CS 515 - Mobile and Wireless Networking
Homework 1

Date: Oct 16, 2002, Wednesday

You may benefit from the following tools if you wish:

- A scientific calculator
- A function plotter like matlab, gnuplot, or any free tool that you can find on the web.
- Tables for Q-function, erf-function, erfc-function
- A programming language and its math library functions

1. Assume a 1Amp-hour battery that is used on a cellular phone. Also assume that the cellular phone draws 35mA in idle mode and 250mA during a call. How long would the phone work:

1. If the user leaves the phone always continually (powered on) and has one 3-minute call every day.
2. If the user leaves the phone always continually (powered on) and has one 3-minute call every 6 hours.
3. If the user leaves the phone always continually (powered on) and has one 3-minute call every hour.
4. What is maximum talk time?

Hint: 1Amp-hour describes a battery that can supply 1 Amp of current for a period of 1 hour (The same battery can supply 100mA for 10 hours, etc).

2. If P_t = 1W, G_t = 0dB, G_r = 0dB, and f_c = 2.4GHz, find P_r in Watts at a free space distance of 50 m.

3. Assume a receiver is located 10 km from a 150 W transmitter. The carrier frequency is 6 GHz and free space propagation is assumed, G_t=1, G_r = 1.

1. Calculate the transmit power in dBW.
2. Calculate the transmit power in dBm.
3. Find the power at the receiver in in Watts and dBm.

4. A base station radiates at a the transmit power of 50W. Let the carrier frequency, f_c, be 900MHz. Let d_0 be 100m. Assume free space path loss model between transmitter and d_0, and log-normal shadowing loss model for distances greater than d_0. Assume path loss exponent, n, of 3 and σ of 5dB for log-normal shadowing model.
Find out:

1. The received power (in dBm) at 100m.
2. The *mean* path loss (in dB) from transmitter at 500m.
3. The mean received power (in dBm) at 500m.

4. The probability that $P_r(500m) >= 0.01mW$.

5. If the received power at a reference distance d_0 = 1km is equal to 1 microwatt, find the received powers at distances of 2 km, 5 km, 10km, and 20km from the same transmitter for the following path loss modes:

1. Free space
2. $n = 3$
3. $n = 4$

6. Five received power measurements were taken at distances of 50m, 100m, 200m, 400m and 1000m from a transmitter. The measured values are given in the table below. It is assumed that the path loss for these measurements follow the log-normal shadowing environment formula, where d_0 is 50m. Assume the received power at d_0 is found to be 0dBm also by analytical models.

1. Find the value of n that minimizes the mean square error (MSE) for the data shown on the table below.
2. Calculate the standard deviation about the mean value of the received power.
3. Write down the exact formula for the resulting model.
4. Estimate the mean received power at d = 500m using the resulting model.
5. Predict the likelihood that the received signal level at 500m will be greater than -25dBm.
6. Predict the percentage of area within a 500m radius cell that receives signals greater than -25dBm.

Distance from Transmitter	**Received Power**
50m	0 dBm
100m	-10dBm
200m	-15dBm
400m	-25dBm
1000m	-50dBm

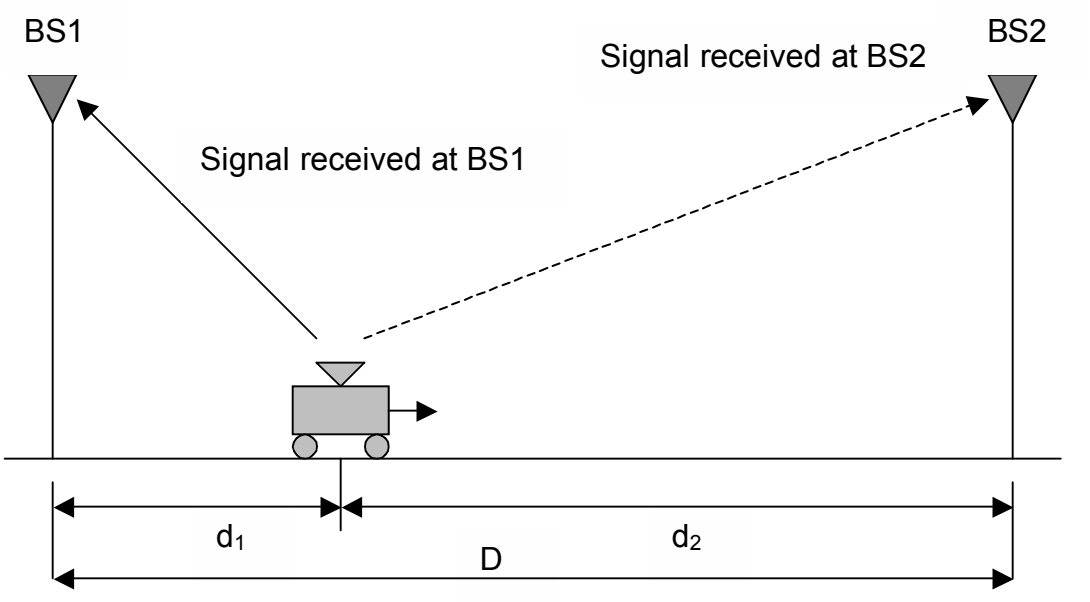
7. Suppose that a mobile is moving along a straight line between base station BS1 and BS2, as shown in the figure below. The distance between the base stations is D = 1600m. The received power (in dBm) at base station i, from mobile station, is modeled as (reverse link):

$$P_{r,i}(d) = P_0 - 10n\log(d_i / d_0) + X_i \text{ (dBm)} \quad i = 1,2$$

where d_i is distance between the mobile and base station i, in meters, P_0 is the received power at distance d_0 from the mobile antenna, and n is the path loss exponent. The term $P_0 - 10n\log(d_i / d_0)$ is usually called *local area mean power*. The terms X_i are zero-mean Gaussian random variables with standard deviation σ, in dB, that model the variation of the received signals due to shadowing. Assume that the random components X_i of the signals received at different base stations are independent of each other, n is the path loss exponent.

The minimum usable signal for acceptable voice quality at the base station receiver is $P_{r,min}$, and the threshold level for handoff initiation is $P_{r,HO}$, both in dBm.

Assume that the mobile is currently connected to BS1. A handoff occurs when the received signal at the base station BS1, from mobile, drops below threshold $P_{r,HO}$, and the signal received at candidate base station BS2 is greater than the minimum acceptable level $P_{r,min}$.



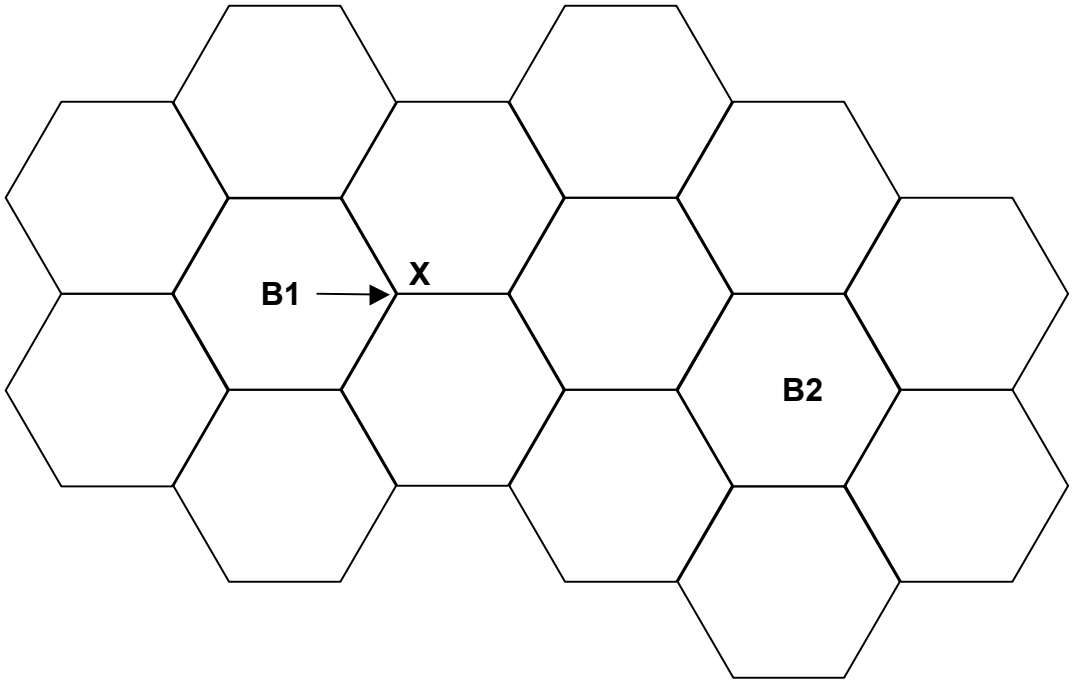
Parameter	Value
n	4
σ	6 dB
P_0	0 dBm
d_0	1 m
$P_{r,min}$	-118 dBm
$P_{r,HO}$	-112 dBm

Using the parameters in the table above, determine:

1. The probability that a handoff occurs (*Pr[handoff]*), as a function of distance between the mobile and its serving base station BS1. You can include the Q-function or error functions in your handoff probability function.
2. The probability that handoff occurs at 100m, 500m, 1000m distances from base station BS1.

8. Consider the coverage region below that are covered by cells modeled as hexagons. The structure uses frequency-reuse scheme. Cells belonging to base stations B1 and B2 are using the same frequency for transmission and all other cells are using different frequencies. Therefore, co-channel interference could exist only between cells B1 and B2. Cell B1 is our desired cell where our vehicle is moving in, and B2 is co-channel cell that can create interference. Assume the following:

1. Co-channel interference is due to base station B2 only.
2. Carrier frequency is 900MHz.
3. Reference distance d_0 is 1km (Assume free space propagation from transmitter B1 or B2 to d_0).
4. Cell radius is 10 km.
5. Assume omni-directional antennas for both transmitter and receiver, where gain of transmitter antenna is 6dB and gain of mobile antenna is 3dB.
6. Transmitter power of **10W** for all base stations.
7. Path loss formula between mobile and base station B1 is given with: $PL(d_1)(dB)$ = mean_$PL(d_0)$ + 10*(2.5)*log(d_1 / d_0) + X_σ (dBm) σ = 0dB.
8. Path loss formula between mobile and base station B2 is given with: $PL(d_2)(dB)$ = mean_$PL(d_0)$ + 10*(4.0)*log(d_2 / d_0) + X_σ (dBm) σ = 7dB.



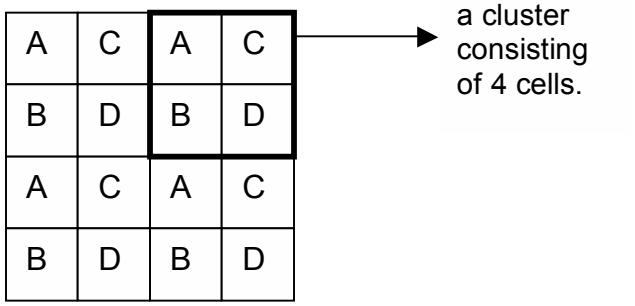
For a mobile moving on a line that connects the center of B1 to point X, a horizontal line, answer the following:

1. Express the C/I (carrier-to-interference ratio) value as a function of distance *d* between B1 and mobile (d_0 <= *d* <= *R*)
   Hint: Your formula may include a random variable.
   C/I is also called SIR (signal-to-interference ratio)

2. Express the mean_C/I_value as a function of distance *d* between B1 and mobile (d_0 <= *d* <= *R*)
   Hint: Your formula should not include a random variable.
3. Compute the mean C/I value at a distance of 5km from B1.
4. Compute the mean C/I value at a distance of 10km from B1 (at point X).

9. A PCS operator plans to build a wireless network to cover a big city. The PCS band given to him is: 1850 to 1880 MHz (reverse link) and 1930 to 1960 MHz (forward link). They intend to use DCS1900 like radio equipment which provides GSM-like service and supports 8 users per 200kHz radio channel using TDMA. The path loss exponent is 4 and the system will be deployed using a simple four-cell frequency reuse scheme.

A simple four-cell frequency scheme is as follows. The all available channels are divided into 4 groups (called a cluster): A, B, C, and D. The set of frequencies in these four groups are disjoint (the set of frequencies in group A is completely different than the set of frequencies in group B for example). The coverage region is covered by these clusters. Thereby the frequencies are re-used (for example, the set of frequencies in group of a cluster is used somewhere else in an other cluster).



Answer the following:

1. At most how many users can be supported in a cluster (4 cells) (Remember a user needs to have a forward and also a reverse channel allocated to himself/herself).
2. The operator wants to cover a big city of 2500 square km. The base stations use 20W transmitter power and 10dB gain omni-directional antennas. Determine the forward link coverage area (radius (R)) of a base station and number of cells (or base stations) required to provide forward cell coverage to the whole city. Assume that:
   - The city is square-shaped with dimensions: 50km x 50km.
   - Four-cell frequency re-use scheme.
   - Path loss exponent of 4.
   - Standard deviation of 8dB for log-normal shadowing path loss model for the city
   - An average required signal level of -90dBm should be received at the boundary of a cell (d=R)
   - Each mobile is using 3dBi gain antenna

- d_0 is 1km.
- Assume $PL(d_0)$ is 85 dB and assume it is independent of the carrier frequency (f).

3. What is the capacity of the system that you designed. (Number of users that can simultaneously use the system).
4. What is the percentage of a cell that will receive signal that is equal or greater than -90 dBm.

10. Provide brief answers for the following questions:

1. Write down your dream application of ubiquitous computing.
2. Write down the characteristics of wireless links that are different than wireline links and that affects the design of mobile computing systems and applications.
3. Who invented wireless telegraphy and in which year.
4. Write down the differences between CDMA2000 and W-CDMA
5. Write down the differences between GSM, GPRS and EDGE.
6. Give complete names of the following acronyms: AMPS, BER, CDMA, EDGE, ETSI, FDD, TDMA, FSK, LOS, PSTN, RSSI, UMTS.
7. Write down differences between CDPD and GPRS
8. Write down the differences and similarities between WLANs (for example IEEE 802.11b networks) and PLANs (for example Bluetooth networks) . (It is enough if you compare only IEEE 802.11b and Bluetooth).
9. Compare and contrast the following systems: AMPS, GSM, CDMA, PDC for the following features
    - Modulation technique that is used
    - Duplexing scheme (FDD or TDD)
    - Multiple Access Technique (FDMA, TDMA, or CDMA)
    - Voice (Speech) encoding scheme and rate
    - Channel bandwidth (such as 200KHz)
    - Allocated spectrum range (band) that the systems is using
    - Number of channels: forward and reverse
10. What are the similarities and differences between SNOOP and AIRMAIL
11. Write down the advantages of caching in the Coda File System.
12. What does hoarding mean?.