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Energy Efficient Algorithm for Routing Problem in Wireless Sensor Networks

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***Abstract*— Wireless Sensor Network (WSN) is a collection of sensor nodes. A sensor node covers all information which is present in its sensing range. To access the information present in some other sensor range, the networks use a process called Routing. Routing problem in wireless sensor network (WSN) concerned with maximizing the sensor network lifetime while continuously routing the collected data (information) to the base station (central server). A route (sometimes called as Path) is a set of sensors that establish a connection between a source node and a sink node (base station). The routing problem is used to determine a set of different routes with maximum aggregated lifetime while constraining the life of each sensor by its initial battery life. In WSN, we demand an energy-efficient path which is used to send collected information to the center base station. At the base station, the received data are processed further. In this paper, we try to design maximum number of energy- efficient routes in such a way that every path is a set of selected sensors (instead of all sensors). In this paper, we also give detailed analysis of earlier techniques and propose a new energy-efficient algorithm for designing these paths to maximize the total lifetime of the sensor network. The simulation section gives a clear proof of effectiveness of proposed algorithm when compared with some existing approaches.**

Keywords— Wireless Sensor Networks (WSN); Routes; Network Lifetime; Routing problem; Energy –Efficiency

I. INTRODUCTION

Wireless Sensor Network (WSN) consists of sensor nodes, which are used to collect the information in a network. These sensors are deployed in the network in a particular manner. Number of sensors to be deployed completely depends on the requirement of the application. Normally, sensors are deployed in large proximity for quality of service (QOS) parameter. These nodes have wireless communication and sensing computing capabilities [1, 2].

Now a days, due to recent technologies, manufacturing of sensor nodes become feasible in both ways economically and technically [3]. Sensors have limited battery life (energy level) and it is necessary to utilize the energy in an efficient manner to increase the sensor network lifetime. The batteries of sensors are impossible to replace or renewed [8]. For example, we also place sensors in the wild forest therefore, sometimes, it is very dangerous for a human being to replace the batteries of sensors over there, Because of this battery constraint, and sensors must be used in an efficient way so that it will function for a long time. Sensor nodes can be used in various applications like Environmental monitoring, Military, Fire detection, Humidity, Medical industry which require unattended operation [5].

Wireless Sensor Network can be of either type homogeneous or heterogeneous. In homogeneous network all the sensor nodes has same battery life and in Heterogeneous networks, sensors may have different batteries [8].

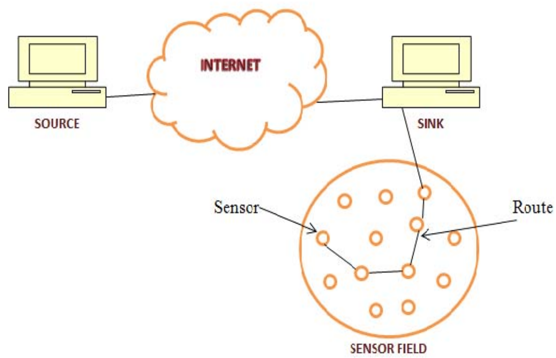

Fig. 1. Wireless Sensor network

As shown in Figure1, these sensor nodes communicate directly to each other or to an external base station which is called as sink node. A sensor node sends the information to base station (sink node) and at sink node process received data further.

There are two types of algorithms in Wireless Sensor Network: centralized and distributed. In centralized approach, algorithms are always executed at base station and then pass the result to each sensor in the network. In distributed approach, a number of sensor nodes perform the required task and then pass the result to other sensor nodes. Sensor nodes can be of mobile or static. Mobile sensor nodes do not have the fixed location because they are moving in the network as per application requirement. Static sensor nodes have fixed location and location can initialize at starting or they are randomly generated in the network [4]. A sensor has either type of mode active or sleeping. In active mode sensor is used to find a route while in sleeping mode sensors do not involved for finding a route. In large scale sensor network, at a time some sensors are used to find a route and remaining sensors are not used. Therefore, remaining sensors goes to sleeping state until they are not used to find a route.

Sensors can be selected by two approaches: disjoint approach and non-disjoint approach. In disjoint approach, one sensor can participate in only one sensor cover. And, in non-disjoint approach a sensor can participate in more than one cover.

Our objective is to activate/deactivate sensor nodes in a manner so that sensor network will be functional for a long time. One has to do this because it is impossible to recharge the sensor nodes battery. Therefore, in this paper, the proposed heuristic always tries to find maximum number of routes in such a way that total network lifetime can be maximized.

As discussed earlier, sensors are deployed in large proximity. Also, sensors are using limited battery life. So, here main objective is not to activate all of the sensors to route information from source to sink, but design a multiple energy-efficient paths and then alternatively activate these paths to achieve maximum life for the sensor network. There are many existing routing techniques [3, 4, 5, 6] presented by various researchers. This paper reviews all the techniques which can be used in routing and then proposes a new energy-efficient routing algorithm to maximize the sensor network lifetime.

The rest of this paper is organized as follows: Section 2 describes the review of some papers which we have studied to solve this routing problem. Section 3 presents problem statement. Section 4 explains the proposed scheme. Finally, conclusions and future work are given in section 5.

II. LITERATURE REVIEW

All the routing techniques by which one can find a path between two sensor nodes are presented by Al-Karaki [3]. This paper contains all the routing techniques by which a route is found between a source node and a sink node. Routing techniques are divided in the following categories:

A. *Network Structure*

1) *Flat Routing*: In this technique [1,4], all sensor node has the same role or functionality and they collaborate together to perform any task. In this. data centric routing is used where base station sends a query to certain regions and waits until it gets reply from sensors located in those regions.

2) *Hierarchical Routing*: In this routing technique, all sensor nodes have different roles. In this, mainly two functions are used. One of them is Routing and another is selection of cluster head [1, 4]. Higher energy nodes used to send data and lower energy nodes used for sensing the information.

3) *Location Based Routing*: In this routing, node's positions are exploited to route data. Sensor nodes are addressed by means of their locations [4]. Distance can be estimated on the basis of incoming signal strengths.

B. *Protocol Operation*

1) *Negotiation based Routing*: This technique uses high-level data descriptors [4] in order to eliminate redundant data transmissions through negotiation. In this type of Communication, decisions are also made based on the resources available to them.

2) *Multi-path based Routing*: This technique uses multiple paths to enhance the network performance. The fault tolerance is measured by that a path is available when our path fails. This can be increased by maintaining multiple paths which increases the traffic and consume more energy [13]. By maintaining multiple paths one can increase network reliability.

3) *Query based Routing*: In query based routing, destination node sends a query for data through the network and the sensor nodes that have this data send data to the node who initiate this query. These queries are written in High level languages or in natural language [4].

4) *QOS based Routing*: In this routing, there is a balance between the data quality and the consumption of the energy and network will satisfy some QOS metrics like energy, bandwidth or delay, when it delivered data to the base station [1, 4].

5) *Coherent and non-coherent based Routing*: These are the data processing techniques. In non-coherent techniques, we locally process the data before sending it to other nodes for the further processing. Nodes which perform further processing are called as aggregators. In coherent techniques, data is forwarded to aggregators after minimum processing like duplicate suppression and time stamping. In non-coherent technique we have low data traffic loading as compare to coherent technique [14].

A QOS based routing protocol in wireless sensor network is presented by M. Cardei et. al [15] where proposed approach uses QOS support to forward the packet in the network. The data is routed as packet type. Later on, to route the packets with different priorities, it use multiple transmission queues. To choose next hop, it select the node which is closer to the sink, has low load, high residual energy and high link quality until we reach the destination node (sink node).

Location aware event-driven multipath routing protocol in wireless sensor network is presented in [3] by A.V. Sutagundar et. al. Here, a user select special intermediate nodes for finding the three paths between the source and sink node. Then it computes rising and falling angle by using the location of special nodes. In this multiple paths are available so we can say that the network is so much reliable. But again energy consumption is not taken care to maximize the total life of network.

A location based routing protocol is present by Kihyun Kim et.al [5]. The location based routing protocol uses three phases as follows:

- Start Advertisement Phase: In this phase, Source has limited routing space and it transmits an advertisement message to neighbor nodes.
- Conditional Reply Phase: Node who gets advertisement message decides whether to reply or not.
- Routing of data: Now Source nodes forward the data to those nodes which sends him reply for advertisement message.

This routing technique assumes that each node knows its own energy level, current location and the location of the sink node using a global positioning system (GPS). This method generally focus to route the data but the energy consumption issue is not solved which is the measure issue in wireless sensor network. Location aided energy-efficient routing protocol is presented in [7] by P.T.V. Bhuvaneswari et.al. where the whole functionality is divided in four phases as shown in Fig. 2.

- Localization Engine: This phase finds the location of each sensor node.
- Neighborhood Management: This phase finds all the neighbors of a particular sensor and called them as forwarding nodes.
- Routing Management: Now it sends the data to the nodes which we select in the second phase.
- Energy Management: Here sensors which are not used goes to either sleep state or either idle state.

Location based Opportunistic routing protocol is presented in [6] by Jubin Sebastian E et.al. In this paper, a GPS based protocol is proposed where several forwarding nodes caches the data that has been received. If the best forwarder does not forward the data, then suboptimal node will forward that data to sink node. By doing so the data which source node wants to send to the sink node is always delivered by best available forwarding node. In this, user finds that all nodes carry the data so there is memory wastage and first give chance which has higher priority than next so more time consuming also.

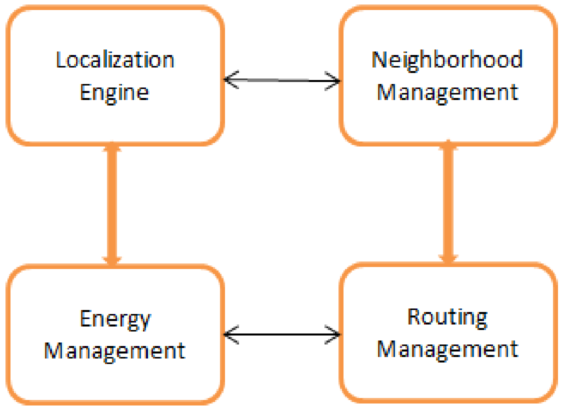

Fig. 2. Inter-Connection between different Phases

By studied all these papers, we propose a new energy-efficient routing algorithm which primarily takes care of energy consumption to maximize the total network lifetime. Our proposed algorithm finds a shortest path by selecting those sensors that has highest remaining energy (battery). So, we mainly focus on both constraints reliability and the energy consumption to increase the life of the sensor network.

III. PROBLEM DEFINITION

Let the n sensors s_1, s_2,...s_n be randomly deployed to cover objects in given sensor field. Sensor s_i has a battery life of b_i and can cover the objects if it lies within the sensing range of s_i. Routing is the process by which information can be send from one sensor node to another sensor node. So, the main problem is to find the route between the source and the sink node by choosing some intermediate nodes for finding the route in the sensor network. Selection of sensor nodes to participate in a particular route is done in a way so that life of a sensor network should maximize. The path which is selected would be energy-efficient and reliable which delivered the information to the sink node in proper time.

IV. PROPOSED METHODOLOGY

This section propose an algorithm which is energy-efficient in nature for solving the routing problem for both heterogeneous and homogeneous network based on the attributes such as reliability and energy-efficiency. This algorithm observe that total lifetime parameter of the sensor network play an important role in getting a better optimal solution. Hence this will prioritize the sensors according to their remaining battery life. There are following phases in the proposed energy-efficient routing algorithm (EER):

A. Generate a Cover

This phase generates a coverage cover by selecting the sensors which are needed to cover all the targets present in the network.

B. Generate a Route

This phase generates a route P by selecting the sensor that is present in the cover which is generated in the above step. Therefore route is constructed by selecting sensors of high priorities from cover till we reach the sink node (base station).

C. Shortest Path

This will find the shortest path between the source node and the sink node from the route P. ***Generate a route*** return a path which is not the shortest path sometimes, so, we use this phase in algorithm to find the shortest path. This gives always the shortest route.

D. Lifetime

After finding the ***shortest path*** which is also energy-efficient, this phase decide the lifetime of that path (means for how much time the path exist). This is denoted by X (P).

E. Update battery

After finding the value of lifetime of a path in above step, this phase will update the battery of all sensor nodes those who are participating in above shortest path. We subtract the value of X (P) from all sensors battery.

The pseudo code for the above said algorithm is as follows:

```
Initialize Stot=all sensors, S=stack and
batt[]=battery of all sensors
While (no path possible for network)
Generate a Cover
        K=0
        Repeat until all targets covered
                Select kth sensor that covers the critical
                target and have the maximum energy

                Cov1[ ]←Stot[k]

                Find the critical target from the uncovered
                targets
        End repeat

        i=0,t[targetnumber]
        while(t[ ] has element=0)
                Select ith sensor from cov1[ ] and find all
                targets covered by it.

                We marked covered  target as 1 in t[ ] at
                their position.
                Cov[ ]←cov1[ i]
        End while

Generate a Route
J=0

//While sink (base station) has connectivity with network

While(j is last position of cov1[] )

        Select j element from cov1[] until we reach at last
        position

        Do

        Initialize S=∅

        For all sensors,
                Set v[i] =0 where i=1, 2, 3……… Stot

        Generate an array P          //contain route
        Select the sensor cov[j]
                                     // it covers the data
        Add s to S
        Do while S ≠∅
                Pop from S and find its neighbor nodes
                If v[s] =0,
                        Add it to P and set v[s] =1
                End if
                If s is connected to sink node
                   Return
                else
                  Add all neighbor nodes 'n' to S, whose
                  v[n] = 0
                End if
        End do

    Shortest path
        k=0,
        p=last element index of P
        do
           while k=p
                Find connectivity of P[k] to the last node
                P[p]

                if connected
                        delete the value present between `
                        P[k] and P[p]
                        and return

                else,
                        k++
                        p- -
        end do

j++

end while
```

Lifetime

//have the time value for which route is exist
X (P)← maximum - lifetime (P)

Update battery

m=0,g;
Repeat For all sensor∈ cov[ ]
g = cov[m]
//Update
batt[g] =batt[g] - X (P)
If batt[i] =0,
Stot= Stot-si
Else
Return
m++
End repeat

End while

V. EXPERIMENTAL ANALYSIS

The proposed energy-efficient routing (EER) algorithm is implemented in C language for experimental study. This section evaluates the performance of QOS based routing algorithm [15] with energy efficient routing (EER) algorithm. It simulates a stationary network with coordinates [300m, 100m] and [450m, 250m]. Sensors and targets are randomly located in the given area and all the sensors are heterogeneous in nature. All sensors have same sensing range in which they can cover targets. This section shows the comparison of performance of both algorithms in below graphs (Fig. 3 and Fig. 4):

A. Experiment 1

Here the experimentation carried on fixed number of targets (20) randomly located in network and varying the number of sensors from 20 to 60 with an increment of 10, when sensing range (r) is 50. For a particular value of sensor, EER calculates average lifetime for 5 random problem instances. Both EER and QOS are experimented with lifetime (w) of one route is 1. The following Fig. 3 is showing the results.

B. Experiment 2

Here the experimentation carried on fixed number of sensors (40) randomly located in network and varying the number of targets from 20 to 40 with an increment of 5, when sensing range (r) is 50. For a particular value of sensor we calculate average lifetime for 5 random problem instances. Both EER and QOS are experimented with lifetime (w) of one route 1. The results are shown in Figure 4.

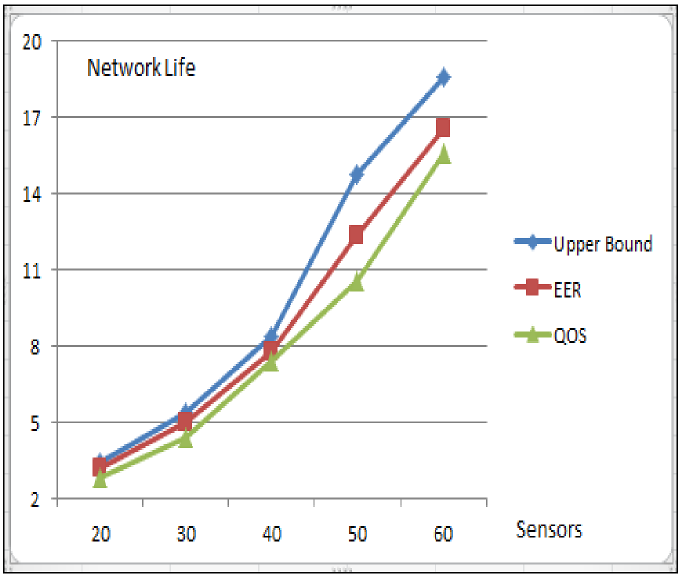

Fig. 3. Sensors versus Network lifetime Graph

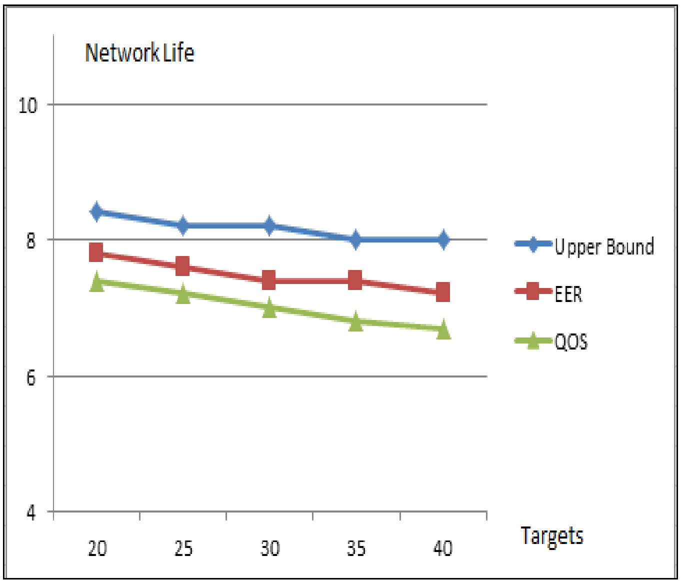

Fig. 4. Targets versus network lifetime graph

VI. CONCLUSION AND FUTURE WORK

In our study, we have discussed a hierarchy of techniques briefly in terms of reliability with energy-efficiency and varied research techniques used in past for routing in wireless sensor network (WSN). Our ongoing research is to use the EER algorithm which has been described in section 4 to find a route which is the shortest and energy-efficient path, and we can maximize our sensor network lifetime. By using this EER algorithm, our objective was to somehow maximize the total network lifetime (with battery constraint) while finding routes from source to sink.

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