**Class Exercises**

**Wireless Sensor and Actuator Networks**

**Question 1**

2m

4m

Sink

3m

**Figure 1**

Figure 1 shows motion sensor mote deployed in a secluded server room to monitor human movement. Node S1 can either forward the motion data to node S2 or node S3 depending on the residual energy of the nodes or its energy harvesting capability. S1 to S2 and S1 to S3 have the same energy consumption for every packet being delivered and it takes one packet to be delivered in 1 second. Both S2 and S3 have the same battery capacity Eb and residual energy on both nodes is Eb-3 and Eb-5 respectively. And energy harvesting rates at 3 and 2 units per second respectively. S2 and S3 both consume 4 energy units to relay a packet to the A.

1. Calculate the remaining battery of the sensor nodes S1 and S2 after 10 seconds imagining that the same amount of data is sent to both nodes.
2. Given a scenario of remaining energy in both nodes when a) S2 is relaying the data to the sink b) S3 is relaying the data to the sink
3. Give a scenario for energy aware routing, whereby the nodes with the highest remaining energy will be selected as the next hop.

**Question 2**

2m

4m

Sink

3m

3m

**Figure 2**

Referring to Figure 2, now imagine that a cluster head can be chosen at random in which node S1 becomes cluster head and S2 and S3 forward the data to S1 and S1 takes the average of the sensor data forwards to node A and in the next rounds node S2 becomes cluster head whereby S1 and S3 forwards to S2 and S2 forwards the average to A and the next round S3 becomes cluster head the process happens in the same manner. (consider how many cycles of cluster head rotation can take place). Calculate the lifetime with the parameters given below:

Energy to send/receive per packet Ec = 3 µJ

Energy required for transmit amplifier Et = 0.1 µJ

Energy for calculating average EA = 2 µJ

Initial energy of each node = EI  = 45 µJ

Distance between S2 and S3 is 8m

Hint : (Et X d)

**Question 3**

d= 5m

**Figure 3**

Figure 3 shows a simple deployment of sensor nodes in a home environment to detect elder movement. The 3 sensor nodes (n) are deployed in a linear manner with equal distance between each other.

energy required for TX/RX circuitry, Ec=100 [nJ/bit],

energy required for transmission power Etx(d) = kd2 [nJ/bit], being k=1 [nJ/bit/m2],

packets size a =1000 [bits],

1. Is it more energy efficient to use direct transmission (from S1 to S3) or minimum per-transmission energy routing or multihop (S1 to S3).
2. How many nodes are required so that direct transmission consumes the same amount of energy as multihop
3. Discuss the situation in b and explain under what circumstances that direct transmission is suitable.
4. As we know, energy consumption is directly proportional to data packet size. Calculate to show that how doubling the packet size can increase the total energy consumption. Compare the results with the previous. (you may just use direct transmission only). Suggest one way how data size can be reduced?

Energy consumption = *Energyelec X a + Energyamp X d2 X a*

Energy consumption α a

Energy consumption α d

1. Energy consumption is directly proportional to the distance. Calculate to show that how doubling the distance d can increase the total energy consumption. Compare the results with the previous. (you may just use direct transmission only).

**Question 4**

Sink

2m

4m

2m

**Figure 4**

A linear personal area network (PAN) (see Figure 4) is composed of 3 close-by motes and a distant Gateway. The communication is performed by electing a cluster head among the three motes which collects the traﬃc from the other motes and sends it remotely to the gateway.

energy required for TX/RX circuitry, Ec=100 [nJ/bit],

energy required for transmission power Etx(d) = kd2 [nJ/bit], being k=1 [nJ/bit/m2],

packets size a =1000 [bits],

Initial energy of each node = EI  = 150 nJ

1. Find the total energy consumption for three cases a) when S1 is the cluster head, b) when S2 is the cluster head and c) when S3 is the cluster head.

2. Which setup would give the most efficient energy consumption, a, b or c?.

3. What is the total energy consumption when direct transmission is used without cluster head election. Which setup is better?

4. Calculate the lifetime under all these cases.

5. Calculate the lifetime when cluster head election follows the following sequence S1-S1-S2-S3-S3

**Question 5**

4m

D=15m

Sink

**Figure 5**

Figure 5 shows a simple personal area network (PAN) that consists of n number of sensor motes and a Pan coordinator that collects periodical humidity data from the motes and finally conveys the messages to the sink.

Calculate total energy consumption in i) when 4 motes send the humidity data to the coordinator and coordinator just relay the received data to the sink. ii) coordinator performs average of the humidity and only then sends the average data to the sink. iii) Is there a possibility that energy consumption using averaging is less efficient than without averaging?

Energy to send/receive per packet Ec = 3 µJ

Energy required for transmit amplifier Et = 100 µJ

Energy for calculating average EA = 2 µJ

Initial energy of each node = EI  = 105 µJ

Packet size b = 100 byte

Hint : (Et X d)

**Question 6**

In a simple WSAN network, temperature measurement has to be taken every 250ms whereby every reading takes 10ms and sending is required only once per second. When a node sends a packet, it is expected that the node receives a packet as well. The packet size is 250 bytes and the radio bandwidth is 6400 bits/s. More properties of energy consumption is given below:

Idle mode : 0,05mA

CPU computation: 9mA

Sending of wireless data: 10mA

Receiving of wireless data: 5Ma

1. Calculate the lifetime of each node?
2. There are several factors not considered here which might affect the overall energy consumption. List down FOUR (4) factors that may increase or decrease the energy consumption calculated in Q2.(c ).(i).

**Question 7**

You are required to design a wireless sensor and actuator system for a smart home. The main task is to monitor the apparels at home, automatic monitoring of electrical appliances and lights as well as to monitor intruders.

1. Name all the parameters that your sensor should monitor
2. List down all the sensor modalities required
3. What kind of actuators needed in this case

**More exercises**

**Question 8**

A

Event

For the network shown explain how the following works. Use suitable table to show or you may re draw the diagram.

1. SPIN
2. Directed Diffusion
3. Rumor Routing
4. Clustering

**Question 9**

A border tracking system is to be developed for detecting human intrusion or movement within the border of countries. For this you need to identify the following

1. Aspects
2. Sensor modality
3. How to detect presence of human
4. System and experiment