1. (a) Consider a window flow controlled virtual circuit going over a satellite link. All packets have a transmission time of 5 msec. The round-trip processing and propagation delay is 0.5 sec. What is the maximum speed transmission rate in packets/sec? Find a lower bound on the window size for the virtual circuit to be able to achieve maximum speed transmission when there is no other traffic on the link. Transmission time for the acknowledgment is negligible.

(b) Suppose the virtual circuit goes through a terrestrial link in addition to the satellite link. The transmission time on the terrestrial link is 20 msec, and the processing and propagation delay is negligible. What is the maximum speed transmission rate in packets/sec? Find a lower bound on the end-to-end window size for the virtual circuit to be able to achieve maximum speed transmission when there is no other traffic on the link. Transmission time for the acknowledgment is negligible and routers use a store-and-forward scheme.

(c) Suppose that node-by-node windows are used in the two-link system. Find lower bounds on the window size required along each link in order to achieve maximum speed transmission, assuming no other traffic on the links. Transmission time for the acknowledgment is negligible and routers use a store-and-forward scheme.

2. Consider a token bucket with token arrival rate of $\rho$ bytes/sec and a token credit capacity of $W$ bytes. The data rate is $M$ bytes/sec. Let $S$ be the duration of the maximum output burst rate from the full token-bucket.

(a) Carefully derive an expression for $S$.

(b) What is $S$ if $\rho = 16$ Mbps and $W = 500$ KB and if a burst arrives over a channel with data rate 200 Mbps and lasts 40 msec?

(c) Complete (b) by indicating what happens after $S$ seconds, assuming bursts arrive every second.

3. The standard “packet-counting” implementation of the leaky bucket algorithm allows one packet to be transmitted per token generated, independent of the length of the packet. The “byte-counting” variation defines a token not as 1 packet but $k$ bytes. Thus if $k = 1024$, one token can be used to transmit either one 1024-byte packet, or two 512-byte packets (conversely two tokens are needed to transmit one 2048-byte packet). What are the pros and cons of these two approaches for congestion rate control in networks?

4. A leaky bucket is used to control the rate of traffic which arrives as a Poisson distribution with an average rate of $\lambda$ packets per second. The packet lengths are exponentially distributed with an average length of $L$ bytes. The average token rate is $r$ bits/sec seconds. What is the average waiting time an arriving packet waits to be transmitted? How would you modify your answer for a token bucket that can accumulate up to $W$ tokens in credit?

5. Consider a single channel with capacity $C$ bps. The net packet arrivals across all $N$ stations is Poisson distributed with an average arrival rate of $\lambda$ frames/sec and each frame is drawn from an exponential probability density function with mean $L$ bits/frame.

(a) Derive the mean time spent in the system, $T$. What convenient assumption has been made in this analysis?

(b) Now assume FDM is used to allocate $N$ independent identical sub-channels to each of $N$ stations. Derive the mean time spent in the system using FDM, $T_{\text{FDM}}$. Can you see why FDM is not a good idea for a LAN system?