Computer Networks Basic Protocols
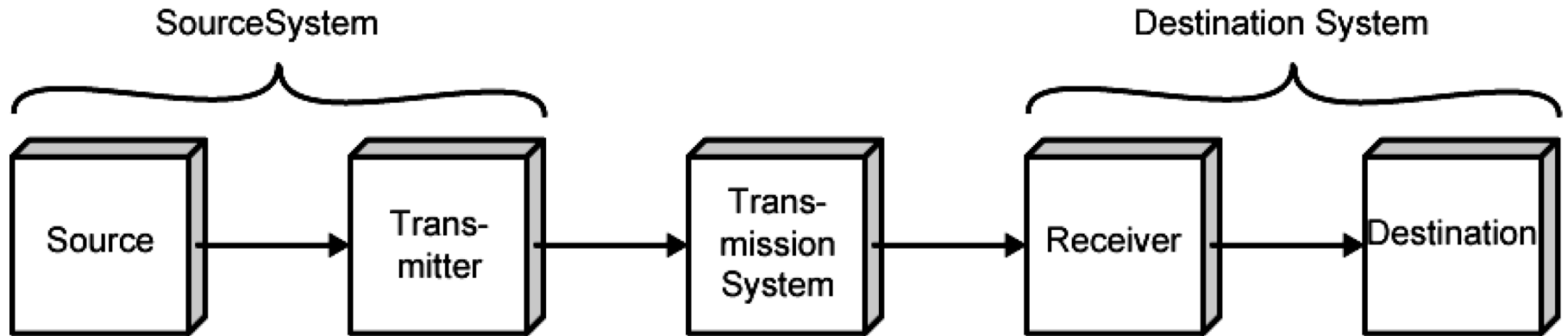
Assoc. Prof. Dr. Berk CANBERK
bcrg.itu.edu.tr

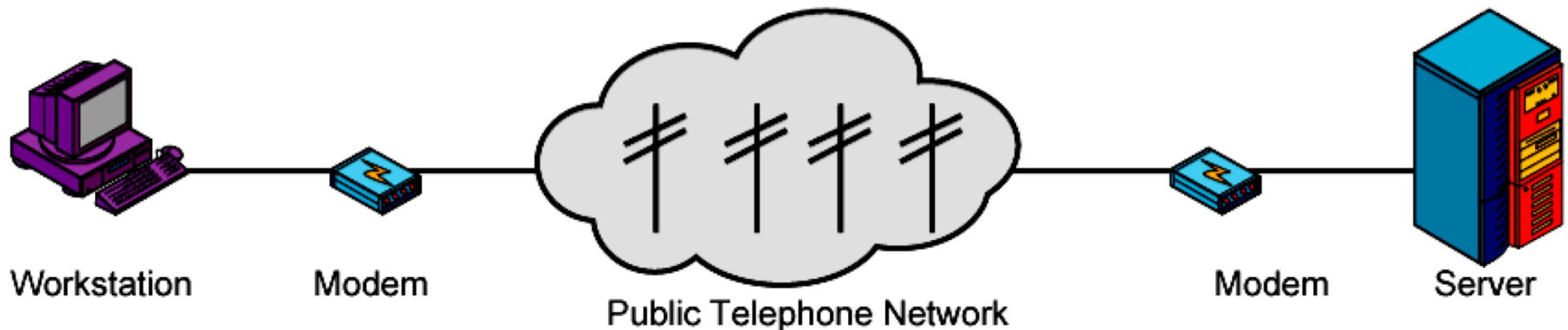# 18 September 2019
-Introduction-

References:

-Data and Computer Communications, William Stallings, Pearson-Prentice Hall, 9th Edition, 2010.

-Computer Networking, A Top-Down Approach Featuring the Internet, James F.Kurose, Keith W.Ross, Pearson-Addison Wesley, 6th Edition, 2012.
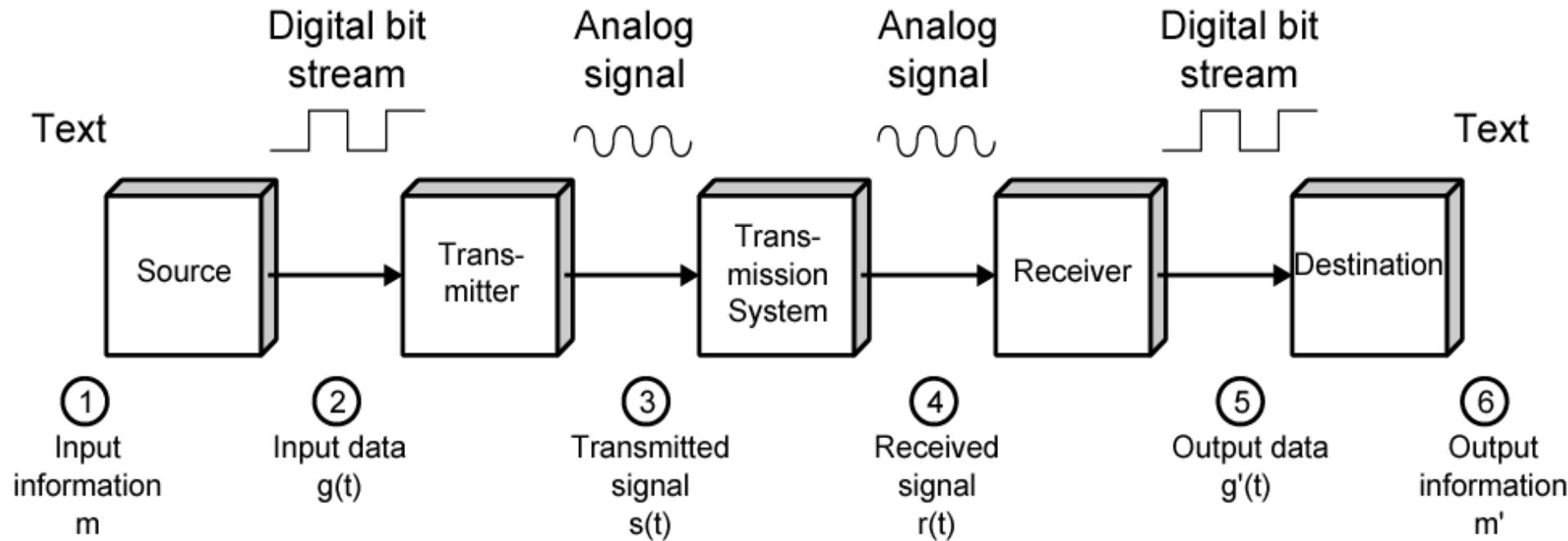
Communications Model

SourceSystem

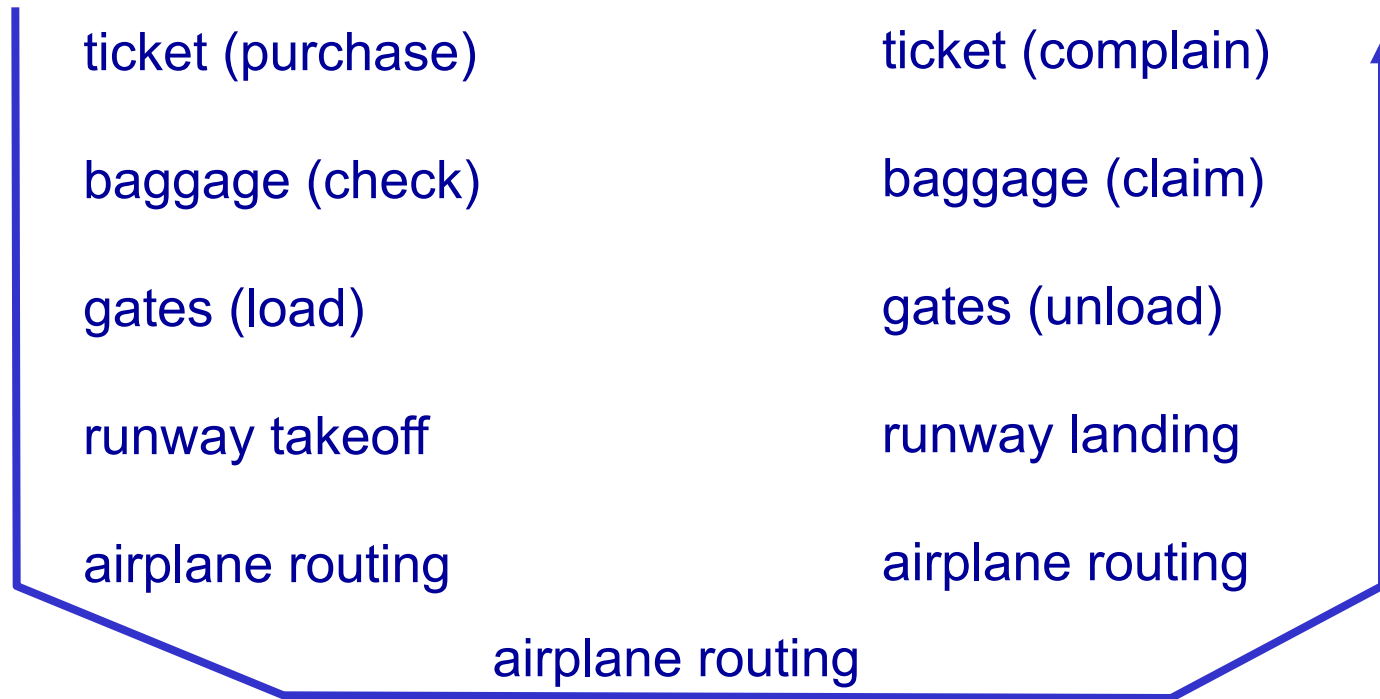Destination System

| Source | → | Trans-mitter | → | Trans-mission System | → | Receiver | → | Destination |

(a) General block diagram

Workstation Modem Public Telephone Network Modem Server

(b) Example

Data Communications Model

Organization of air travel

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

airplane routing

❖ a series of steps

Layering of airline functionality

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

departure airport   intermediate air-traffic control centers   arrival airport
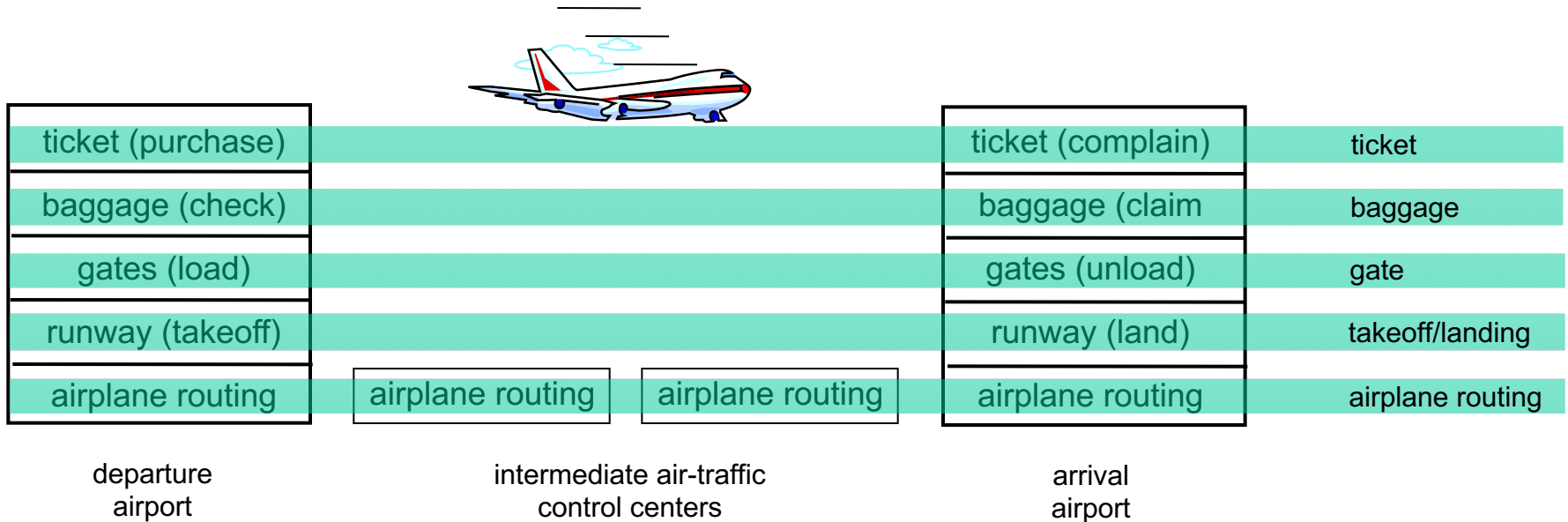
layers: each layer implements a service
- via its own internal-layer actions
- relying on services provided by layer below

Why layering?

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?

What's a protocol?

human protocols:

- ❖ "what's the time?"
- ❖ "I have a question"
- ❖ introductions

… specific msgs sent

… specific actions taken when msgs received, or other events

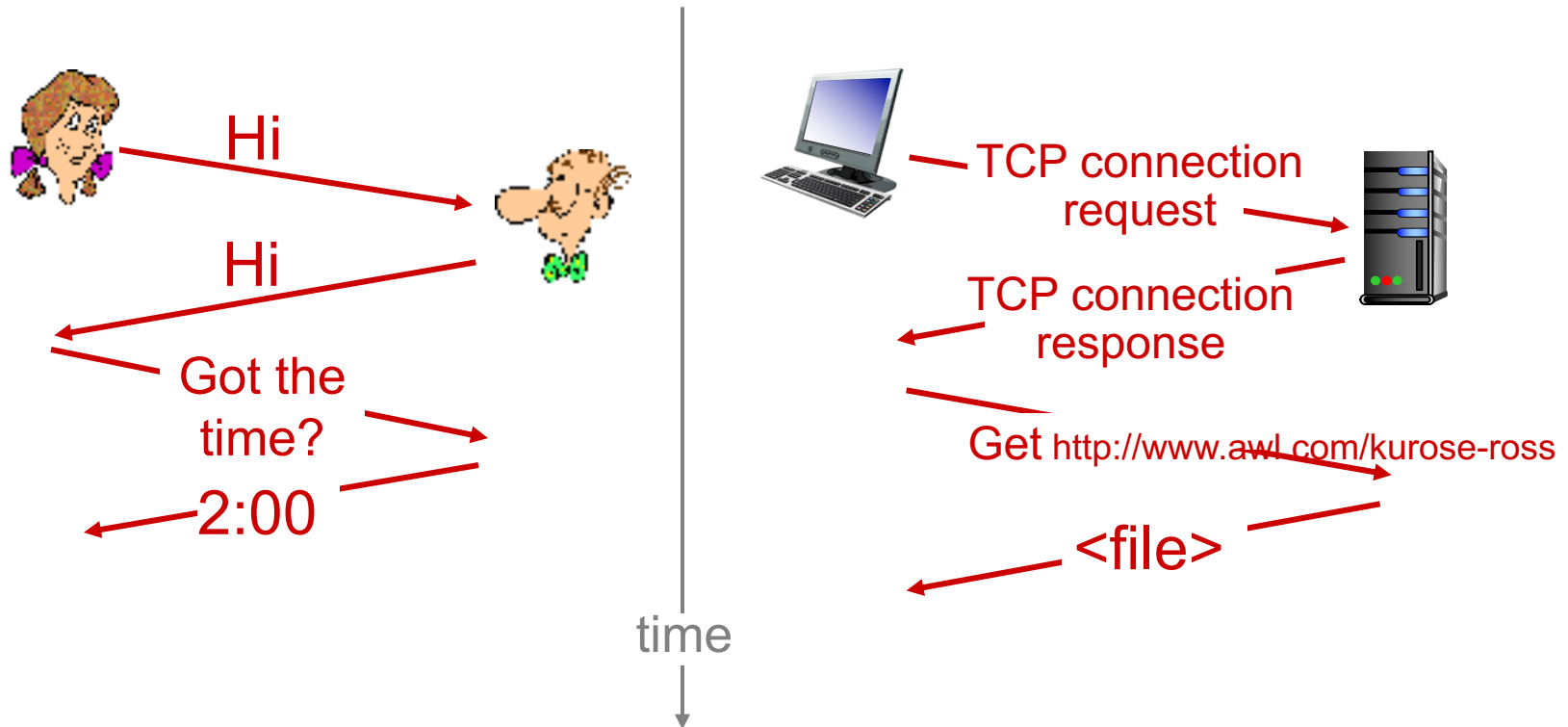**_network protocols:_**

- ❖ machines rather than humans
- ❖ all communication activity in Internet governed by protocols

> **_protocols_** _define_ **_format, order_** _of_ **_msgs sent and received_** _among network entities, and_ **_actions taken_** _on msg transmission, receipt_

What's a protocol?

a human protocol and a computer network protocol:

| Hi |
| Hi |
| Got the time? |
| 2:00 |

| TCP connection request |
| TCP connection response |
| Get http://www.awl.com/kurose-ross |
| <file> |

time

Q: other human protocols?

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"

| application |
| --- |
| transport |
| network |
| link |
| physical |
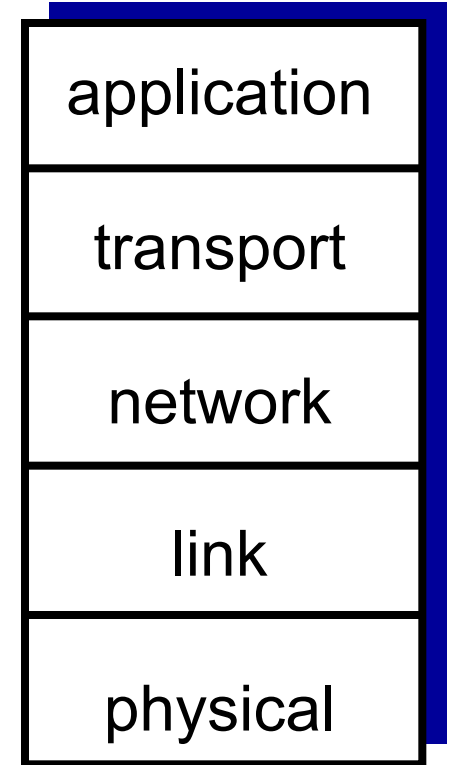
ISO/OSI reference model

- ❖ *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
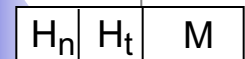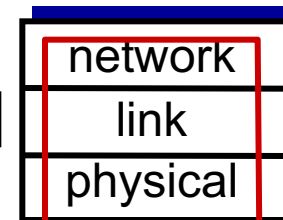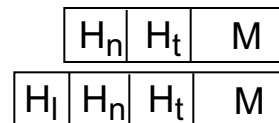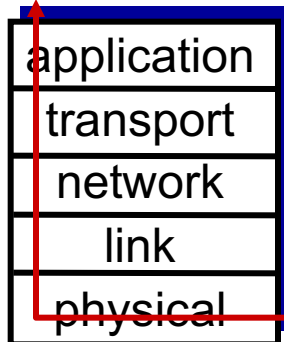 - needed?

application
presentation
session
transport
network
link
physical
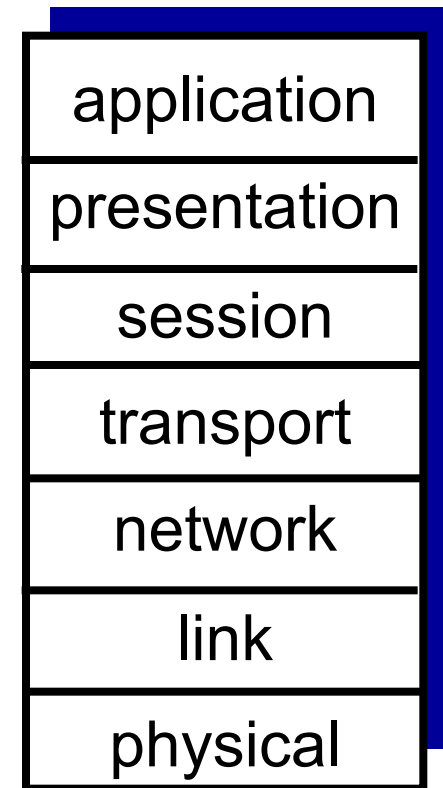
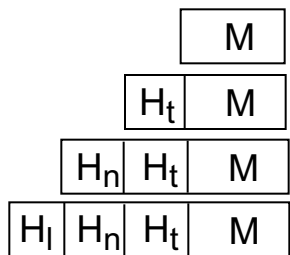# Encapsulation
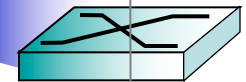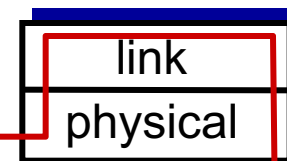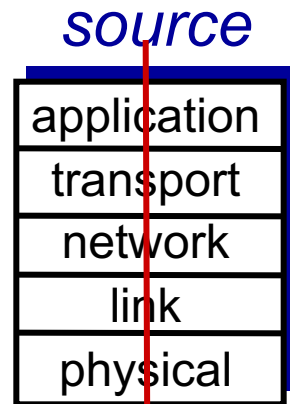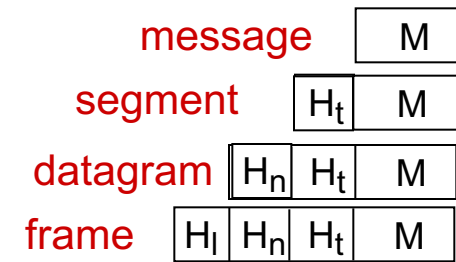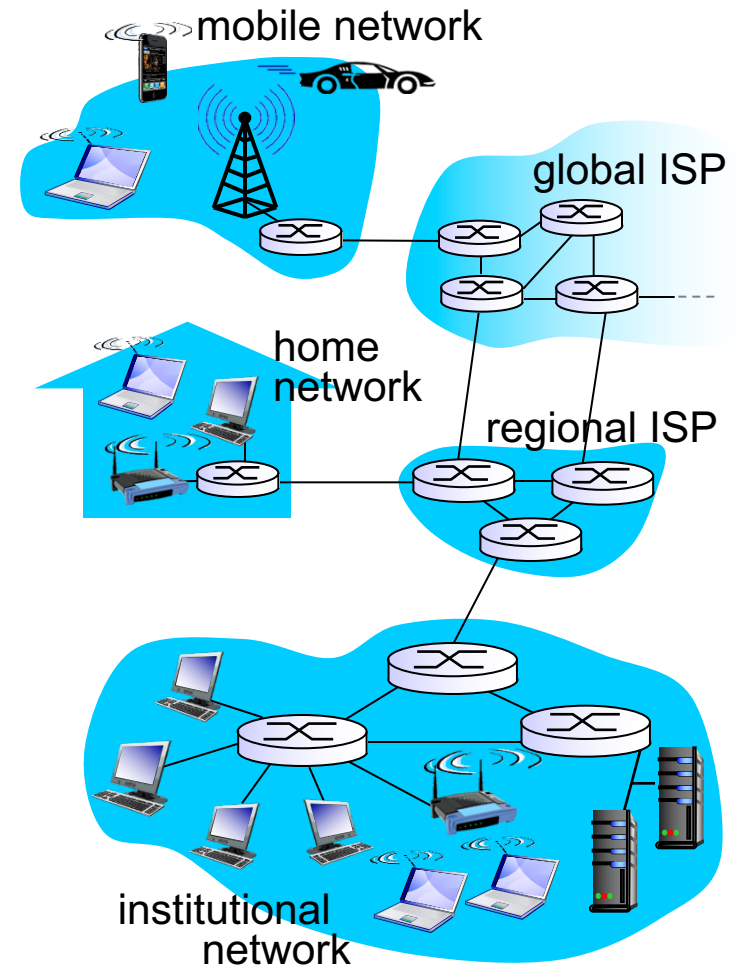
A closer look at network structure:

- ❖ *network edge:*
  - ▪ hosts: clients and servers
  - ▪ servers often in data centers

- ❖ *access networks, physical media:* wired, wireless communication links

- ❖ *network core:*
  - ▪ interconnected routers
  - ▪ network of networks

mobile network

global ISP

home network

regional ISP
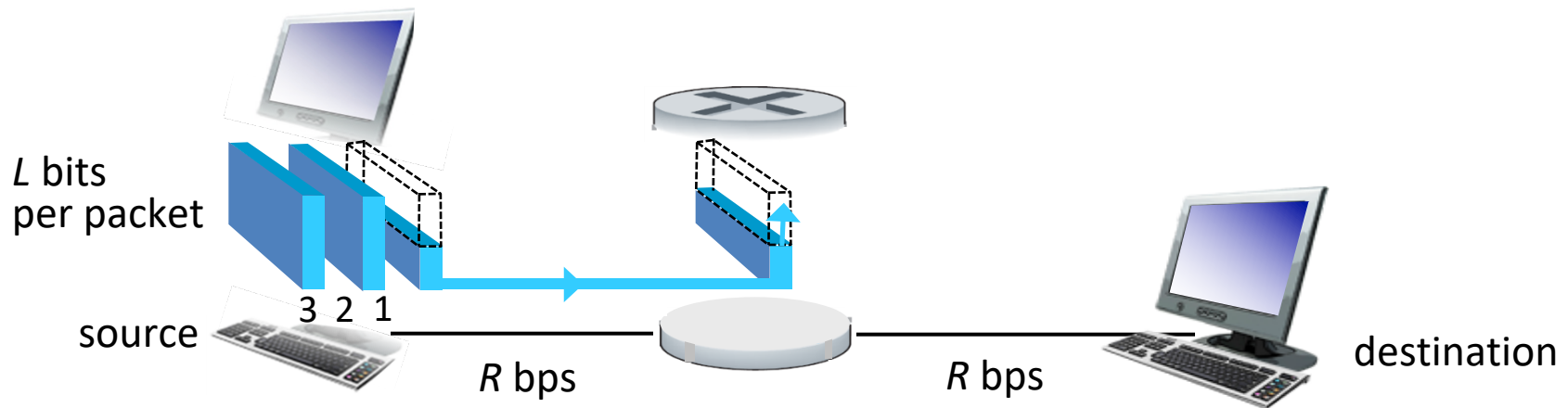
institutional network

Host: sends *packets* of data

host sending function:

❖ takes application message

❖ breaks into smaller chunks, known as *packets*, of length *L* bits

❖ transmits packet into access network at *transmission rate R*

  ▪ If this is max link transmission rate, then link *capacity*

two packets, *L* bits each

2 1

host

R: link transmission rate
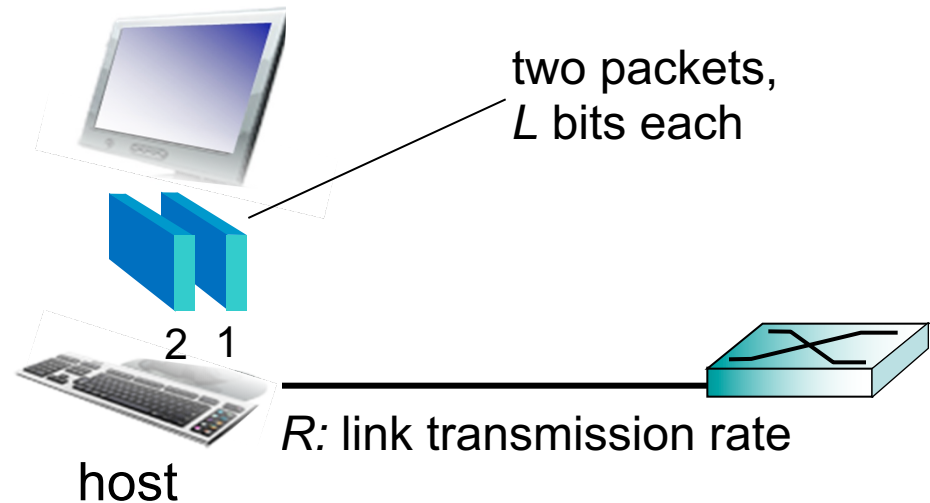
$$\begin{array}{c}\text{packet} \\ \text{transmission} \\ \text{delay}\end{array} = \begin{array}{c}\text{time needed to} \\ \text{transmit } L\text{-bit} \\ \text{packet into link}\end{array} = \dfrac{L \text{ (bits)}}{R \text{ (bits/sec)}}$$

Packet-switching: store-and-forward

L bits per packet

3 2 1

source

*R* bps   *R* bps

destination

❖ 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
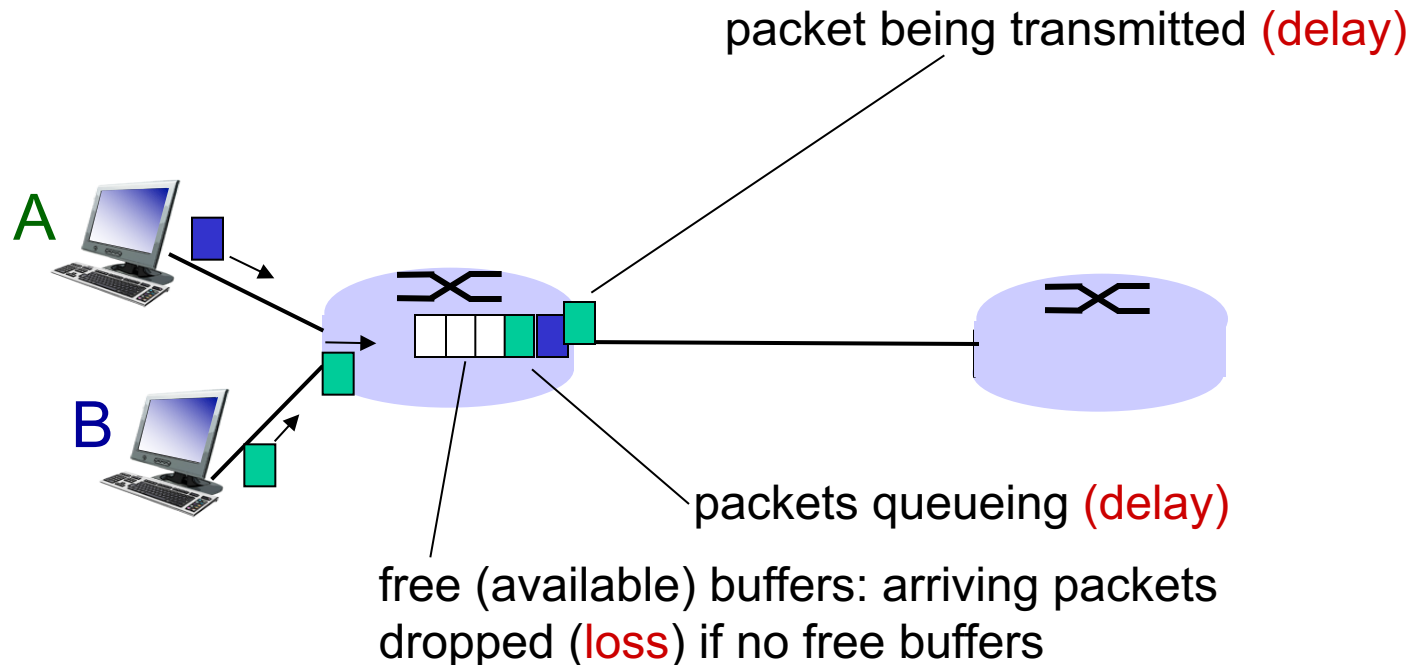

queue of packets
waiting for output link
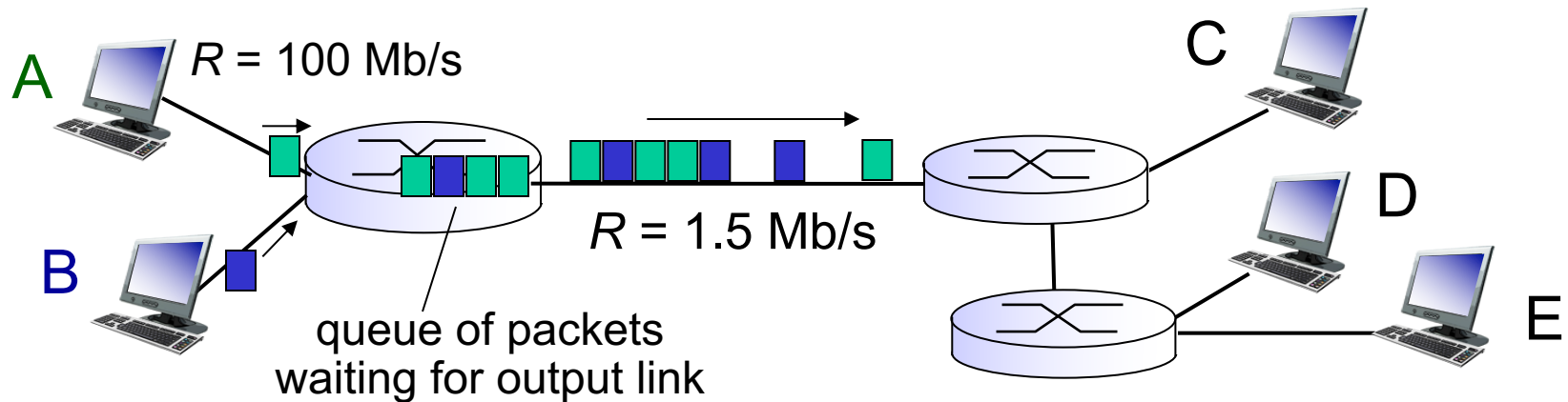
queuing and loss:

❖ 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
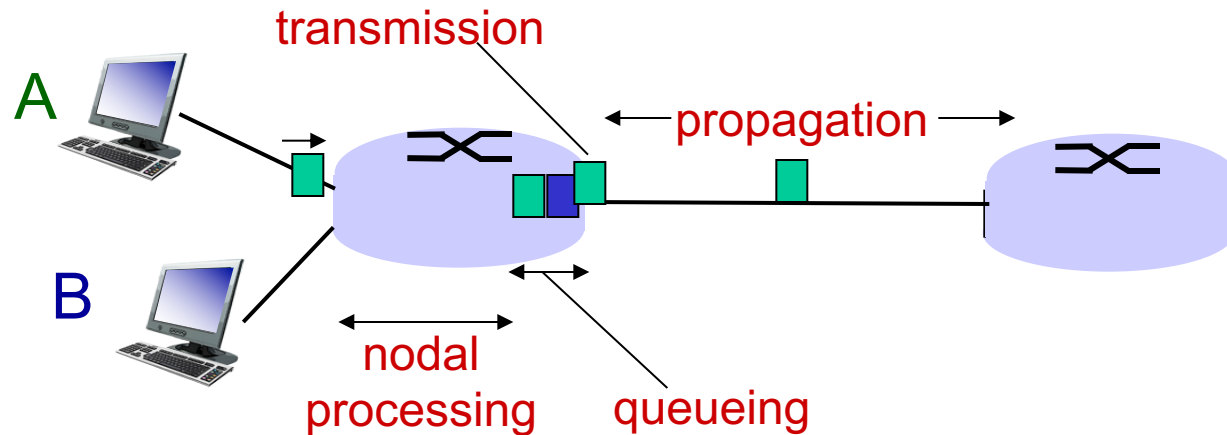- packets can be dropped (lost) if memory (buffer) fills up

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

packet being transmitted (delay)

A

B

packets queueing (delay)

free (available) buffers: arriving packets dropped (loss) if no free buffers

Four sources of packet delay

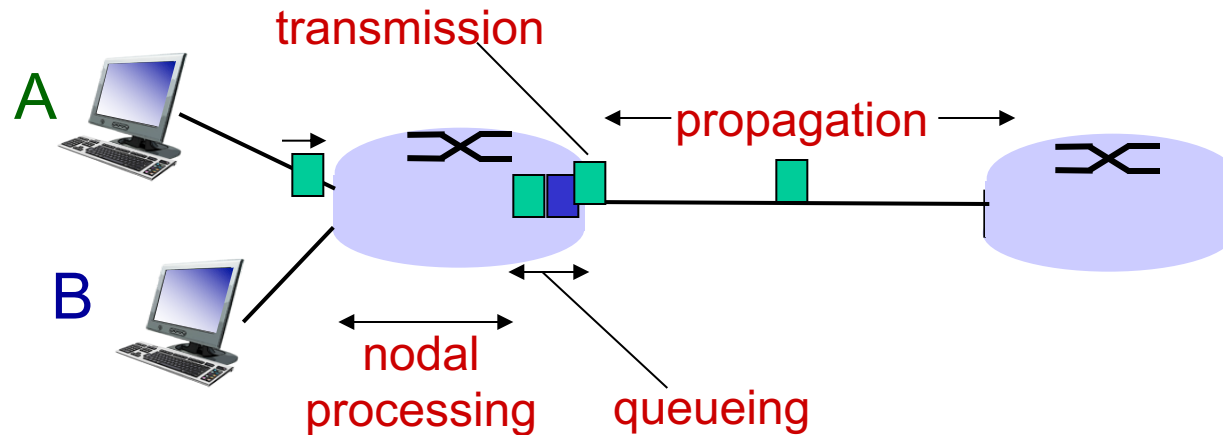$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

d_{proc}: nodal processing
- 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

$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$
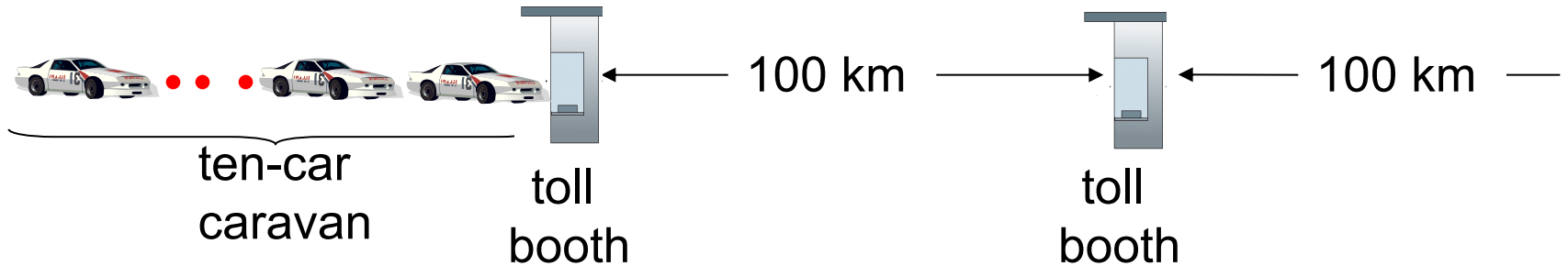
d_{trans}: transmission delay:
- L: packet length (bits)
- R: link *bandwidth (bps)*
- $d_{trans} = L/R$

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

d_{trans} and d_{prop}
very different

Caravan analogy

ten-car caravan

toll booth

100 km

toll booth

100 km

- ❖ cars "propagate" at 100 km/hr
- ❖ toll booth takes 12 sec to service car (bit transmission time)
- ❖ car~bit; caravan ~ packet
- ❖ *Q: How long until caravan is lined up before 2nd toll booth?*

- ■ time to "push" entire caravan through toll booth onto highway = 12*10 = 120 sec
- ■ time for last car to propagate from 1st to 2nd toll both: 100km/(100km/hr)= 1 hr
- ■ *A: 62 minutes*

Queueing delay

- *R:* link bandwidth (bps)
- *L:* packet length (bits)
- a: average packet arrival rate: average occupancy of a server or resource during a specified period of **time**

average queueing delay

traffic intensity = La/R

La/R

1

- *La/R ~ 0*: avg. queueing delay small
- *La/R -> 1*: avg. queueing delay large
- *La/R > 1*: more "work" arriving than can be serviced, average delay infinite!
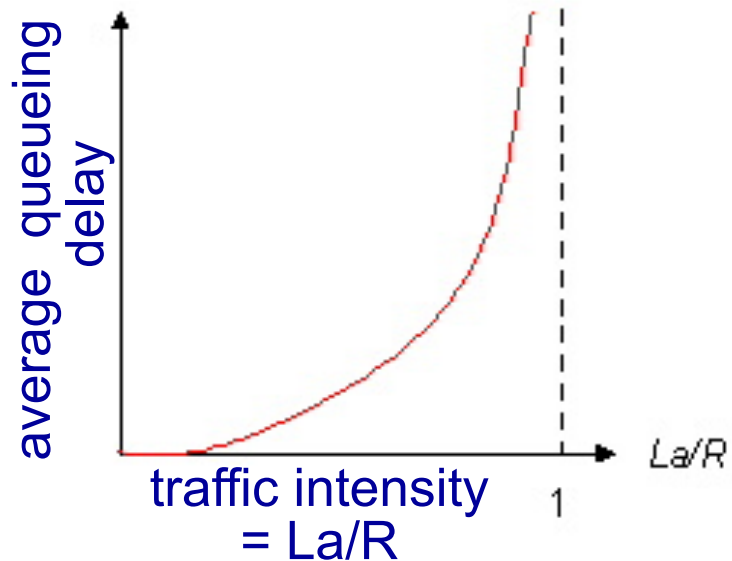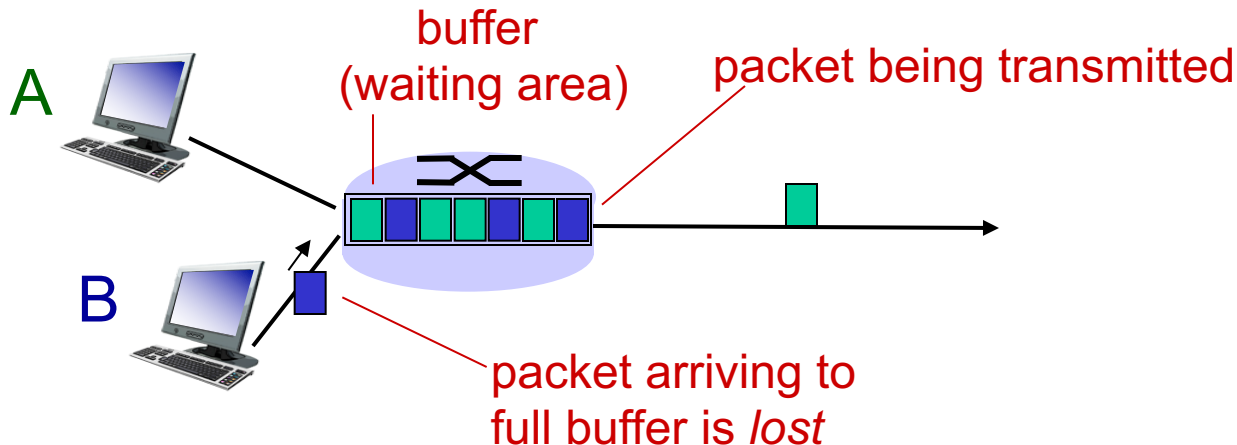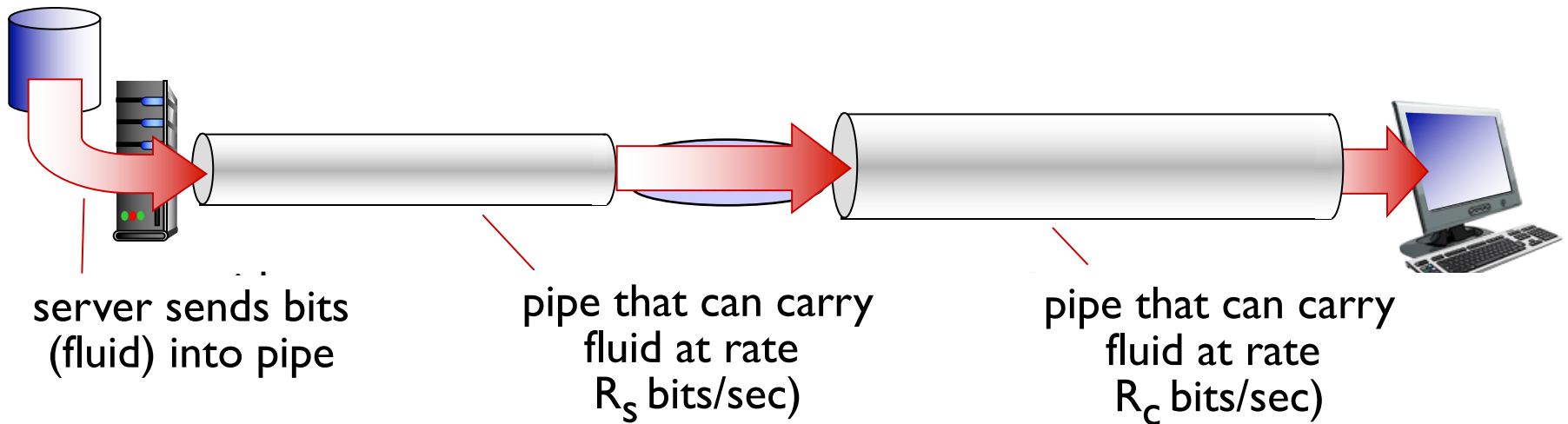

La/R ~ 0

La/R -> 1

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

A

buffer
(waiting area)

packet being transmitted

B

packet arriving to
full buffer is *lost*

* Check out the Java applet for an interactive animation on queuing and loss

Throughput

❖ *throughput:* rate (bits/time unit) at which bits transferred between sender/receiver

  ▪ *instantaneous:* rate at given point in time
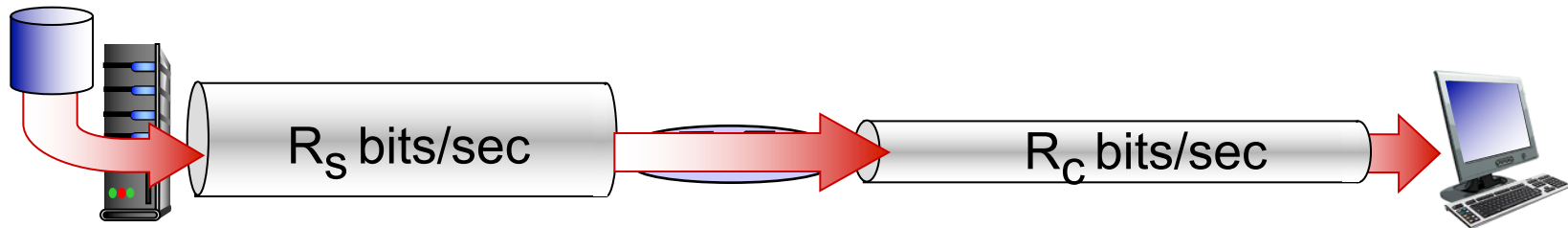
  ▪ *average:* rate over longer period of time

server sends bits
(fluid) into pipe

pipe that can carry
fluid at rate
R_s bits/sec)

pipe that can carry
fluid at rate
R_c bits/sec)

Throughput (more)

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

R_S bits/sec   R_C bits/sec

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

R_S bits/sec   R_C bits/sec
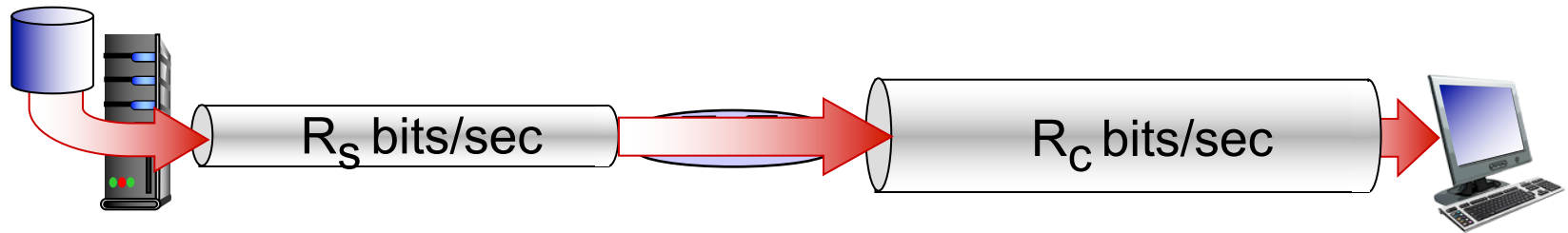
bottleneck link
link on end-end path that constrains end-end throughput