Optimal Relay Node Placement to Improve the Expected Life Time in Wireless Sensor Network Design

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***Abstract* — Wireless sensor network has become one of the main emerging technologies used to enhance the performance and the scalability of real-time monitoring design and IOT today. The functionality of wireless sensor networks differs from one application to another application. The expected lifetime also differs according to the application. Sensor nodes operate under extreme power constraints. So, minimizing the power consumption of each node by placing relay nodes in optimum locations is important to expand the lifetime of the whole network. Because the death of a single node may lead to the failure of the whole network. However, a two-tiered network architecture is used to reduce the power consumption in the network. To simulate the proposed algorithm and to evaluate its performance comparing an available algorithm we use the COOJA simulator. Then the network lifetime is measured and observed.**

Keywords — WSN, Node Placement, lifetime optimization

I. Introduction

Wireless sensor networks (WSN) are used to measure physical phenomenon changes. Applications like health care monitoring, industrial supervision, military applications are supported by WSN. WSN consist of several sensor nodes that are deployed in a target geographical area according to the instructions of specialists. A sensor node that has the capacity to monitor the physical changes communicates with other nodes in the network. Sensed data is collected by the Sink node using multi-hop or single-hop communication.

Sensor nodes (SN) operate on small batteries and have limited power. The lifetime of the network is determined by the time taken for the failure of the first sensor node due to lack of battery power. More energy is taken up for the communication process within the network. If one of the nodes fails, then the whole network will be failed. The factors affecting the performance of WSN are the efficiency of the network, cost, coverage, power consumption, packet drop rate, delay, and the network lifetime.

Special nodes called Relay nodes (RN) which have more power and higher transmission range are used to connect all sensors and establish a connection to pass all sensed data to the sink. The connectivity between the sink and sensor may be direct or it may be through relays.

There are two types of WSN namely, single-tiered or two-tiered. In a single-tiered network, both sensors and relays can pass data to other nodes. While in a two-tiered network, sensor nodes are not responsible for forwarding the packets sensed by other sensor nodes. when the devices have the same hardware capabilities such as memory, battery, processor, and features in communication devices then that is called A homogenous network. Heterogeneous networks are when the devices have different hardware capabilities [1].

In [2] Nitesh and Jana proposed an algorithm for the connectivity problem by placing a minimum number of relay nodes and minimizing the overall communication cost as the constraint. The arbitrarily deployed sensor nodes were generated by an algorithm based on a spiral sequence.

According to Sapre and Mini [3], The proposed algorithm is to ensure that all the SNs have connectivity to the sink node using the minimum number of RNs.

The research carried out is presented as an optimization problem. To enhance the lifetime of the network the RNs are placed in optimum places. In this network, an environment with already deployed SNs in an open area having a line of sight is considered.

II. Objectives

The goal of this research is to formulate a mathematical model to show the optimal placement of RNs and to design the network in order to increase the expected network lifetime.

III. Methodology

Let's assume that all nodes in the network are homogeneous and sensor nodes are already deployed. Relay nodes are layered according to the proposed algorithm. Here we are considering a two-tiered network because if the sensor node will transmit the data collected from other SNs, then the battery life of the SN will be dissipated so quickly. So, here sensor nodes can only communicate with relay nodes to pass the sensed data but do not pass the sensed data of other nodes. Relay nodes can communicate with both sensor nodes and relay nodes.

Here we assume, there are n number of SNs and m number of RNs. The value of m, i.e. the no of RNs, is given by the algorithm. Let's say Di is the Euclidean distance from the sink to the sensor node Si

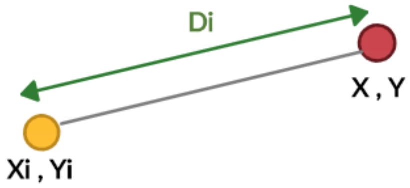

Fig 1.- Euclidean distance between SN and Sink

$$Di = \sqrt{((X - Xi)^2 + (Y - Yi)^2)} \qquad (1)$$

Here Xi, Yi are the X and Y coordinates values of SN and X, Y are the coordinates of the Sink node.

A SN can communicate with a RN only if the relay is in the range of the SN. If the range of the RN is r and the range of the SN is R, then to establish the connectivity between two nodes,

$$\| Di - r \| \leq R \qquad (2)$$

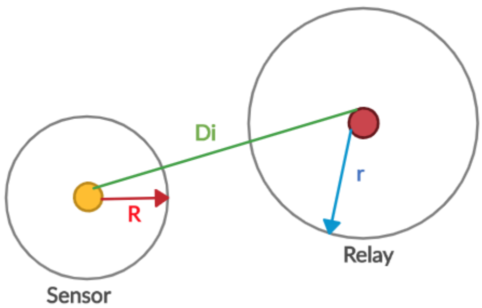

Fig 2.- Communication distance between SN and RN

In our proposed algorithm we measure Euclidean distance between each sensor node and sink. Sensors which having Euclidean distance less than the range of the sink node are covered directly. The sensor node which has the longest distance from the sink node is selected and check around the transmitting radius of the sensor, for the placement location of the relay node which covers the maximum number of relays. To find that position we scan all the possible positions of the relay nodes at a distance of R, which is the range of SN from the selected sensor node which has the highest Euclidean distance from the sink node. After scanning all 360̊ a relay is placed at the position where the relay can cover a maximum number of sensors. But if there is more than one probable position that covers the maximum number of SNs then we take the Euclidean distance also into consideration. From those probable positions where it covers the maximum number of RNs, we place the RN in the place where the Euclidean distance from the sink to the RN that we are going to deploy is minimized. The SNs which are get covered from the deployed relay node are not required to be taken into consideration. So, we eliminate them. Then all remaining sensors are considered and repeat the same procedure until all SN establish the connectivity path to the sink.

Algorithm		
Input	:	Positions of sensor nodes, Geographical area, Sensor range.
Output	:	Positions of relay nodes
Step 1	:	The sink is placed at 0,0 position.
Step 2	:	Sensors are placed in a given geographical area.
Step 3	:	Marked the ranges of sensor nodes.
Step 4	:	calculate the Euclidean distance from the sink to each and every sensor node.
Step 5	:	Separate the sensors within the range of the sink node which has direct connectivity to the sink.
Step 5	:	starting from the sensor node with the highest Euclidean distance from the sink node find a position around that sensor at a distance equal to its range among all possible positions which can cover maximum no. of neighbor sensors.
Step 6	:	If there are more probable positions that cover the maximum no. of relay nodes, then select the position which has the minimum distance to the sink node.
Step 7	:	eliminate the selected sensor node and its covered neighbors leaving the relay node at the placed position
Step 8	:	repeat steps 5,6 and 7 until all sensor nodes are covered and the connectivity is established.
Step 9	:	Find the optimum position to place relay nodes considering the selected relay node positions.

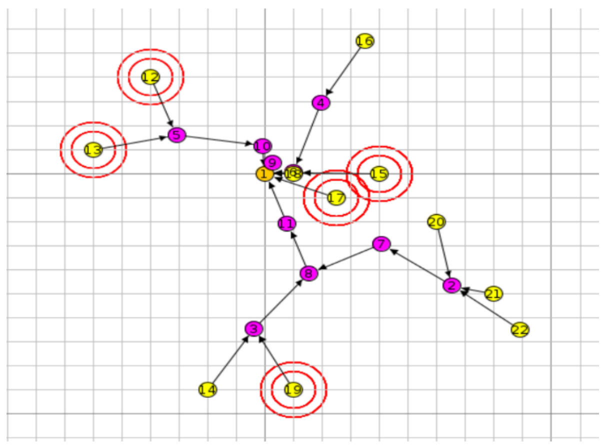

Fig 3.- Topology of the proposed algorithm

IV. Results and Discussion

According to given sensor locations first, the number of RNs needed to establish the connectivity in the network and their locations were obtained using our proposed algorithm. Then, various data sets for different sensor locations were set.

And relevant to those sensor locations the required number of relay nodes and their locations were obtained.

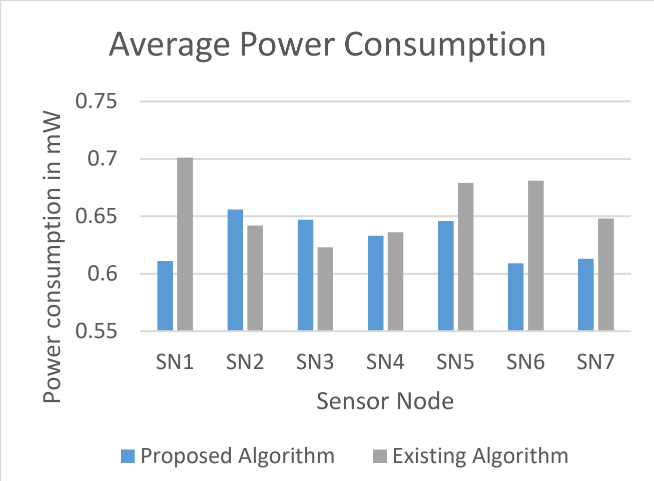

Fig 4.-Average power consumption comparison between sensor nodes of proposed and existing algorithms.

The power consumption of the sensor nodes is varying with the placement of the relay nodes. We took two scenarios where the SN locations are the same, but the relay nodes are placed using an existing algorithm and using the proposed algorithm. After simulating the sensor network using the Cooja simulator it could be observed that as a whole, sensor nodes in the network where the RNs are placed using the proposed algorithm consume less power than the SNs in the network where RNs are placed using the existing algorithm. Fig.4 represents a comparison between the power consumption of the SNs in both scenarios. According to fig. 4, it can be seen that some SNs in the proposed algorithm consume more power compared to the existing one. It is because of the difference in RN locations. The power used to transmit data from a SN to a RN varies according to the placement of RNs. The performance of the proposed network can be affected by; the power consumption due to the distance from the SN to the RN when SN transmits the data and when more RNs connect to the SN according to the proposed algorithm. Therefore, the network can show a lower performance

However, our aim is not to reduce the power consumption or to increase the performance of each and every SN. But it is to improve the expected lifetime of the whole network. The lifetime of the network is determined by the time taken for the failure of the first sensor node due to lack of battery power. So, according to fig 4, the probability of the failure of sensor node 1 (SN1) where the RNs are placed using the existing algorithm is high as its power consumption is very high when comparing with other sensors. So, the lifetime of the network in the existing network is less compared to the proposed network. Though some sensor nodes consume more power in the proposed algorithm the possibility of failure of the first sensor node is less when compared to the existing one. So, the lifetime of the proposed network is higher than the existing one.

The average power consumption of all the SNs in the network where the RNs are placed using the proposed algorithm is graphed after the simulation using the COOJA simulator. And it is shown in fig. 5

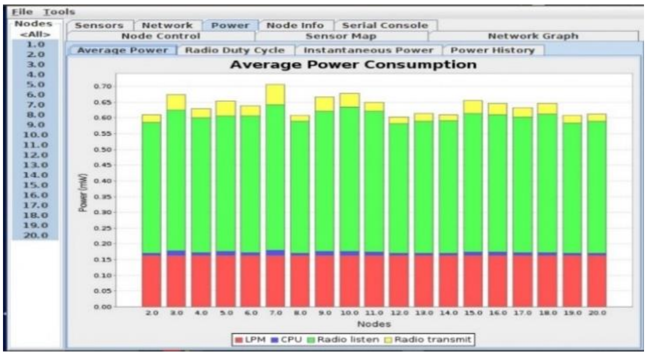

Fig 5.-Average power consumption comparison of the sensor nodes in the proposed algorithm

V. CONCLUSION

In this paper, we have presented an algorithm to enhance the lifetime of the overall network. The relay node placement was done by minimizing the communication cost and overcoming the connectivity problem. Therefore, the locations we obtained through this algorithm can be considered as the optimal locations for the placement of relays in the WSN. We took a comparison with an existing algorithm and the obtained results were analyzed to show that our proposed algorithm contributes to prolonging the lifetime. Through this research, we have proved that the algorithm we proposed takes prominent places in the successful deployment of relay nodes.

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