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1. Consider two nodes A and B directly connected to each other over a link that has the transmission rate of 1 Mbps. The propagation delay between the two nodes is 5ms. Now assume at time t = 0, 300 packets arrive simultaneously at node A and all of them have to be sent to node B (one by one). Assume that at t = 0, there were no packets in the queue at node A, and node A has a buffer that is large enough to hold all 300 packets. Ignore the processing delay at both nodes. Assume that the size of each packet is 5000 bytes. Answer the following questions, and make sure to show your work.

1. Consider the 200th packet. How much time does the packet have to wait in the queue at node A before it can be transmitted? //
2. By the time the 200th packet is completely transmitted, how many packets are already received by node B? //
3. How much time will it take before the 300th packet is completely received at node B? //
4. .

2. Let’s consider two computers (A and B) are connected via a single link of rate R bps. Also, assume that the two computers are separated by m meters and the propagation speed along the link is s meters/sec. Host A is to send a packet of size L bits to Host B.

1. Express the propagation delay, dprop , in terms of m and s.
2. Determine the transmission time of the packet, dtrans , in terms of L and R.
3. Ignoring nodal processing and queuing delays, obtain an expression for the end-to-end delay.
4. Suppose Host A begins to transmit the packet at time t=0. At time t= dtrans , where is the last bit of the packet?
5. Suppose dprop is greater than dtrans . At time t=dtranst , where is the first bit of the packet?
6. Suppose dprop is less than dtrans . At time t=dtrans , where is the first bit of the packet?
7. Suppose s=2.5x10^8, L=120 bits, and R=56 kbps. Find the distance m so that dprop equals dtrans.

3. A packet switch receives a packet and determines the outbound link to which the packet should be forwarded. When the packet arrives, one other packet is halfway done being transmitted on this outbound link and four other packets are waiting to be transmitted. Packets are transmitted in order of arrival. Suppose all packets are 1,500 bytes and the link rate is 2 Mbps.

1. What is the queuing delay for the packet?
2. More generally, what is the queuing delay when all packets have length L, the transmission rate is R, x bits of the currently-being-transmitted packet have been transmitted, and n packets are already in the queue?

4. Take a look at the following (fake) traceroute data. For simplicity, let’s assume that queueing delay and processing delay at all nodes is 0. The network looks like

l1 l2 l3

A--------------------R1-----------------------R2--------------------B

1000km 2000km 3000km

1 R1 12ms 12ms 12ms

2 R2 36ms 36ms 36ms

3 B 76ms 76ms 76ms

Assuming propagation speed on all links is 2.5x10^8 m/s and the length of the traceroute packets (requests and responses) is 50 bytes, what is the transmission rate of all links (A-R1, R1-R2, R2-B)? Remember the delay values reported by traceroute for each hop are round-trip times.