ECCS-3631
Networks and Data Communications

Module 4
Delay and Loss in Networks

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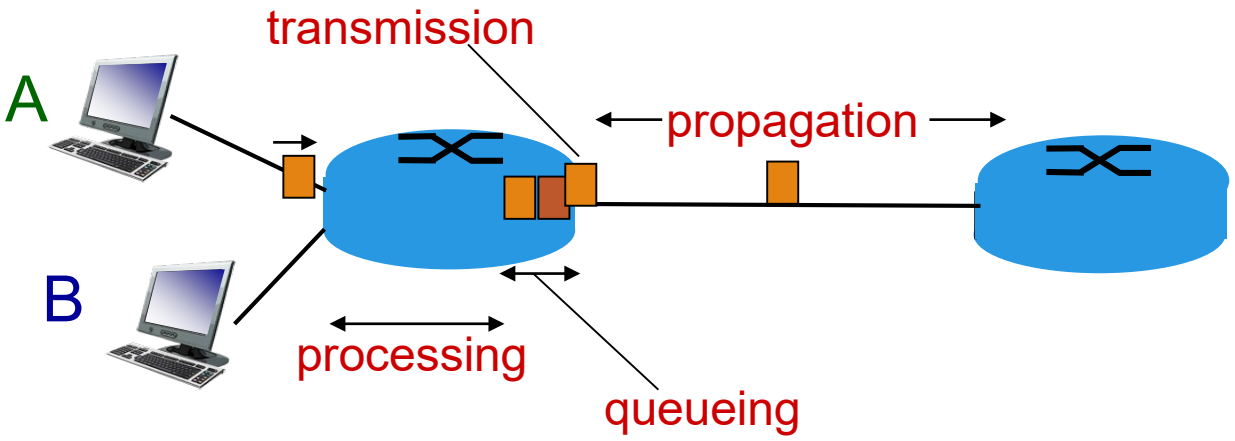
Delay in Packet-Switched Networks

- In a packet-switched network, a packet starts in a host (the source), passes through a series of routers, and ends its journey in another host (the destination).
- As the packet travels from one node (host or router) to the subsequent node (host or router) along this path, the packet suffers from several types of delays at each node along the path.
- The important of these delays are the processing delay, queuing delay, transmission delay, and propagation delay.
- All these delays accumulate to give a total nodal delay.

Four Sources of Packet Delay



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

d_{proc}: processing delay

- Time required to examine packet's header
- Time required to determine where to direct the packet
- Time required to check bit errors
- typically on the order of micro-seconds

d_{queue}: queueing delay

- time waiting at output link for transmission
- depends on the number of earlier-arriving packets
- depends on congestion level of router
- Typically on the order of micro-sec

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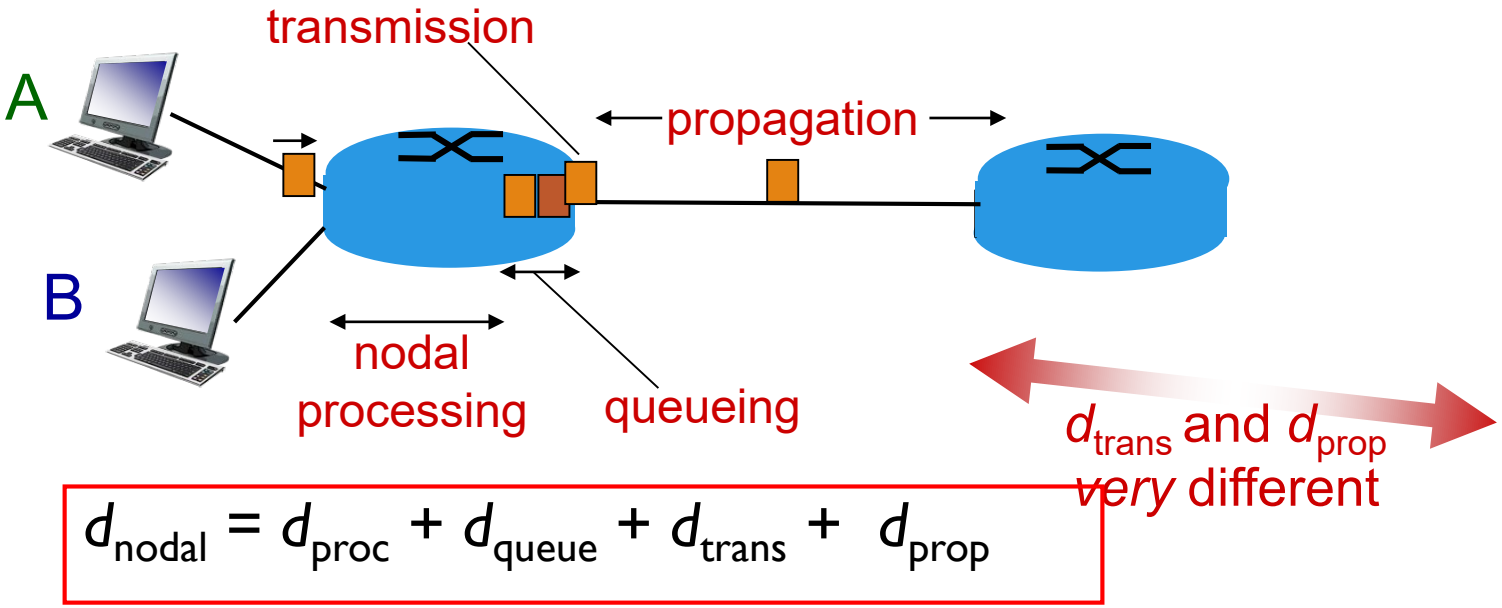


$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

d_{trans}: transmission delay:

- L: packet length (bits)
- R: link *bandwidth (bps)* (transmission rate of the link)
- $d_{trans} = L/R$
- Typically in micro-seconds

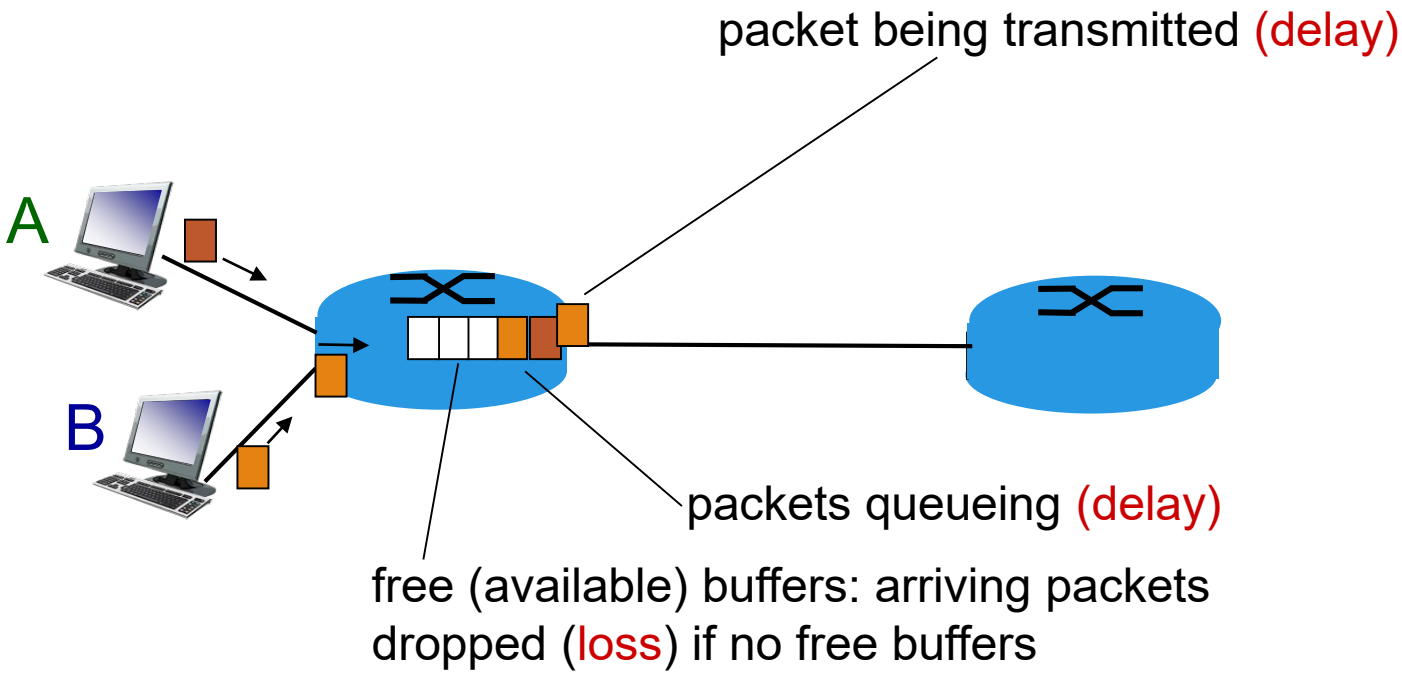
d_{prop}: propagation delay:

- Time required to propagate from the beginning of the link to the other end
- d: length of physical link
- s: propagation speed in medium (~2×10^8 m/sec)
- $d_{prop} = d/s$ (distance between two nodes divided by the propagation speed). Typically in m-sec

How do Packet Loss and Delay occur?

At router, when packet arrival rate exceeds output link capacity. Packet queue in the router buffer and wait for their turn to leave.

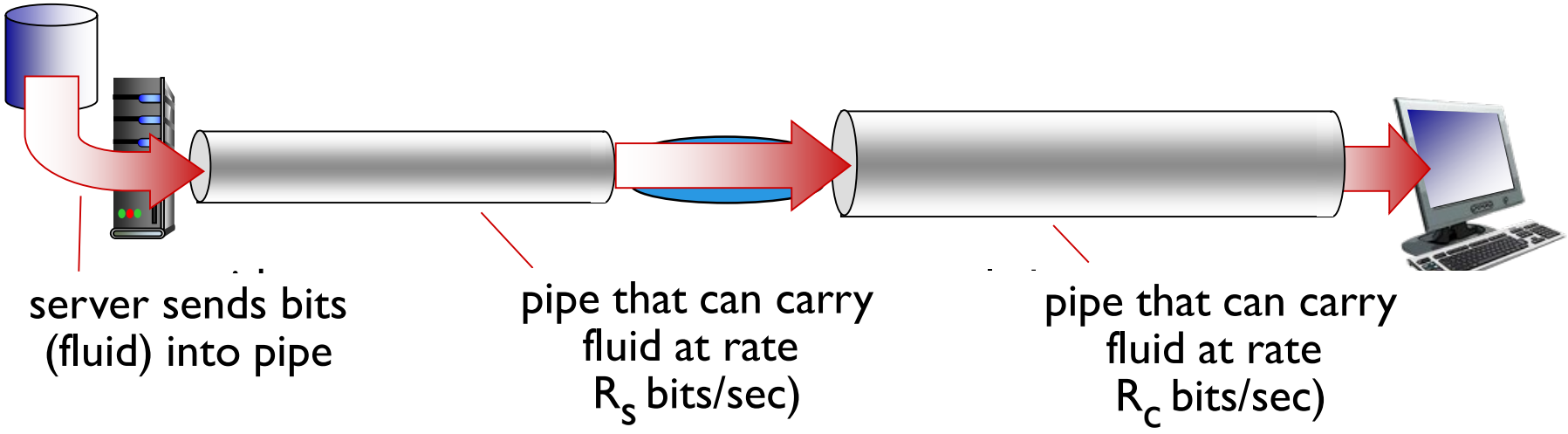
When more packet arrives and buffer has become full, then router discards new arriving packets.



Throughput

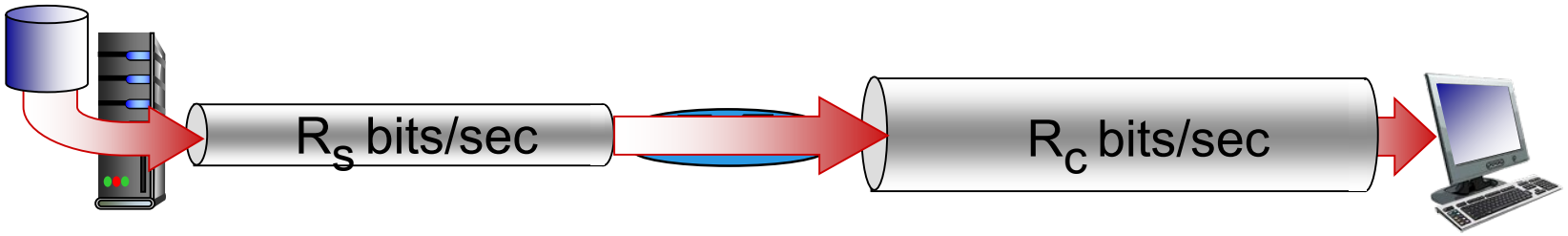
Instantaneous throughput at any instance of time is the rate (in bits/sec) at which bits transferred between sender/receiver

Average throughput of the file transfer is F/T bits/sec, where F is the file size in bits and T is time transfer to the destination,



Throughput

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



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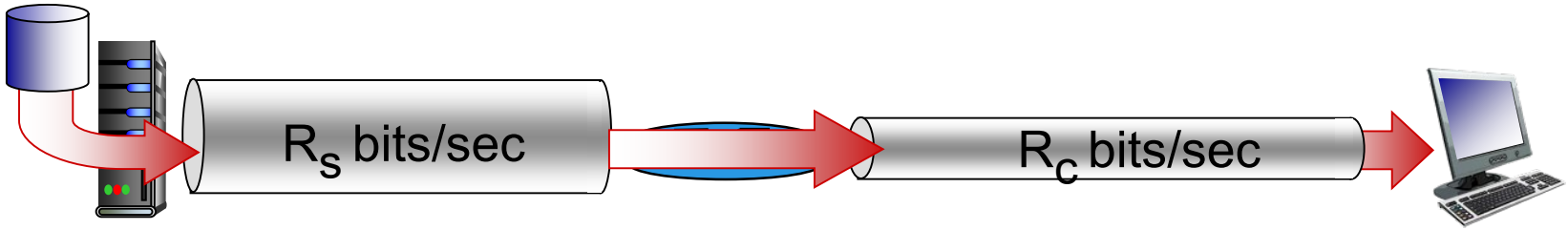

bottleneck link

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

Practice Problem 1

- How long does it take a packet of length 1,000 bytes to propagate over a link of distance 2,500 km, propagation speed 2.5×10^8 m/s, and transmission rate 2 Mbps. What is the total time of the packet to reach to the destination?

Practice Problem 2

- Suppose Host A wants to send a large file to Host B. The path from Host A to Host B has three links, of rates R1=500 kbps, R2=2 Mbps, and R3=1 Mbps.

(a) Assuming no other traffic in the network, what is the throughput for the file transfer?

(b) Suppose the file is 4 million bytes. Dividing the file size the by the throughput, roughly how long will it take to transfer the file to Host B?

(c) Repeat (a) and (b), but now with R2 reduced to 100 kbps.

Practice Problem 3

In this problem, we consider sending real-time voice from Host A to Host B over a packet-switched network (VoIP). Host A converts analog voice to a digital 64 kbps bit stream on the fly. Host A then groups the bits into 56-byte packets. There is one link between Hosts A and B; its transmission rate is 2 Mbps and its propagation delay is 10 msec. As soon as Host A gathers a packet, it sends it to Host B. As soon as Host B receives an entire packet, it converts the packet's bits to an analog signal. How much time elapses from the time a bit is created (from the original analog signal at Host A) until the bit is decoded (as part of the analog signal at Host B)?

Practice Problem 4

Suppose there is a 10 Mbps microwave link between a geostationary satellite and its base station on Earth. Every minute the satellite takes a digital photo and sends it to the base station. Assume a propagation speed of 2.4×10^8 m/s. What is the propagation delay of the link?