38. Compare the delay in sending an x-bit message over a k-hop path in a circuit-switched network and in a (lightly loaded) packet-switched network. The circuit setup time is s sec, the propagation delay is d sec per hop, the packet size is p bits, and the data rate is b bps. Under what conditions does the packet network have a lower delay? Also, explain the conditions under which a packet-switched network is preferable to a circuit-switched network.

40. In a typical mobile phone system with hexagonal cells, it is forbidden to reuse a frequency band in an adjacent cell. If 840 frequencies are available, how many can be used in a given cell?

14. Packets arrive at a node to be transmitted. The packets arrive at random times $T_1, T_2, \ldots$ and are transmitted in the order that they arrive. Packets that cannot be transmitted immediately are stored in a buffer until they can be. Assume that each packet is P bits long and the transmission rate is R bps. Draw a diagram showing how many bits are stored in the node buffer as a function of time. That number is zero before time T_1. At time T_1, that number is assumed to jump instantaneously to P. Between T_1 and T_2, the number of bits stored decreases by R bits every second, and so on. Using your diagram, determine the delay faced by the first, second, and third packets as a function of (T_1, T_2, T_3). Note that the delay of a packet is the sum of the transmission time

$$\frac{P}{R}$$

and some *queueing time*. Give a simple condition on the arrival times (T_1, T_2, T_3) for the queueing time to be zero. Exhibit arrival times $\{T_n, n \geq 1\}$ that lead to a very large average queueing time per packet, even though the average arrival rate (in packets per second) is very small. (*Hint:* Consider infrequent arrivals of large batches of packets.)

5.74. Suppose that packets arrive from various sources to a statistical multiplexer that transmits the packets over 64 kbps PPP link. Suppose that the PPP frames have lengths that follow an exponential distribution with mean 1000 bytes and that the multiplexer can hold up to 100 packets at a time. Plot the average packet delay as a function of the packet arrival rate.

5. *Reliability*. A physical link consists of N segments. The link is "up" if and only if all the segments are up. Moreover, the segments are up each with probability $p \in (0, 1)$, independently of each other, and are "down" otherwise. What is the probability that the link is up? Consider now two computers that are connected by two independent links. The first link is as described above, and the second one is similar but is made up of M segments that are up, each with probability $q \in (0, 1)$, independently of each other. The connection is working if and only if one of the two links is up. Find the probability that the connection is working. Generalize to an arbitrary topology (a mesh of independent segments).