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Lifetime Maximization Using Modified Leach Protocol for Energy Efficient Routing In Wireless Sensor Networks

[1],Nandakishor Sirdeshpande, [2], Vishwanath Udupi
[1],*Department of Electronics and Communication*
[2],*KLS Gogte institute of technology, Belgaum*

Abstract

Wireless Sensor Networks (WSN) are networks of typically small, battery-powered, wireless devices, equipped with on-board processing, communication, and sensing capabilities. Especially wireless sensor network suffers from excessive packet loss, over hearing, retransmission of the packets due to node mobility and constant energy dissipation. A current technique for routing and data transmission does not take into account of optimizing the transmission through Energy Balancing. There are several power and energy aware algorithms that claim to compensate for the energy losses. The main fundamental of most of the techniques is to route the packets through the highest energy nodes which lead to quick battery drainage of those node. Therefore the network lifetime decreases. In this project we have proposed a unique protocol for Network lifetime improvement by modifying the Leach protocol. The fundamental of the protocol is to develop a cluster based routing where cluster heads should be selected based on maximum coverage and should have sufficient energy to prolong the communication. Clusters are dynamically formed and changed with transmission. The technique is compared with conventional LEACH. Result shows that the proposed system achieves high data delivery with extended lifetime.

Keywords: *Modified Leach, Lifetime Maximization, Energy Efficiency*

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I. INTRODUCTION

Recent advances in wireless communication technologies and the manufacture of inexpensive wireless devices have led to the introduction of low-power wireless sensor networks. Due to their ease of deployment and the multi-functionality of the sensor nodes, wireless sensor networks have been utilized for a variety of applications such as healthcare, target tracking, and environment monitoring. The main responsibility of the sensor nodes in each application is to sense the target area and transmit their collected information to the sink node for further operations. Resource limitations of the sensor nodes and 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. Meanwhile, designing suitable routing protocols to fulfill different performance demands of various applications is considered as an important issue in wireless sensor networking. In this context, researchers have proposed numerous routing protocols to improve performance demands of different applications through the network layer of wireless sensor networks protocol stack. Most of the existing routing protocols in wireless sensor networks are designed based on the single-path routing strategy without considering the effects of various traffic load intensities. In this approach, each source node selects a single path which can satisfy performance requirements of the intended application for transmitting its traffic towards the sink node. Although route discovery through single-path routing approach can be performed with minimum computational complexity and resource utilization, the limited capacity of a single path highly reduces the achievable network throughput. Furthermore, the low flexibility of this approach against node or link failures may significantly reduce the network performance in critical situations. For instance, whenever the active path fails to transmit data packets (as a result of limited power supply of the sensor nodes, high dynamics of wireless links and physical damages), finding an alternative path to continue data transmission process may cause extra overhead and delay in data delivery. Therefore, due to the resource constraints of sensor nodes and the unreliability of wireless links, single-path routing approaches cannot be considered effective techniques to meet the performance demands of various applications. In order to cope with the limitations of single-path routing techniques, another type of routing strategy, which is called the multipath routing approach has become as a promising technique in wireless sensor and *ad hoc* networks. Dense deployment of the sensor nodes enables a multipath routing approach to construct several paths from individual sensor nodes towards the destination. Discovered paths can be utilized concurrently to provide adequate network resources in intensive traffic conditions. Alternatively, each source node can use only one path for data transmission and switch to another path upon node or link failures. The latter one is mainly used for fault-tolerance purposes, and this is known as *alternative path routing*. In the past decade, multipath routing approach has been widely utilized for different network management purposes such as improving data transmission reliability, providing fault-tolerant routing, congestion control and Quality of Service (QoS) support in traditional wired and wireless networks. However, the unique features of wireless sensor networks (e.g., constrained power supply, limited computational capability, and low-memory capacity) and the characteristics of short-range radio communications (e.g., fading and interference) introduce new challenges that should be addressed in the design of multipath routing protocols. Accordingly, existing multipath routing protocols proposed for traditional wireless networks (such as *ad hoc* networks) cannot be used directly in low-power sensor networks. During the past years, this issue has motivated the research community of wireless sensor networks to develop multipath routing protocols which are suitable for sensor networks.

There are several papers surveying proposed routing protocols for wireless sensor networks. These surveys describe and analyze the general routing strategies proposed for sensor networks. However, none of these literatures has provided a comprehensive taxonomy on the existing multipath routing protocols for wireless sensor networks. Al-Karaki *et al.* presented routing challenges and design issues in wireless sensor networks. They classified all the existing routing strategies based on the network structure and protocol operation. Alwan *et al*. provided a brief overview on the existing fault-tolerant routing protocols in wireless sensor networks and categorized these protocols into retransmission-based and replication-based protocols. Tarique *et al.* and Mueller *et al.* classified the existing multipath routing protocols in *ad hoc* networks based on the primary criterion used in their design. Accordingly, the principal motivation of conducting this research was lack of a comprehensive survey on the proposed multipath routing protocols for wireless sensor networks. To the best of our knowledge, this paper is the first effort to classify and investigate the operation as well as benefits and drawbacks of the existing multipath routing protocols in sensor networks.

II. RELATED WORK

In this section, highlighting the previous works on improving the lifetime of wireless sensor networks by using various scheduling algorithms and data aggregation techniques for sensors. Routing with data aggregation targets at jointly exploring the data structure and network topology to reduce energy consumption for data gathering in resource limited sensor networks. If the complete knowledge of all source correlations is available in advance at each source, theoretically the best approach is to use distributed source coding typified by Slepian-Wolf coding [3]. In this technique, compression is done at original sources in a distributed manner to achieve the minimum entropy and hence avoid the need for data aggregation on the intermediate nodes. In [4], an optimal rate allocation algorithm is proposed for nodes in the network and SPT is employed as the routing scheme. However, implementation of distributed source coding in a practical setting is still an open problem and likely to incur significant additional cost because of the aforementioned assumption. Routing-driven algorithms emphasize source compression at each individual node and aggregation occurs when routes intersect. In [5] the directed diffusion scheme was proposed where sensors create gradients of information in their respective neighborhoods. If the gradients match the broadcasted interests from the sink and data is aggregated at the intersections. So the extra overhead is required. To improve path sharing a greedy incremental tree (GIT) is described in to adjust aggregation points on the routes. Energy-aware routing [6] shows that to use a set of sub-optimal paths occasionally to increase the lifetime of the network.

These paths are chosen by means of a probability function, which depends on the energy consumption of each path. The approach shows that using the minimum energy path all the time will deplete the energy of nodes on that path. Instead, one of the multiple paths is used with a certain probability so that the whole network lifetime increases. The protocol assumes that each node is addressable through a class-based addressing which includes the location and types of the nodes. In addition, the approach requires gathering the location information and setting up the addressing mechanism for the nodes, which complicate route setup. Low-Energy Adaptive Clustering Hierarchy (LEACH) [7] is one of the most popular hierarchical routing algorithms for sensor networks. The idea is to form clusters of the sensor nodes based on the received signal strength and use local cluster heads as routers to the sink. This will save energy since the transmissions will only be done by such cluster heads rather than all sensor nodes. LEACH uses single-hop routing where each node can transmit directly to the cluster-head and the sink. Therefore, it is not applicable to networks deployed in large regions. In Power Efficient Gathering in Sensors Information Systems (PEGASIS)[8] sensors form chains along which a node transmits and receives from a nearby neighbor. PEGASIS introduces excessive delay for distant node on the chain. In addition the single leader can become a bottleneck, which causes decreases of network lifetime WSNs. For example, every sensor needs to be aware of the status of its neighbour so that it knows where to route that data. Such topology adjustment can introduce significant overhead especially for highly utilized networks. In [9], the maximum lifetime data aggregation (MLDA) problem. The objective is to find a set of data gathering schedules to maximize the system lifetime a schedule is defined as a collection of directed spanning trees rooted at the sink node. MLDA is performing better than the other protocols in terms of system lifetime; the algorithm is computationally expensive for very large sensor networks. In [10], the impact of the data correlation on the routing schemes is studied and a static clustering scheme is showed that they achieve a near-optimal performance for various spatial correlations. The main goal of this project work is by jointly optimizing routing and data aggregation, the network lifetime can be extended from two dimensions. One is to reduce the traffic across the network by data aggregation, which can reduce the power consumption of the nodes close to the sink node. The other is to balance the traffic to avoid overwhelming the bottleneck nodes. The energy consumption can be minimized if the amount of data that needs to be transmitted is also minimized. The solution to this is data aggregation. Data compression techniques are used to remove the redundancy information. Removing the redundancies results in transmitting fewer numbers of bits, and hence reduces energy Consumption and increases the network lifetime.

III. Existing MODEL

LEACH-distributed or LEACH [2] is a self-organizing, adaptive clustering protocol that uses randomization to distribute the energy load evenly among the sensors in the network. LEACH makes some assumptions about both the sender nodes and the underlying network, being some of them very strong. LEACH assumes that all sensor nodes can adapt their transmission range. Furthermore, energy consumption during transmission scales exactly with the distance and every sensor node is able to reach a base station (BS). Moreover, nodes support several MAC layers and perform signal-processing functions. LEACH uses a distributed algorithm to determine the cluster heads in the set-up phase whereas in the steady phase nodes send their data according to the time schedule provided by their cluster heads. This operation of LEACH is divided into rounds as shown in figure1.

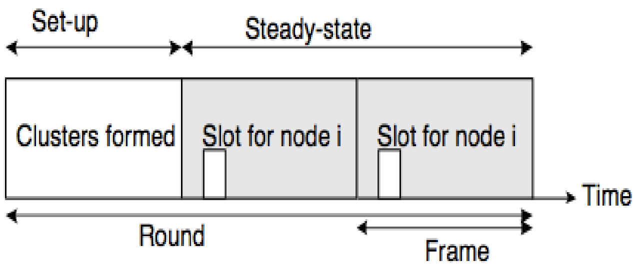

Figure 1: LEACH operations

A. Advertisement Phase

When clusters are created, each node *n* autonomously decides if it will be a cluster head for the next round. The selection is stochastic and each node determines a random number between 0 and 1. If this number is lower than a threshold *T(n)*, the node becomes a cluster head. *T(n)* is determined according to the equation.

$$T_1 (n) = P/1-P*(r \bmod 1/P) \text{ ----- } (1)$$

for nodes that have not been cluster head in the last 1/*P* rounds, otherwise *T1(n)* is zero. Here *P* is the desired percentage of cluster heads and *r* is the current round. Using this algorithm, each node will be a cluster head exactly once within 1/*P* rounds. After 1/*P* – 1 rounds, *T1 (n)* = 1 for all nodes that have not been a cluster head. When a node has elected itself as a cluster head, it broadcasts an advertisement message telling all nodes that it is a cluster head. This advertisement is done using a CSMA MAC protocol. Non-cluster heads use these messages from the cluster heads to choose the cluster they want to belong for this round based on the received signal strength of the advertisement message.

B. Cluster Set-Up Phase

After each node has decided to which cluster it belongs, it must inform the cluster head node that it will be a member of its cluster. Each node transmits this information back to the cluster head again using CSMA MAC protocol. During this phase, all cluster head nodes must keep their receivers on.

C. Schedule Creation

The cluster head receives all the messages from the nodes that would like to join the cluster. Based on the number of nodes in the cluster, the cluster head creates a TDMA schedule telling each node when it can transmit the data. This schedule is broadcasted back to the nodes included in the cluster.

D. Data Transmission

Once the clusters are created and the TDMA schedule is fixed, nodes can start to transmit their data. Assuming nodes always have data to send, they send it during their allocated transmission time to the cluster head. This transmission uses the minimal amount of energy based on the received strength of the cluster head advertisement. The radio of each non-cluster head can be turned off until the node's allocated transmission time, thus minimizing energy dissipation. The cluster head node must keep its receiver on to receive all the data from the nodes in the cluster. Once all the data has been received, the cluster head performs optimization functions such as data aggregation or other signal processing functions to compress the data into a single signal. This composite signal, which is a high-energy transmission since the base station is far away, is then sent to the base station. The cluster heads send these data packets using a fixed spreading code with CSMA. This is the steady-state operation of LEACH networks. After a certain time, which is determined a priori, the next round begins with each node determining if it will become a cluster head for this round and advertising the decision to the rest of nodes as described in the advertisement phase.

IV. PROPOSED MODEL

The fundamental of the protocol is to develop a cluster based routing where cluster heads should be selected based on maximum coverage and should have sufficient energy to prolong the communication. The following Figure 4..1 shows the proposed algorithm, where we are routing through high energy node. And for cluster formation, selecting node with high node energy.

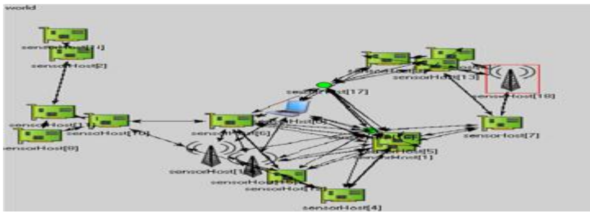

Figure 4.1: Proposed Model For Energy Aware Modified LEACH Protocol.

Algorithm: Modified LEACH Algorithm.

[1]. Let W,H be the Network width and Height. Network Area A=WxH.
[2]. Let there be N nodes with Ei Energy at (Xi,Yi) point.
[3]. Let Node 0 be the Sink node located at W/2,H/2.
[4]. The problem can be summarized as to get a connected graph G={V,E} from S number of sources such that V are the Nodes and E are set of all edges or Links, So as to maximize L where L is the Lifetime and is defined as time tl when Ei<=0, where i can be any node other than the Sink.
[5]. Initially all node broadcast HELLO packets and let the other nodes know their Energy and Position.
[6]. Initially When Sink wants to gather data from Sources, It Selects the nodes with Maximum Neighbors and Sufficient Energy as Cluster Heads.
[7]. Each Cluster head is notified that it is cluster head.
[8]. Source generates RREQ packet.
[9]. A node forwards RREQ packet only if it is a cluster head.
[10]. Route is formed between each source to sink through cluster heads.
[11]. Data is transmitted from source to Sink.
[12]. Nodes looses Energy as
[13]. Eloss= Eidle + Etransmit + Ereceive
[14]. and E=E-Eloss where Eidle=1pJ/s
[15]. Etranmit = 3mJ/Packet(considering packet is of
[16]. Length 1024)
[17]. Ereceive = 1mJ/Packet
[18]. During the Transmission if any Ei is less than 0, mark the time as Network Lifetime.
[19]. If a cluster head looses it's energy bellow 30% of the Max energy, then it notifies the source. An alternative cluster head is selected, all the routes through previous cluster head generates RERR and new routes are formed.

A. Packet Delivery Ratio
   Number of Packet delivered from source to sink/Number of Packets Generated at source Node.
B. Latency
   Average time of transmission of all packets from Source to Sink.
C. Control Overhead
   Number of Control packet sent(RREQ,RERR, HELLO,RREP)/Number of data packet Delivered.
D. Average Energy Consumption
   Avg (Emax-Ei) where i=1,2..N and i!=Sink.

V. RESULTS

The analysis of the proposed cluster based routing scheme where cluster heads should be selected based on maximum coverage and should have sufficient energy to prolong the communication. is carried out using OMNeT++ to evaluate the energy consumption and maximize the lifetime of the sensor network. A sensing field of dimension WxH (W =500 & H=500 m) with a population of N= 25, 50 nodes is considered for simulation. The system parameters used for nodes 25, 50 for the simulation is listed in Table 1.

Area	500*500 m
Packet Size	512 Bytes
Initial Energy of node	1000 mJ
Packet Rate	500
Number of Active Session	14
Energy from MAC	0.003mJ/bit
Energy from Outside Module	0.001mJ/bit

Table 1: Simulation parameters for 25 nodes.

Area	500*500 m
Packet Size	512 Bytes
Initial Energy of node	1000 mJ
Packet Rate	500
Number of Active Session	30
Energy from MAC	0.003mJ/bit
Energy from Outside Module	0.001mJ/bit

Table 2: Simulation parameter for 50 nodes.

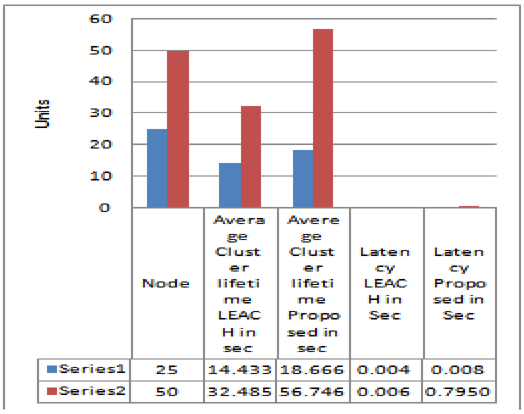

Figure 5.1.: Average cluster lifetime and Latency For 25 & 50 nodes.
In this fig. it shows that Average Cluster Lifetime of Proposed Modified LEACH is better than LEACH.

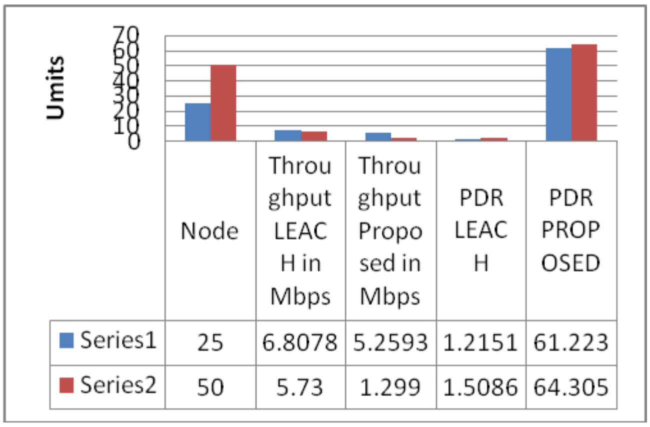

Figure 5.2: Throughput and Packet Delivery Ratio For 25 & 50 nodes.
In this fig. it shows that PDR of Proposed Modified LEACH is better than LEACH.

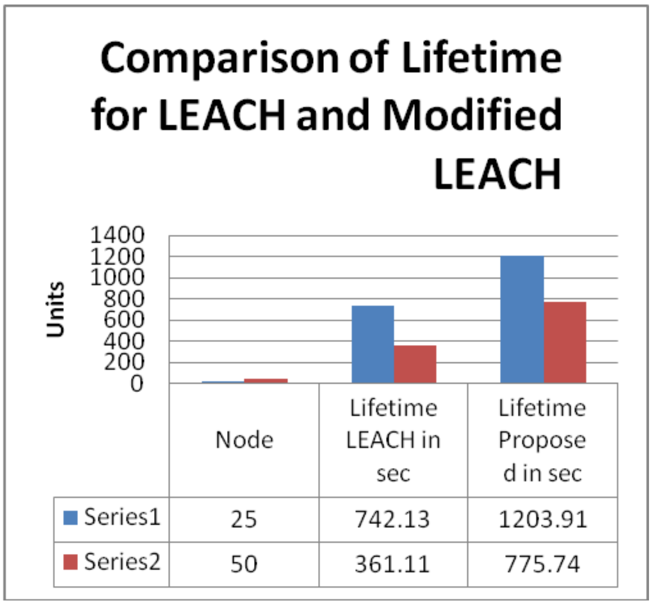

Figure 5.3 Comparison of Lifetime for LEACH and Modified LEACH.
In this fig. it shows that lifetime of Proposed Modified LEACH is better than LEACH.

VI. Conclusion

There are several challenges in designing the routing and transmission for wireless sensor network. Sensors are small electronic devices with limited processing and transmission capabilities. Generally they are deployed over a wide area. Therefore continuously monitoring the energy of such nodes are difficult. Hence utmost care should be taken to ensure that in a communication scenario, the nodes do not loose too much energy and that the network remains active over longer period of time. The conventional sensor network protocols like direct diffusion and Leach fails to ensure the credibility of the network and fails to ensure longer lifetime. The lifetime maximization problem is generally seen as an isolated problem in comparison to QOS problem. In this work a QOS aware protocol is provided that ensures maximum lifetime of the edges through which routing is performed and thus minimizing the losses due to node mobility or collision, thereby enhancing the lifetime by minimizing the Energy losses. Result show that the lifetime of the proposed system is better than the conventional Leach. There are several other factors like bandwidth, delay that affects the performance of the network which are correlated. But resolving the acute relationships among the parameters are difficult. Hence the work can be further improved by incorporating fuzzy decisions along with hard decision Maximization problem.

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