Assignment 1 (Due Date: 23:59 pm, Oct. 2, 2015)

Important Notes

1. Questions marked with (CSC569) are for CSc 569 students only.
2. Each question has two weights; the first one is for CSc 463, and the second for CSC 569.
2. You should submit your solutions in pdf format to the Connex dropbox. Other format will NOT be accepted.

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(1) (20%, 15%) Consider the following network topology shown in Figure 1. We make the following assumptions:

- The transmission power at each node is the same.
- A simplified Free space radio model is adopted: $P_r(d) = P_t/d^2$, where d is the distance between sender and receiver.
- Regarding the so-called "EE model" taught in class, β =1.25 (i.e. the condition for correct transmission is that the SNR at the receiver is not smaller than 1.25)
- Regarding the so-called simplified "CS model" taught in class, we assume that condition for correct transmission is that the distance between the sender and the receiver is not larger than 1.
- The nodes are distributed in the intersection points of a 2 * 2 square grid. The side of each grid is 1 meter (i.e. the distance between 1 and 2 is 1 meter).

(a) With the "EE model", what is the maximal number of successful, simultaneous transmissions that can occur in the network? Please list all possible simultaneous transmissions.
(b) With the simplified "CS model", what is the maximal number of successful, simultaneous transmissions that can occur in the network? Please list all possible simultaneous transmissions.

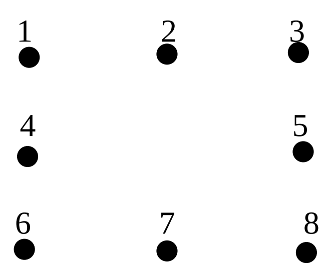

Figure 1

(2) (15%, 15%) Consider a chain of *n* nodes as shown in Figure 2. Assume that the distance between the adjacent nodes in the chain is *d*. Assume that IEEE 802.11 DCF protocol is used. Also, assume that a node can reliably receive the transmission from another node within distance d_2 or less, and a node can sense the transmission from

another node at distance at most d_3, where $d_3 = 1.5 * d_2$. What is the maximum number of nodes that can reliably transmit message simultaneously when $d = 0.5 * d_2$?

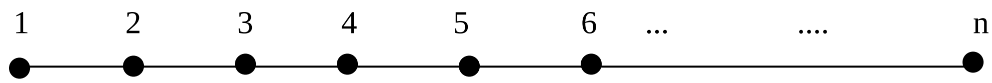

Figure 2

(3) (20%, 15%) Consider two laptops using the same radio channel to communicate with the same Access Point (AP). Both laptops use the same type of wireless card in which only basic access mechanism of IEEE 802.11b is implemented. Assume that the following parameters are used:

Frame payload	1024 bits
MAC header	272 bits
PHY header	128 bits
ACK	112 bits + PHY header
Channel Bit Rate	1 Mbps
Slot time (specified in the 802.11b standard)	50 μs
CW_{min} (specified in the 802.11b standard)	16
CW_{max} (specified in the 802.11b standard)	1024
DIFS	128 μs
SIFS	28 μs
ACK_Timeout	300 μs

Assume that both laptops have one frame to send and thus begin to sense the radio channel at ***exactly*** the same time. Assume that no hidden/exposed terminals exist. Also assume that no fragmentation of packets is needed and the radio channel is reliable.

(a) Sketch a time diagram showing how the two laptops can successfully transmit their first packet.

(b) What is the expected delay from the time when both laptops begin to sense the channel to the time when at least one laptop successfully transmits its first packet?

(4) (25%, 25%) (Network planning for all-wireless networks) Consider a cellular all-wireless network consisting of four stations (A, B, C, and D) which are placed at the vertexes of a square in a two-dimensional plane (see Figure 2). In order to transmit a message to a receiver, the sender consumes energy $E_{Tx}(d) = c*d^2$ J/bit, where d is the Euclidean distance between the sender and the receiver and c is a constant depending on the environment. In addition, the receiver consumes energy E_{Rx} J/bit to receive this message. Hence, the total energy cost for sending one bit from a sender directly to a receiver over distance d is $E = E_{Tx}(d) + E_{Rx}$. In Figure 3, each station can communicate with other nodes directly.

Now, assume that a new station (E) is placed within the square. For each message from E, it will be sent to A with a probability of 0.5, to B with a probability of 0.2, to C with a probability of 0.2, and to D with a probability of 0.1. For each message from A or B or C or D, it will be sent to E with a probability of 0.6 and to another randomly selected vertex of the square with a probability of 0.4. Assume that the traffic loads generated by A/B/C/D/E are the same. Please find the position of E such that the total energy consumption of the network in a long run is minimized. For simplicity, we assume that there is no message collision or message retransmission.

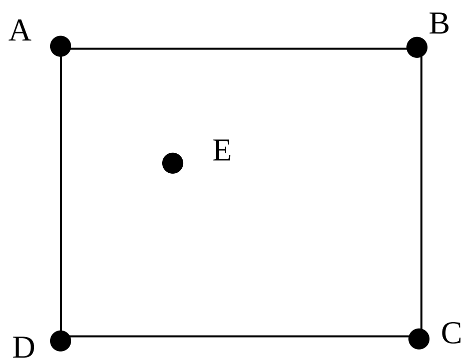

Figure 3

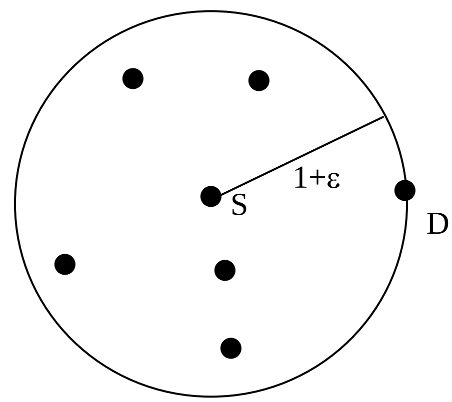

Figure 4

(5) (20%, 30%) In order to transmit a message to a receiver, the sender consumes energy $E_{Tx}(d) = c*d^{\alpha}$ J/bit, where d is the Euclidean distance between the sender and the receiver, c is a constant, and α is a constant between 2 and 4 depending on the wireless environment. Assume that the energy consumption at the receiver is ignored. Given three nodes A, B, C placed at the vertexes of a triangle in a two-dimensional plane, A has two choices to send messages to C: one is that A sends messages directly to C, the other is that A sends messages to B and B relays the messages to C. Assume that d_1 is the distance between A and B, d_2 is the distance between B and C, d_3 is the distance between A and C, and $\angle BAC = \theta$.

A. Prove that the first choice consumes more energy than the second choice under the following conditions:
(a) $d_1 < d_3 * \cos(\theta)$, if $\alpha=2$
(b) $X^{\alpha} - 1 > (1+X^2 - 2X*\cos(\theta))^{\alpha/2}$ where $X = d_3/d_1$, if $2<\alpha\leq 4$.

Note that the above fact has been used in energy-aware routing protocol design.

(CSc 569 Only) B. Consider the following simple greedy algorithm that tries to find a minimal energy route from a source node to a destination node: a node always selects the nearest node as its next hop until the destination node is reached. To avoid loop, a node that has already been included in the path will not be considered again. When a node has several neighboring nodes with the same smallest distance, the node randomly selects one nearest neighbor to break the tie.

As shown in Figure 4, node S wants to send messages to node D that is on the circle centered at S with radius $1+\varepsilon$ (ε is an arbitrarily small positive value). Assume that there are other five nodes falling either within the circle or on the circle. Assume that $\alpha=2$ and $c=1$. Prove that the above greedy algorithm may find a path from S to D with the total energy cost of 6 J/bit, which manifests the ineffectiveness of the algorithm. Can you modify the above heuristic algorithm to avoid the problem?