UNIVERSITY OF CALIFORNIA, DAVIS

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EEC173B/ECS152C **Winter 2006**

Homework 1

1. **(20%) Power limitation of mobile devices.** In order to reduce power usage, many cellular phones (as well as other wireless devices) have sleep modes. In such cases, a terminal can be in 1) sleep mode; 2) wake-up mode during which it receives control messages from the base station; or 3) transceiver mode when it transmits and receives a phone call. Assume that such a wireless device with 1 Amp-hour battery draws 1mA when in sleep mode, 5mA when in wake-up mode, and 250 mA in transceiver mode. Furthermore, let us assume that the duty cycle between wake-up and idle mode is 10%; that is, during 10 minutes when there is no phone call, the cell phone is in sleep mode for 9 minutes and in wake-up mode for 1 minute.

   a) Determine the maximum amount of time the phone will work before recharging if the user leaves the phone on continually and receives one 3-minute call during a day. Now calculate this time before recharging if the phone is left on continually but the user receives one 3-minute call every hour.

   b) Next, assume the duty cycle is equal to 50%; that is, during 10 minutes when there is no phone call, the cell phone is in sleep mode for 5 minutes. Redo part a) for this new duty cycle.

   c) Finally, redo part (i) for a duty cycle of 80%.

2. **(25%) Wireless transmissions.** In wireless channels, a transmitted signal can take many paths (referred to as multipaths) in reaching the receiver antenna. This problem explores some potential problems that arise when multipaths interfere with each other.

   Consider a situation in which a cell phone desires to transmit three bits, first a ‘one’ and then two ‘zeros’: ‘100’. These bits are transmitted using rectangular pulses of time duration T_b as shown in Figure 1. A ‘one’ bit is transmitted using *p(t)* and a ‘zero’ bit is transmitted using -*p(t).* Assume that the wireless channel has the impulse response shown in Figure 2.

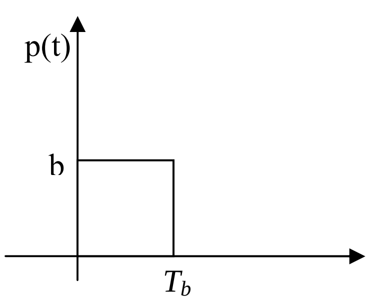


Figure 1

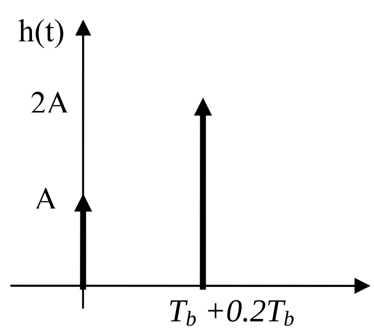


Figure 1

a) Calculate the received signal *r(t)*. (Either draw the received signal or write the equation for it).

b) Now assume that the received signal is processed in following manner during each bit interval *i*, where *i* = 1,2,3:

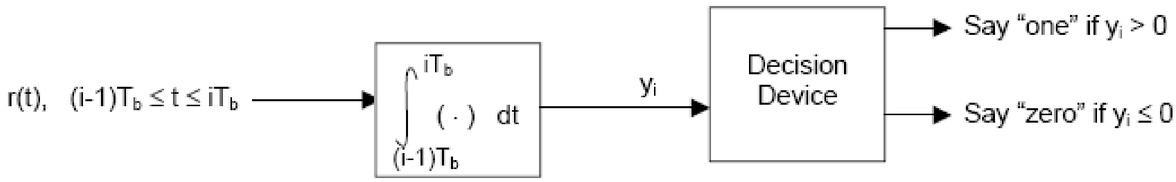


Figure 3

This receiver takes *r(t)* and breaks it into time intervals of duration T_b. The received signal during each interval is then integrated. The output of the integrator during an interval *i* is called y_i. The value y_i is fed into a decision device that declares a bit "one" was transmitted during interval *i* of $y_i > 0$; if $y_i \leq 0$, then the device decides that a "zero" was transmitted. For the received signal computed in part a), determine the sequence of bits outputted from the receiver. Do not just give the sequence of bits; show how to compute this sequence by following the receiver structure above, i.e., give the values of y_i for each interval *i*. (The receiver shown here is called a matched filter receiver for *p(t)* and commonly used in digital communications.)

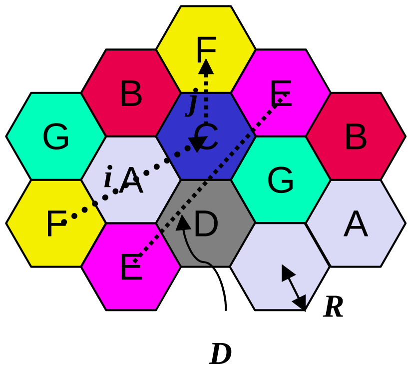
3. **(35%) Frequency reuse in cellular network.** In class, it was stated that for hexagonal cells the ratio *D/R* is equal to $\sqrt{3N}$, where *R* = radius of the cell, *D* = distance between two cells where frequency is reused, and *N* is the cluster size, i.e., total number of frequencies in the system.

   a) In this problem you are asked to prove this. In order to work out this proof, you need the following fact: for hexagonal cells that tessellate it is required that the cluster size, *N*, can only take on those values that satisfy the following condition:

   $$N = i^2 + j^2 + ij$$

   where *i* and *j* are non-negative numbers. To find the nearest co-channel neighbor of a particular cell, you have to (1) move *i* cells along any chain of hexagons and then (2) turn 60 degrees counter-clockwise and move *j* cells. Using this fact, plus the law of cosines prove that $D/R = \sqrt{3N}$ in a system of hexagonal cells.

   b) For an ideal hexagonal cellular layout which has identical cell coverage, what is the distance between the centers of two nearest co-channel cells for seven-cell reuse? For four-cell reuse?



An example of a cluster where $N = 7$.
$i = 2$ and $j = 1$ in this case.

R = radius of the cell
D = distance between two cells where frequency is reused

Figure 4

c) A cellular service provider uses digital TDMA which can tolerate a C/I (co-channel interference) of 15 dB in the worst case. Considering only the first tier of interference, find the optimal value of N (assuming tessellating hexagonal cells) for omni-directional antennas and path loss exponent of 4.

Reminder: Assume a cell with radius R, and frequency reuse distance of D. Worst-case SIR happens when a user is at a cell boundary (distance R from the cell tower), and the interferer using the same frequency is of distance D away. For simplicity, assuming all interfering base stations are of equal distance from the mobile station.

4. **(20%) Thresholds for handoffs.** Suppose that a mobile station is moving along a straight line between base stations BS1 and BS2, as shown in Figure 2. The distance between the base station is D=2000m. For simplicity, assume small scale fading is neglected and the received power (in dBm) at base station I, from the mobile station, is modeled as a function of distance on the reverse link

$$P_{r,i}(d_i) = P_o - 10n\log_{10}(d_i / d_o) \text{ (dBm) } i=1,2$$

where d_i is the distance between the mobile and the base station i, in meters. P_o is the received power at distance d_o from the mobile antenna. Assume that P_o=0dBm and d_o=1m. Let n denote the path loss which is assumed to be equal to 2.9.
Assume the minimum usable signal level for acceptable voice quality at the base station receiver is $P_{r,\min}$=-88dBm, and the threshold level used by the switch for handoff initiation is $P_{r,HO}$. Consider that the mobile is currently connected to BS1, and is moving toward a handoff (time required to complete a handoff, once that received signal level reaches the handoff threshold $P_{r,HO}$ is Δt=4.5 seconds).

a) Determine the minimum required margin $\Delta = P_{r,HO} - P_{r,\min}$ to assure that calls are not lost due to weak signal condition during handoff. Assume that the base station antenna heights are negligible compared to the distance between the mobile and the base stations.

b) Describe the effects of the margin $\Delta = P_{r,HO} - P_{r,\min}$ on the performance of cellular system.

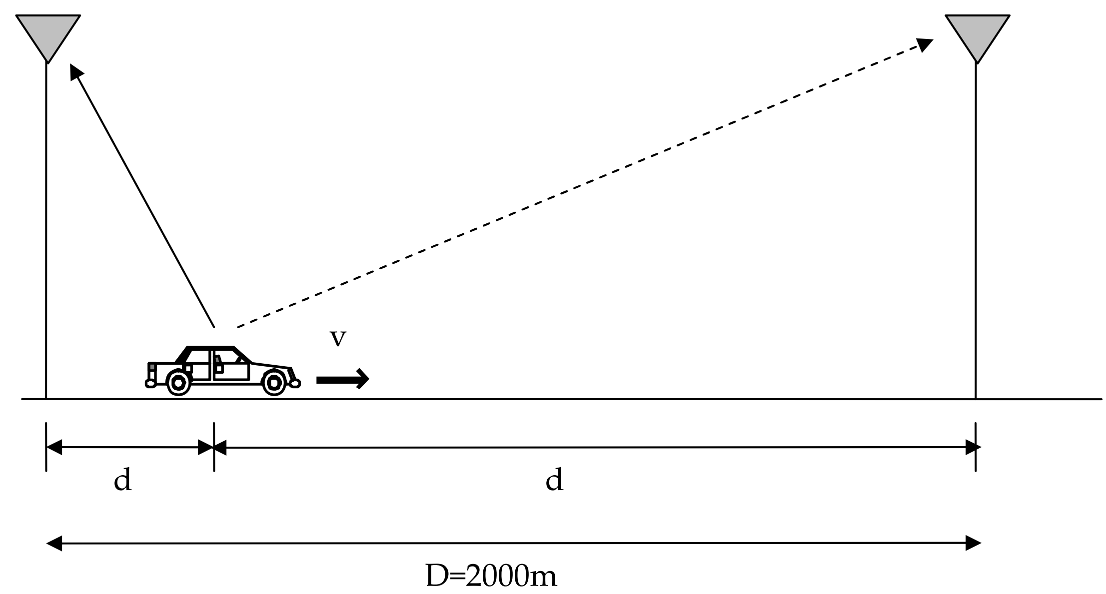


Figure 5. Cellular system with two base stations.