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

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Abstract— Wireless sensor network has become one of the main emerging technologies today in the world to enhance performance and scalability of the real-time monitoring designs. Functionality of wireless sensor networks differ from one application to another. This paper proposes an algorithm which is capable of enhancing the expected lifetime of a wireless sensor network by placing relay nodes in optimum locations. The sensors are operated under extreme power constraints. However, we use two tired network architecture to reduce power consumption in the network. We use COOJA network simulator to simulate the proposed algorithm. And therefore, network lifetime is measured and observed.

Keywords—WSN, Relay node placement, Lifetime optimization.

I. Introduction

Wireless sensor network (WSN) consists of number of sensor nodes deployed in a target geographical area to measure the physical phenomenon change in that area. Many applications are supported by WSNs including applications related to health care monitoring, industrial supervision, military applications etc. Therefore, this highly flexible, easy to deploy, autonomous network is much over traditional networks.

Sensor node is an electronic device which has capacity to monitor the physical changes like temperature, pressure, motion in the target geographical area, performs processing and communicates with the other connected nodes in the network. In WSN design, sensor nodes are placed by the logical parameters which are designed by the specialists in that particular area of study. Sink node collects the sensed data from the sensor nodes using multi-hop or single hop communication and so connects the network to the outside world.

Sensor nodes are identical in nature and is operated on small batteries with limited power. more of the energy is taken up by the communication taking place within the network more than the computation. The network lifetime is defined by the time taken for the first sensor to fail due to lack of battery power. Because of this, sensor nodes are unable to achieve the expected lifetime of the network due to the power consumption in transmission and reception of data packets. So, when sensor nodes are out of battery, they are assumed to get disposed and the whole network goes down if one of the sensor nodes fail. Long-range communications therefore become a problem and so short-range communications should be used. There are several factors affecting the performance of the WSN such as efficiency of the network, cost, coverage, power consumption, packet drop rate, delay and network lifetime.

To restore connectivity, special nodes known as relay nodes have been introduced into the network. These types of nodes have more power, higher transmission range and is expensive as compared to the sensor nodes in a network which enforces only a minimum of them to be used. This is used to establish a network to connect all the sensor nodes to gather information from physical world and to forward the sensed data thereby offering a new path for each sensor node and sink.

Here in our paper, we propose an algorithm to determine an optimal relay node placement to an already deployed sensor network to extend the lifespan of the overall network while establishing the connectivity of the network. Thereby through this network, all the sensor nodes will be covered, where each of these nodes which will be out of the reception range of sink node will be connected via relay nodes. And the relay nodes will establish a connectivity to the sink node directly or through other relay nodes.

The remained of paper is organized as follows. Several researches done so far under this topic of WSN relay node placement is described in section II. Section III describes the model of the WSN. In section IV, we present the proposed algorithm. In section V the results and the analysis of the proposed algorithm is described. The paper is concluded in section VI. Section VII is separated for future works.

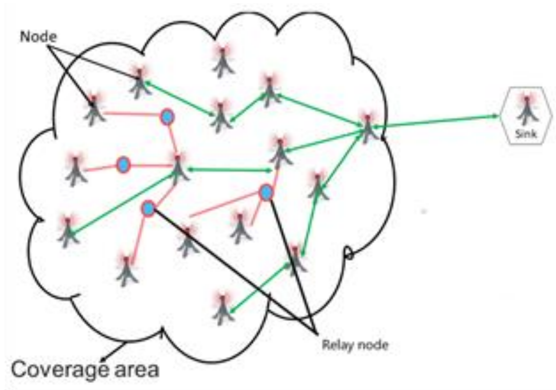

Figure 1: Architecture of WSN.

II. Related work

Deployment of relay in WSNs has been one of the major discussing topics in the world today. Many researches have been done in order to find solutions for that problem. Below discussed are some of the prior works for the relay node placement problem in WSN design.

This network can be mainly classified basically into two, single-Tiered and two-tiered. In single-tiered network, both the sensors and relays can pass on the packets to other nodes. Else it can transmit directly to the sink node, if the sink node is in range of the transmitting node. In two-tier architecture, sensor nodes are not responsible for forwarding the packets sensed by other sensor nodes. A homogenous network is a network when the devices have the same hardware capabilities such as memory, battery, processor and features in communication devices. Heterogenous networks are when the devices have different hardware capabilities [1].

Many researches under this topic have been conducted soo far, but relatively only a little has been conducted on constrained relay placement. In this placement, the positions which are potential for relay node placement is limited due to various restrictions such as coverage, delay, packet drop rate and mainly the lifetime of the network.

In [2] Nitesh and Jana proposed an algorithm for the connectivity problem by placing 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 spiral sequence.

According to Sapre and Mini [3], The proposed algorithm is to ensure that all the SNs have the connectivity to the sink node using minimum number of RNs. Connected components are formed by grouping together the sensor nodes in the same communication range and then placing a relay node in between each of the connected component and then forming a single component to form the full connectivity.

In many of the WSN applications, the deployment success is dependent upon network communication efficiency. This is stated in [4] a drastical network lifetime reduction will be due to a higher number of packet transmissions.

The aim of the authors who have done this research[5] is that when the locations of sensor nodes, , cluster heads and base station are given on a grid of wireless sensor network, the optimal locations of RNs that maximize the lifetime of the network is determined satisfying the constraints on cost budget and connectivity.

Here the authors in [7] have considered the energy provisioning problem for a two-tiered WSN. Relay node placement is also considered here to mitigate geometric deficiencies of the network. This is also done to prolong network lifetime, both energy provisioning and Relay node placement are jointly considered here into a mixed-integer nonlinear programming (MINLP) problem. This WSN has a cluster where each and every cluster is deployed around a location which is strategic and consists a number of microsensor nodes (MSNs) and one aggregation and forwarding node (AFN).

The authors [8] of this paper begins with placing relay nodes in WSN given a limited set position. A solution is proposed which consists of using a weighted communication graph drawn based on outage probabilities. Here pathloss, fast fading, interference is considered. So, the aim of this research is to minimize the outage when constructing the routing tree by adding minimum number of RNs that guarantee the connectivity. A heuristic is carried here because determining an optimal solution for a two-tiered constrained RN placement is NP-hard.

In this paper [9] an approximate algorithm is presented for RNP problem to in order to maximize the lifetime of the network with a connectivity guarantee. First, the RNs are connected through a greedy scheme to make the connectivity and then redundant RNs are placed on the known positions of RNs to maximize the network lifetime. Those authors have carried out experiments in order to show the performance of their algorithm compared with optimal placement.

The research carried out is presented as an optimization problem. The RNs are placed in optimum places to enhance the lifetime of the sensor network. In this network, we have considered an environment with already deployed SNs in an open area having line of sight. Forming a fully connected network using additional nodes to transmit data efficiently with low power consumption is the main idea of our proposed algorithm. The algorithm proposed through this research is therefore compared with an existing algorithm.

III. Network model

Sensor nodes and relay nodes are the two types of nodes which are consisted in a wireless network model. Sink is the node that collect data to the network. We assume in our proposed model all nodes in the network is homogeneous and sensor nodes are placed according to a logical algorithm of specialists in that area. Relay network is layered according to the proposed algorithm. According to the two tired architecture sensor nodes communicate only with relay nodes but not with sensor nodes. Relay nodes can communicate with both sensor nodes and relay nodes.

Here we assume,

- the no of SNs is n
- the no of RNs is m

The value of *m*, i.e. the no of RNs, is given by the algorithm.

1. SNs Set= S= {S1, S2, S3, S4…………., Sn}

2. RNs Set = R = {R1, R2, R3, R4………….., Rm}
3. Di = Euclidean distance from the sink to the sensor node Si

$$Di=\sqrt{\{|Xi - X|2 - |Yi - Y|2\}}$$

Here Xi = X coordinate value of SN, Si

Yi = Y coordinate of SN Si

X = X coordinate of the sink

Y = Y coordinate of the sink

4. r = Range of a relay node
5. R = Range of a sensor

The SN can communicate with the RN only if the relay is in the range of the SN. That is,

$$\| Si – r \| \leq R$$

C_{ij} -is binary variable value,

$$C_{ij} = \begin{cases} 1; \text{ If sensor is in the cluster} \\ 0; \text{ Otherwise} \end{cases}$$

Neighbors (N_i) – Set of sensors within the range of a relay

Covered (D_i) - Set of sensors within are within the rage of a sensor

For the cluster formation each cluster should assign to connect only to one relay node,

$$\sum_{J=1}^{m} C_{ij} = 1 \quad \text{,where } 1 \leq i \leq n$$

IV. Proposed algorithm

We considered two tired network architecture. Where sensors only can communicate with the relay nodes not with the sensor nodes. That is because our aim is to maximize the lifetime of the WSN. If the sensor node will transmit the data collected from other SNs, then the battery life of the SN will be dissipated so quickly. In the considered WSN the locations of sensors are already known and they are fixed and some relay nodes should be placed to establish connection between sensor node and relay node which are not in the range of sensor node. A sensor is able to communicate with a relay only if it is within the range of the sensor node.

In our proposed algorithm we measure Euclidean distance between each sensor node and sink. Sensors which having Euclidean distance less than rage of the sink node is covered directly. Sensor node which have longest distance from the sink node is selected and check around the transmitting radius of the sensor ,for the placement location of relay node which cover 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 are more than one probable position which cover maximum number of SNs then we take the Euclidean distance also into consideration. From those probable positions where it covers 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 01		
Input	:	Positions of sensor nodes, Geographical area, Sensor range.
Output	:	Positions of relay nodes
Step 1	:	Sink is placed at 0,0 position.
Step 2	:	Sensors are placed in the 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 a 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 which cover 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 step 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.

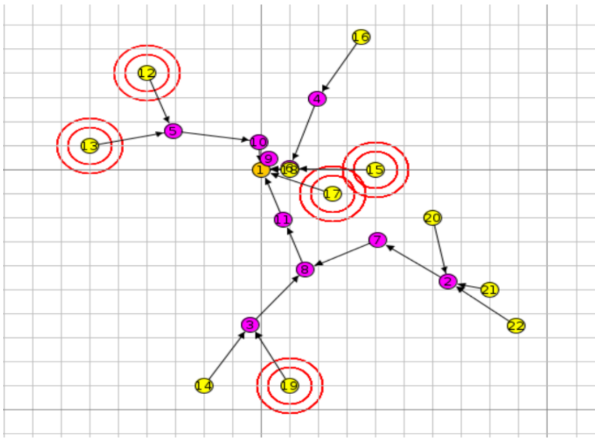

Figure 2:Topology of proposed algorithm.

V. SIMULATION RESULTS

According to sensor locations first we found the number of RNs and their locations using our proposed algorithm. We set several data sets for sensor locations and obtained the number of RNs and their relevant locations for those data sets.

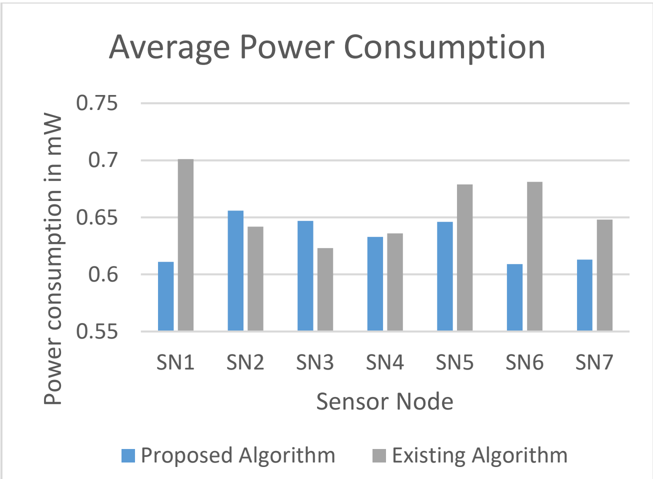

Figure 3:Average power consumption comparison between sensor nodes of proposed and existing algorithms.

Power consumption of the sensor nodes are varying with the placement of the relay nodes. We took two scenarios where the SN locations are the same and placed RNs using both existing and proposed and algorithms. After simulating the sensor network using cooja it could be observed that sensor nodes in the proposed algorithm consume less power than the existing one.

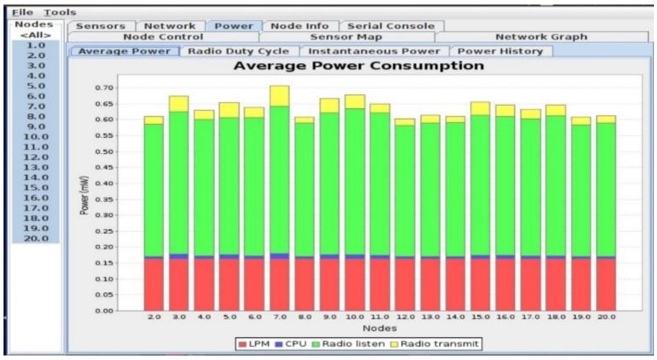

Figure 4:Average power consumption comparison of the sensor nodes in the proposed algorithm

VI. CONCLUSION.

In this paper, we have presented an algorithm to enhance the lifetime of the overall network. The placement of relay nodes 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. To show that our proposed algorithm contributes in prolonging the lifetime, we took a comparison with an existing algorithm and the obtained results were analyzed. Through this research, we have proved that the algorithm we proposed takes prominent places in the successful deployment of rely nodes.

VII. FUTURE WORK.

Here in the simulation using Cooja an area with a line of sight is assumed. But in real world such a situation can not be found. So, the project should be modified in order to make the algorithm suitable even for areas with interferences.

The algorithm can be modified by jointly considering the packet drop rate and packet delay. There are no such algorithms yet jointly considering all of them.

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