PROJECT DESCRIPTION[1]

In this project, you are required to generate a network model for a wireless sensor network and calculate the network's lifetime.
It is recommended to use Matlab for the required simulations. However, it is not mandatory. Any other network simulator or programming tool can be used.

The wireless sensor network under study is composed of homogeneous sensor nodes that are deployed in the area of interest. Sensors are randomly distributed in the deployment area. It should be noted also that sensor nodes need to be located close to each other to ensure that they always have correlated data.

The sink node is assumed to be static and located far away from the sensors field. Although it may be more energy effective that the sink is located in a nearby location to minimize the communication distances, but in some cases this may be impractical. In some scenarios, the sink may be a mobile one, but this project is targeting static networks in which the sensor nodes, as well as the sink are static.

A. Assumptions

In the model under study, several basic assumptions are considered:

- All the sensors are homogeneous and energy constrained. This imposes the challenge of lifetime elongation subject to this constrained energy.
- All the sensors are sensing the environment at a fixed rate, and thus they all always have data to send at predetermined time instants.
- All the sensors can transmit with enough power to reach the sink if needed. This assumption becomes more valid for small sized networks such as the network example under study.
- The sensors can use power control to vary the amount of transmit power. This allows the sensor nodes to use the minimum amount of energy to ensure that the required message reaches its destination.
- Each sensor has the computational power to perform different signal processing functions. This enables any sensor to be selected for tasks that require high computational power.
- The sensors have a method to be aware of their position after deployment. This can be guaranteed via many methods. Sensor nodes may be equipped with a position finding system (e.g. GPS). Signal strength measurements may be also used to have knowledge about locations.

B. Energy Consumption Model

A sensor node uses its available energy in order to carry out three main functions:

- *Acquisition*: The energy consumed to carry out the acquisition is generally negligible.
- *Communication*: This consumes more energy than any other task. This covers the communication in terms of transmission and reception.
- *Data processing*: The energy consumed for the calculation operations is very low as compared to the communication energy. This processing may be data aggregation, diffusion, packetization and/or coding.

[1]The problem described in this project, as well as the energy and radio models are adopted from:
Samy S. Soliman, "*Hierarchically Clustered Wireless Sensor Networks: Lifetime Optimization Techniques*," ISBN 978-384-840-321-9, LAP LAMBERT Academic Publishing, Mar. 2012.

C. Transceiver Radio Energy Model

A simplistic radio model is considered here. Although there may be more realistic and complex models, yet this model is still used in the literature due to its simplicity.

The model assumes that for transmission, the radio dissipates E_{elec}, which represents the energy dissipated in the electronic circuitry of the transceiver block as well as other electronic circuitry, to run the transmitter circuitry and E_{amp}, which is the energy used by the transmit amplifier to provide the signal with power gain in order to achieve an acceptable signal-to-noise ratio. For reception, the radio dissipates only E_{elec} to run the receiver circuitry.

D. Channel Propagation Model

In a wireless channel, the electromagnetic wave propagation can be modeled as falling off as a power law function of the distance between the transmitter and receiver. So, generally the received power decreases as the distance between the transmitter and receiver increases.

In this project, both the free space model and the multi-path fading model are used, depending on the distance between the transmitter and receiver. For short distance communications, $d \leq d_0$, the free space model, for which the path loss factor is equal to 2, is used. For long distance communications, $d > d_0$, a fading model with path loss factor equals to 4 is used.

To transmit a "k" bits message aver a distance d, the transmitter consumes

$$E_{\text{tx-short}} = k\, E_{elec} + k\, \varepsilon_{\text{amp-short}}\, d^2 \quad \text{, for short distances}$$

$$E_{\text{tx-long}} = k\, E_{elec} + k\, \varepsilon_{\text{amp-long}}\, d^4 \quad \text{, for long distances}$$

where $\varepsilon_{\text{amp-short}}$ and $\varepsilon_{\text{amp-long}}$ are the amplifier gains at the transmitter for short and long distance communications, respectively. To receive a "k" bits message, the receiver consumes

$$E_{rx} = k\, E_{elec}.$$

Network and system parameters are summarized in Table I.

REQUIRED

Part A Generate a WSN that consists of $N = 100$ identical sensor nodes, randomly distributed in a network area $A = 100m \times 100m$.
You may need to use the same network realization of Project 1.

Part B Consider the sink is located at the network center. Assume that all the sensor nodes start with an initial energy of 2 joules. Assume that both direct transmission and dual-hop transmission are used, and that $d_0 = \sqrt{\frac{\varepsilon_{\text{amp-short}}}{\varepsilon_{\text{amp-long}}}}$.
Define a cycle as the duration from sensing the data by the sensor till it reaches the sink.
Assume that sensor nodes within R meters from the sink node directly transmit their data to the sink, while sensor nodes at a distance greater than R meters from the sink use dual-hop transmission to the sink through an intermediate sensor node. The intermediate node is chosen such that the sum of its distances to the sending node and to the sink is minimum.
Write an .m file to implement the function of the intermediate relay node selection.
Plot a graph of the number of active (not dead) nodes versus the number of cycles, till the death of the last node for $R = 30$ meters.
Note: One sensor node is allowed to be the intermediate note for more than one sensor node.
Hint: Assume that the intermediate node does not aggregate its data and the data it receives from other sensor nodes.

Part C On the graph obtained in Part B, **Identify** the network's lifetime, T_1, to the death of the first node.
Plot the remaining energies of the N nodes after T_1 cycles.
What are your observations?

TABLE I: Network and System Parameters

Parameter	**Symbol**	**Value**
Network size	$M \times M$	100 m $\times$ 100 m
Number of sensors	N	100 sensors
Transmitter / Receiver electronics	E_{elec}	50 nJ/bit
TX Amplifier for short distance	$\varepsilon_{\text{amp-short}}$	10 nJ/bit/m^2
TX Amplifier for long distance	$\varepsilon_{\text{amp-long}}$	0.0013 nJ/bit/m^4
Aggregation energy	E_{agg}	50 nJ/bit/signal
Data packet size		500 Byte
Overhead packet size		125 Byte

Part D It is required to find the radius R that achieves the longest lifetime T_1. Assume that $R = [10 : 10 : \max R]$, where $\max R$ represents the limiting case when all sensor nodes are directly transmitting their data to the sink.
Plot the lifetime T_1 versus R.
Find the optimum R that maximizes T_1.
Plot the remaining energies of the N nodes after T_1 cycles for the case of optimum R.
Comment on your results.

Part E **Repeat** Parts B - D assuming the sink node is located at 175 meters from the network center, i.e. if the network center in (x_0, y_0), the sink is located at $(x_0, y_0 + 175)$
Compare the figures to those of Parts B - D.
Comment on your results.

Part F Can you think of a better criteria of selecting the intermediate node?
Test your criteria on the optimum R for the case of the far away sink by **plotting** a graph of the number of active nodes versus the number of cycles, till the death of the last node (a curve for the given criteria as obtained in part E, and a similar curve for your proposed criteria).
Comment on your findings.

Deliverable

Deliver, electronically, the following in a .zip file

1) **Source codes** (.m files) of all parts.
2) **Figures** in .fig format.
   Label the axes of each figure properly. Choose meaningful figure names.
3) **A complete .pdf report**, divided according to the required parts, with requirements labeled clearly. Make sure to write your observations and your comments of such observations.
4) A 5-**minutes comprehensive recorded video** showing your functioning simulation and your comments on the results.

Instructions

- Project 3 will be a continuation to this project, so work hard and seriously on this project.
- This is a **team** project, teams can be composed of $2 - 3$ students.
- All team members are accountable for all project parts.
- Team reports (including source codes, figures or comments) are not to be shared with others, neither before nor after submission. However, in-person discussions are encouraged.
- Any copied reports, either fully or partially, will receive 0 points. This applies to both the original and the copy.
- Late submission will be penalized at the rate of 15% for the first 2 days, another 15% for the next 2 days, after which no submissions will be considered.
- In submission, you have to submit **.m files** separately. In addition, the figure should be submitted in **.fig format** and should be **included** in the **.pdf report**. Reports should be comprehensive and readable on their own.
- The **.pdf report** is the main document to be evaluated, *i.e.* no credit is given for the source codes. However, source codes are to be checked against plagiarism.
- The grading criteria will be as follows:
  - **40%:** Completeness and correctness of every deliverable (as per the .pdf report).
  - **20%:** Clarity of figures, and proper labeling (as per the .pdf report).
  - **20%:** Report writing and organization.
  - **20%:** Comprehensiveness and clarity of content in the recorded video.