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1. [20pt] Consider two nodes A and B directly connected to each other over a link that has a transmission rate of 200 Kbps. The propagation delay between the two nodes is 5ms. Now assume at time t = 0, 400 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 400 packets. Ignore the processing delay at both nodes. Assume that the size of each packet is 2000 bytes. Answer the following questions, and make sure to show your work.
   a. Consider the 300th packet. How much time does the packet have to wait in the queue at node A before it can be transmitted?
   b. By the time the 300th packet is completely transmitted, how many packets are already received by node B?
   c. How much time will it take before the 400th packet is completely received at node B?

$D_{nodal} = D_{tran} + D_{proc} + D_{queue} + D_{prop}$

2000 bytes = 2Kb/packet

$D_{trans} = \frac{\text{size of packet}}{\text{transmission rate}} = \frac{2\text{Kb/p}}{200\text{Kbps}} = 1\times10^{-2}\text{ sec}$

$D_{prop} = 5\text{ms}$

a. $299 \times D_{trans} = 299 \times 1\text{ms} = 299\text{ms}$

b. time to transfer: $300 \times D_{trans} = 300\text{ms}$

in 300ms, no. of packets = $300\text{ms} / D_{prop}$

$= 300\text{ms} / 5\text{ms/packet}$

$= 60\text{ packets}$

c. $T_{total} = T_{transmission} + 400 \times D_{prop}$

$= 1\text{ms} + 400 \times 5\text{ms}$

$= 2001\text{ms}$

2. [10pt] 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.
   a. What is the queuing delay for the packet?
   b. 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?

$Delay_{queue} = \frac{\text{packets}\left(\text{Length of packet}\right) + \left(\text{Length of packet} - \frac{\text{Length}}{2}\right)}{\text{rate of transmission}}$

$= 4(1500) + \left(1500 - \frac{1500}{2}\right) = 6750$

$= 6750 \times 2\times4 = 54000$

$= 54000 / 2\times10^{6} = 0.054\text{ sec}$

3. [20pt] Take a look at the following (fake) traceroute data. For simplicity, let's assume that queueing delay and processing delay at all nodes are 0. The network looks like

1	R1	12ms	12ms	12ms
2	R2	36ms	36ms	36ms
3	B	76ms	76ms	76ms

Assuming the 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.

Propagation speed $= 2.5 \times 10^8$ m/s

$A \to B = \frac{1000\text{km}}{2.5 \times 10^8} = \frac{1}{2.5 \times 10^5} = 4$ ms

$RTT = 12\text{ms} = 2 \times 4\text{ms} + 2 \times T_{trans}$

$= 8 + 2T_{trans}$

$T_{trans} = 2$ ms

$R_1 \to R_2 = \frac{2000\text{km}}{2.5 \times 10^8} = 8$ ms

$RTT = 36\text{ms} = 2(8\text{ms}) + 2T_{trans}$

$= 16 + 2T_{trans}$

$T = 10$ ms

$R_2 \to B = \frac{3000\text{km}}{2.5 \times 10^8} = 12$ ms

$RTT = 76\text{ms} = 2(12) + 2(T)$

$= 24 + 2T$

$52 = 2T$

$T = 26$ ms