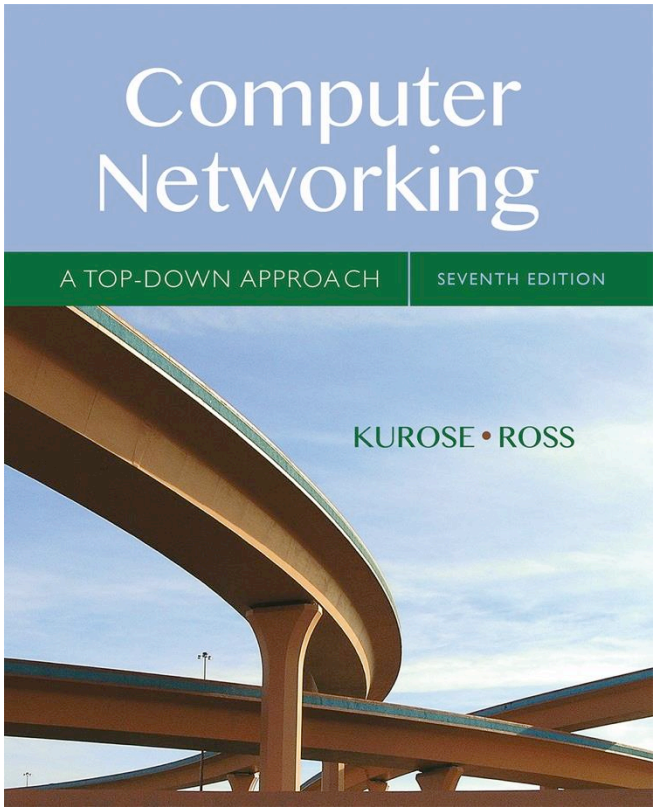
# Chapter 1 (review) Introduction




*Computer Networking: A Top Down Approach*

7th edition
Jim Kurose, Keith Ross
Pearson/Addison Wesley
April 2016

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Thanks and enjoy! JFK/KWR

# Chapter 1: roadmap

1.1 what *is* the Internet?

1.2 network edge

- end systems, access networks, links

1.3 network core

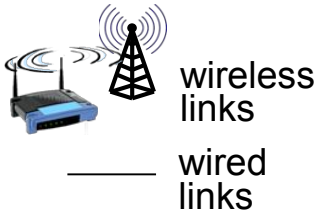
- packet switching, circuit switching, network structure

1.4 delay, loss, throughput in networks

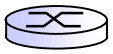
1.5 protocol layers, service models

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

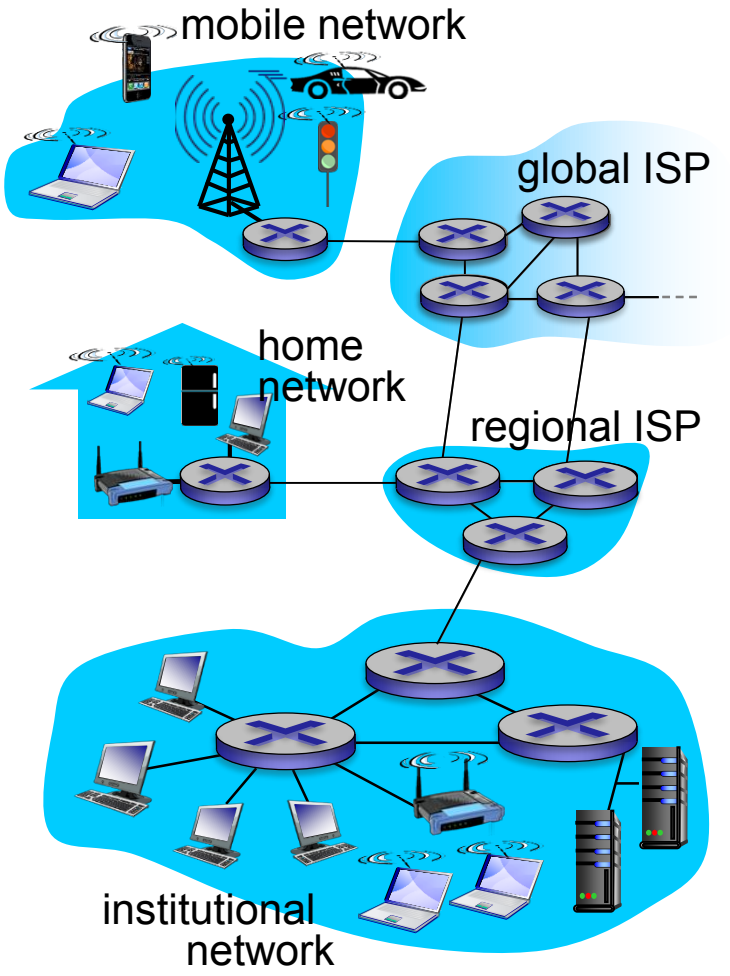

- billions of connected computing devices:
  - *hosts* = *end systems*
  - running *network apps*




- *communication links*
  - fiber, copper, radio, satellite
  - transmission rate: *bandwidth*

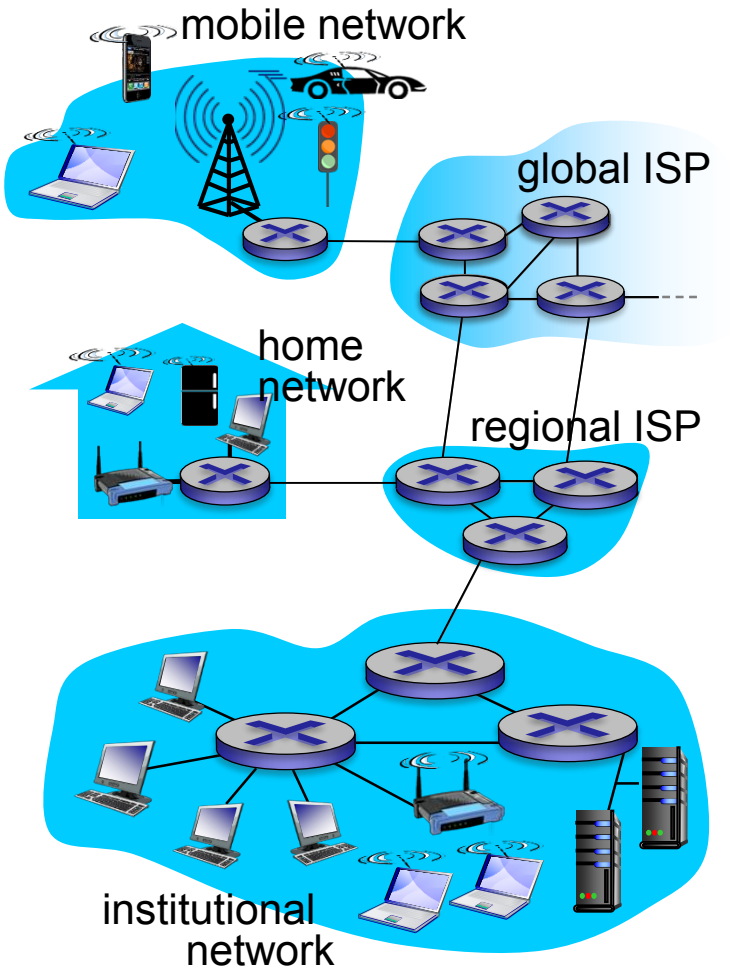



- *packet switches:* forward packets (chunks of data)
  - *routers* and *switches*



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

- *Internet:* "network of networks"
  - Interconnected ISPs
- *protocols* control sending, receiving of messages
  - 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

… specific messages sent

… specific actions taken when messages received, or other events

*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*

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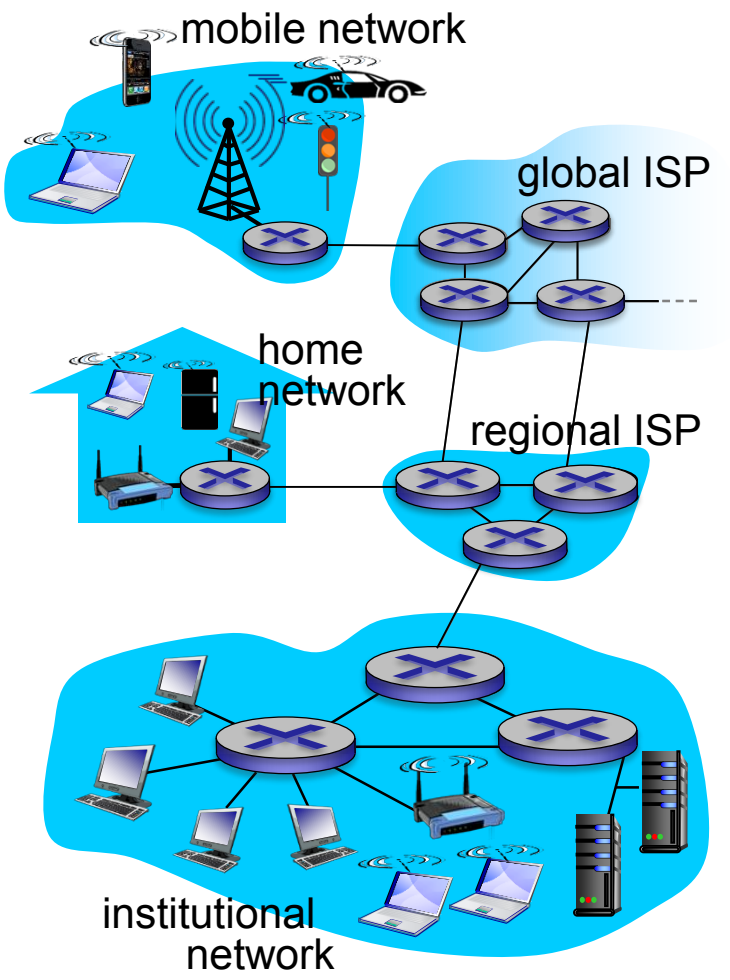
# A closer look at network structure:

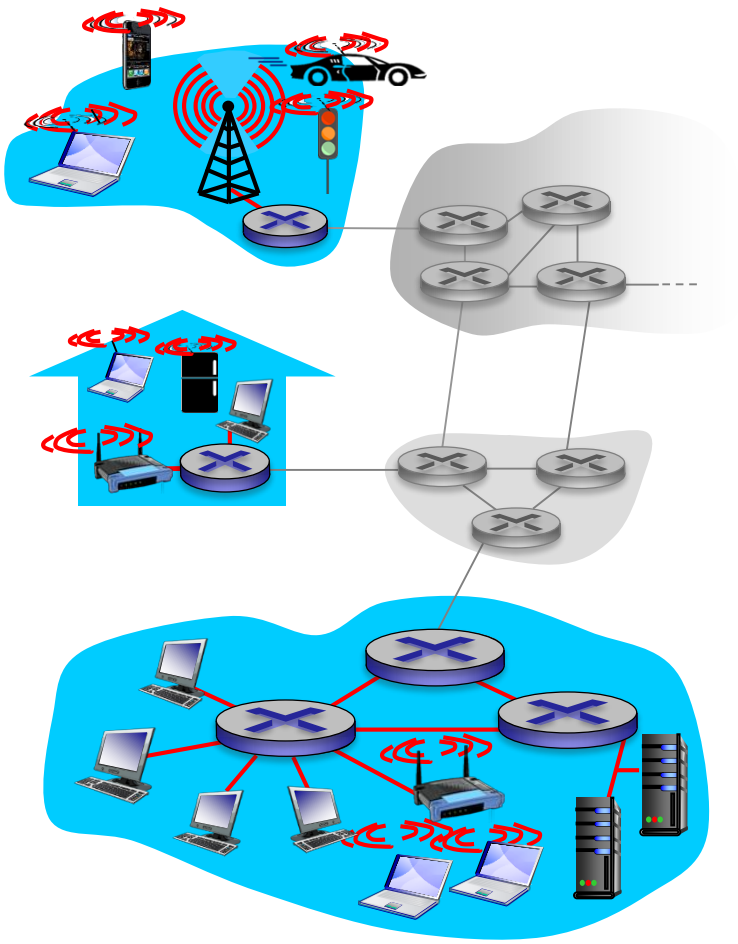
- *network edge (网络边缘):*
  - hosts: clients and servers
  - servers often in data centers
- *network core (网络核心)*
  - interconnected routers
- *access networks (接入网), physical media (物理媒介):* wired, wireless communication links



# Access networks and physical media

*Q: How to connect end systems to edge router?*

- residential access nets
- institutional access networks (school, company)
- mobile access networks



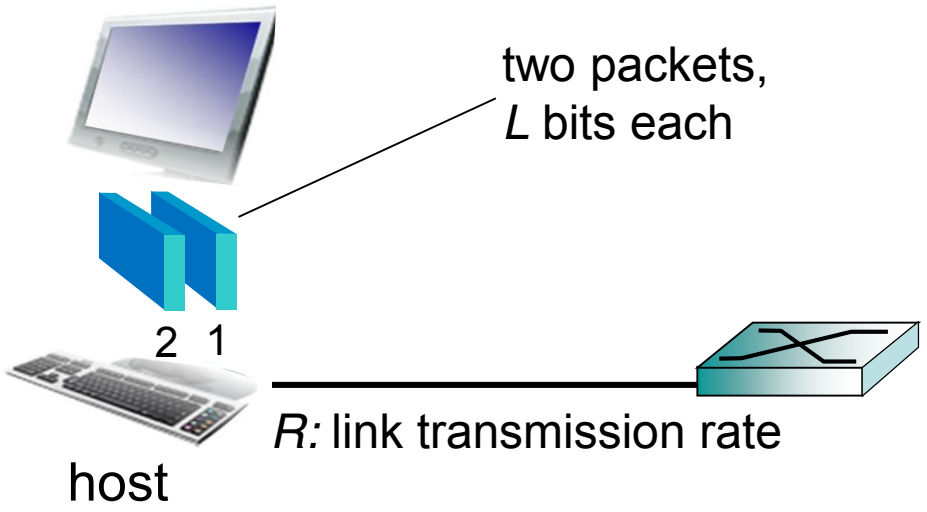
# Host: sends *packets* of data

host sending function:

- takes application message
- breaks into smaller chunks, known as *packets(分组)*, of length ***L*** bits
- transmits packet into access network at *transmission rate* ***R***

a.k.a

- link *capacity,*
- *aka link bandwidth*




$$\text{packet transmission delay} = \text{time needed to transmit } L\text{-bit packet into link} = \frac{L \text{ (bits)}}{R \text{ (bits/sec)}}$$

# Physical media

- bit: propagates between transmitter/receiver pairs
- physical link: what lies between transmitter & receiver
- **guided media(导引型):**
  - signals propagate in solid media: copper, fiber, coax
- **unguided media(非导引型):**
  - signals propagate freely, e.g., radio

# Physical media: twisted pair, coax, fiber

***twisted pair (TP)***

- two insulated copper wires
  - Category 5: 100 Mbps, 1 Gbps Ethernet

  **100 meters**

*coaxial cable:*

- two concentric copper conductors
- bidirectional
- broadband:
  - multiple channels on cable

*fiber optic cable:*

- glass fiber carrying light pulses, each pulse a bit
- high-speed operation:
  - high-speed point-to-point transmission (e.g., 10's-100's Gbps transmission rate)
- low error rate:
  - repeaters spaced far apart
  - immune to electromagnetic noise

# Physical media: radio(**unguided media**)

- signal carried in electromagnetic spectrum
- no physical "wire"
- bidirectional
- propagation environment effects:
  - reflection
  - obstruction by objects
  - interference

*radio link types:*

- terrestrial microwave
  - e.g. up to 45 Mbps channels
- LAN (e.g., WiFi)
  - 54 Mbps
- wide-area (e.g., cellular)
  - 4G cellular: ~ 10 Mbps
- Satellite channel
  - Kbps to 45Mbps channel (or multiple smaller channels)
  - 270 msec end-end delay
  - geosynchronous versus low altitude

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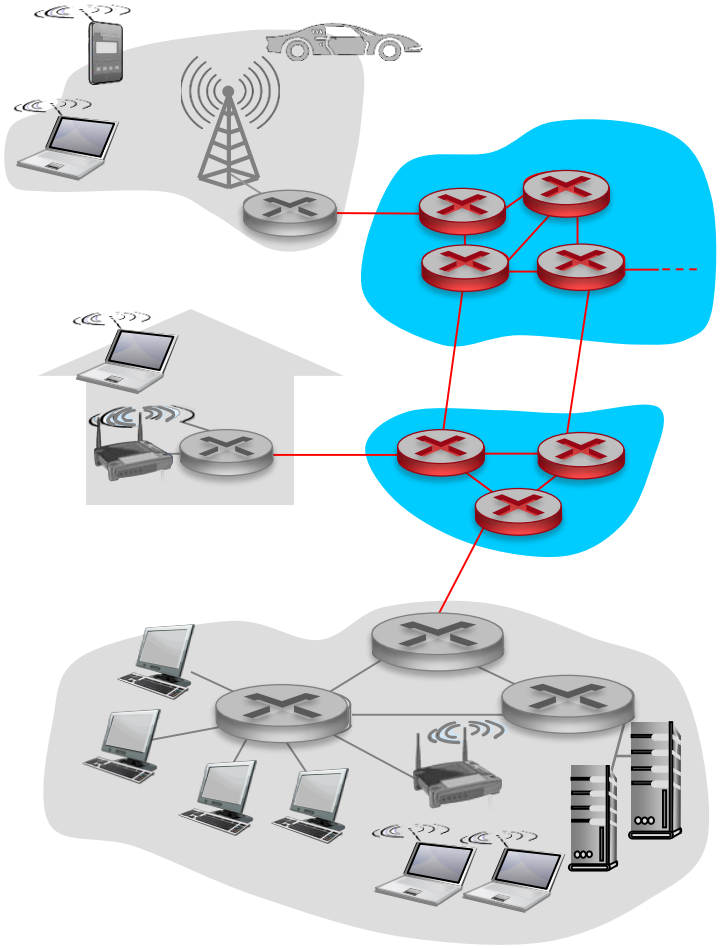
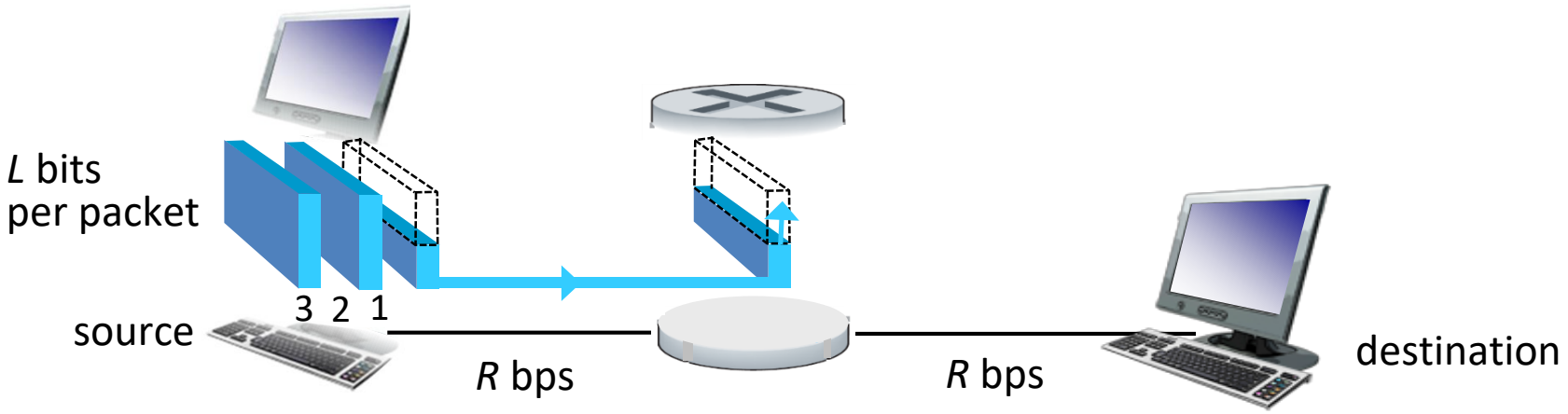
# The network core

- mesh of interconnected routers
- packet-switching: hosts break application-layer messages into *packets*
  - forward packets from one router to the next, across links on path from source to destination
  - each packet transmitted at full link capacity



# Packet-switching: store-and-forward



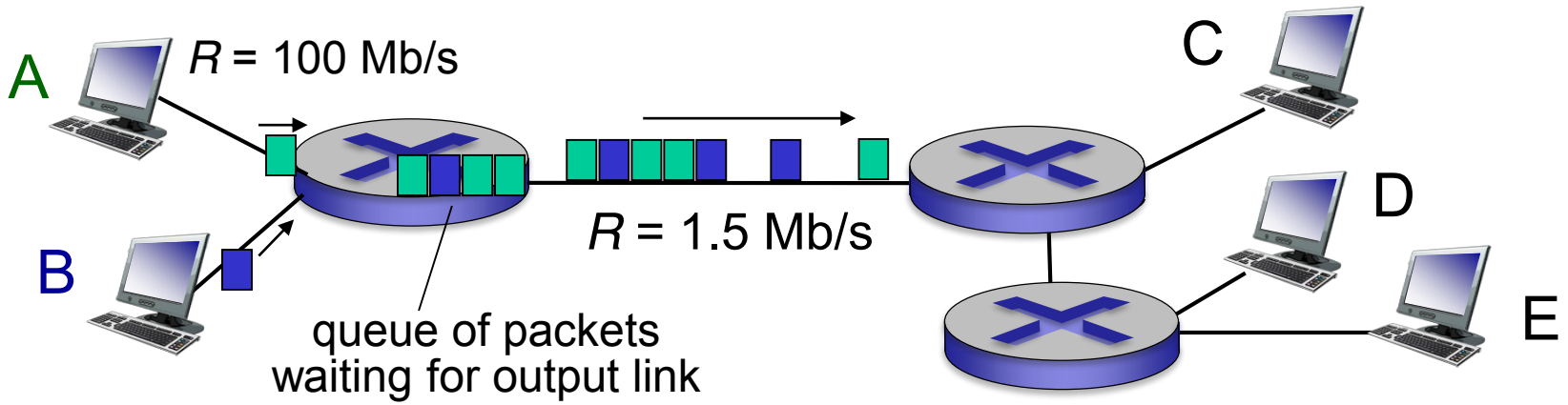

- takes *L*/*R* seconds to transmit (push out) *L*-bit packet into link at *R* bps
- *store and forward:* entire packet must arrive at router before it can be transmitted on next link
- end-end delay = 2*L*/*R* (assuming zero propagation delay)

*one-hop numerical example:*

- *L* = 7.5 Mbits
- *R* = 1.5 Mbps
- one-hop transmission delay = 5 sec

more on delay shortly …

# Packet Switching: queueing delay, loss




queuing and loss:

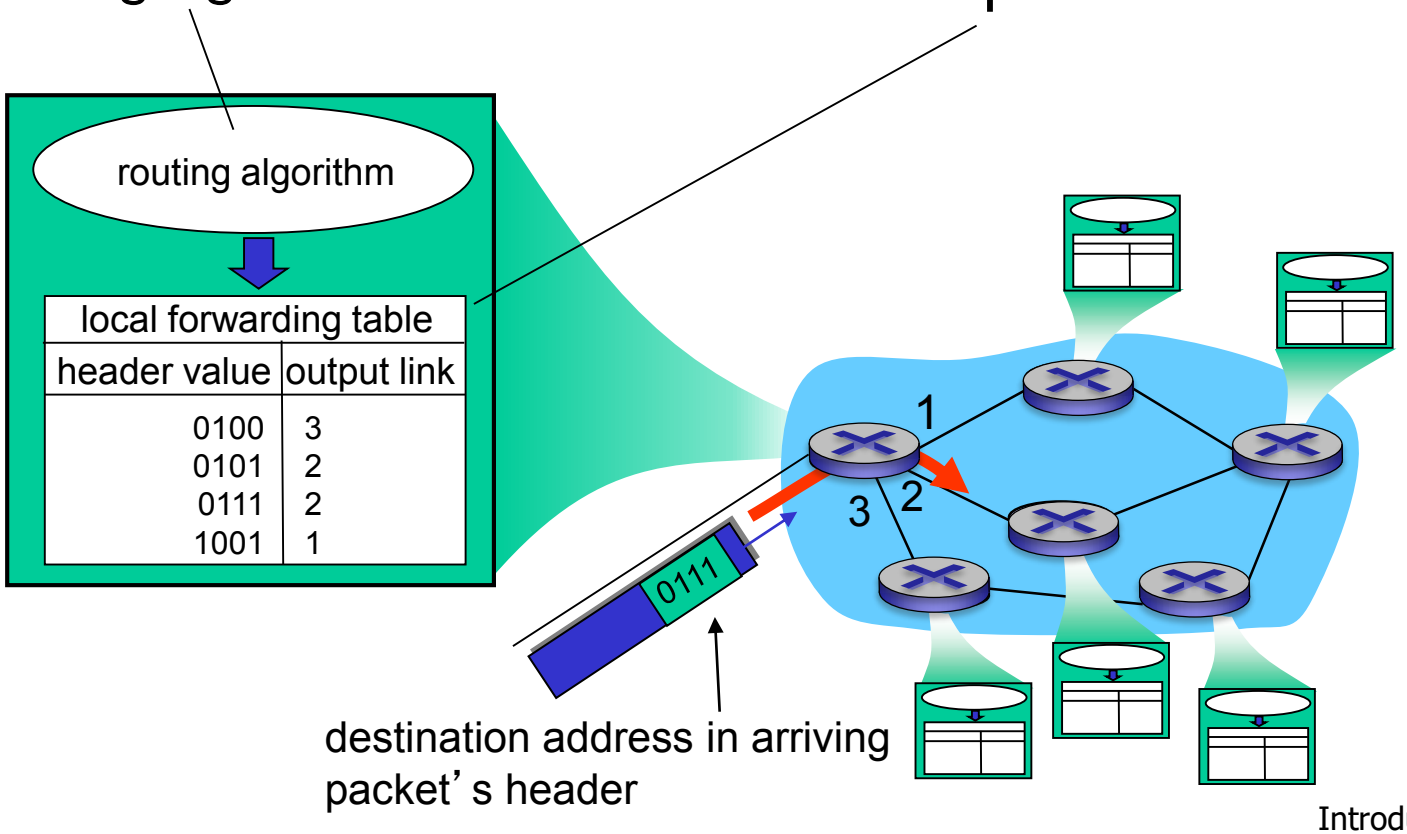
- if arrival rate (in bits) to link exceeds transmission rate of link for a period of time:
  - packets will queue, wait to be transmitted on link
  - packets can be dropped (lost) if memory (buffer) fills up

# Two key network-core functions

*routing:* determines source-destination route taken by packets

- *routing algorithms*

*forwarding:* move packets from router's input to appropriate router output

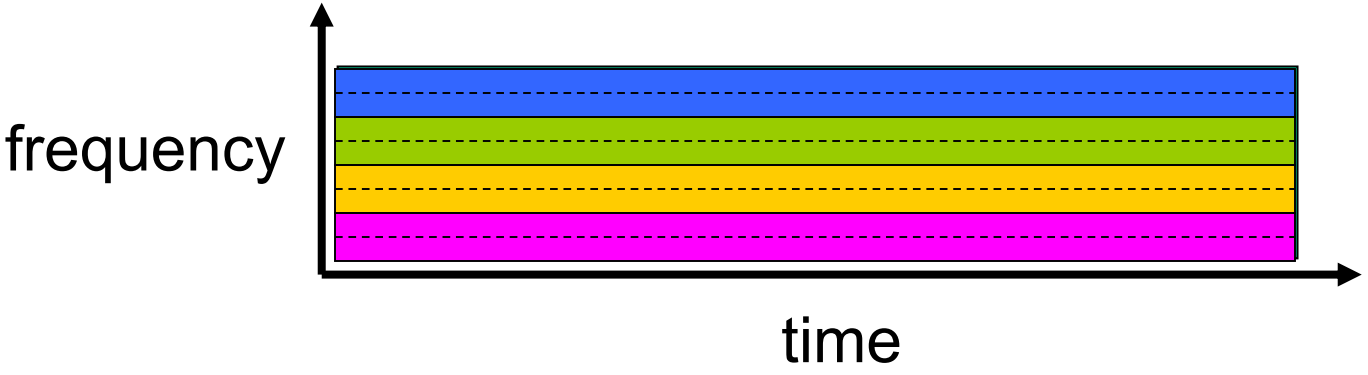


# Circuit switching: FDM versus TDM

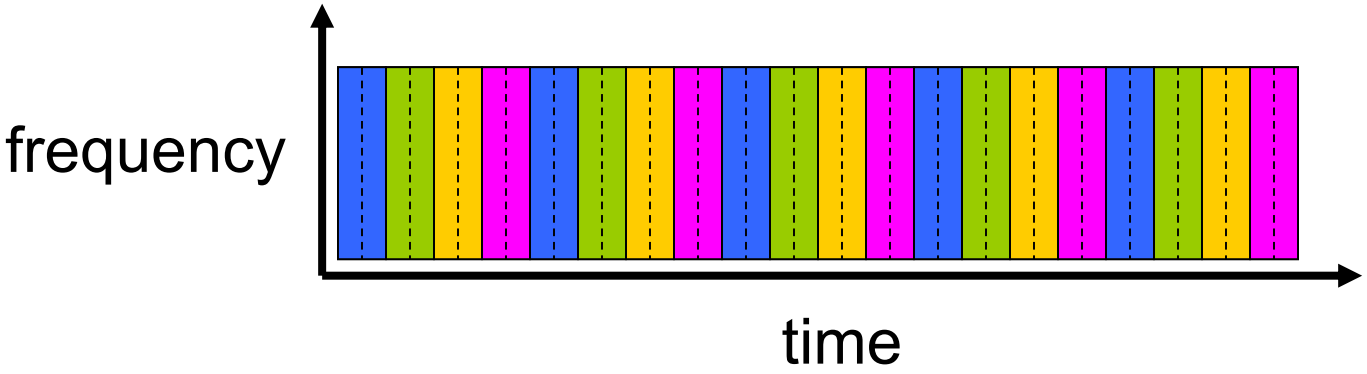
Example:

4 users

FDM




TDM



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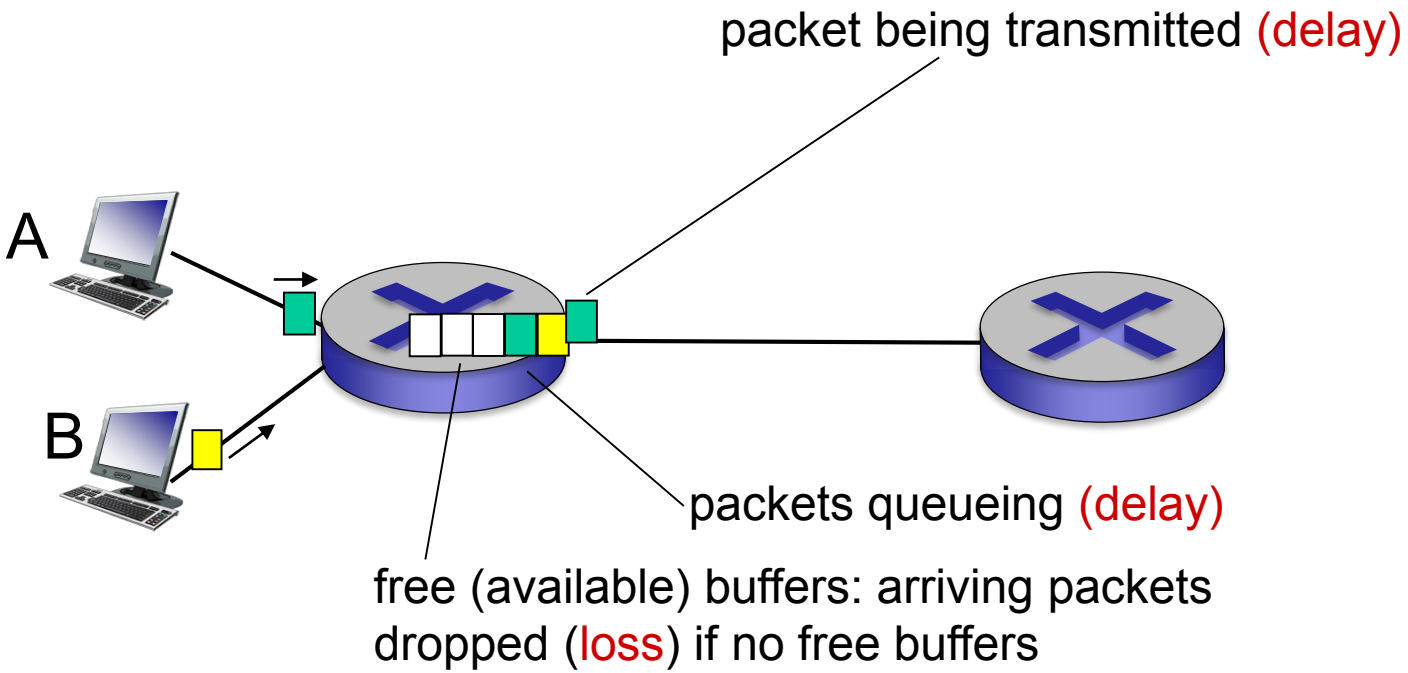
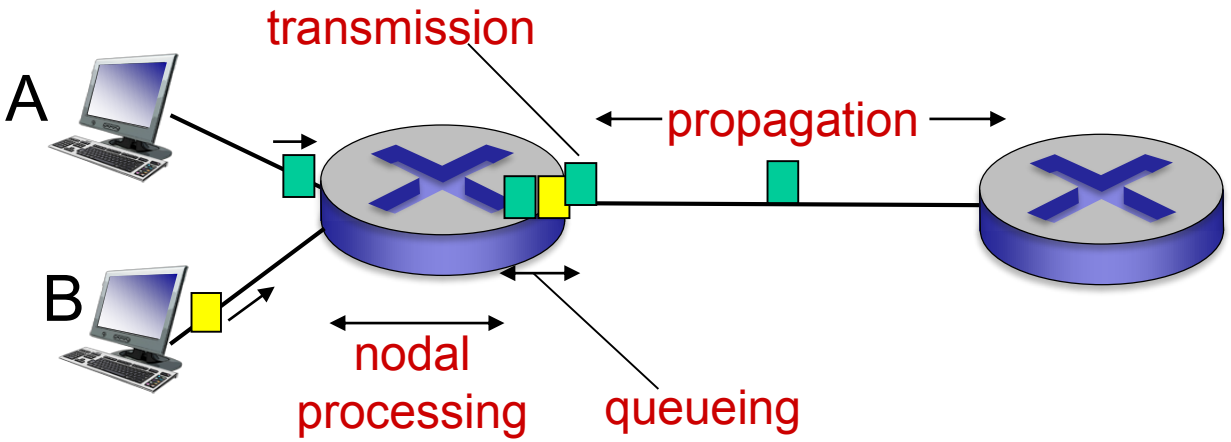
# How do loss and delay occur?

packets *queue* in router buffers

- packet arrival rate to link (temporarily) exceeds output link capacity
- packets queue, wait for turn



# Four sources of packet delay 延时




$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

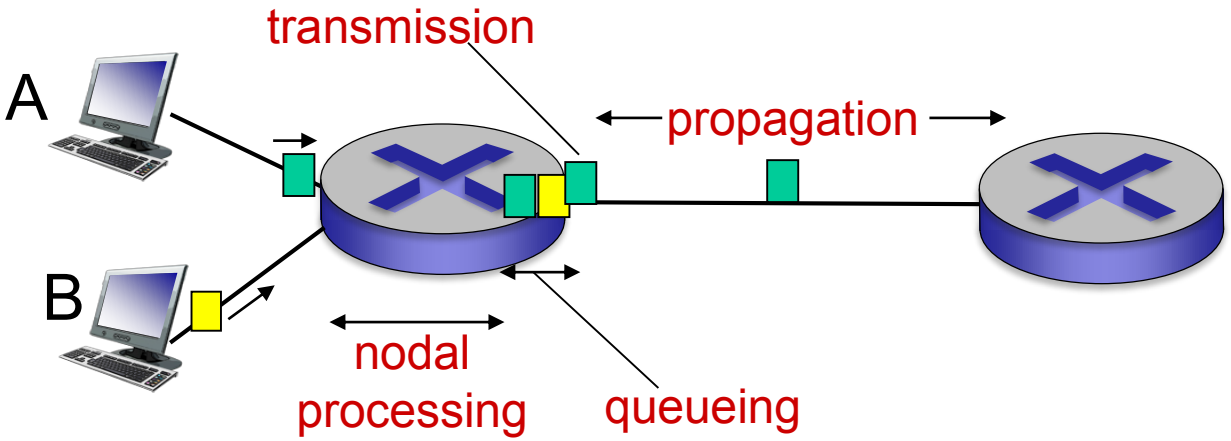
## $d_{proc}$: processing delay

- check bit errors
- determine output link
- typically < msec

## $d_{queue}$: queueing delay

- time waiting at output link for transmission
- depends on congestion level of router

# Four sources of packet delay




$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

$d_{trans}$: transmission delay:

- $L$: packet length (bits)
- $R$: link *bandwidth (bps)*
- $d_{trans} = L/R$

$d_{trans}$ and $d_{prop}$ *very* different

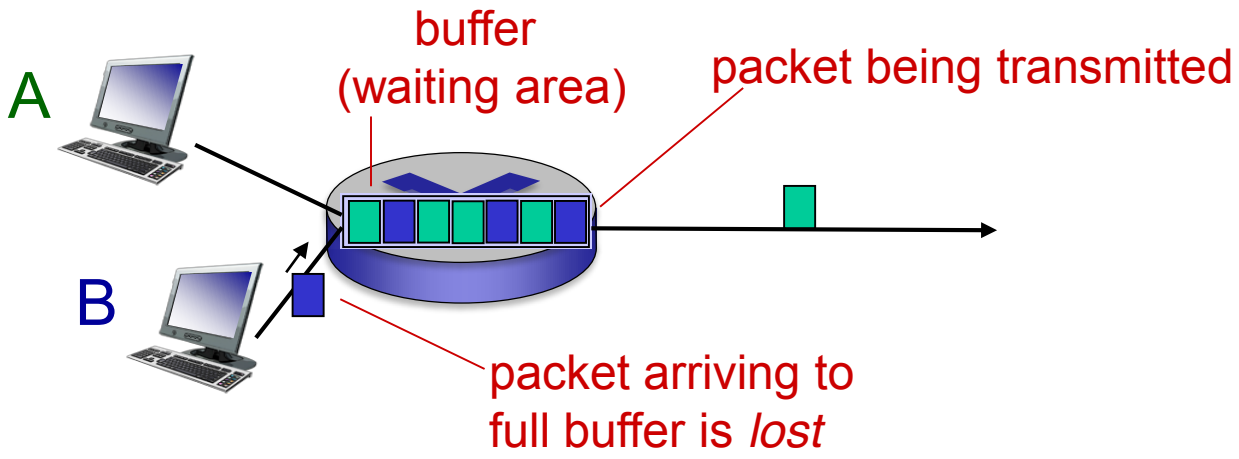
$d_{prop}$: propagation delay:

- $d$: length of physical link
- $s$: propagation speed (~$2 \times 10^8$ m/sec)
- $d_{prop} = d/s$

* Check out the online interactive exercises for more examples: http://gaia.cs.umass.edu/kurose_ross/interactive/
* Check out the Java applet for an interactive animation on trans vs. prop delay

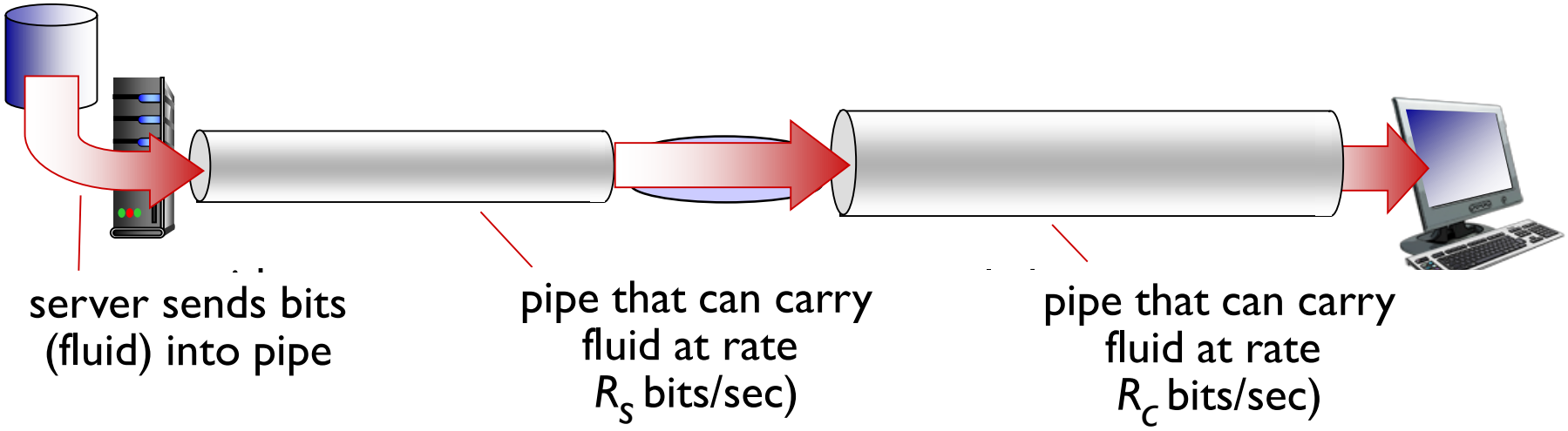
# Packet loss 丢包

- 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



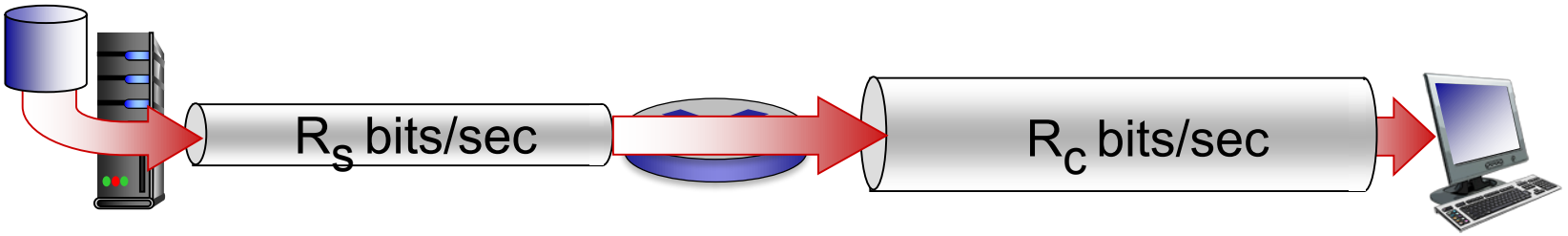
# Throughput 吞吐量

- *throughput:* rate (bits/time unit) at which bits transferred between sender/receiver
  - *instantaneous:* rate at given point in time
  - *average:* rate over longer period of time

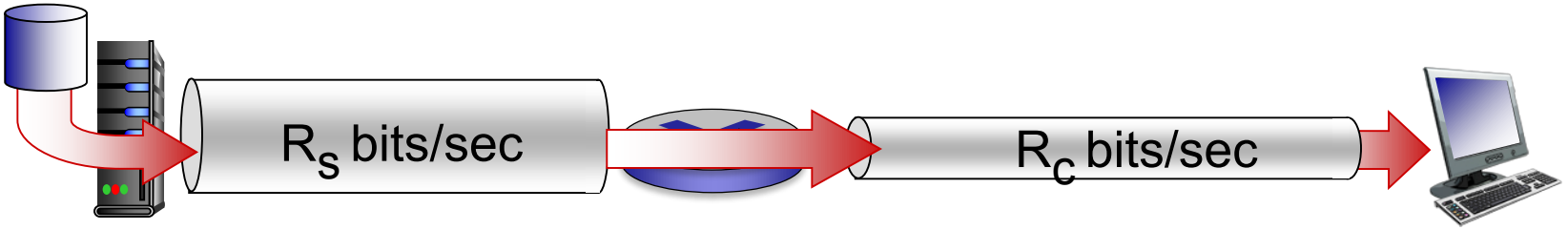


# Throughput (more)

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




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




*bottleneck link*

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

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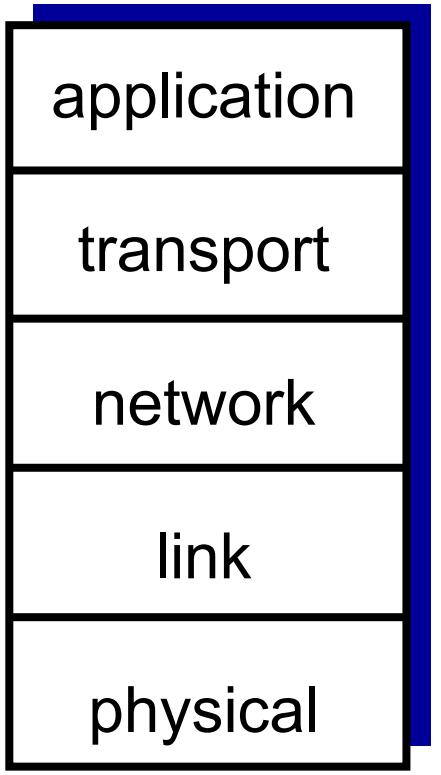
# Why layering? 为什么分层

dealing with complex systems:

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

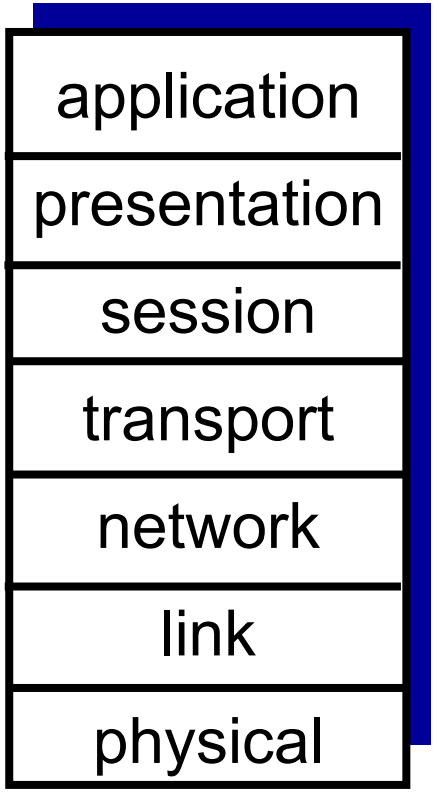
# Internet protocol stack

- *application:* supporting network applications
  - FTP, SMTP, HTTP
- *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"

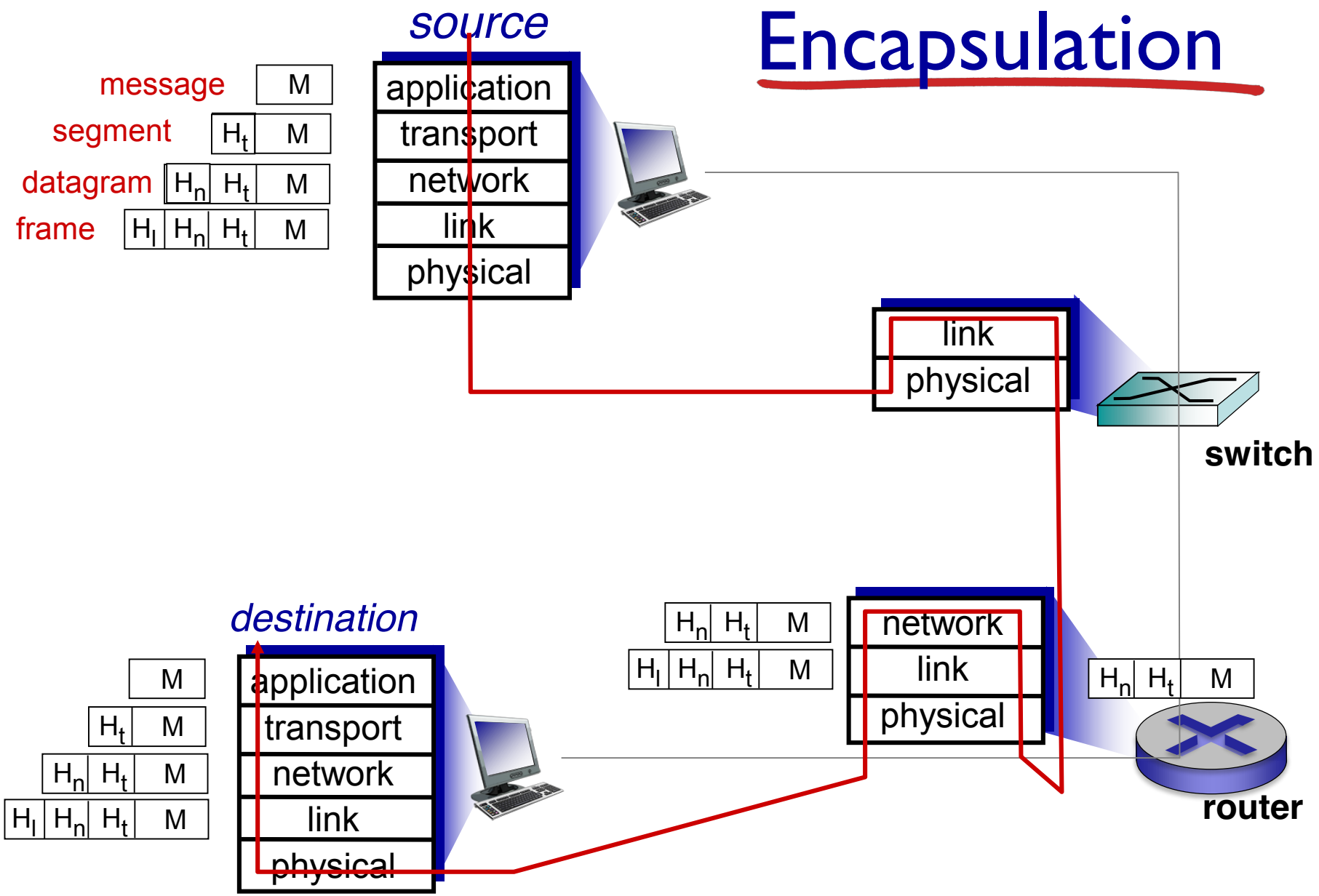


# ISO/OSI reference model

- *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?



# Encapsulation



# Chapter 1

# End