consider a circuit-switched network with  $N=100$  users where each user is independently active with probability  $p=0.2$  and when active, sends data at a rate of  $R=1\text{Mbps}$ . How much capacity must the network be provisioned with to guarantee service to all users?

- A. 100 Mbps
- B. 20 Mbps
- C. 200 Mbps
- D. 50 Mbps
- E. 500 Mbps

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## Quiz: Statistical Multiplexing

Consider a packet-switched network with  $N=100$  users where each user is independently active with probability  $p=0.2$  and when active, sends data at a rate of  $R=1\text{Mbps}$ . What is the expected aggregate traffic sent by the users?

- A. 100 Mbps
- B. 20 Mbps
- C. 200 Mbps
- D. 50 Mbps
- E. 500 Mbps

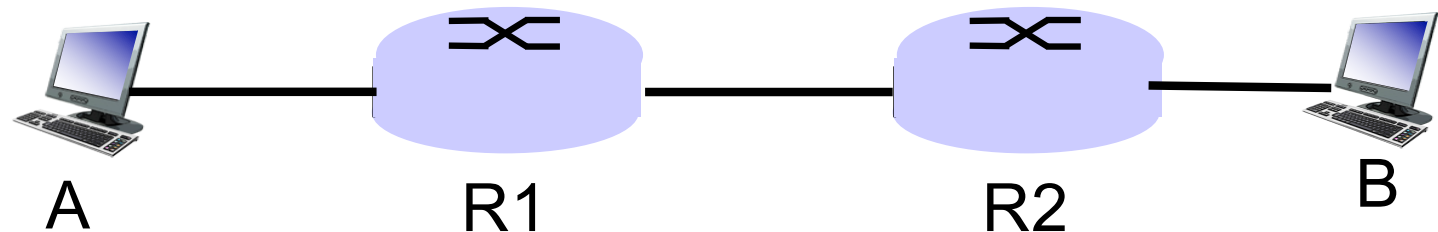
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## Quiz: Delays



Consider a network connecting hosts A and B through two routers R1 and R2 like this: A-----R1-----R2-----B. Does whether a packet sent by A destined to B experiences queuing at R1 depend on the length of the link R1-R2?

- A. Yes, it does
- B. No, it doesn't



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# Three (networking) design steps

- ❖ Break down the problem into tasks
- ❖ Organize these tasks
- ❖ Decide who does what

# Tasks in Networking

- ❖ What does it takes to send packets across?
- ❖ Prepare data (Application)
- ❖ Ensure that packets get to the dst process. (Transport)
- ❖ Deliver packets across global network (Network)
- ❖ Delivery packets within local network to next hop (Datalink)
- ❖ Bits / Packets on wire (Physical)

This is decomposition...

Now, how do we organize these tasks?

Let us have an example

# Inspiration...

- ❖ CEO A writes letter to CEO B
  - Folds letter and gives it to administrative aide

Dear John,

» Aide:

Your days are numbered.

» Puts letter in envelope with CEO  
B's full name

» Takes to FedEx

--Pat

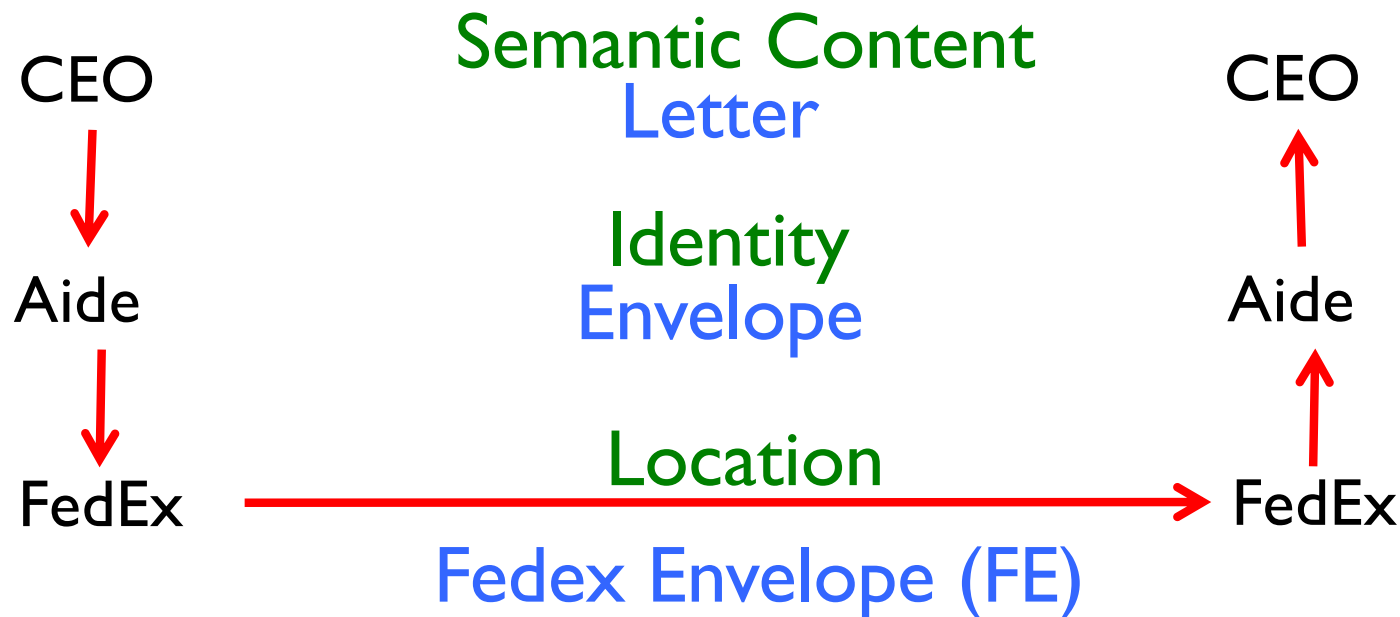
- ❖ FedEx Office
  - Puts letter in larger envelope
  - Puts name and street address on FedEx envelope
  - Puts package on FedEx delivery truck
- ❖ FedEx delivers to other company

# The Path of the Letter

“Peers” on each side understand the same things

No one else needs to (abstraction)

Lowest level has most packaging

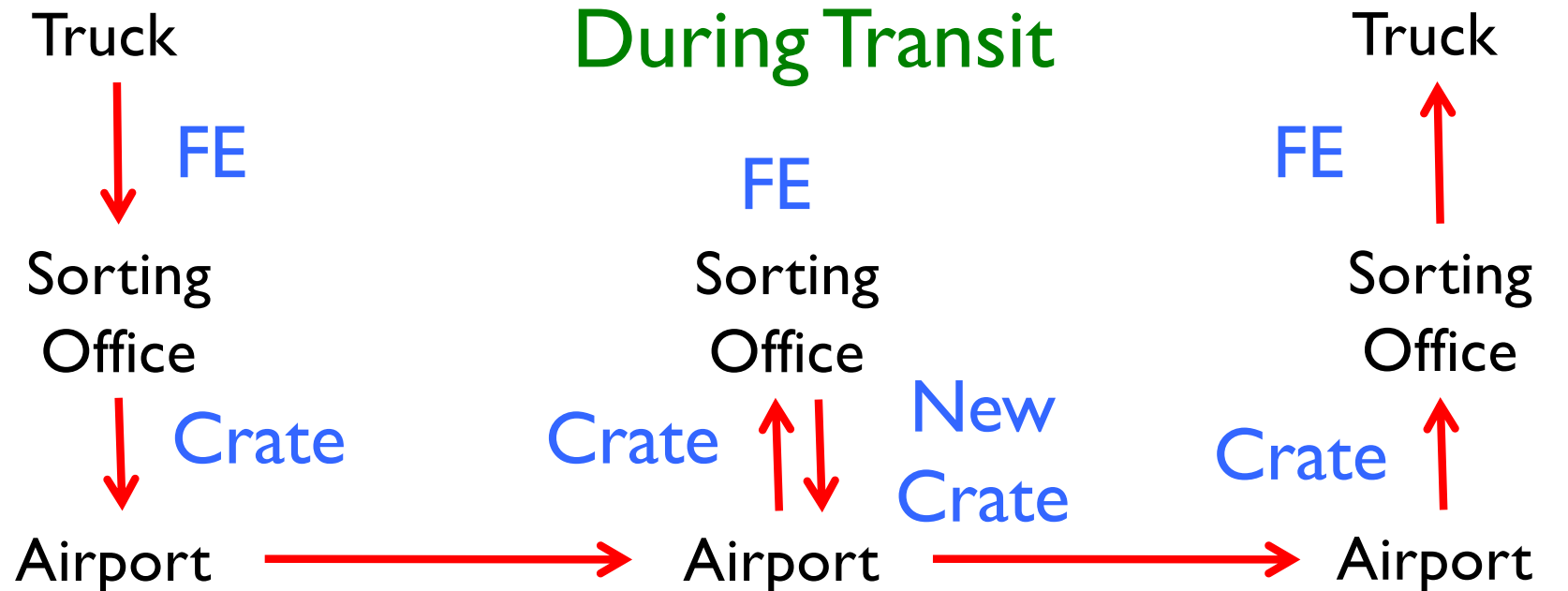




# The Path Through FedEx

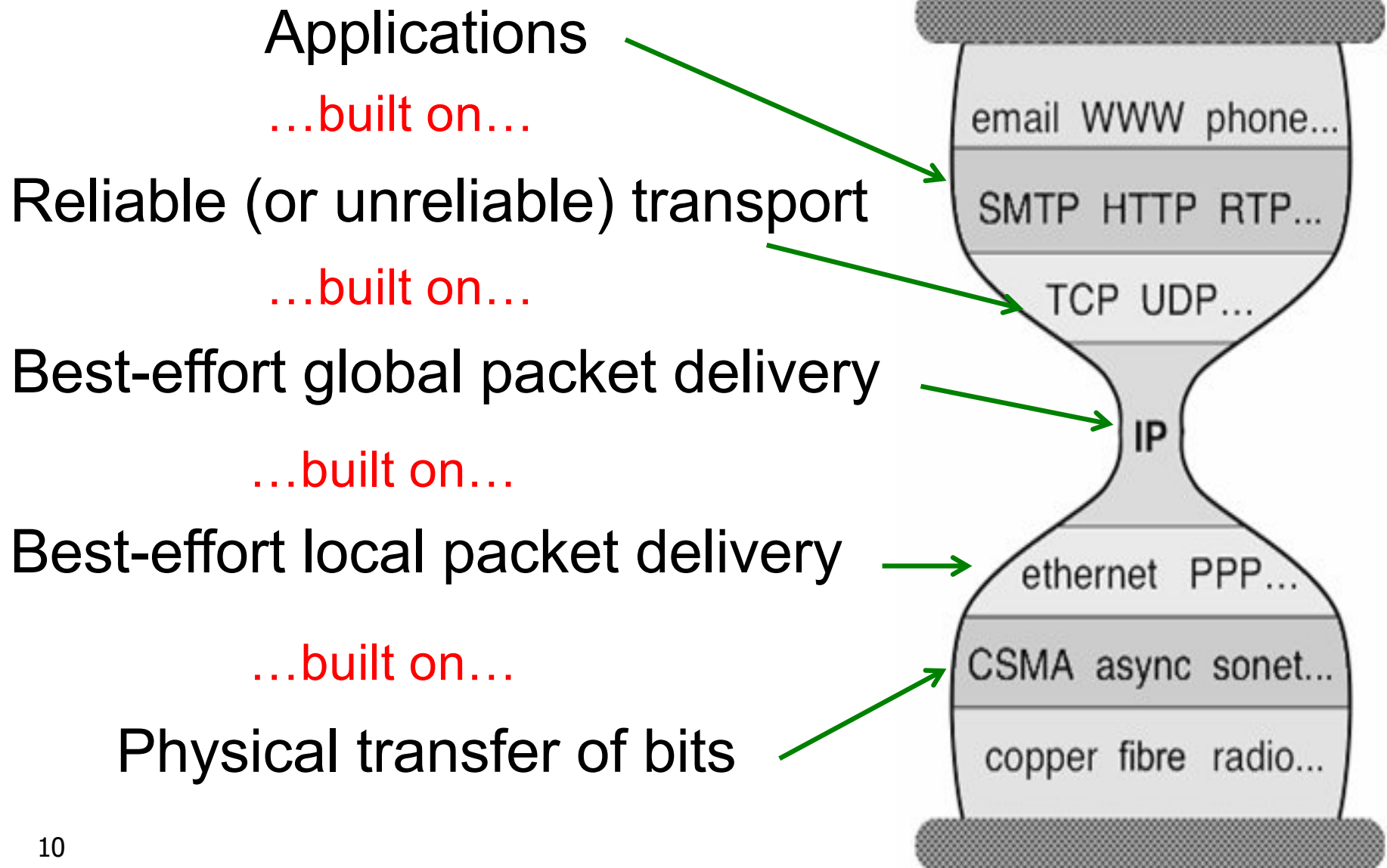
Higher “Stack”  
at Ends

Partial “Stack”  
During Transit



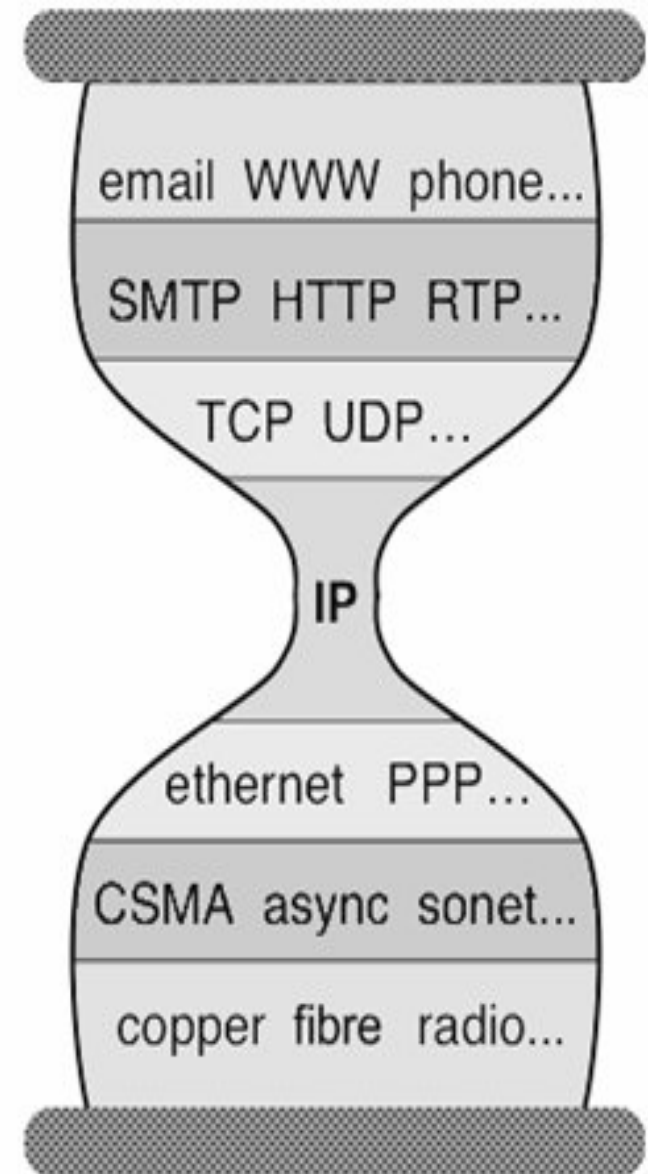
Deepest Packaging (Envelope+FE+Crate)  
at the Lowest Level of Transport

# In the context of the Internet



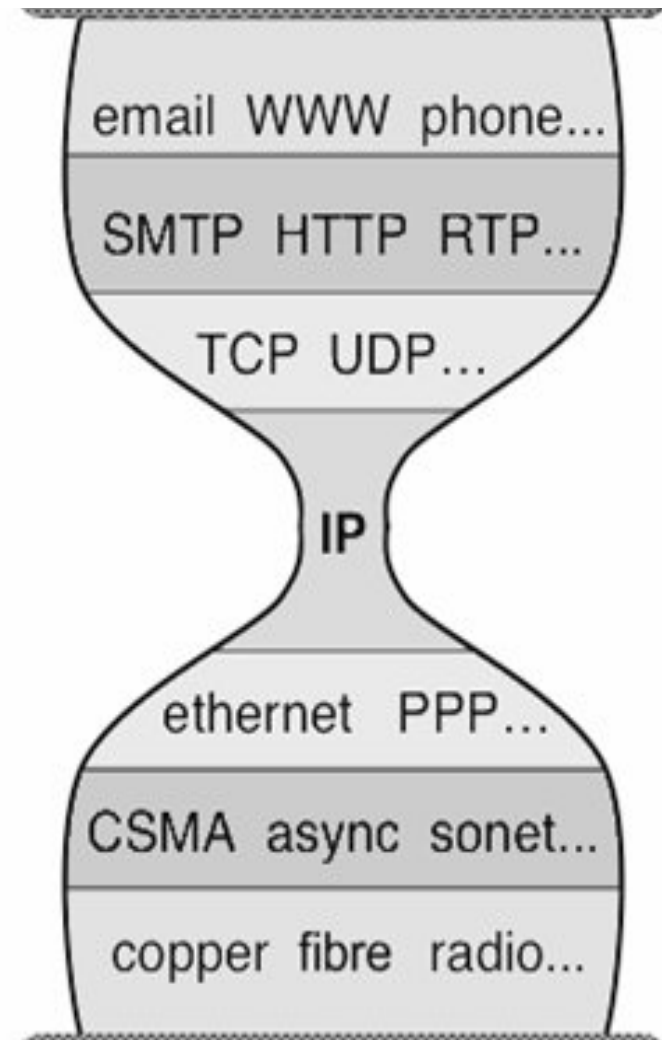
# Internet protocol stack

- ❖ *application*: supporting network applications
  - FTP, SMTP, HTTP, Skype, ..
- ❖ *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, 802.111 (WiFi), PPP
- ❖ *physical*: bits “on the wire”

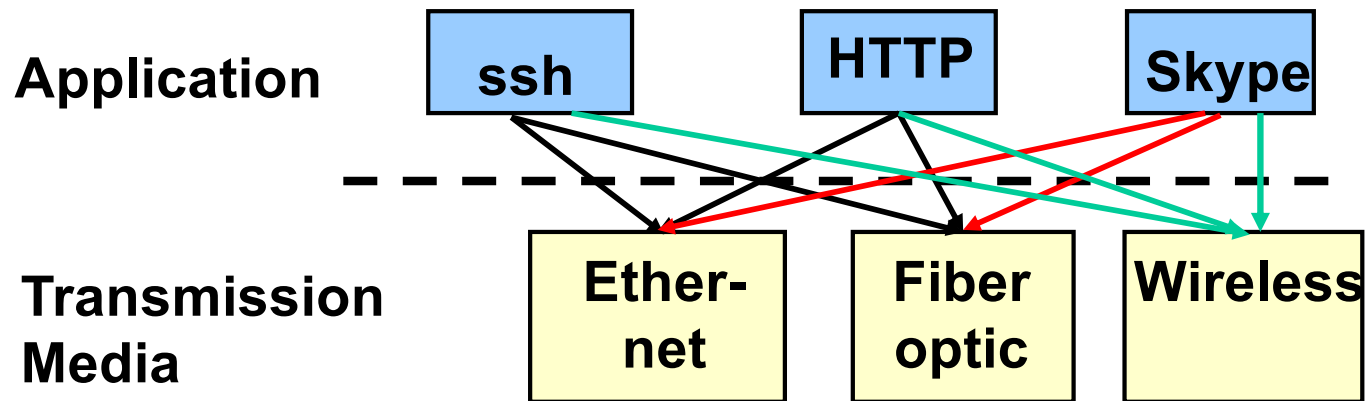


# Three Observations

- ❖ Each layer:
  - Depends on layer below
  - Supports layer above
  - Independent of others
- ❖ Multiple versions in layer
  - Interfaces differ somewhat
  - Components pick which lower-level protocol to use
- ❖ But only one IP layer
  - Unifying protocol



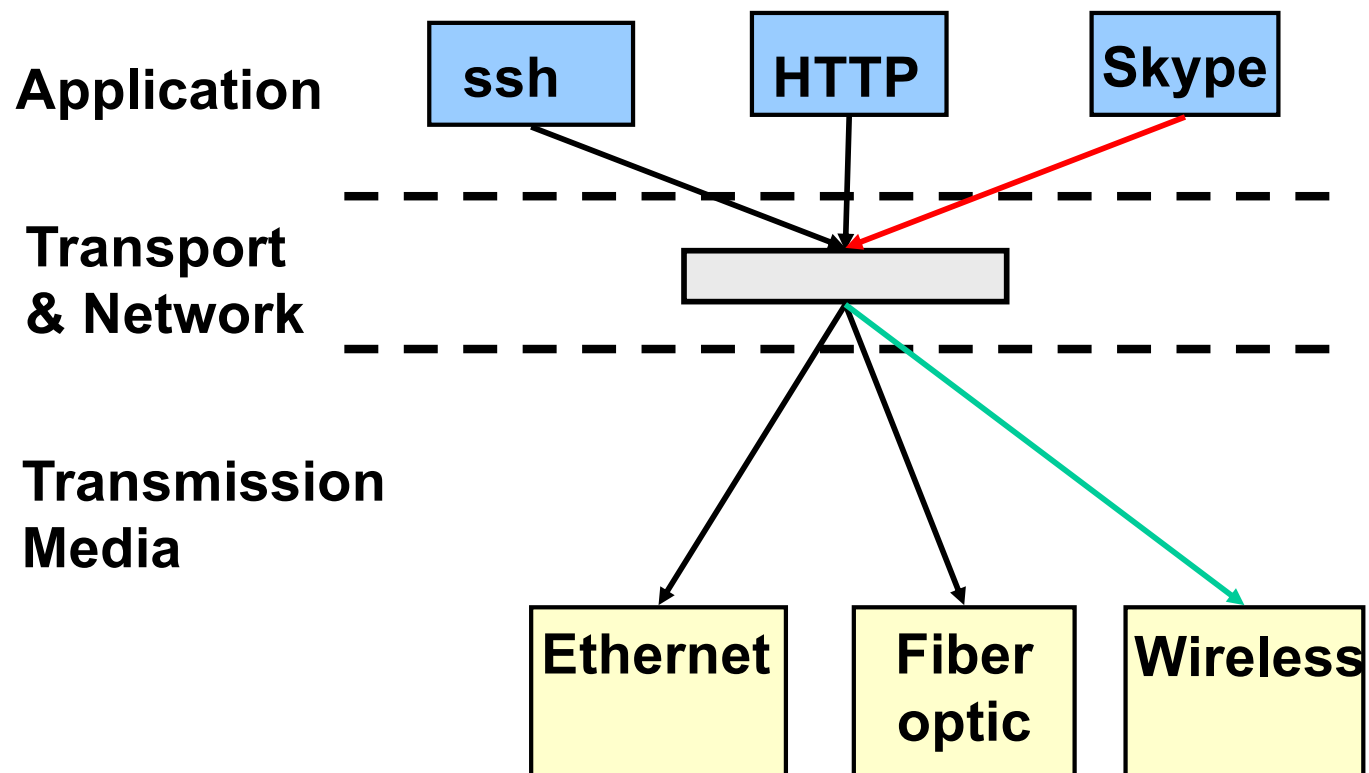
# An Example: No Layering



- ❖ No layering: each new application has to be **re-**implemented for every network technology !

# An Example: Benefit of Layering

- ❖ Introducing an intermediate layer provides a **common** abstraction for various network technologies



# Is Layering Harmful?

- ❖ Layer N may duplicate lower level functionality
  - E.g., error recovery to retransmit lost data
- ❖ Information hiding may hurt performance
  - E.g. packet loss due to corruption vs. congestion
- ❖ Headers start to get really big
  - E.g., typically TCP + IP + Ethernet headers add up to 54 bytes
- ❖ Layer violations when the gains too great to resist
  - E.g., NAT
- ❖ Layer violations when network doesn't trust ends
  - E.g., Firewalls

# Distributing Layers Across Network

- ❖ Layers are simple if only on a single machine
  - Just stack of modules interacting with those above/below
- ❖ But we need to implement layers across machines
  - Hosts
  - Routers
  - Switches
- ❖ What gets implemented where?



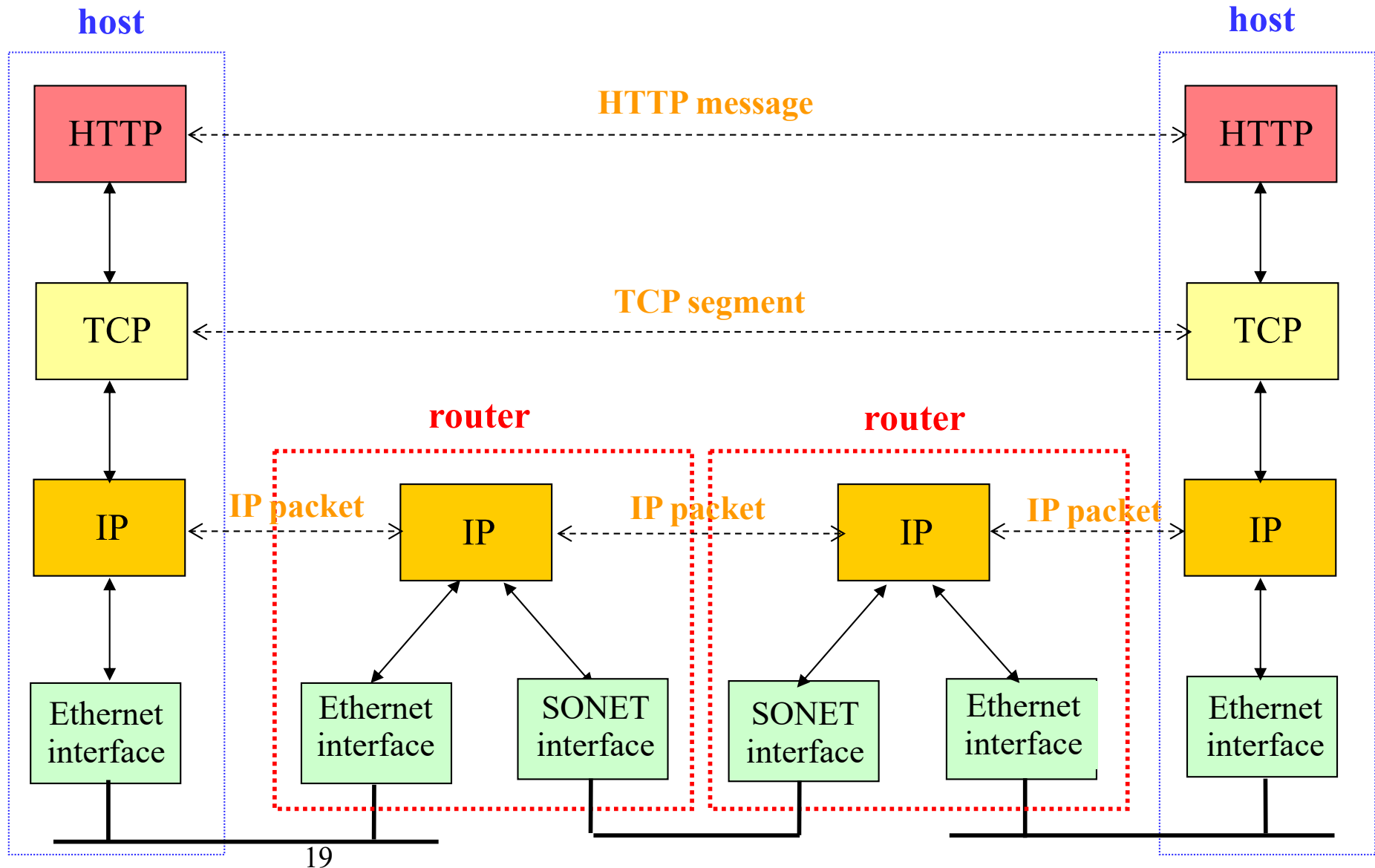
# What Gets Implemented on Host?

- ❖ Hosts have applications that generate data/messages that are eventually put out on wire
- ❖ At receiver host bits arrive on wire, must make it up to application
- ❖ Therefore, all layers must exist at host!

# What Gets Implemented on Router?

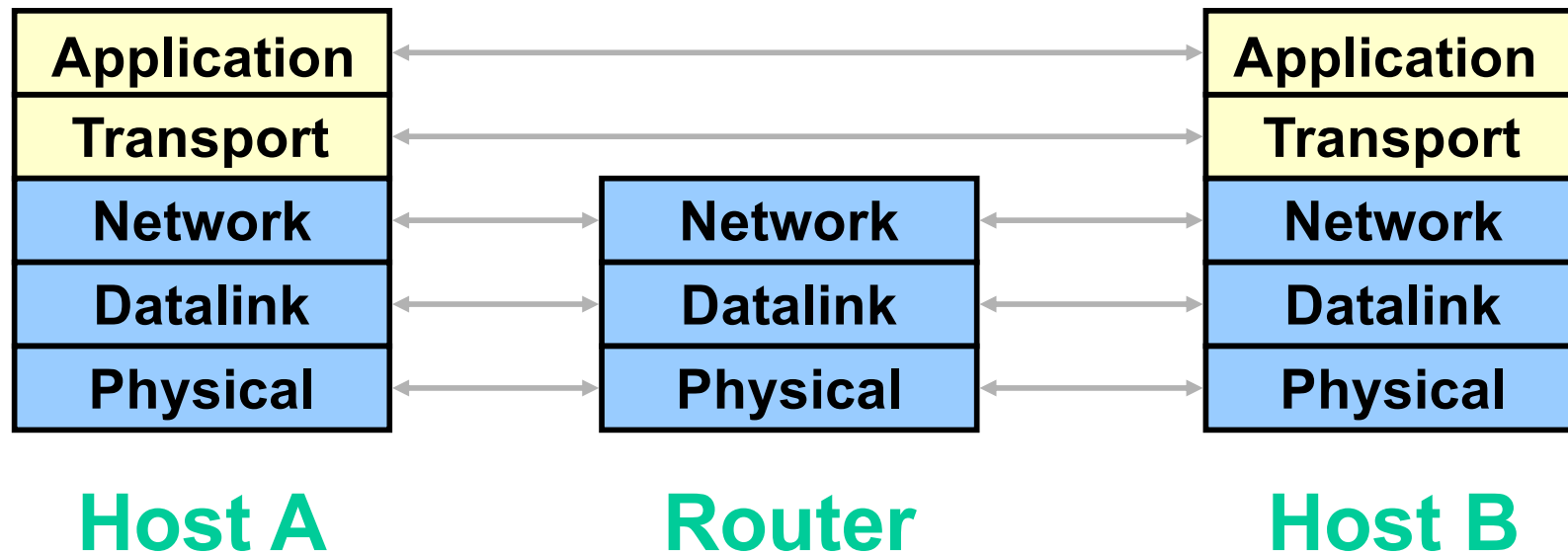
- ❖ Bits arrive on wire
  - Physical layer necessary
- ❖ Packets must be delivered to next-hop
  - datalink layer necessary
- ❖ Routers participate in global delivery
  - Network layer necessary
- ❖ Routers don't support reliable delivery
  - Transport layer (and above) **not** supported

# Internet Layered Architecture



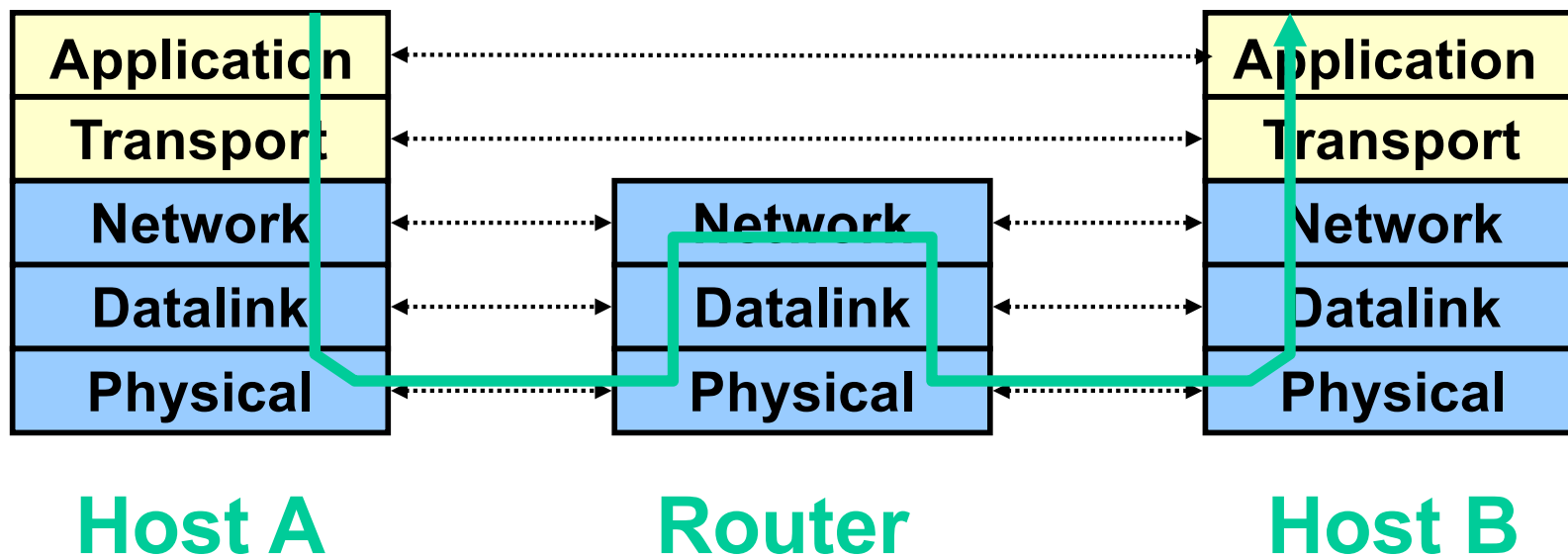
# Logical Communication

- ❖ Layers interacts with peer's corresponding layer

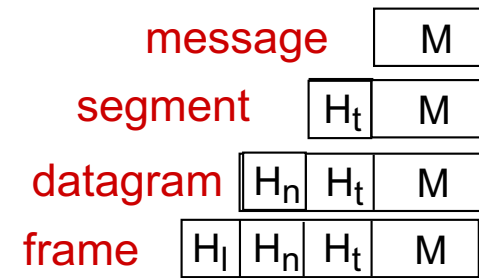


# Physical Communication

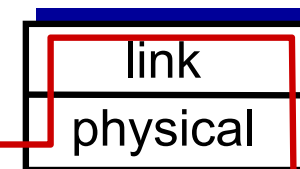
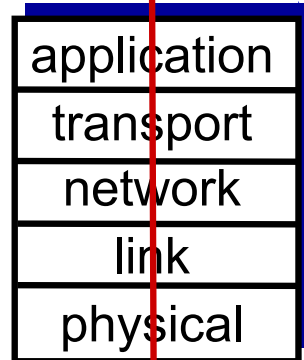
- ❖ Communication goes down to physical network
- ❖ Then from network peer to peer
- ❖ Then up to relevant layer



# Encapsulation

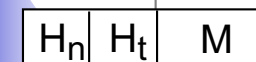
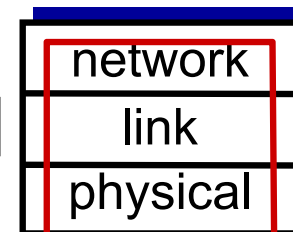
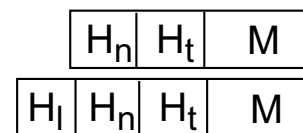
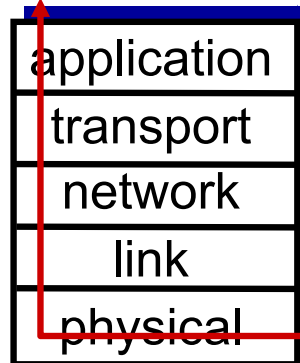
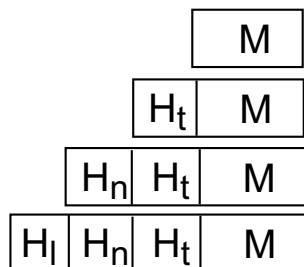


*source*



switch

*destination*



router

## Quiz: Layering



What are two benefits of using a layered network model ? (Choose two)

- A. It makes it easy to introduce new protocols
- B. It speeds up packet delivery
- C. It allows us to have many different packet headers
- D. It prevents technology in one layer from affecting other layers
- E. It creates many acronyms

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