Principles of Computer Networks
Tutorial 2

Problem 1

a) $d_{end-to-end} = (m/s + L/R)$ seconds.

b) The first bit is in the link and has not reached Host B.

c)

$$m = \frac{L}{R}s = \frac{120}{56\times10^3}\left(2.5\times10^8\right) = 536\,\text{km}.$$

Problem 2

a) For $0 \le n \le k$, the probability that we have n arrivals in the time interval [0, $k\Delta_t$] is given

$$\binom{k}{n}(\lambda\Delta_t)^n(1-\lambda\Delta_t)^{k-n},$$

which corresponds to a binomial distribution.

b) Let T be the inter-arrival time, then we have that

$$P(T=t) = (\lambda\Delta_t)(1-\lambda\Delta_t)^{t-1}, \qquad t \ge 1,$$

i.e. the inter-arrival time is given by a geometric distribution.

Problem 3

a) Time to send message from source host to first packet switch = $\frac{8\times10^6}{2\times10^6}\sec = 4\sec$

With store-and-forward switching, the total time to move message from source host to destination host = $4\sec\times3\,hops = 12\sec$

b) Time to send 1st packet from source host to first packet switch = . $\frac{1\times10^4}{2\times10^6}\sec = 5\,m\sec$.

Time at which 2nd packet is received at the first switch = time at which 1st packet is received at the second switch = $2\times5m\sec = 10\,m\sec$

c) Time at which 1st packet is received at the destination host = $5\,m\sec \times 3\,hops = 15\,m\sec$. After this, every 5msec one packet will be received; thus time at which last (800th) packet is received = $15\,m\sec + 799 * 5m\sec = 4.01\sec$. It can be seen that delay in using message segmentation is significantly less (almost 1/3rd).

d)

i. Without message segmentation, if bit errors are not tolerated, if there is a single bit error, the whole message has to be retransmitted (rather than a single packet).

ii. Without message segmentation, huge packets (containing HD videos, for example) are sent into the network. Routers have to accommodate these huge packets. Smaller packets have to queue behind enormous packets and suffer unfair delays.

e)

i. Packets have to be put in sequence at the destination.

ii. Message segmentation results in many smaller packets. Since header size is usually the same for all packets regardless of their size, with message segmentation the total amount of header bytes is more.

Problem 4

a) The queuing delay is 0 for the first transmitted packet, *L/R* for the second transmitted packet, and generally, *(n-1)L/R* for the n^{th} transmitted packet. Thus, the average delay for the *N* packets is:

$$(L/R + 2L/R + ... + (N-1)L/R)/N$$
$$= L/(RN) * (1 + 2 + ... + (N-1))$$
$$= L/(RN) * N(N-1)/2$$
$$= LN(N-1)/(2RN)$$
$$= (N-1)L/(2R)$$

Note that here we used the well-known fact:

$$1 + 2 + ... + N = N(N+1)/2$$

b) It takes LN/R seconds to transmit the N packets. Thus, the buffer is empty when a each batch of N packets arrive. Thus, the average delay of a packet across all batches is the average delay within one batch, i.e., $(N-1)L/2R$.