Bandwidth and Propagation Delay Exercises ANS

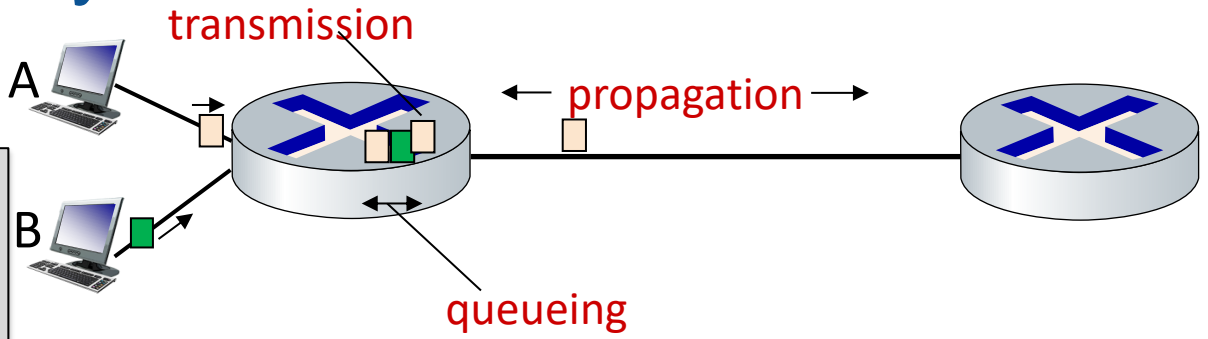
Lecture 3, Spring 2026

Links

- **Bandwidth and Propagation Delay**
- **Pipe Diagrams**
- **Overloaded Links**

IMPORTANT

Packet delay: four sources



The nodal processing delay (check bit errors, determine output link) is typically very small and can be ignored

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

d_q: queueing delay

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

d_{tx}: transmission delay:

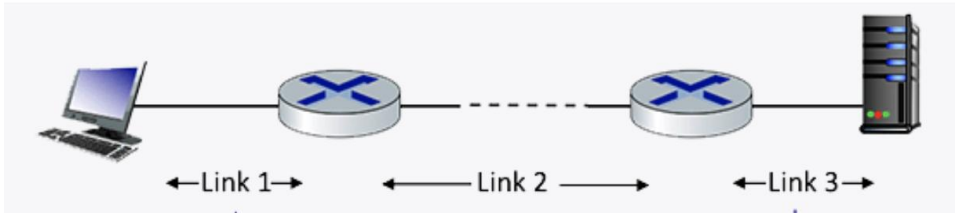
- L: packet length (bits)
- R: link *transmission rate (bps)*
- $d_{trans} = L/R$

d_{prop}: propagation delay:

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

Q1 End-to-end delay

- Consider the network shown in the figure, with three links, each with a transmission rate of 1 Mbps, and a propagation delay of 1 msec per link. Assume the length of a packet is 1000 bits.
- What is the end-end delay of a packet from when it first begins transmission on link 1, until is it received in full by the server at the end of link 3. Assume that queueing delays are zero.



Q2 End-to-end delay

- Consider the scenario shown in Figure 1: a server is connected to a router by a 100Mbps link with a 50ms propagation delay. This router is connected to two other routers, each over a 50Mbps link with a 200ms propagation delay. A 1Gbps link connects each host to each of these routers with 0 propagation delay. All packets in the network have size of 20,000 bits.
- What is the end-to-end delay (in ms) from when a packet is transmitted by the server to when it is received by the client? Assume there's no queuing delay at the routers.

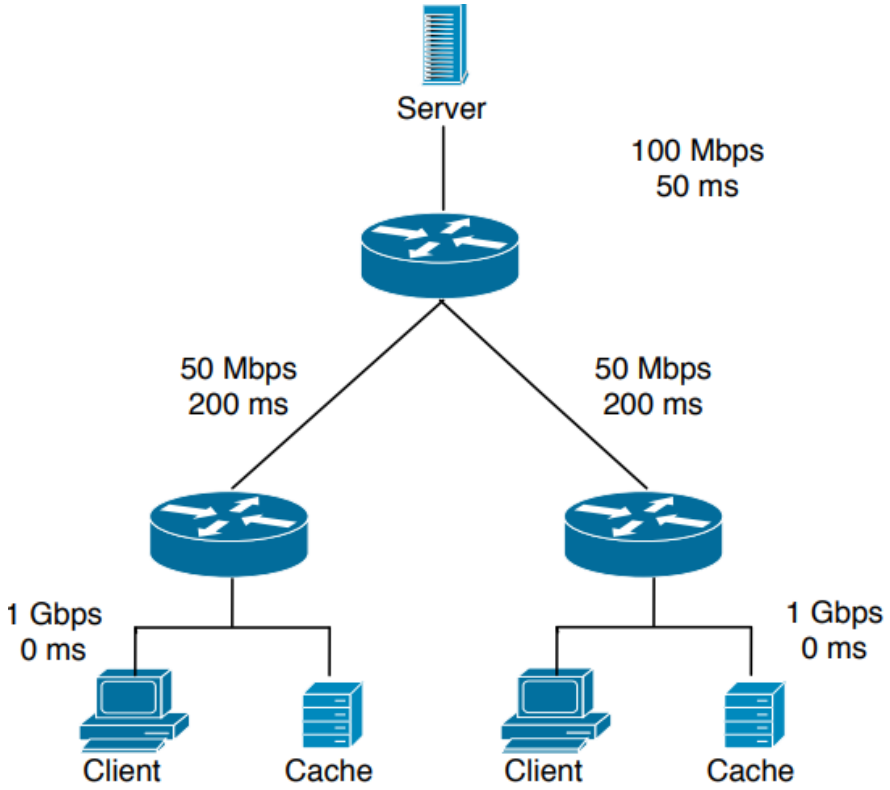


Figure 1

Q3 End-to-end delay

- Consider a 100 Mbps link between an earth station (sender) and a satellite (receiver) at an altitude of 2100 km. The signal propagates at a speed of 3×10^8 m/s. Calculate the time taken (in ms) for the receiver to receive a packet of 1000 bytes transmitted by the sender. (There is no router so there is no queuing delay.)

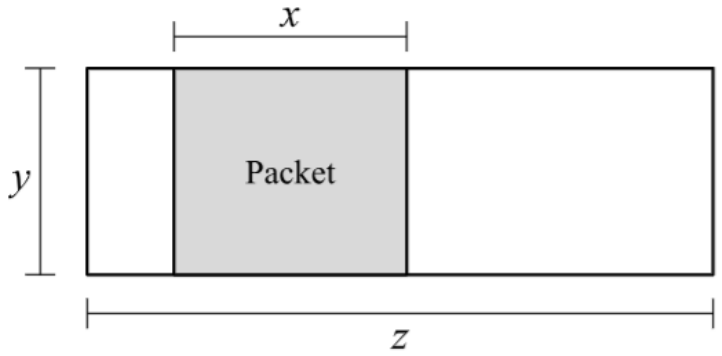
Q4 End-to-end delay

- Consider two computers X and Y connected via a single link of bandwidth 512 Gbps. Suppose that both hosts are separated by distance M meters, and the propagation delay along the link is 2×10^9 meters/sec. Computer X has to send a packet of size 1 Kbyte to computer Y. What will be the distance M such that the propagation delay is equal to the transmission delay?

Q5 Transmission delay

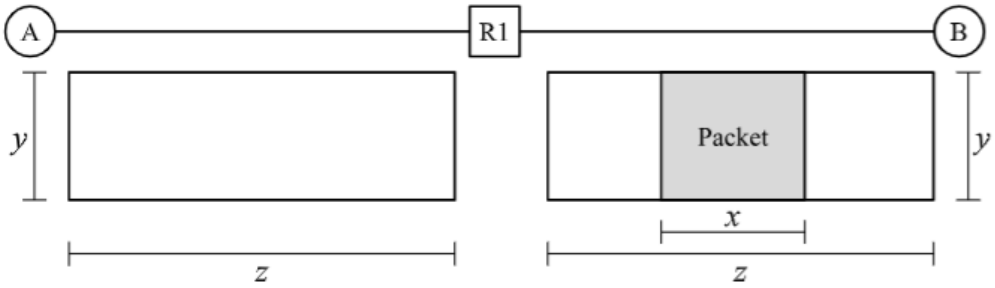
- 1. Calculate transmission delay for message size $L = 8000$bits, network bandwidth $B = 8000$bits/sec
- ANS:
- 2. Calculate transmission delay for message size $L = 1$ Kbytes, network bandwidth $B = 8$ *Kbps*
- ANS:

Q5.1 Pipe Diagram



- Consider the pipe diagram, with a single packet in the p
- 1) What is the size of this packet?
- 2) How long does it take to send a packet of the same size as the packet shown?(Count from the time the first byte is sent, to the time the last byte is received.)
- 3) How long does it take to send 7 packets, all of the same size as the packet shown?(Count from the time the first byte of the first packet is sent, to the time the last byte of the last packet is received.)
- 4) What is the maximum number of packets that could be in the process of being sent alongthis link, at any given moment?Don't worry about fractions and rounding (e.g. assume x, y, and z are defined such that all answerchoices are integers).

Q5.2 Pipe Diagram



- Now, consider the network topology with a Router R1, which has an infinite-size queue, and R1 continually processes packets in its queue in FIFO order. R1 can only start transmitting a packet once it has received the entire packet. All packets are the same size as the packet shown in the diagram in Q5.1. A wants to send a packet to B. No other packets are being sent along the links (i.e. suppose the packet in the diagram is not there).In the next two subparts, select how long it takes to send the packet from A to B. Count from the time the first byte of the packet is sent at A, to the time the last byte of the packet is received at B.
- 5) In this subpart, suppose R1 has 1 other packet in its queue when A sends the packet. How long does it take to send a single packet from A to B?
- 6) In this subpart, suppose R1 has 20 other packets in its queue when A sends the packet. How long does it take to send a single packet from A to B? Assume that the queue at R1 is notempty when this packet arrives at R1.
- 7) What is the maximum number of packets that can be queued at R1, such that when thelast byte of the A-to-B packet reaches R1, there is no queue at R1? Don't worry about fractions and rounding (e.g. assume x, y, and z are defined such that all results of division are integers.)