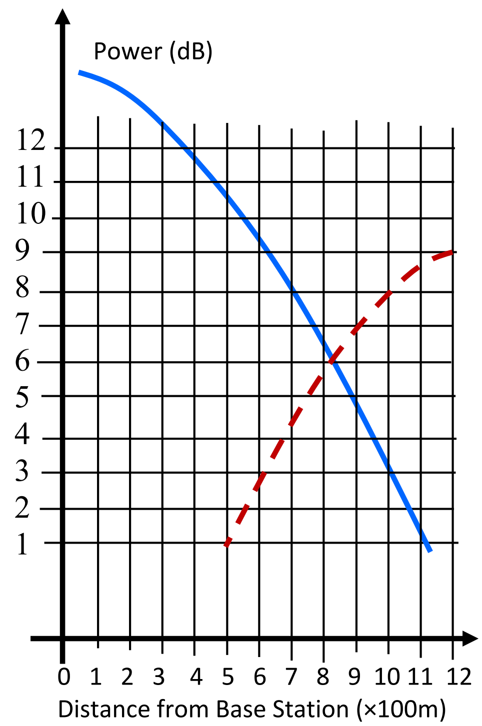
Mobile Networks and Applications: **Assignment 3** Spring 2015-2016

Due Date: March 17, 2015

Problem 1. The graph on the right illustrates the power profile of a GSM cell's Base Station's transmitter (left curve), and that of an interfering adjacent cell (right curve). All base stations are transmitting in a medium having a path loss coefficient η = -0.35. Suppose the measured noise level in the channel is 1 dB, and the desired minimum SNR is 5 (not in dBs).



a) First, explain the difference between an SNR in dBs and an SNR not in dBs.
   There is a difference between the SNR in dB and the SNR not in dB. In fact, SNR (dB) = $10\log_{10}$(SNR).

b) What is the maximum radius of the cell based on the SNR requirement?

   SNR=5
   Therefore, SNR(dB)=10log(5)=6.982
   We know that:
   SNR(dB) = Signal(dB) - Noise(dB)

   Therefore, S(dB)=N(dB)+SNR(dB)=1+6.982=7.982. which is approximately 8dB. This corresponds on the graph to 700m.
   So d(MAX)=700m.

c) Now considering the same graph, but now we focus on the interference that is depicted in the dashed curve. If the minimum SIR (Signal to Interference Ratio) that can be afforded is 3.5 (not in dBs), what is the maximum radius of the cell?

   SIR(dB) = 10*log(3.5) = 5.44 dB = S(dB) – I (dB)
   Therefore, the signal level should be 5.44 dB higher than the interference level. On the graph, S is higher than I with difference at least 5.44 dB for all $d \leq 650\ m$.
   ⇨ Maximum radius = 650 m.

d) What should be the minimum separating distance between two base stations using the same frequency bands?

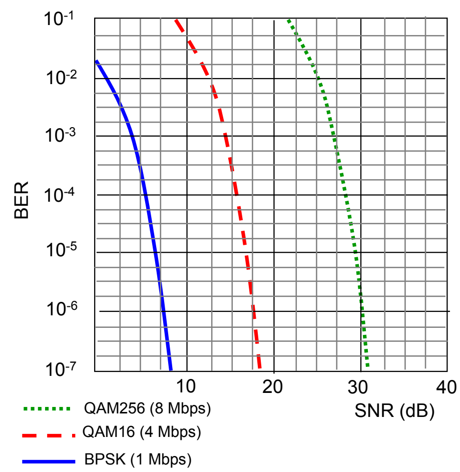
   On the graph, we locate the distance at which the difference between the power levels in dB of the received signal (in red) and of the interfering signal (in blue) is equal to 5.5 dBs. This occurs at a distance of 1050 m (approximately). This is the distance between BS1 and MS; so to get the minimum distance between BS1 and BS2, we add to 1050 the maximum radius of a cell (650 meters).
   The distance required between two base stations is 1050+650=1700m.

e) What is the size of the cluster in this network?

Number of cells from the formula: $N = \frac{(D/R)^2}{3}$

N (Cluster) = 3 cells per Cluster

Problem 2. Consider the chart on the right displaying the waterfall curves for three modulation schemes in a network that employs EDGE for communication.



Suppose in this network the noise level was so low that the base station transmitter's power was adjusted to yield a signal-to-noise ratio equal to 550 (not in dBs).

a) What would be the modulation scheme that the base station will be using?

First, let us get the SNR in dB.
SNR (dB) = $10\log_{10}(550)$ = 27.4 dB, approximately 27.5 dB.
Using the graph, we notice that 27.5 dB falls within the range of SNR values of the green dashed curve, i.e. the base station would use the modulation scheme QAM 256.

b) In Voice-over-IP (VoIP), a frame's size is 768 bytes. If the base station transmitted 10KB of VoIP data to a mobile user in the cellular network, how many bytes are expected to arrive in error in each frame at the mobile device?

Let us get the probability that a byte is in error or byte error rate.
First of all, let us get the bit error rate: we use the graph and read the value of BER corresponding to an SNR of 27.5 dB. We get a BER of $10^{-3.25}$.
To get the byte error rate, we do the following: the probability that a byte is in error is (1 – p) where p is the probability that the byte arrived correctly (no bit is incorrect), i.e. p = probability that every bit from the 8 bits composing the byte is correct,
i.e. $p = (1 - BER)^8$.
So, Byte error rate = $1 - (1 - BER)^8 = 1 - (1 - 10^{-3.25})^8 = 4.49 * 10^{-3}$
So, we expect $4.49 * 10^{-3} * 768 = 3.44832$ => 4 bytes to arrive in error within one frame.

Problem 3. Suppose there are 3 users who are transmitting simultaneously in a UMTS network. The codes assigned to User1, User2, User3 are 11001100, 11000011, 1111, respectivelyMoreover, suppose these 3 users have the following data bytes to send: 10010110, 10011111, 01110000.

a) What would the *channel* output if these users are the only ones transmitting?

Each bit is multiplied by the corresponding spreading code, and the channel output is obtained by adding the resulting spread bits. The table below shows the results.

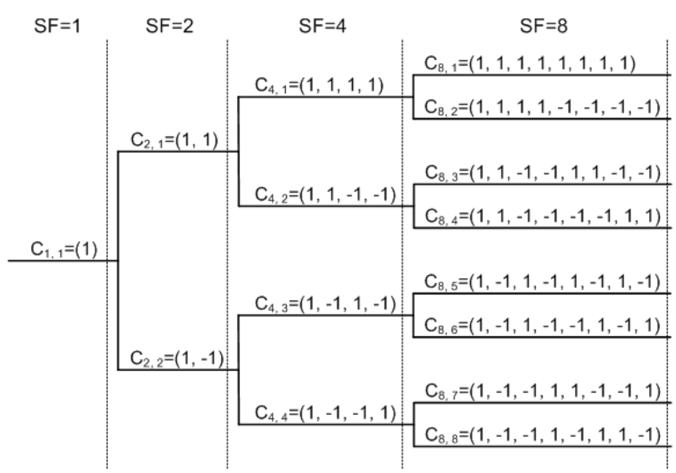
d1	1	-1	-1	1	-1	1	1	-1
Code2	11-1-111-1-1	11-1-111-1-1	11-1-111-1-1	11-1-111-1-1	11-1-111-1-1	11-1-111-1-1	11-1-111-1-1	11-1-111-1-1
d2	1	-1	-1	1	1	1	1	1
Code2	11-1-1-1-111	11-1-1-1-111	11-1-1-1-111	11-1-1-1-111	11-1-1-1-111	11-1-1-1-111	11-1-1-1-111	11-1-1-1-111
d3	-1 1	1 1	1 -1	-1 -1				
Code2	1111	1111	1111	1111				
Channel output	11-3-31111	-1-1331111	-3-311-1-1-1 -1	11-3-3-1-1-1 -1	0000-2-222	22-2-20000	22-2-20000	0000-2-222

b) Illustrate how the NodeB will recover the data of the third user.

To recover the data of the third user, NodeB does the following computation using the code of user 3:
di = *Summation* (Ci * Zi) / 4
where 4 is the number of bits of code of user 3 (i.e. the spreading factor of user 3).

For the first bit: 1(1) + 1(1) + 1(-3) + 1(-3) = - 4 => -4/4 = -1 => bit recovered 0
For the second bit: 1(1) + 1(1) + 1(1) + 1(1) = 4 => 4/4 = 1 => bit recovered 1
For the third bit: 1(-1) + 1(-1) + 1(3) + 1(3) = 4 => 4/4 = 1 => bit recovered 1
For the fourth bit: 1(1) + 1(1) + 1(1) + 1(1) = 4 => 4/4 = 1 => bit recovered 1
For the fifth bit: 1(-3) + 1(-3) + 1(1) + 1(1) = -4 => -4/4 = -1 => bit recovered 0
For the sixth bit: 1(-1) + 1(-1) + 1(-1) + 1(-1) = -4 => -4/4 = -1 => bit recovered 0
For the seventh bit: 1(1) + 1(1) + 1(-3) + 1(-3) = -4 => -4/4 =-1 => bit recovered 0
For the eighth bit: 1(-1) + 1(-1) + 1(-1) + 1(-1) = -4 => -4/4 = -1 => bit recovered is 0
We get: 0 1 1 1 0 0 0 0

Problem 4. Consider the part of the OVSF code tree to the right as a reference. Suppose the maximum length of a spreading code that can be used is 32. If currently one user has a code with SF=4, another one with a code whose SF=8, a third with a code whose SF=16, and a fourth user whose code has an SF=32.



a) If these users are to keep their current spreading codes, what is the maximum number of users who can be communicating simultaneously, including the above four users?

We know that no two users can be assigned codes from the same branch of the tree; thus if the maximum SF is 32, and if we remove the 4 branches corresponding to the 4 users above, we are left with a total of 16 + 1 = 17 different branches (or codes).
Thus, the total number of users that can communicate simultaneously is:
17 + 4 = 21 users.

b) If the operator has a total of 1000 subscribers, and the average cumulative time that a subscriber is active during a day is 90 minutes. What is the probability that all subscribers are active at the same time?

$$P = \left(\frac{1.5\ hrs}{24\ hrs}\right)^{1000} = 0.0625^{1000} \cong 0$$

For all users to be active at the same time, the value of p will be close to zero.

c) As a follow up on Question b), what is the average spreading factor that the operator will be assigning to the subscriber? You need to detail your answer and show how you arrived to it.

The expected number of active users at a given time is 0.0625*1000 = 62.5 > 32, the maximum number of available spreading codes.
Therefore, the system will not be able to accommodate all users at the same time.
A spreading factor of 32 given to all users will allow for the maximum number of users being served at the same time.