The following are selected from the end of Chapter 1 problem set beginning at page 69 of the textbook. The problem numbers are shown in the parentheses.

1. (3 points) (P2) Equation 1.1 gives a formula for the end-to-end delay of sending one packet of length L over N links of transmission rate R. Generalize this formula for sending P such packets back-to-back over the N links:

2. (14 points) (P6) This elementary program 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. The hosts are capable of transmitting rate R bps. Suppose the two hosts are separated by m meters and the propagation speed along the link is s meters/second. Host A is to send a packet of size L bits to host B.

   (a) Express the propagation delay d_{prop} in terms of m and s

   (b) Determine the transmission time of the packet d_{trans} in terms of L and R

   (c) Ignoring processing and queueing delays, obtain an expression for the end-to-end delay

   (d) Suppose host A begins to transmit the packet at time $t = 0$. At time $t = d_{trans}$ where is the last bit of the packet?

   (e) Suppose $d_{prop} > d_{trans}$. At time d_{trans} where is the first bit of the packet?

   (f) Suppose $d_{prop} < d_{trans}$. At time d_{trans} where is the first bit of the packet?

   (g) Suppose $s = 2.5 \times 10^8$ m/sec, $L = 1500$ bytes $= 1500 \times 8$ bits, and $R = 10$Mbps. Find the distance m so that $d_{prop} = d_{trans}$.

3. (5 points) (P7) In this problem, we consider sending real-time voice from host A to B over packet-switched network (VoIP). Host A converts analog voice to a digital 64 kbps bit stream on the fly. Host A then groups the bits into 56-byte packets. There is one link between hosts A and B; its transmission rate is 10 Mbps and its propagation delay is 10 msec. As soon as Host A gathers a packet, it send it to Host B. As soon as host B receives a packet, it converts the packet bits to an analog signal.

   How much time elapses from the time a bit is created (from the original analog signal at host A) until the bit is decoded (as part of the analog signal at host B)?