Homework 5

1) Suppose a wireless node has traffic to send to an access point (AP). It can either send via one-hop to the AP or over multiple hops through nearby wireless nodes which further relays to the AP. Every wireless node has the same energy profile: the net energy consumed per unit time at node i is \( \sum_j p_{tx,ij} f_{ij} + \sum_j p_{rx,ij} f_{ji} \) where the transmit power is \( p_{tx,ij} = \varepsilon_c + \varepsilon_t d_{ij}^2 \) and receiver power is \( p_{rx} = \varepsilon_c \). \( d_{ij} \) is the distance between nodes i and j, and \( \varepsilon_c \) and \( \varepsilon_t \) are some constants.

Should we prefer single-hop routing or multihop routing when the transmit energy dominates? How about when the circuit energy dominates? Why? (20 points)

If transmit energy (tx power) dominates – prefer multihop routing. This is because multihop routing means each hop is shorter and incurs less transmission energy. Note that reduction in distance results in at least quadratic reduction of tx power.

If circuit energy dominates, prefer single hop. Circuit energy does not depend on the distance, and in such a case it is preferable to reduce the energy by using fewer nodes on the route, hence single hop routing.

2) RFID reader transmits 1W power on the channel whose frequency is \( f_c = 2.45 \text{ GHz} \). A tag is located at a distance 3m from the reader. The reader antenna has a gain \( G = 2 \).

(a) Compute the power \( PT \) received by the tag in dBm using a free space propagation model. (10 points)

(b) Assuming that the tag reflects 70% of the incident power to its antenna, compute power \( PR \) received by the reader in dBm. (10 points)

(c) Compute the round-trip delay of the signal sent from and received by the reader. (6 points)

(a) \( PT = (TxPower*G1*G2*\text{lambda}^2)/(4*\pi*\text{d}^2*L) \) where lambda is the wavelength = c/frequency = 0.1224m

Substituting in the formula above,
\[
PT = 1*1*2*(0.1224)^2/((4*\pi)^2*(3)^2.1) = 2.1*10^{-5} \text{ W} = 2.1*0.01 \text{ mW} = -16.76 \text{ dBm}
\]

(b) \( 0.7 * 0.021 \text{ mW} = 0.0147 \text{ mW} \)

Thus, \( PR = 0.0147 * 1 * 2 * (0.1224)^2/((4*\pi)^2*(3)^2.1) = 3.0992e-07 \text{ mW} = -65.0875 \text{ dBm} \)

(c) \( 2*3/\text{speed of light} = 2*3/(3*10^8) = 2*10^{-8} \text{ second} \)
3) Consider two anchor nodes whose coordinates are (0,0) and (0, 2m), respectively. Suppose the received power at distance 1 meter is 1 mW. Your current received signal strength are 0.125 mW and 0.0625 mW from these nodes, respectively.

(a) Derive the coordinate of your current location assuming the attenuation factor is 3. (10 points)

(b) Why received signal strength based localization may not be reliable. (6 points)

(c) How can we improve the accuracy? (6 points)

First derive the distance from each anchor node. From the 1st anchor node, given $Pr = 1$mW at 1m, we have distance = 2 m to get $Pr' = 1/8$ mW because $Pr'/Pr = (d/d')^3 = 1/8 = (1/2)^3$. Similarly, the distance from anchor 2 can be computed as $Pr'/Pr = (d/d')^3 = 1/16 \Rightarrow d' = 2.5198$ m

Then we compute the coordinate such that they satisfy our distance constraints:

$x^2 + y^2 = 4$
$x^2 + (y-2)^2 = 2.5198^2 \Rightarrow x^2 + y^2 - 4y + 4 = 6.35 \Rightarrow -4y + 4 = 2.35 \Rightarrow y = 0.4125$m

Plugging $y$, we get $x = 1.957$m

So the node’s coordinate is (1.957m, 0.4125m).

Received signal strength based localization may not be reliable because it depends on the propagation environment. Due to obstacles and multipath, the relationship between RSS and distance may not have a known pattern, and may change across different locations. (Correct if something along the first or second line is mentioned.)

We can improve accuracy by (i) adding more anchor nodes, (ii) use calibration to figure out the relationship between distance and RSS in the given environment, and/or (iii) combined with other signals (e.g., motion sensors). (correct if one of them is mentioned.)

4) List three differences between Bluetooth and 802.11 WLANs. (12 points)
http://www.diffen.com/difference/Bluetooth_vs_Wifi

5) Compare classic Bluetooth and Bluetooth Low Energy in terms of throughput, latency, range, power consumption. Please feel free to read other materials online to answer the questions. (8 points)

6) Name one application each that uses RFID, NFC, classic Bluetooth, and Bluetooth Low Energy. (12 points)
RFID: inventory, attendee tracking, remote keyless entry, toll collection
NFC: ticketing, payment, device pairing
Classic Bluetooth: streaming (e.g., Bluetooth headphone)
Bluetooth low energy: localization, monitoring