Chapter 1

Problem 5

Tollbooths are 75 km apart, and the cars propagate at 100km/hr. A tollbooth services a car at a rate of one car every 12 seconds.

a) There are ten cars. It takes 120 seconds, or 2 minutes, for the first tollbooth to service the 10 cars. Each of these cars has a propagation delay of 45 minutes (travel 75 km) before arriving at the second tollbooth. Thus, all the cars are lined up before the second tollbooth after 47 minutes. The whole process repeats itself for traveling between the second and third tollbooths. It also takes 2 minutes for the third tollbooth to service the 10 cars. Thus the total delay is 96 minutes.

b) Delay between tollbooths is 8*12 seconds plus 45 minutes, i.e., 46 minutes and 36 seconds. The total delay is twice this amount plus 8*12 seconds, i.e., 94 minutes and 48 seconds.

Problem 10

The first end system requires $L/R_1$ to transmit the packet onto the first link; the packet propagates over the first link in $d_1/s_1$; the packet switch adds a processing delay of $d_{proc}$; after receiving the entire packet, the packet switch connecting the first and the second link requires $L/R_2$ to transmit the packet onto the second link; the packet propagates over the second link in $d_2/s_2$. Similarly, we can find the delay caused by the second switch and the third link: $L/R_3$, $d_{proc}$, and $d_3/s_3$.

Adding these five delays gives

$$d_{end-end} = L/R_1 + L/R_2 + L/R_3 + d_1/s_1 + d_2/s_2 + d_3/s_3 + d_{proc} + d_{proc}$$

To answer the second question, we simply plug the values into the equation to get $6 + 6 + 6 + 20 + 16 + 4 + 3 + 3 = 64$ msec.

Problem 31

a) Time to send message from source host to first packet switch = $\frac{8 \times 10^6}{2 \times 10^6}$ sec = 4 sec With store-and-forward switching, the total time to move message from source host to destination host = $4 \text{sec} \times 3 \text{ hops} = 12 \text{ sec}$

b) Time to send 1st packet from source host to first packet switch = $\frac{1 \times 10^4}{2 \times 10^6}$ 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 = $2 \times 5m \text{ sec} = 10 \text{ m sec}$

c) Time at which 1st packet is received at the destination host = $5 \text{ m sec} \times 3 \text{ hops} = 15 \text{ m sec}$ . After this, every 5msec one packet will be received; thus time at which last (800th) packet is
received = 15 m sec + 799 * 5 m 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.

Chapter 2

Problem 9

a) The time to transmit an object of size $L$ over a link or rate $R$ is $L/R$. The average time is the average size of the object divided by $R$:

$$
\Delta = (850,000 \text{ bits})/(15,000,000 \text{ bits/sec}) = .0567 \text{ sec}
$$

The traffic intensity on the link is given by $\beta\Delta = (16 \text{ requests/sec})(.0567 \text{ sec/request}) = 0.907$. Thus, the average access delay is $(.0567 \text{ sec})/(1 - .907) \approx .6 \text{ seconds}$. The total average response time is therefore $.6 \text{ sec} + 3 \text{ sec} = 3.6 \text{ sec}$.

b) The traffic intensity on the access link is reduced by 60% since the 60% of the requests are satisfied within the institutional network. Thus the average access delay is $(.0567 \text{ sec})/[1 - (.4)(.907)] = .089 \text{ seconds}$. The response time is approximately zero if the request is satisfied by the cache (which happens with probability .6); the average response time is $.089 \text{ sec} + 3 \text{ sec} = 3.089 \text{ sec}$ for cache misses (which happens 40% of the time). So the average response time is $(.6)(0 \text{ sec}) + (.4)(3.089 \text{ sec}) = 1.24 \text{ seconds}$. Thus the average response time is reduced from 3.6 sec to 1.24 sec.

Problem 10

Note that each downloaded object can be completely put into one data packet. Let $T_p$ denote the one-way propagation delay between the client and the server.

First consider parallel downloads using non-persistent connections. Parallel downloads would allow 10 connections to share the 150 bits/sec bandwidth, giving each just 15 bits/sec. Thus, the total time needed to receive all objects is given by:
Now consider a persistent HTTP connection. The total time needed is given by:

\[
(200/150+T_p + 200/150 + T_p + 200/150+T_p + 100,000/150+ T_p ) \\
+ (200/(150/10)+T_p + 200/(150/10) +T_p + 200/(150/10)+T_p + 100,000/(150/10)+ T_p ) \\
= 7377 + 8*T_p \text{ (seconds)}
\]

Assuming the speed of light is 300*10^6 m/sec, then \( T_p = 10/(300*10^6) = 0.03 \) microsec. \( T_p \) is therefore negligible compared with transmission delay.

Thus, we see that persistent HTTP is not significantly faster (less than 1 percent) than the non-persistent case with parallel download.