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Energy Saving Multipath Routing Protocol for Wireless Sensor Networks

Yash Arora*, Himangi Pande**
*(Department of Information technology, Pune University, Pune, India)
** (Department of Computer Science, Amravati University, India)

ABSTRACT : The Wireless sensor networks have many characteristics such as limited energy resources, low bandwidth and unreliable links. Due to these characteristics there are many challenges in the design of sensor networks. Routing in WSN is very challenging task. Multipath establishes several path for data transmission rather than single path. Due to this data delivery is high.

In this paper, we propose energy saving multipath routing protocol (ESMRP). ESMRP make use of load balancing algorithm to transfer the data. ESMRP calculates node strength to discover its next best hop. Our protocol uses two versions, in the first version, data is transmitted through single path, if some path failure occurs or discovered path node strength goes below 15% of alternative path node strength then it will switch to next alternative path. In the second version of ESMRP, message is split into various segments and some correction codes are added to these segments. After that these segments are transmitted across multiple paths.

Simulation results shows that the proposed protocol is more energy saving than previous protocol in providing efficient resource utilization.

Keywords – Correction codes, Energy Saving, Load Balancing, Multipath Routing, Wireless Sensor Networks

I. Introduction

Wireless sensor network consists of various smart tiny devices called sensor nodes and these nodes monitor the environment by measuring parameters such as temperature, pressure humidity that are used in target tracking, healthcare services etc. Sensor nodes sense target area and transmit their collected information to the sink node. Resource limitations of the sensor nodes, unreliability of low-power wireless links in combination with various performance demands of different applications impose many challenges in designing efficient communication protocols for wireless sensor networks. The main aim is to discover ways for route setup and reliable relaying of data from the sensor nodes to the sink to increase the network lifetime. Numerous routing protocols have been proposed by researchers to improve performance of many applications.

Routing protocols considers all the characteristics of sensor nodes [1, 2, 3]. The routing protocols can be classified as negotiation based, query based, QOS based, and multipath based [4]. The negotiation based protocols eliminate the redundant data by including high level data descriptors in the message exchange. In query based protocols, the sink node initiates the communication by broadcasting a query for data over the network. The QOS based protocols makes a tradeoff between the energy consumption and some QOS metrics before delivering the data to the sink node. Finally, multipath routing protocols use multiple paths rather than a single path to transfer data from source to sink. Multipath routing establishes multiple paths between the source-destination pair. In single-path routing each source sensor sends its data to the sink via the shortest path. In single path new route discovery process is initiated, which increases energy consumption. Node failure also causes packets to be dropped and may cause a delay in delivering the data to the sink, thus the real-time requirements of the multimedia applications are not met. Multi-path routing increases the number of possible routes and through this it increases the robustness and throughput of the transmissions. Multipath routing is commercial for heavy load scenario than single path. Multipath routing is mainly used either for load balancing or for reliability. Load balancing can be achieved by balancing energy utilization among the nodes improving network lifetime. The paper is organized as follows: Section 2, describes Related Work. Section 3, describes Proposed Protocol. Section 4, describes Performance Evaluation, Section 5, defines, Conclusion.

II. Related Work

The routing in wireless sensor network is challenging task now a days. There exists several routing algorithm but our focus is to develop routing algorithm that is more energy saving and increases the life of sensor nodes. There are various proposals being made in this area. In this section we present some work being done to proposed protocol.

The author in [5] proposed N to 1 multipath routing algorithm. This protocol uses flooding mechanism to find multiple node-disjoint paths from every sensor node to the common destination. This flooding mechanism is used to construct a spanning tree and discover several paths from sensor nodes towards a single sink node. Multipath is used to distribute the data. The N-to-1 routing protocol does not consider node residual energy during construction phase. This protocol also lacks in efficient use of each node resources.

The author of [10] proposed multiple node-disjoint paths between the sink and source nodes are discovered. Load balancing algorithm is being implemented for distribution of traffic over multiple paths and these multiple paths are discovered based on their cost. Cost of each path is calculated by the energy levels and also the hop distances of nodes. This protocol support node with limited mobility.

The author of [11] uses two versions of protocol REER-1 uses a single path among set of discovered paths to transfer the data, when path cost falls below a certain threshold, then it switches to the next alternative path. In REER-2 message is split into N segments of equal size and correction is added to that segments and transmit it over multiple paths. In this protocol it drains out node battery through which delay in data transfer takes place.

In our proposed protocol we try to utilize node resources through Load balancing and to make it more energy saving and increases delivery ratio.

III. Proposed Protocol

In this section, we first explain some assumptions. Then we will define various constituent parts of the proposed protocol.

3.1. Assumptions

We assume that N identical nodes are randomly distributed in the sensing environment. Each sensor node is assigned a unique ID. Each sensor nodes have same battery power. Furthermore, we assume that each sensor node is able to compute its residual energy, and its available buffer size, as well as calculate signal-to-noise ratio (SNR) between itself and neighbouring nodes.

3.2. Node Strength

The Node Strength is based on the three factors residual energy, available buffer size and signal to noise ratio. Node Strength is used by the node to select the best next hop during route discovery phase. Let Nx denotes the set of neighbouring nodes of x. Then our node strength includes:

$$\text{Next hop} = \max_{y \varepsilon N_x} \{\alpha E_{resd, y} + \beta B_{buffer, y} + \gamma I_{interference, xy}\} \quad (1)$$

Where, E_{resd}, y is the current residual energy of node y, where y ε N_x, B_{buffer}, y is the available buffer size of node y, and $I_{interference}$, xy is the SNR for the link between nodes x and y.

The total node strength C_{total} for a path P consists of a set of K nodes is the sum of the individual node strength $l_{(xy)i}$, iεK along the path. Then we have:

$$C_{total}\, P = \sum_{i=1}^{K-1} l(xy)_i \quad (2)$$

3.3. Route Discovery Phase

Route discovery idea is obtained from direct diffusion [6], the sink node create set of neighbours that forward data towards the sink from the source node. The constructed multipaths have no common nodes except the source and the destination. Node-disjoint paths are fault-tolerant so there is a minimum impact to the diversity of the routes [12]. Route discovery includes several phases explained as:

3.3.1. Initialization Phase

Each sensor nodes gain some information concerning its neighbouring nodes. At the first step each nodes broadcasts a HELLO message to know which of its neighbours can provide it with the highest quality data. Each node updates its neighbouring table. The neighbour table, also contains link quality(in term of signal-to-noise ratio), Residual energy of next node and free buffer. HELLO message structure shown in Fig. 3.3.1 contains Hop Count that gives the distance of message from its originator. Source ID field contains the ID of the message originator.

Source ID	Hop Count	Residual Energy	Free Buffer	Link Quality

Figure 3.3.1: Message structure

3.3.2. Primary Route Discovery Phase

Each sensor node computes the Node Strength for its neighbouring nodes. Next, using the node strength sink node locally computes its next best node and send RREQ message to nest next hop. This process continues until reaches to source node.

3.3.3. Alternate Route Discovery

The sink node sends RREQ message to next neighbour node. If the node is already in use then in used node will send INUSE message and then the node will find another node from table.

3.3.4. Data Transmission through Load Balancing

We propose a load balancing algorithm for better utilization of each route resources. After discovering multiple paths, source node begins to transmit data message to sink node. We propose two versions of the protocol to route data to sink node. In first version, **Data transmission through single path using Load balancing, ESMRP1,** and the idea behind [13] is being used. Each time we send Route_Reply packet across the path to update node strength of each node. This Route_Reply packet contains some information regarding its traversed path. This information is useful to apply efficient load balancing algorithm. Data transmission continues over the primary path until its strength fallen below the next available path, and then next available path is being used, and so on. If a node fails or any rote failure occurs, error message is initiated to the source node. Source node then removes the error route and selects the next best available paths from the routing table and resumes the transmission process. If all the routes contained in the routing table are failed then source broadcast a request message for the sink to initiate a route discovery message. This technique improves the message delivery and improves resource utilization that always finds a way to deliver the data to the sink.

In the second version, **Data transferring through multipath routes using Load balancing ESMRP2.** In this we select routes from N available routes discovered in route discovery. We assume that each path is associated with some rate *pi* (i=1,2, .. n). pi is the probability of successfully delivering a message to the destination. The number of required paths is calculated as:

$$K = x\alpha \left(\sqrt{\sum_{i=1}^{N} pi\,(1-pi)} + \sum_{i=1}^{N} pi\right) \quad (3)$$

$x\alpha$ is the bound from the standard normal distribution. The message to be transferred is split into segments (S1, S2, and S3...SN-1) and some error control bits are added to the original message. These segmented messages are sent out across the *k* best available paths. While performing all above operations, Route_reply packet is send to update strength of each node and hence total node strength of each path. This information is used to compare total strength of path used in subset of k with total strength of path available in N. If there is a change to their last broadcast value then path having low cost value in subset of k will be replaced with path available in N. A similar operation is applied according to the residual battery and node strength values whenever they are changed more than 10% compared to their last broadcast values.

IV. Performance evaluation

We used NS2 [19] to implement our routing protocol and compare it with REER (Robust and energy efficient multipath routing protocol).

A two dimensional square area is used for node deployment. The network consists of Common sensor node, access point and sink node. Nodes are randomly deployed in area. No of common sensor nodes sense the data from temperature and carbon monoxide application data generator. Source node sends the request message to the neighbouring nodes to discover multiple paths. Total node strength of each path is calculated and data transfers take place. The disseminating time, takes transmission power, receiving power, initial energy of various types of node in network is same.

The main experiment parameters are Number of Nodes, Topology size, Initial energy, Sending power, receiving power, packet size. Parameters like Number of Nodes can vary at the time of implementation and different scenarios can be studied and compared to get the optimized results.

Our simulation environment consists field 300m x 300m containing N sensor nodes (N varies from 50 to 300 nodes) randomly deployed. Radio transmission range is set to 25m for all identical nodes. Table 4 shows the simulation parameters.

In the rest of this section, we evaluate our protocol in multihop topology. The performance metrics used in the evaluation are the average energy consumption, average delivery ratio and average delay.

4.1. Average Energy Consumption

It is defined as the average energy consumed by the nodes used in message transfer from source to sink node. Fig. 4.1(a) and 4.1(b) shows the results for the energy consumption. From the Fig. 4.1(a), we observe that there is a save in energy of both versions of protocol ESMRP1 using load balancing protocol over REER protocol. As the network size increases, ESMRP1 becomes more stable than REER-1 protocols. In Fig. 4.1(b), ESMRP2 consumes less energy than REER-2, because of the load balancing, which updates node strength of path every time transmission takes place. This approach helps nodes in the path not to drain their constraint energy resources with continual use of same route and hence achieves longer lifetime.

Network field	300m X 300m
Number of Sensor	50-200
Number of Sinks/Number of Sources	1/1
Transmission Range	25m
Packet Size (Data + Over head	Up to 1024
Transmit Power	0.01 Units
Receive Power	0.02 Units
Initial Battery Power	0 Joules
MAC layer	IEEE 802.11
Energy Threshold	10 Units
Max Buffer Size	256 K-bytes
Simulation Time	200 seconds
Alpha/beta/gamma	3/1/3

Table 4: Simulation Parameters

4.2. Average Delivery Ratio

The average delivery ratio is defined as the number of packets generated by the source to the number of packets received by the sink node. Fig. 4.2(a) & 4.2(b) shows the average delivery ratio. As the network size gets large, there are more available nodes, and hence more routes, to forward data, resulting slight increase of the delivery ratio. ESMRP1 is showing better results than REER-1 protocol but as network size increases its performance degrades. ESMRP2 shows good performance, because the multiple paths are used simultaneously to transfer data and better path and resource utilization.

4.3. Delay

The delay is the time required to transfer data from source node to the sink node. Fig. 4.3(a) & 4.3(b) shows the delay of the compared protocols. The delay for all tested protocol increases with the increase in network size, but still our protocol ESMRP using load balancing protocols shows good performance even for large network sizes. As in our protocol it will not wait for nodes battery to get drained, as every time updated node strength is received through Route_Reply. Thus a minimum tradeoff with delay should be made to reduce the energy expenditure.

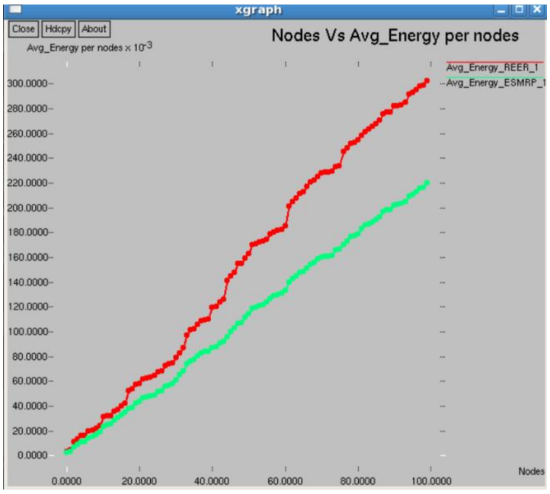

Figure 4.1(a) Average Energy for ESMRP1

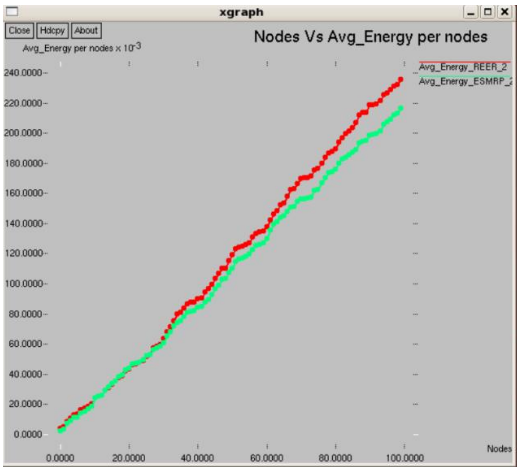

Figure 4.1(b) Average Energy for ESMRP2

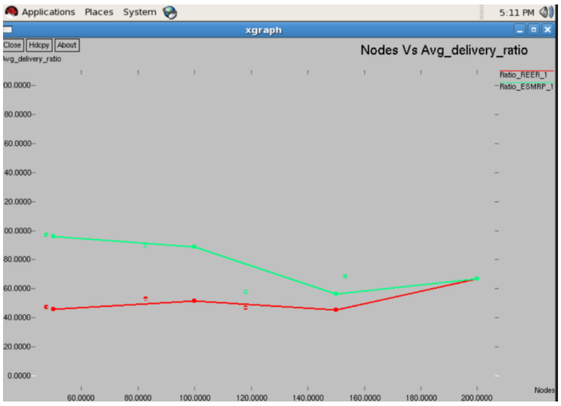

Figure 4.2(a) Average Delivery ratio

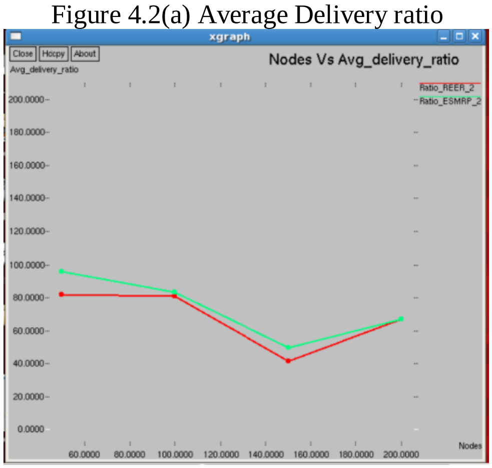

Figure 4.2(b) Average Delievery Ratio

Figure 4.3(a) Delay

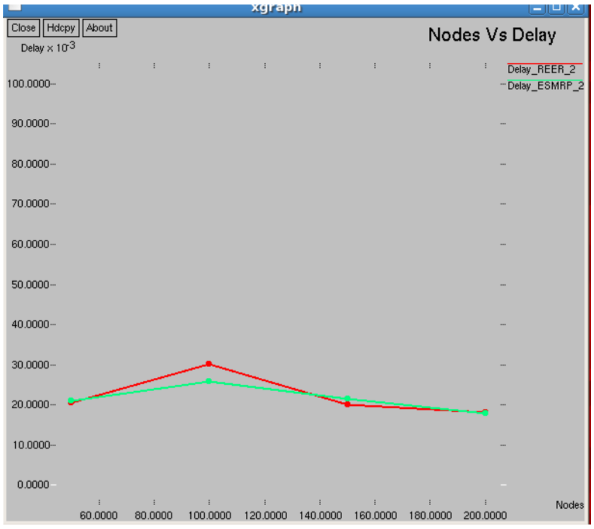

Figure 4.3(b) Delay

V. Conclusion

In this paper, we proposed an energy saving multipath routing protocol (ESMRP) to improve data delivery ratio and decreases delay. ESMRP discovers multipath for transmission of data from source to sink. We have also used load balancing algorithm that make effective use of resources and node strength is used as routing metric. Through computer simulation, we have evaluated and studied the performance of our routing protocol and compared it with REER protocol.

Simulation results have shown that our protocol achieves more energy savings, lower average delay and higher data delivery ratio than REER protocol.

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