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Efficient Energy Utilization in Wireless Sensor Networks by installing Relay Stations

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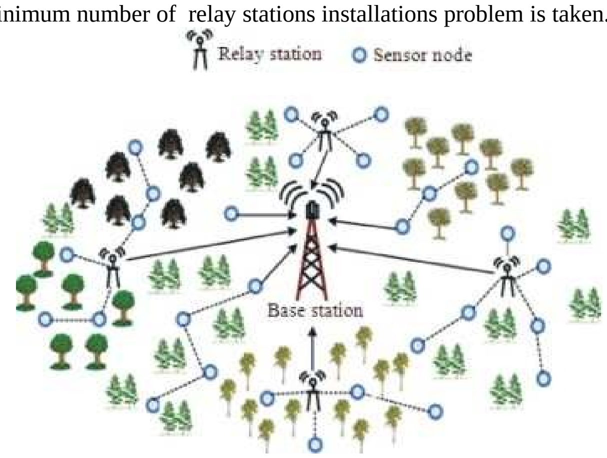
***Abstract*—This research presents a study of efficient energy utilization in Wireless Sensor Networks (WSNs) by installing relay stations(RSs). We first focus on the problem of optimal installation of RSs so that the cost of network can be reduced. Then we focus on the efficient utilization of energy in sensor nodes(SNs). Here we use the method of Integer Linear Programming to design the network. This model takes into consideration not only the minimal number of relay station installment but also the lifetime of network and its reliability in transferring the packets from sensor nodes to base station.**

Keywords- Wireless sensor network, Energy utilization in sensor nodes, relay station installation, Integer linear programming, assignment problem, relay station failure.

I. INTRODUCTION

Wireless sensor networks(WSNs) find its applications mainly in the fields of security monitoring, military applications where they transmit the information to the base stations. Sensor nodes can send the information directly to the base station or indirectly through the sensor nodes. SNs run on limited energy resources and it is highly unlikely to repair or replace the dead ones. Hence there is need for efficient utilization of energy of sensor nodes. This can be done by installing relay stations in the sensing field. The RSs are to be installed such that with the minimum number of relay stations maximum area is covered (as shown in fig.(1)). Moreover, highly sophisticated energy resources like large solar batteries can be used in relay stations. While installing relay stations parameters like cost of installation, reliability of network and range of radio communication between the nodes are considered. Optimal placement of RSs is also developed by considering the failure of one of the relay stations. If an RS is failed then the nearest nodes to that RS have to find an alternate route to the BS. So they will send the data to the nearest node or BS whichever is nearer just as in the case as no relay stations.

The main concern for energy saving in sensor nodes is put forward from the studies of [1],[2],[6],[9],[10]. There are proposed models of base station placement from [1],[2],[6],[9]. The problems on the lifetime of network are studied from routing techniques [2],[3] and rate allocation[5]. Since the energy consumption is based on the distance traveled by the data from nodes the shortest path to the base station is obtained by [3]. The relay station placement problem is considered from [7] where minimum number of relay stations installations problem is taken.



Fig(1)

II. PROBLEM DEFINITION

The main aim of the WSN design proposed is to install relay stations optimally in the sensor field from a set of favourable sites and minimizing the route of travel of sensor information by using RS placement and assignment problems. In the network there are many routes an information can be transferred from sensor node to base station. It may take the path of node to node or node to relay station or node to base station directly. If the node carries information a long way, it requires high amount of energy. Hence instead of sending the data directly to the base station it selects the nearest node/RS/BS and send the data through it. It improves the lifetime of the node. The model proposed focuses on the efficient route to carry data so that no information is lost.

1)Problem Formulation:

The proposed WSN design problem is formulated as Integer Linear Programming (ILP) models. It includes two problems. Relay station placement and assignment problem and minimum energy relay station placement problem.

2)RS Placement and assignment problem:

The RS placement and assignment problem is mainly concerned with the parameters of installing least number of relay stations in optimal sites and yet network functioning is guaranteed and reliable.

3)Minimum energy-RS placement problem:

The minimum energy-RS placement problem is concerned with minimal energy consumption of sensor nodes by assigning the shortest path to the data and also lifetime of network and packet delivery to base station.

$$\text{Minimize} \sum_{\forall j \in J} X_j \quad \text{--------} (1)$$

The above objective function is to minimize the no. of relay stations.

Sets:

I A set of Sensor Nodes (SNs)

J A set of sites for Relay Stations (RSs) installation

M A set of Base Stations (BSs)

Decision variables:

x_j It is 1 if RS is installed at a site j, $\forall j \in J$ and 0 otherwise

s_{ik} Data sent from SN i to SN k; i and k $\in$ I

r_{ij} Data sent from SN i to RSj; i $\in$ I and j $\in$ J

b_{im} Data sent from SN i to BSm; i $\in$ I and m $\in$ M

Constant parameters:

C_{tSN} Coefficient of energy consumption for data transmission from SN i to SN k; i and k $\in$ I

C_{tRS} Coefficient of energy consumption for data transmission from SN i to RS j; i $\in$ I, j $\in$ J

C_{tBS} Coefficient of energy consumption for data transmission from SN i to BS m; $i \in I$, $m \in M$
C_r Coefficient of energy consumption to receive data
P_{tSN} Threshold for the strength of received signal for SNs
P_{tRS} Threshold for the strength of received signal for RSs
P_{tBS} Threshold for the strength of received signal for BS
P_{ik} Strength of the signal that a SN k receives from SN i; i and $k \in I$
P_{ij} Strength of the signal that a RS j receives from SN i; $i \in I$ and $j \in J$
P_{im} Strength of the signal that a BS m receives from SN i; $i \in I$ and $m \in M$
B Buffer size limitation of RSs
T The required lifetime for the network
E_i Initial energy of battery of SNs
g_i Data generating rate of SNs

Constraint equations:

$$s_{ik}(P_{ik} - P_{tSN}) \geq 0, \forall i,k \in I, i \neq k \text{----}(2)$$

$$r_{ij}(P_{ij} - P_{tRS}) \geq 0, \forall i \in I, \forall j \in J \text{----}(3)$$

$$b_{im}(P_{im} - P_{tBS}) \geq 0, \forall i \in I, \forall m \in M \text{----}(4)$$

$$(T^*g_i) + \sum_{\forall n \in I}^{n \neq i} s_{ni} = \sum_{\forall k \in I}^{k \neq i} s_{ik} + \sum_{\forall j \in J} r_{ij} + \sum_{\forall m \in M} b_{im}, \forall i \in I \text{----}(5)$$

$$\sum_{\forall j \in J}(T^*g_i) = \sum_{\forall j \in J}\sum_{\forall i \in I} r_{ij} + \sum_{\forall m \in M}\sum_{\forall i \in I} b_{im}, \forall j \in J \text{----}(6)$$

$$\sum_{\forall i \in I} r_{ij} = Mx_j, \forall j \in J \text{----}(7)$$

$$\sum_{\forall n \in I}^{n \neq i} C_r s_{ni} + \sum_{\forall k \in I}^{i \neq k} C_{tSN} s_{ik} + \sum_{\forall j \in J} C_{tRS} r_{ij} + \sum_{\forall m \in M} C_{tBS} b_{im} \leq E_i, \forall i \in I \text{----}(8)$$

$$x_j \in \{0,1\}, \forall j \in J \text{----}(9)$$

$$s_{ik} \geq 0 \ \forall i,k \in I, i \neq k \text{----}(10)$$

$$r_{ij} \geq 0 \ \forall i \in I, \forall j \in J \text{----}(11)$$

$$b_{im} \geq 0 \ \forall i \in I, \forall m \in M \text{----}(12)$$

4)Minimum energy-RS placement problem:

$$\text{Minimize} \sum_{\forall i \in I}^{i \neq k \neq n} \left(\sum_{\forall k \in I}^{k \neq i} s_{ki} C_r + \sum_{\forall n \in I}^{i \neq n} s_{in} C_{tSN} + \sum_{\forall j \in J} r_{ij} C_{tRS} + \sum_{\forall m \in M} b_{im} C_{tBS} \right) \text{----}(13)$$

The minimum energy-RS placement problem, denoted as MERP, aims to minimize energy consumption of SNs in the network with the use of mathematical model written in equation 13. Furthermore, we enforce that the resulting network can guarantee the required network lifetime and the packet delivery from all SNs to BS. We incorporate these network design requirements through a set of constraints 2-12 described above:

5)Relay station failure problem:

Sometimes due to many reasons there may be a failure of a relay station. There will be loss of information sent by sensor nodes in this case. To avoid this as soon as a problem occurs in RS, it alerts the administrators of the network who shuts it off momentarily and makes it invisible for the SNs until it is repaired. During this period the SNs will be directed to send the information to nearest sensor nodes in the destination way. This may consume some more energy by SNs but guarantees the data integrity.

III. RESULTS

Different cases are considered for installation of relay stations. When the relay stations are installed in large numbers, then more nodes will be covered by a single relay station. Hence the energy required for SN to send the information is less, thus increasing its lifetime. In this case the cost of installation is more. Otherwise if optimal installation of RSs is considered then some of the sensor nodes may have to use more energy, thus reduction of lifetime. Hence a balanced approach is needed. In either case the lifetime of SNs is more when compared to the case when relay stations are not installed. But in case of an RS failure the information is carried by only sensor nodes which consumes more node energy but no data will be lost.

IV. CONCLUSIONS

In this study, efficient utilization of energy in wireless sensor networks using the relay stations is observed. Relay station placement and assignment problem is considered for optimal placement of RSs across the sensing field to collect data from the nearest nodes and send it to base station. Second problem is about the minimum energy relay station placement problem which deals with optimal energy utilization in sensor nodes guaranteeing the packet delivery and maintaining the data reliability.

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