Principles of Computer Networks
Tutorial 2

Problem 1

This elementary problem begins to explore propagation delay and transmission delay, two central concepts in data networking. Consider two hosts, A and B, connected by a single link of rate R bps. Suppose that the two hosts are separated by m meters, and suppose the propagation speed along the link is s meters/sec. Host A is to send a packet of size L bits to Host B.

a) Ignoring processing and queuing delays, obtain an expression for the end-to-end delay.

b) Suppose d_{prop} is greater than d_{trans}. At time $t = d_{trans}$, where is the first bit of the packet?

c) Suppose $s = 2.5 * 10^8$, $L = 120$ bits, and $R = 56$ kbps. Find the distance m so that d_{prop} equals d_{trans}.

Problem 2

We will use the following discrete-time model to characterize packet arrivals. Suppose that time is divided into slots of length Δ_t and consider the following packet arrival process with rate λ:

1. The probability of one packet arriving during a time-slot is equal to $\lambda\Delta_t$.
2. The probability of zero arrival in the interval Δ_t is $1 - \lambda\Delta_t$.
3. Arrivals are memoryless: An arrival (event) in one time interval of length Δ_t is independent of events in previous intervals.

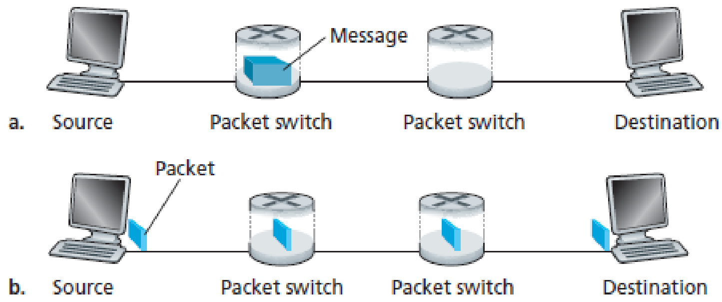
Using this model, answer the following questions.

a) Consider a time interval of length $k\Delta_t$. What is the probability that we have n arrivals in the time interval $[0, k\Delta_t]$ for $n = 0, ..., k$?

b) What is the distribution of the time between two successive packet arrivals (inter-arrival time)?

Problem 3

In modern packet-switched networks, including the Internet, the source host segments long, application-layer messages (for example, an image or a music file) into smaller packets and sends the packets into the network. The receiver then reassembles the packets back into the original message. We refer to this process as *message segmentation*. The following figure illustrates the end-to-end transport of a message without (a.) and with (b.) message segmentation.



Consider a message that is $8 * 10^6$ bits long that is to be sent from source to destination in the figure above. Suppose each link in the figure is 2 Mbps. Ignore propagation, queuing, and processing delays.

a) Consider sending the message from source to destination *without* message segmentation. How long does it take to move the message from the source host to the first packet switch? Keeping in mind that each switch uses store-and-forward packet switching, what is the total time to move the message from source host to destination host?

b) Now suppose that the message is segmented into 800 packets, with each packet being 10,000 bits long. How long does it take to move the first packet from source host to the first switch? When the first packet is being sent from the first switch to the second switch, the second packet is being sent from the source host to the first switch. At what time will the second packet be fully received at the first switch?

c) How long does it take to move the file from source host to destination host when message segmentation is used? Compare this result with your answer in part (a) and comment.

d) In addition to reducing delay, what are reasons to use message segmentation?

e) Discuss the drawbacks of message segmentation.

Problem 4

a) Suppose N packets arrive simultaneously to a link at which no packets are currently being transmitted or queued. Each packet is of length L and the link has transmission rate R. What is the average queuing delay for the N packets?

b) Now suppose that N such packets arrive to the link every LN/R seconds. What is the average queuing delay of a packet?