Problem Set 3 (due Tuesday, March 9)

1. (10 points) The DCF mode of IEEE 802.11

An ad hoc network running 1 Mbps IEEE 802.11 has 4 nodes: N1, N2, N3, N4. Assume that at the beginning the channel is idle (no transmission) and all packet queues are empty. At time 10 μs, N1 has a packet to be sent to N4. At instant 20 μs, N2 has a packet to be sent to N4. At instant 40 μs, N3 has a packet to be sent to N4. Assume that the random number generator (for backoff) will give the following values for N1: 1, 5, …; for N2: 4, 3, …; and for N3: 4, 4, …. (These are in slots.)

Show the execution of the DCF mode of IEEE 802.11 for the above transmissions. Assume that SIFS is 10 μs, DIFS 50 μs, and slot time is 20 μs. Assume that we don't use RTS/CTS or fragmentation, and that all data packets have the same length of 125 bytes and that the Ack packet has length 25 bytes. Furthermore the channel bit error rate is assumed to be 0, and 802.11 provides the maximum possible throughput when there are no collisions.

2. (12 points) Analysis of a cellular system

Consider a cellular system with hexagonal cells of radius $R = 1$ km. Suppose the required SIR that system aims to achieve is 22 dB.

(a) Find the minimum distance D between the cell centers using the same frequency.

(b) What is the minimum reuse factor N achievable by the hexagonal cellular system that will guarantee this minimum distance?

(c) If the total number of chanels for the system is 1350, find the number of channels that can be assigned to each cell.

Suppose the average number of calls per user during a busy hour is 1.2, the average holding time of a call is 100s, and the call blocking probability is 0.02.

(d) Use Table 10.3 of the Stallings text to determine the total traffic carried per cell, in Erlangs/cell. Then convert that to Erlangs/km^2. (Use simple straight-line interpolation, if necessary.)

(e) Calculate the number of calls/hour/cell and the number of calls/hour/km^2.

3. (20 points) Access points and handoffs

Consider a network consisting of two access points: AP1 and AP2, located at positions (-100, 0) and (100, 0) on the plane, respectively, where the distance unit is meter. A mobile unit is communicating through this network, which offers a data rate of 1 Mbps, using BPSK modulation and operating at a frequency spectrum centered around 2.4 GHz. Each access point transmits at the level of 90mW and the noise density in the area is 10^{-16} W/Hz. Assume that all packets have the same size: 100 bytes.

(a) Draw a two-dimensional graph that (approximately) indicates the region in which the mobile incurs a frame error rate of at most 5% on transmissions from access point AP1.

(b) Suppose the mobile decides to switch from one access point to another whenever the signal from the newer access point is at least 10% stronger than from the first one. Draw a two-dimensional graph that indicates the points at which a mobile will switch from AP1 to AP2.

(c) Repeat part (b) for the case when the mobile decides to switch whenever the signal from the newer access point is at least 10% stronger than from the first one *or* the frame error rate for communication with previous access point exceeds 5%. An approximate curve will suffice.

You may adopt a free-space loss model for idealized isotropic antenna (ignoring gains) and may use the following formula for the Bit-Error-Rate (BER) of BPSK modulation:

$$BER = \int_{\sqrt{2E_b/N_0}}^{\infty} \frac{1}{\sqrt{2\pi}} e^{-\frac{u^2}{2}} du.$$

(To calculate the above numerically, you can use the complement of the error function used in statistical analysis – e.g., the ERFC function in Excel.)

4. (8 points) The Near-Far Problem

Distances within a cell in a cellular system or in a Wi-fi network often have a wide range. Consider a cell in a CDMA cellular system where the distance of a mobile unit from the base station ranges from 100m to 1 km. Assume a propagation loss model where the power attenuates as the fourth power of the distance (instead of the square of the distance, as in the free space model).

What spreading rate would be need in the CDMA system to allow a mobile unit to communicate from the farthest distance simultaneously with a mobile unit communicating from the nearest distance?