ECE/CS 438 (Fall 2012) Name: Dennis McWherter (dmcwhe2)
Homework 6 Due: 2 p.m., November 9, 2012 (Friday)
Standard extension of 48 hours changed to 72 hours for Homework 6

Enter your answers in the space provided below. **If needed, attach additional sheets to show the details of your work.**

1. Consider a transmitter-receiver pair at distance d. Assume the free-space propagation model. The path *gain* is 10^{-3} when distance is d_0. Determine the path gain for distance $d = 2d_0$ and $4d_0$.

   Path loss at $d = 2d_0$: 4000

   Path loss at $d = 4d_0$: 16000

2. Consider four nodes A, B, C and D. Host C uses transmit power equal to 10 mW. Noise at each host is negligible, and may be assumed to be 0 for the purposes of calculations in this question. Assume the following path gains: $g_{AB} = g_{CD} = 10^{-3}$, $g_{AD} = 10^{-9}$ and $g_{CB} = 10^{-7}$. Any path gains not specified here can be assumed to be 10^{-15}.

   Suppose that host A transmits to host B, and at the same time host C transmits to host D. Determine the *range* of transmit power values that may be used by host A while achieving SINR *greater than or equal* to 4000 for both the transmissions?

   Answer: $0.4\text{mW} \leq P_A \leq 250\text{mW}$

3. Consider a network with two flows, one flow from host P to Q, and another from host S to R. Suppose that the nodes in this network use IEEE 802.11 DCF protocol with a certain carrier sense threshold P_{CS}, and that the two flows are always backlogged.

   Can the aggregate throughput of the two flows *increase* if the physical carrier sensing threshold is made much larger than the original value? Explain your answer briefly.

   Yes / **No** (circle your answer)

   Explanation: The aggregate throughput of the two flows will not necessarily increase if the physical carrier sensing threshold is made much larger. If this threshold is increased enough, then it is possible that neither node detects real transmissions and, as a result, there would be a high amount of collisions (i.e. this will decrease throughput). **NOTE:** This is possible if transmitting to nodes which are not between the two which are transmitting (i.e. the other nodes are far away enough to not detect the collision)

4. Consider a wireless network consisting of 4 nodes, A, B, C, and D, such that nodes A and B always have packets to transmit to nodes C and D, respectively.

   The nodes use a slotted access mechanism with slot size equal to packet size, and synchronized slot boundaries. Each of nodes A and B may transmit in a given slot with probability p.

   Assume the following:

   (i) In a given slot, if exactly one node transmits a packet, then the transmission is successful.

   (ii) In a given slot, if two nodes transmit simultaneously, then exactly one transmission succeeds with probability α, and both transmissions are erroneous with probability $(1-\alpha)$.

   (a) Determine the optimal access probability p that maximizes the total throughput. The optimal probability may be a function of α.

   Answer: $p = \frac{2+\alpha}{4+2\alpha}$

   (b) Determine the maximum achievable throughput (in packets/slot) when $\alpha = 0.5$.

   Answer: $\frac{1}{2}$

5. Circle true or false:

   Consider node A transmitting to node B, and node C transmitting to node D simultaneously. It is given that the transmission to node B is corrupted due to the interference from node C. This *always* implies that the transmission by node C to node D is also corrupted.

   True / **False**

1. $P_r(d) = P_r(d_0)\frac{d_0^2}{d^2}$
   (a) So $P_r(2d_0) = P_r(d_0)\frac{d_0^2}{4d_0^2} = \frac{10^{-3}\cdot P_t}{4}$. Thus, $\frac{P_r}{P_t} = \frac{10^{-3}}{4} = gain$. Therefore, loss is $\frac{1}{gain} = \frac{4}{10^{-3}} = 4000$
   (b) Without loss of generality, $P_r(4d_0) = P_r(d_0)\frac{d_0^2}{16d_0^2}$ so $gain = \frac{10^{-3}}{16}$. The path loss is $\frac{1}{gain} = \frac{16}{10^{-3}} = 16000$.

2. Find the $SINR$ at the receiving nodes to calculate an appropriate signal. Let $N = 0$ in the $SINR$ equation (as per problem description).
   $SINR_D = \frac{10^{-3}\cdot g_{CD}}{P_A\cdot g_{AD}}$

   $SINR_B = \frac{P_A\cdot g_{AB}}{10^{-3}\cdot g_{CB}}$

   Let $SINR_B = 4000$. Then:
   $P_A = \frac{10^{-3}\cdot g_{CD}}{4000\cdot g_{AD}} = \frac{10^{-3}\cdot 10^{-3}}{4000\cdot 10^{-9}} = \frac{1}{4}$ which is an upper-bound. Now, let $SINR_D = 4000$. Then:

   $P_A = \frac{4\cdot g_{CB}}{g_{AB}} = \frac{4\cdot 10^{-7}}{10^{-3}} = \frac{4}{10000} = \frac{1}{2500} = .0004 = 0.4\text{mW}$
   This gives us a lower-bound for P_A. Thus $0.4\text{mW} \le P_A \le 250\text{mW}$

3. See question

4. (a) $p = \binom{n}{1}p(1-p)^{n-1} = \binom{2}{1}p(1-p) = 2p - 2p^2$ is the probability that a packet is successfully sent. However, there is also the probability that both nodes try to transmit and with probability α, the transmission still succeeds. Then the following function needs to be maximized:
   $2p - 2p^2 + \binom{2}{2}p(1-p)\alpha = 2p - 2p^2 + \alpha p - \alpha p^2 = f(x)$

   $f'(x) = 2p - 4p + \alpha - 2\alpha p = 0$
   $p = \frac{2+\alpha}{4+2\alpha}$

   (b) $\frac{2+\alpha}{4+2\alpha} = \frac{2+.5}{4+2(.5)} = \frac{2.5}{5} = \frac{1}{2}$

5. Consider the idea of the hidden terminal. Let nodes A and C be hidden from each other and B be exposed to both. Then there is interference from both A and C's transmissions at node B. However, if D is also hidden from A (or sufficiently far), then D receives C's transmission with no corruption. Therefore, the answer to this question is **false**.