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Mobile Energy Efficient Selective Opportunistic Routing for Mobile Wireless Sensor Networks

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ABSTRACT

When Wireless Sensor Networks (WSN) is considered the energy consumption becomes the major issue. Since the sensor nodes are deployed in a rough terrain with unpredictable environmental conditions the nodes may fail due to battery drain and at many situations the batteries cannot be replaced. When Mobile Wireless Sensor Networks (MWSN) are considered the energy consumption becomes a critical issue. It would be wise to minimize the energy consumption by using a better routing algorithm so that a quality path can be selected. One such routing protocol is Opportunistic routing in this type of routing for each packet the next relay node is selected dynamically, Specifically this paper deals with an opportunistic routing algorithm called Mobile Energy Efficient Selective Opportunistic Routing (MEESOR) that reduces the size of the forwarder list by including the neighbors that are nearer to the destination .The selection of the relay node depends the nodes distance from the destination and the residual energy. The routing of the acknowledgement also takes place in an opportunistic manner as the data packet so that the energy consumption gets balanced. The Route Failure Notification provides a better indication to select a new route. The algorithm provides better results than the existing opportunistic routing algorithms in terms of End-to-End delay, and network life time.

Keywords : Wireless Sensor Networks, Opportunistic Routing, Forwarder List, Delay, Network Lifetime

I. INTRODUCTION

A WSN consists of a large number of sensors, each of which are physically small devices, and are equipped with the capability of sensing the physical environment, data processing, and communicating wirelessly with other sensors. When two nodes wish to communicate, intermediate nodes are called upon to forward packets and to form a multi-hop wireless route. Due to possibilities of node mobility, the topology is dynamic and routing protocols are proposed to search for end-to-end paths. The network nodes rely on peers for all or most of the services needed and for basic needs of communications. Due to the lack of centralized control and management, nodes rely on fully distributed and self-organizing protocols to coordinate their activities. In both scenarios, distributed protocols need to accommodate dynamically to the following changes a node may join or leave the network arbitrarily, links may be broken, and nodes may be powered down as a result of node failures or intentional user actions. With respect to the characteristics previously discussed, wireless sensor networks (or sensor networks for simplicity) are very similar to wireless ad hoc networks, as sensors act as network nodes. Each sensor can only reach its neighboring sensors directly. Intermediate sensors may relay the messages when source sensors and destination sensors are far away from one another.

The number of the nodes in a sensor network is significantly larger than that in a typical wireless ad hoc network. The difference can be of several orders of magnitude. Sensors are usually low-cost devices with severe constraints with respect to energy source, power, computation capabilities and memory. Sensors are usually densely deployed. The probability of sensor failure is much higher. The sensors are usually stationary rather than constantly moving. However, the topology of sensor networks can still change frequently due to node failure. Figure 1 shows an example of WSN.

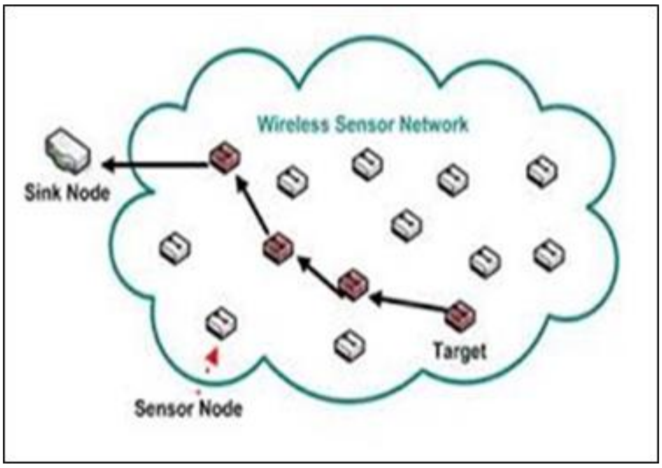

Figure 1. Example of WSN

WSN mechanism is quite easy, simple and applicable to a variety of fields. It is based on smaller nodes, controller, radio transceiver, and battery. The system is totally dependent on the nodes and the harmony established between them through proper frequency. These nodes are of different sizes according to the function they perform. To activate the monitoring or tracking function of these nodes a radio transmitter is attached to forward the information signals in the form of waves. Figure 2 shows the working of WSN . They are controlled by the microcontroller according to the function and device in which they are used. All the system remains in working condition with the help of energy supply which is in the form of battery. Figure 2 shows the working of WSN

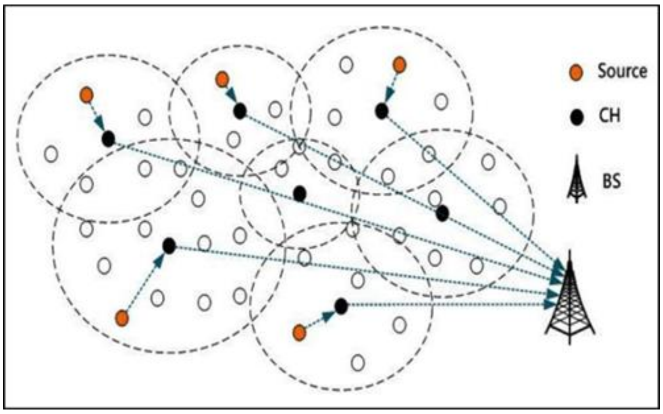

Figure 2. Working of WSN

The WSNs perform function concurrently where nodes are autonomous bodies incorporated in the field spatially for the accurate results. The information transmits through proper channel taking the information collecting it in the form of data and send to the base station. Many applications in wireless sensor networks require information to be transferred between source-destination pairs that may be one or more ho It is an interesting problem to connect the source-destination pairs of a wireless sensor network through the shortest distance, with minimum hops, in a short time with more reliability. When the source and destination are more than one hop away, one of the nodes has to be selected from the set of neighbors of the source to forward the packet towards the destination. The nodes in the forwarder list are prioritized based on different metrics like hop count and packet delivery ratio. The choosing of forwarding node continues till the destination node is reached. Different routing protocols are used in disseminating information from source to destination in a wireless sensor network. Opportunistic routing is one of the flat based reactive routing protocols. Advantages of opportunistic routing protocols are increased reliability and increased transmission range of a node in a wireless sensor network. Network reliability is increased by transmitting a packet through any possible link in the network rather than one specified link. Transmission range is increased by including good quality short-ranged links and poor quality long-ranged links.

The proposed MEESOR protocol achieves better throughput, maximum end-to-end delay and network lifetime, by reducing the size of the forwarder list and opportunistically routing the acknowledgment packet from target to source in the network. The rest of the paper is organized as follows. In Section 2, we discuss the work related to opportunistic routing. The Background required for the design of a new protocol for wireless sensor network is discussed in Section 3. Section 4, we present the assumptions and implementation details of Mobile Energy Efficient Selective Opportunistic Routing. We analyze the newly implemented protocol for different performance parameters in Section 5. Finally, we conclude the paper and discuss future scope in Section 6.

II. METHODS AND MATERIAL

A. Related Works

A vast amount of literature is devoted to opportunistic routing in wireless sensor networks. Some of important works are discussed below. Mao et al., [1] focused on selecting and prioritizing the forwarder list of a node to minimize energy consumption by all the nodes by designing Energy Efficient Opportunistic Routing (EEOR). The network is analyzed for energy consumption, average delivery delay and packet loss ratio. Biswas and Moris, [2] proposed ExOR, to describe an integrated routing and MAC protocol that increases the throughput of multi-hop wireless networks. The protocol chooses each hop destination of a packet's route after the completion of the hop. Wei et al., [3] discussed Assistant Opportunistic Routing (AsOR) protocol that is a unicast routing protocol for multi-hop wireless sensor networks. Bhorkar et al., [4] proposed d-AdaptOR, a distributed, adaptive, and opportunistic routing scheme for multihop wireless ad hoc networks. The advantage of this scheme is optimal performance, with zero knowledge of network topology and channel statistics. The disadvantage of this protocol is ignorance of short-term performance and congestion control in the network. Chachulski et al., [7] presented MORE, a MAC-independent opportunistic protocol that randomly mixes packets before forwarding them. This protocol runs directly on top of 802.11, without the need for any special scheduler. MORE is found to be better than ExOR, with respect to throughput and gain, when there is spatial reuse, both for unicast and multicast. Fang et al., [8] discussed the problems of choosing the opportunistic route to optimize the total utility or profit of multiple simultaneous users in a wireless mesh network. CONSORT, node-CONStrained Opportunistic RouTing, is proposed by combining the primal-dual and subgradient methods. The iterative method reduces the gap between the solutions provided in each iteration and provides the optimal solution, with respect to higher user utilities and profits.

Mazumdar and Sairam, [9] discussed the opportunities and challenges in opportunistic routing, in improving the performance of wireless multi-hop Ad-hoc and wireless sensor networks. Further, the paper outlines several vital design issues that needs to be considered in improving efficiency and deployability of networks. Li et al., [10] proposed the Localized Opportunistic Routing (LOR) protocol that utilizes the distributed minimum transmission selection algorithm to partition the topology into several nested close-node-sets using local information. LOR improves performances over extremely opportunistic routing and MAC-independent opportunistic routing protocol considering the parameters control overhead, end-to- end delay and throughput. Rozner et al., [11] developed a model-driven optimization framework to optimize opportunistic routes and rate limits for both unicast and multicast traffic.

Nasipuri et al., [12] developed algorithms to find the path that consumes minimal energy for node and link-disjoint wireless networks. The performance evaluation shows that the link-disjoint paths consume less energy than node-disjoint paths. The issues related to distributed implementation and optimal centralized algorithms are discussed. Basalamah et al., [13] analyzed opportunistic routing gain under link correlation with the loss of data and acknowledgment packets. A new link- correlation-aware opportunistic routing scheme is introduced, which exploits the diverse uncorrelated forward links. Levorato et al., [14] have used Multiple-Input Multiple- Output technology, to increase communication parallelism in the network, by multiple concurrent information flows. A cooperative cross-layer scheme is proposed integrating distributed incremental redundancy hybrid automatic retransmission request error control with routing. Results in the paper show that the network performance is significantly increased.

Zeng et al., [15] gives a comprehensive study on the impacts of multiple rates, interference, and prioritization on the maximum end-to-end throughput and capacity of opportunistic routing. It is shown that opportunistic routing has a higher potential to improve end-to-end throughput. Wang et al., [16] suggested two opportunistic routing algorithms for P2P networks that exploit the spatial locality, spatial regularity and activity heterogeneity of mobile nodes in a network. Both theoretical analysis and simulation based study reveal that the proposed algorithms outperform the other algorithms in terms of delivery latency and delivery ratio. Shin et al., [17] proposed a parallel opportunistic routing for wireless ad-hoc networks to observe the changes in power, delay and throughput as the number of source-destination pair’s increases in the network. Passarella et al., [18] investigated the use of a series of opportunistic contacts, in an opportunistic routing environment. Myung and Lee [19] proposed a method for avoiding duplicate forwarding of packets in opportunistic routing. The packet includes a small information piggybacked, that reduces the number of repeated packet transmissions that in turn increases the throughput.

B. Proposed Work

Routing Protocols aim at improving the performance of wireless sensor networks, in terms of the lifetime, the delay and the network throughput. Routing protocols are classified as single hop and multi hop networks, depending on the number of hops to connect the source and target in the network. Based on the network structure routing protocols are classified as flat based, cluster based and location based routing protocols. The establishment of routing path in a wireless sensor network gives reactive and proactive routing protocols. Opportunistic routing is a flat based, reactive, multi-hop routing protocol for wireless sensor networks which applies to both small scale and large scale wireless sensor networks. Opportunistic routing exploits the broadcast nature of wireless sensor networks.Opportunistic routing has potential benefits brought to wireless sensor networks. Challenges faced by opportunistic routing are taken based on network coding coordination, multi-flow rate control, power control with proper bit-rate selection, multi-channel scenario, deployment of nodes and combination of opportunistic routing with selection diversity. Opportunistic routing is analyzed for fixed power model and adjustable power model of wireless sensor network.

The forwarding node is chosen depending on the cost assigned to each of the nodes. The protocol computes the expected cost for each node and selecting the forwarder list. From the forwarder list the optimal forwarder list is found by opportunistic routing. The proposed MEESOR performs better than the existing EESOR in terms of average End-to-End delay, maximum End-to-End delay and network lifetime. Wireless sensor network can be single or multi-hop network depending on the transmission range of the sensor nodes. More number of hops increases the delay in transmission and energy consumed by the nodes. The objective of this work is to reduce the energy consumed by the sensor nodes in receiving, transmitting of information and to decrease the delay in transmission of data from source to destination in a wireless sensor network.

Sending a packet from source to target in a network can be considered to include three parts, viz 1) the source sending the packet to one neighbor node and that node is the target node, 2) if the target is more than one hop away from the source, then there is at least one node in the neighbors list to relay the packet to target, and 3) agreement on choosing the actual relay node, among the neighbors of the transmitting node. The time and effort incurred achieving the part 1, is constant. The same for part 2 depends on the distance between the source and the destination. It is assumed that the overall cost of communication is represented by the distance between the nodes to be communicated in the wireless sensor network. The distance refers to the geographical distance between them The distance d between two nodes A(x1,y1) and B(x1,y2) is calculated by the equation 1

$$d = \sqrt{(x2 - x1)^2 + (y2 - y1)^2} \quad (1)$$

Table 1: Network Parameters

Variable	Description
N	Number of nodes in the network
P	Number of packets transmitted between a pair of source and destination
(x, y)	x and y co-ordinates of a node
D	Distance between the nodes
T	Simulation time
E_I	Initial energy of the node
E_c	Critical energy of the node
E_r	Residual energy of the node

Table 1 shows the network parameters assumed In the network considered, the source node forms the set of neighboring nodes to forward the packet, when the destination is more than one hop away from the source. The set of neighbors is sorted according to its distance from the destination and its residual energy, and normally the first of these nodes in the forwarder list relays the packet towards the destination. The procedure continues till the destination node receives the packet. The first field source represents the node that originated the packet. Packet length represents the number of bytes contained in the packet. Packet sequence number is the index of the packet in the overall simulation of the network. x and y coordinates represents the position of the node, and z represents the speed of movement of a mobile node in number of steps per second. The last field is the data to be communicated between the source and the destination nodes. The acknowledgment packet has the same fields, except the data field. Each node has a routing table of all its neighbors, consisting of all the required fields. Distance between node and target node and the residual energy is used in updating the routing table entry of the node during multi-hop transmission. Construction of routing table of a node is considered in the following phasis.

Input : Randomly deployed sensor nodes with source and destination pair to be connected.

Output: Path between source-destination pairs with minimal hops.

Algorithm MEESOR : Mobile Energy Efficient Selective Opportunistic Routing

Step 1 : Construct the routing table for all nodes.
Step 2 : Form the neighbor list of each source node.
Step 3 : Sort it according to ascending order of distance between itself and Destination as well as the residual energy.
Step 4 : Relay the data to first node in the sorted list.
Step 5 : Update the routing table of the forwarding node.
Step 6 : If destination is reached stop else repeat steps 2-4.
Step 7 : Transmit acknowledgment towards the source using steps 1-4.
Step 8 : Repeat steps 1-5 for all the source nodes in the network.

Algorithm MEESOR is given in Table 2.

C. Creation of Routing Table

Initially, the routing table of every node is constructed based on the neighboring node information. This phase starts with the construction of a HELLO packet from the node to all its neighbors. Once it is done, a timer is used to broadcast the HELLO packets to all of its neighbors. The HELLO packet is not sent to any particular node. The node that receives packet, checks the packet source field to find out the address of the node that originated the HELLO packet. If the receiver node routing table already has an entry of the source node of the HELLO packet, it drops the packet. Otherwise, it creates a new entry for the node that has sent the HELLO packet with all the necessary fields.

D. Updating the Routing Table

In this module the entries in the routing table are updated, depending on the distance and the residual energy between the forwarding node and the target node is updated in the routing table entry, so that the next hop node is the one with smallest distance between itself and the target node with high residual energy. According to the concept of MEESOR, the next hop to a particular destination is decided on the fly and new protocol implemented is completely opportunistic. This process is repeated till the destination node is reached.

E. Sending Acknowledgement

The Transport Layer Protocol used in this communication is Transmission Control Protocol (TCP). TCP is a reliable protocol, where every packet is guaranteed to be delivered to the destination, by making use of the acknowledgment packet, sent from target to source node. Normally, the acknowledgment packet flows in the reverse path of the data path, using same intermediate nodes. The newly implemented protocol MEESOR sends the acknowledgment packet opportunistically so the energy spent by the nodes for transmission and reception gets balanced which in turn increases the network life time.

III. RESULTS AND DISCUSSION

The simulator used in the analyzing the wireless sensor network in this paper is NS2. This section provides simulation setup to demonstrate performance of Energy Efficient Selective Opportunistic Routing in the wireless sensor networks. 50 wireless sensor nodes are deployed randomly in a square area of 500m by 500 m, with uniform distribution. The packet generation rate is one packet per second.

A. Performance Evaluation

This section analyzes the performance of the wireless sensor network for Mobile Energy Efficient Selective Opportunistic Routing for the parameters Maximum End-to-End delay, average End-to-End delay and network lifetime .The network scenario is defined as wireless sensor network with 50 nodes randomly deployed in the area of 500 m X 500 m moving randomly. 250 m is the transmission range of each of the sensor nodes in the network.

B. Average End-To-End Delay

End-to-End Delay is defined as the time elapsed between the source node sending the packet and the destination node receiving the packet. The average of the End-to-End delay of all the packets transmitted between each of the pairs of source-destinations gives the average End-to-End delay. The average End-to-End delay is plotted against different pairs of source and destinations as shown in Figure 4

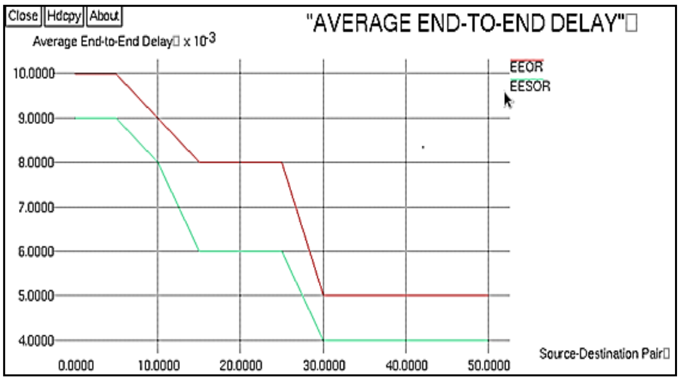

Figure 4. Average End-to-End Delay

C. Maximum End-To-End Delay

Figure 5 shows the plot of maximum of End-to-End delay values, for the same 9 pairs of nodes considered for analyzing average End-to-End delay. Once again, single hop communication takes same amount of time in Mobile Energy Efficient Selective Opportunistic Routing. Two-hop communication between the nodes shows the maximum improvement of around 300 ms, or 3 % of total delay for each source destination pair. And more than two-hop communication yields a maximum reduction of delay by approximately 1000 ms, or 50 %,The reason for this reduction is decrease in the size of forwarder list in case of Energy Efficient Selective Opportunistic Routing, by considering only the neighbor nodes that are nearer to destination.

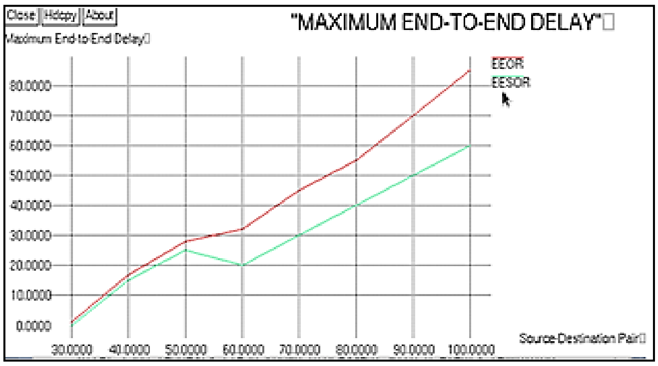

Figure 5. Maximum End-to-End Delay

D. Network Lifetime

The lifetime of a sensor node is considered as the time from its deployment to the time till which the node is having more than 10% of its initial energy. The node is said to be alive in this period. Beyond this period the node is said to be dead. Figure 6 shows the network lifetime for both MEESOR and EESOR protocols plotted against different network sizes. Network size is considered as 25 nodes, 50 nodes, 75 nodes and 100. nodes.

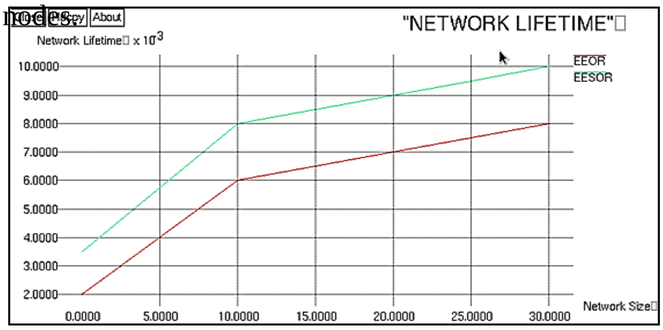

Figure 6. Network Lifetime

IV.CONCLUSION

The presented EESOR algorithm is found to reduce the average end-to-end delay and maximum End-to-End delay lifetime since it includes only the nodes that are nearer to the destination in to the forwarder list so the decision for selecting the next relay node can be done quickly. It also increase the network since the acknowledgement is also being routed opportunistically, as well as the reliability of packet delivery increases. The future enhancements that can be done to EESOR algorithm are: (1) To add mobility to the nodes; (2) To analyze the network for parameters like throughput and turnaround time; (3) To add a Route Failure Notification Packet.

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