Homework Solution 2

1. (30%) Consider an application that transmits data at a steady rate (for example, the sender generates an *N*-bit unit of data every *k* time units, where *k* is small and fixed). Also, when such an application starts, it will continue running for a relatively long period of time. Answer the following questions, briefly justifying your answer:
   a. (15%) Would a packet-switched network or a circuit-switched network be more appropriate for this application? Why?
   A circuit-switched network would be well suited to the application described, because the application involves long sessions with predictable smooth bandwidth requirements. Since the transmission rate is known and not bursty, bandwidth can be reserved for each application session circuit with no significant waste. In addition, we need not worry greatly about the overhead costs of setting up and tearing down a circuit connection, which are amortized over the lengthy duration of a typical application session.

   b. (15%) Suppose that a packet-switched network is used and the only traffic in this network comes from such applications as described above. Furthermore, assume that the sum of the application data rates is less than the capacities of each and every link. Is some form of congestion control needed? Why?
   Given such generous link capacities, the network needs no congestion control mechanism. In the worst (most potentially congested) case, all the applications simultaneously transmit over one or more particular network links. However, since each link offers sufficient bandwidth to handle the sum of all of the applications' data rates, no congestion (very little queuing) will occur.

2. (20%) Suppose users share a 3 Mbps link. Also suppose each user requires 150 kbps when transmitting, but each user transmits only 10 percent of the time. (See the discussion of statistical multiplexing in Section 1.3.)
   a. (5%) When circuit switching is used, how many users can be supported?
   20 users can be supported.

   b. (5%) For the remainder of this problem, suppose packet switching is used. Find the probability that a given user is transmitting.
   $p = 0.1$

   c. (5%) Suppose there are 120 users. Find the probability that at any given time, exactly n users are transmitting simultaneously. (Hint: Use the binomial distribution.)

$$\binom{120}{n} p^n (1-p)^{120-n}$$

d. (5%) Find the probability that there are 21 or more users transmitting simultaneously.

$$1 - \sum_{n=0}^{20} \binom{120}{n} p^n (1-p)^{120-n}$$

We use the central limit theorem to approximate this probability. Let X_j be independent random variables such that $P(X_j = 1) = p$.

$$P(21 \text{ or more users}) = 1 - P\left(\sum_{j=1}^{120} X_j \le 20\right)$$

$$P\left(\sum_{j=1}^{120} X_j \le 20\right) = P\left(\frac{\sum_{j=1}^{120} X_j - 12}{\sqrt{120 * 0.1 * 0.9}} \le \frac{8}{\sqrt{120 * 0.1 * 0.9}}\right)$$

$$\approx P\left(Z \le \frac{8}{3.286}\right) = P(Z \le 2.43)$$

$$= 0.992$$

when Z is a standard normal r.v. Thus $P(21 \text{ or more users}) \approx 0.008$.

3. (35%) 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. (5%) Express the propagation delay, d_{prop}, in terms of *m* and *s*.

$d_{prop} = m / s$ seconds.

b. (5%) Determine the transmission time of the packet, d_{trans}, in terms of *L* and *R*.

$d_{trans} = L / R$ seconds.

c. (5%) Ignoring processing and queuing delays, obtain an expression for the end-to-end delay.

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

d. (5%) 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?

The bit is just leaving Host A.

e. (5%) Suppose d_{prop} is greater than d_{trans}. At time $t = d_{trans}$, where is the first bit of the packet?

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

f. (5%) Suppose d_{prop} is less than d_{trans}. At time $t = d_{trans}$, where is the first bit of the packet?

The first bit has reached Host B.

g. (5%) Suppose $s = 2.5 \cdot 10^8$, $L = 120$ bits, and $R = 56$ kbps. Find the distance m so that d_{prop} equals d_{trans}.

$$m = \frac{L}{R}s = \frac{120}{56 * 10^3}(2.5 * 10^8) = 536\ km$$

4. (15%)

a. (5%) Which layers in the Internet protocol stack does a router process?

Routers process layers 1 through 3. (This is a little bit of a white lie, as modern routers sometimes act as firewalls or caching components, and process layer 4 as well.)

b. (5%) Which layers does a link-layer switch process?

Link layer switches process layers 1 through 2.

c. (5%) Which layers does a host process?

Hosts process all five layers.