Lecture 1: Roadmap

1.1 What is the Internet?

1.2 Network Edge

1.3 Network Core

1.4 Delay, Loss and Throughput in Networks

1.5 Protocol Layers and Service Models

Kurose Textbook, Chapter 1
(Some slides are taken from the book)

"Fun" Internet-connected Devices

IP picture frame
http://www.ceiva.com/

Web-enabled toaster +
weather forecaster

Tweet-a-watt:
monitor energy use

Internet
refrigerator

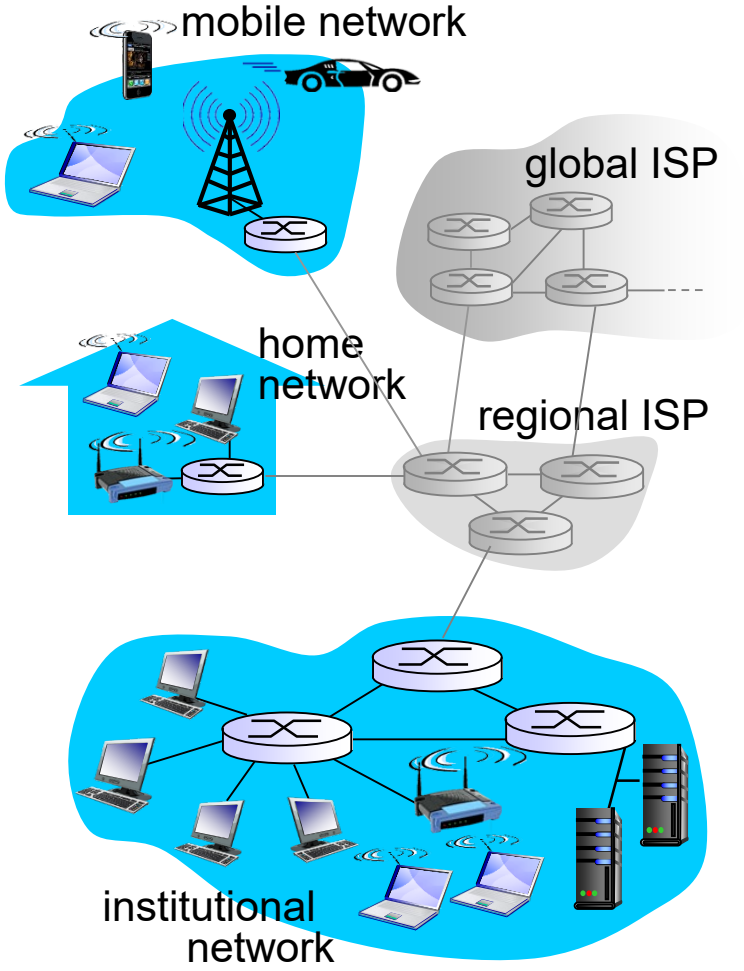
Slingbox: watch,
control cable TV remotely

sensorized,
bed
mattress

Internet phones

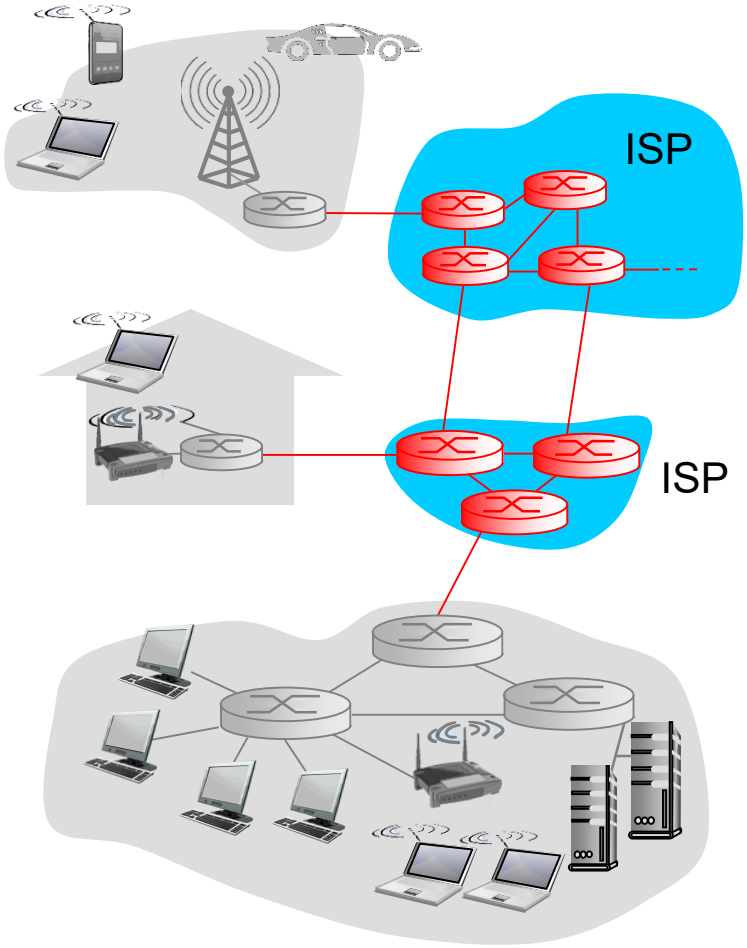
Network Edge (Access Network)

- Hosts access the Internet through *access network*.
  - Residential access networks
  - Institutional access networks (school, company)
  - Mobile access networks

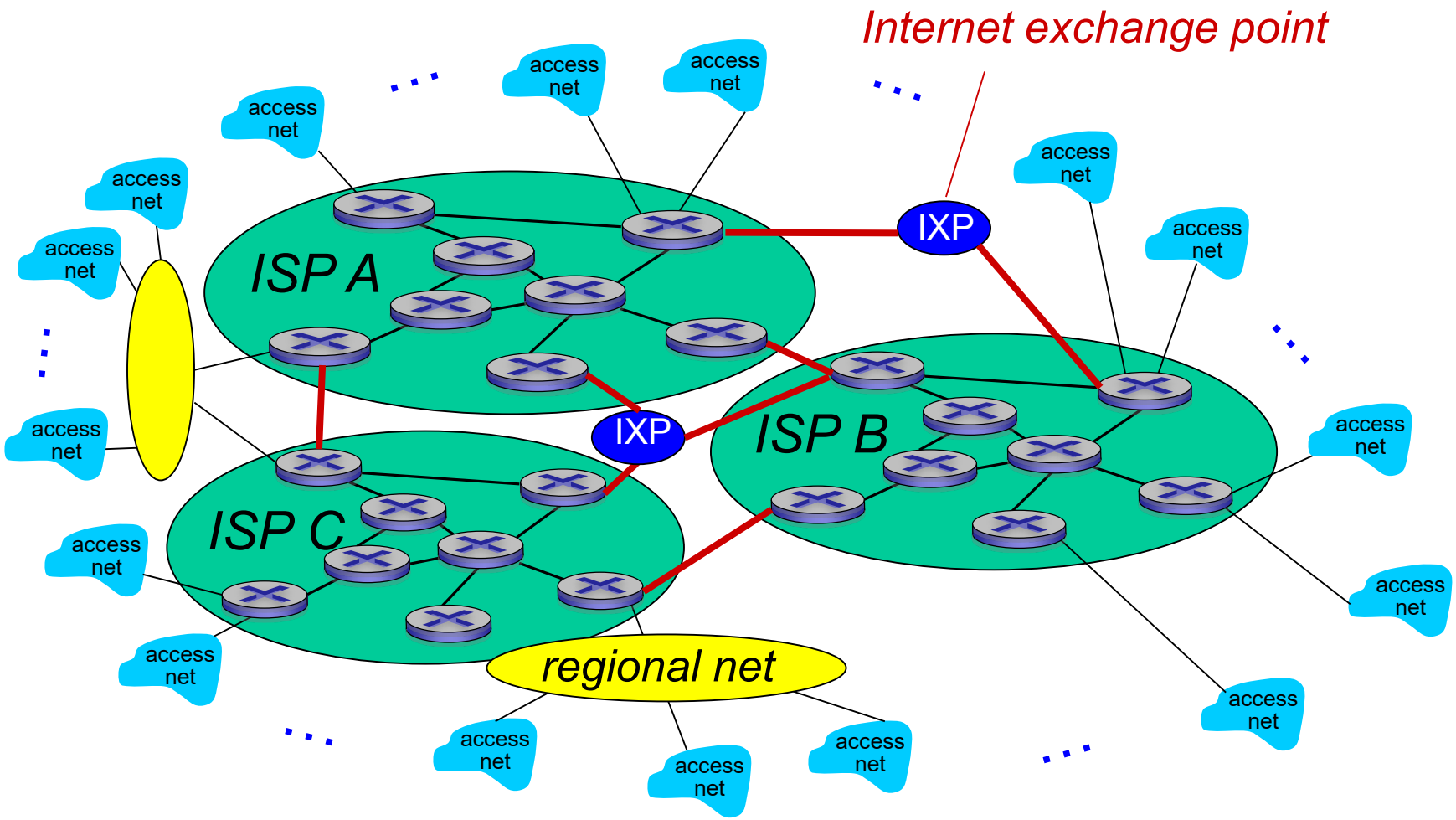


The Network Core

- A mesh of interconnected routers
- How is data transmitted through network?
  - Circuit switching: dedicated circuit per call
  - Packet switching: data sent thru net in discrete “chunks”



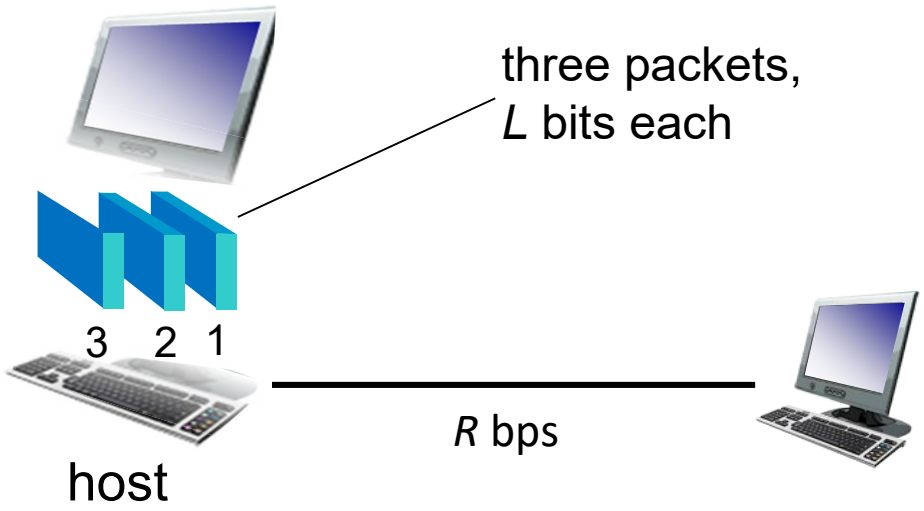
Internet Structure: Network of Networks



Packet Switching

Host sending function:

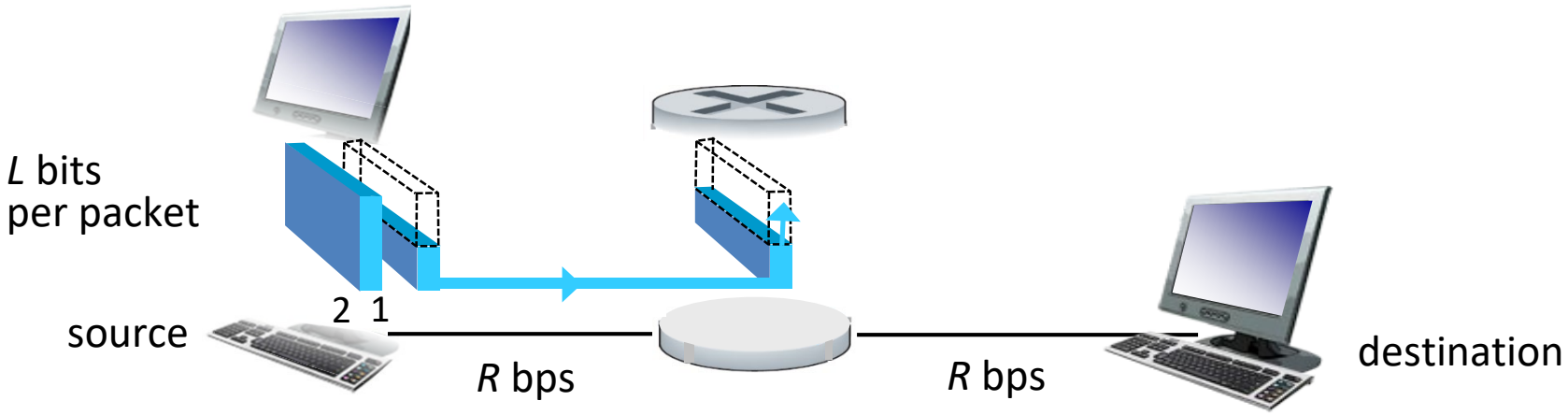
- breaks application message into smaller chunks, known as *packets*, of length *L* bits
- transmits packets onto the link at *transmission rate R*
  - link transmission rate is aka *link capacity* or *link bandwidth*



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

Packet-switching: store-and-forward

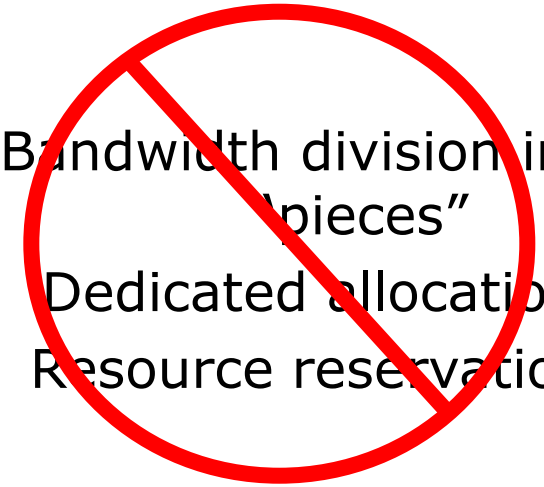
- Packets are passed from one router to the next, across links on path from source to destination.
- *Store and forward:* entire packet must arrive at a router before it can be transmitted on the next link.

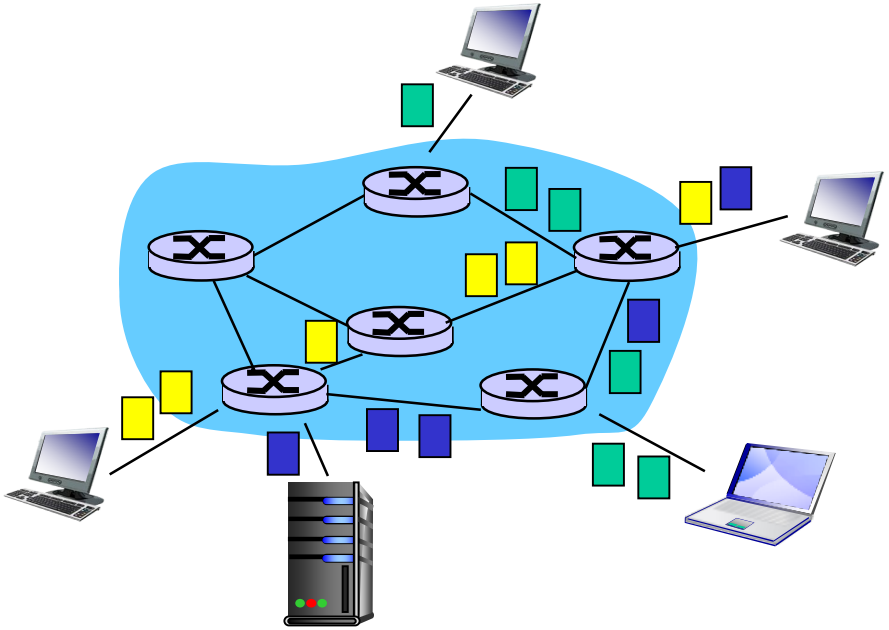


End-to-end delay = 2*L/R (assuming no other delay)

Summary: Packet Switching

- The Internet is a packet switching network
- User A, B … 's packets *share* network resources
- Resources are used on demand
- Excessive congestion is possible





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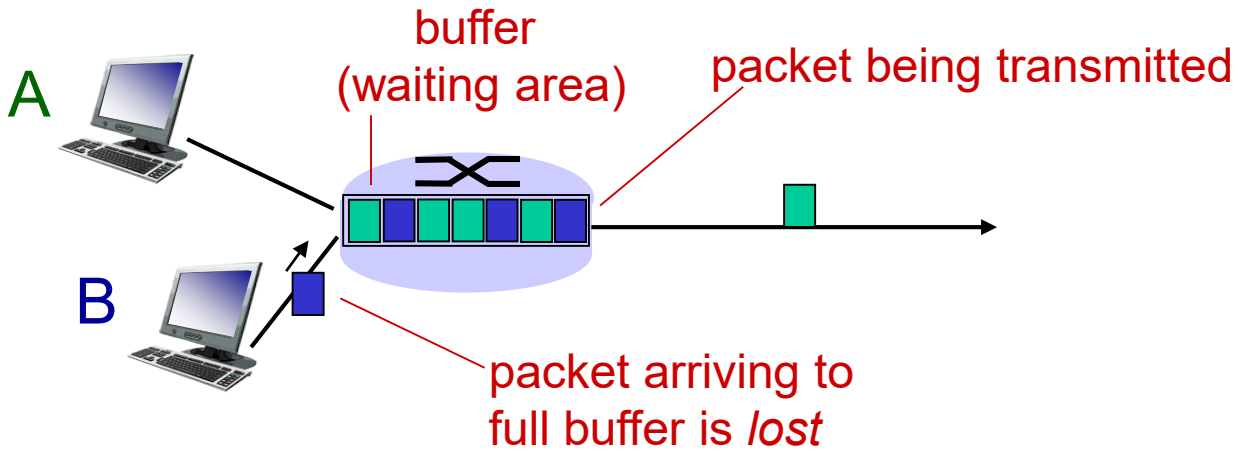
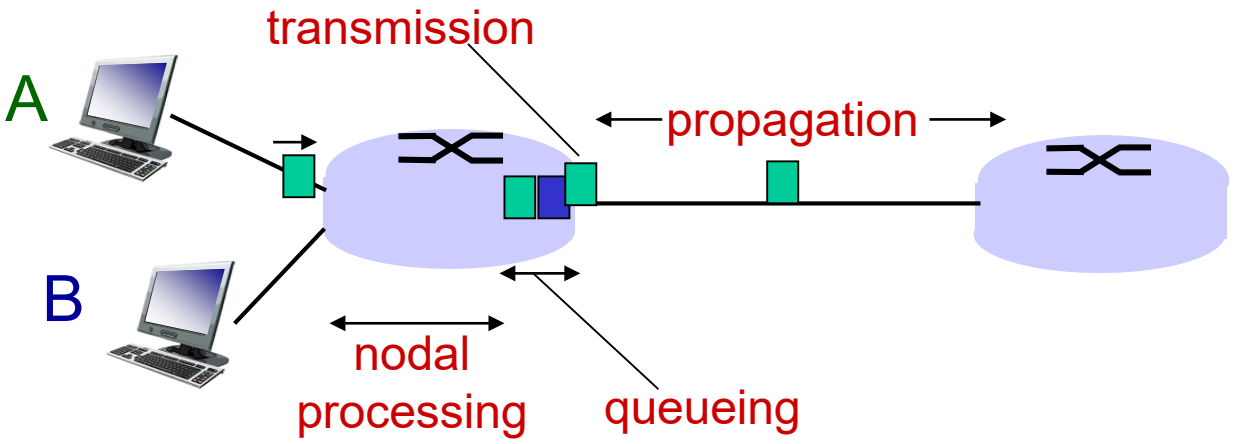
Packet Loss

- Queue (aka buffer) of a router has finite capacity.
- Packet arriving to full queue will be dropped (aka lost).



Four Sources of Packet Delay



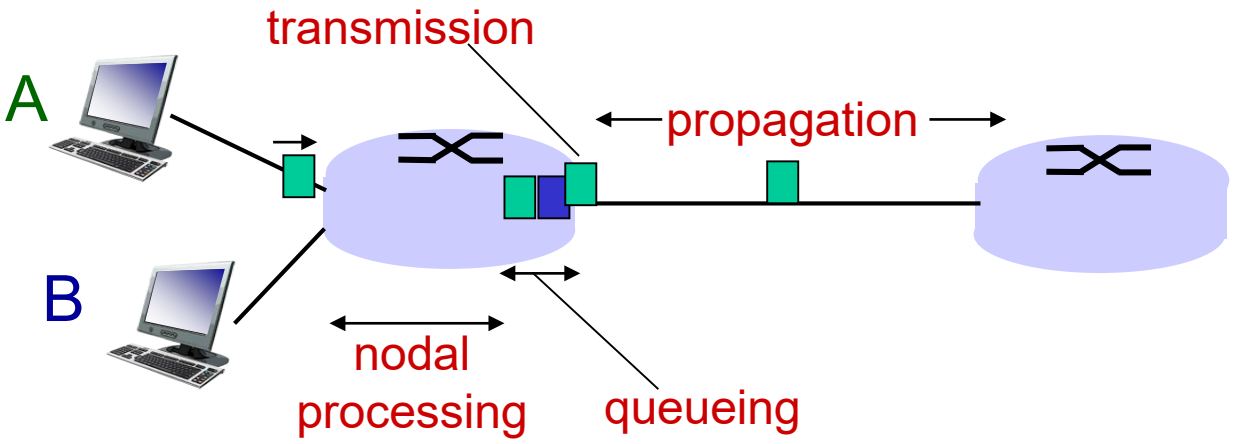
d_{proc}: nodal processing

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

d_{queue}: queuing delay

- time waiting in the queue for transmission
- depends on congestion level of router

Four Sources of Packet Delay



d_{trans}: transmission delay

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

d_{prop}: propagation delay

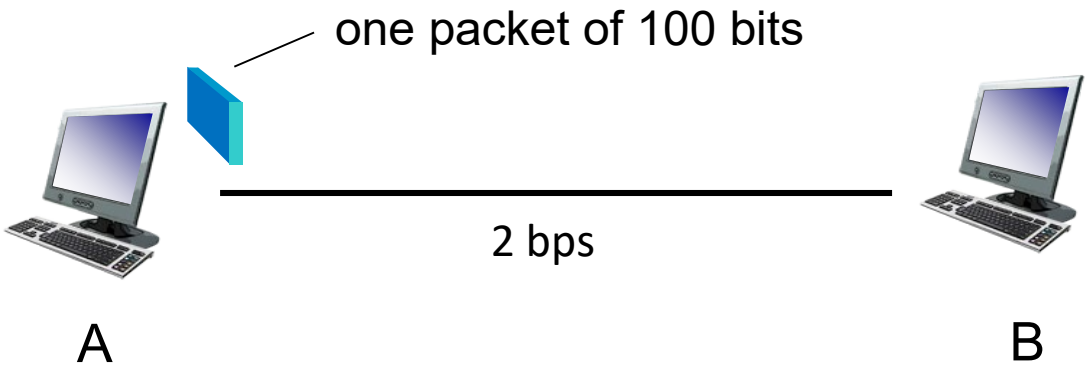
- *d*: length of physical link
- *s*: propagation speed in medium (~2×10^8 m/sec)
- $d_{prop} = d/s$

End-to-end Packet Delay

- End-to-end packet delay is the time taken for a packet to travel from source to destination. It consists of:
  - transmission delay
  - propagation delay
  - processing delay
  - queueing delay

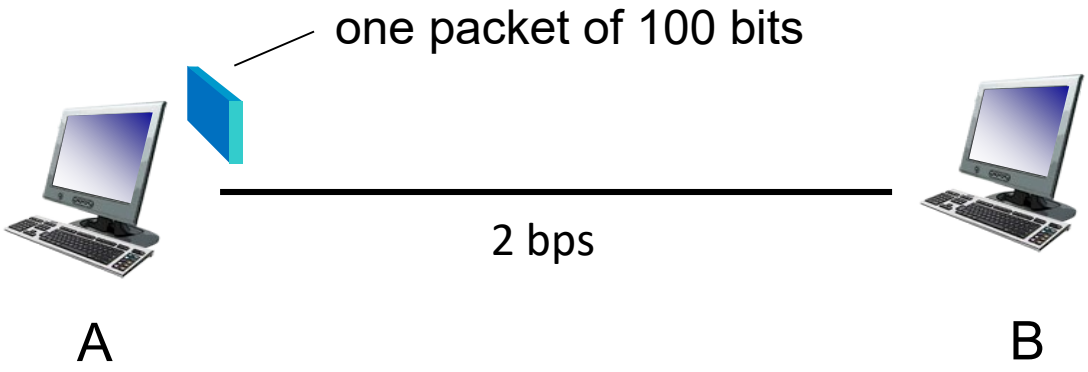
Q1

Hosts A and B are connected by a direct link of 2 bps. A sends a packet of 100 bits to B. Ignore other unmentioned delay, when will B receive the packet?



Q2

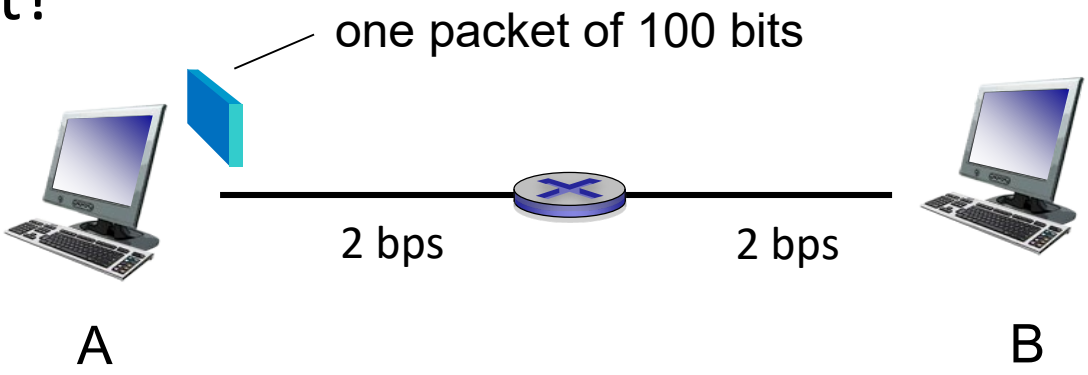
Hosts A and B are connected by a direct link of 2 bps. A sends a packet of 100 bits to B. The propagation delay over the link is 1s. Ignore other unmentioned delay, when will B receive the packet?



Q3

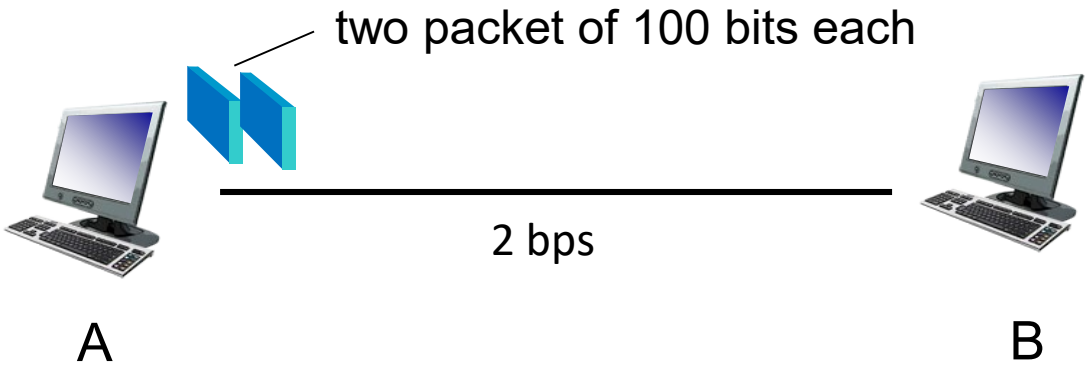
Hosts A and B are connected by a router in between. The bandwidth of each link is 2 bps. Propagation delay over each link is 0.5 s.

A sends a packet of 100 bits to B. When will B receive the packet?



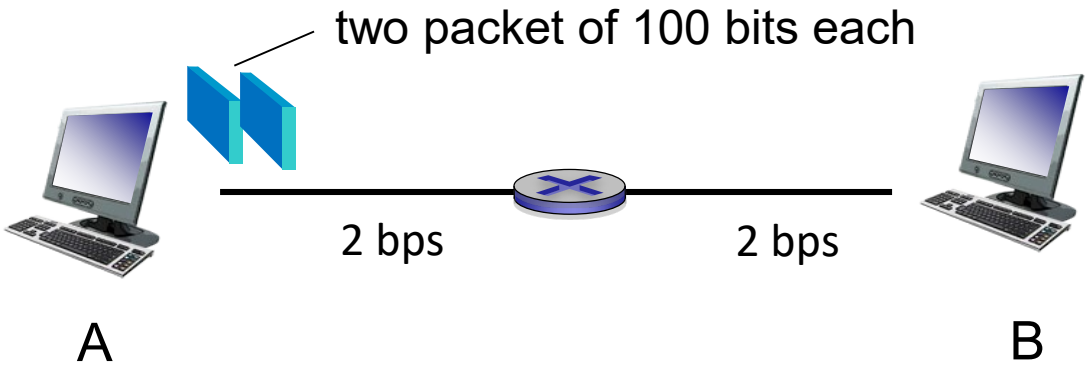
Q4

Hosts A and B are connected by a direct link of 2 bps. A sends two consecutive packets of 100 bits each to B. The propagation delay over the link is 1s. Ignore other unmentioned delay, when will B receive both packets?



Q5

Hosts A and B are connected by a router in between. The bandwidth of each link is 2 bps. Propagation delay over each link is 0.5 s. A sends two consecutive packets of 100 bits each to B. When will B receive two packets?



Q6

Hosts A and B are connected by a router in between. The bandwidth of each link is 2 bps. Propagation delay over each link is 0.5 s. A sends two consecutive packets of 100 bits each to B. What is the throughput of transmission?