Performance Comparison of Leach and GSTEB in Wireless Sensor Network

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Abstract- Wireless sensor network (WSN) is an emerging technology for the data gathering from the unattended and hostile environment. WSN is composed of a large number of sensing nodes, which are called as sensors. This type of network is to collect and transmit different types of information to a base station (BS). WSN is composed of low-cost sensor nodes with limited battery power. As WSN consists of thousands of physically embedded nodes, thus the battery replacement is not possible, due to which energy efficient routing protocols should be employed to provide a long network lifetime. Various routing protocols have been proposed yet to meet the energy efficiency requirement in wireless sensor network. Hierarchical protocols which work upon clustering mechanisms like LEACH and GSTEB are best suited for maintaining energy efficiency. In this paper we will compare these protocols in terms of energy dissipation, packets transferred and number of nodes alive. We will also discuss the advantages and disadvantages of these protocols under different circumstances.

Keywords- Wireless sensor network, hierarchical routing protocol, LEACH, GSTEB.

I. INTRODUCTION

With the recent technological advances in wireless communications, processor, memory, radio, low power, highly integrated digital electronics, and micro electro mechanical systems (MEMS) [1]; it becomes possible to significantly develop tiny and small size, low power, and low priced multifunctional sensor nodes. These nodes are designed for wireless communications, sensing and computation comprising software, hardware and algorithms. WSNs [2] are used for varieties of applications like area monitoring, health care monitoring, industrial monitoring, military surveillances, forest fire detection, transport monitoring etc. Numerous routing, power management and data dissemination protocols have now been created for wireless sensor networks, influenced by both architectures of wireless sensor network and the applications that WSN is supposed to support.

As in WSN the sensor nodes are very densely distributed thus monitoring of these nodes becomes very difficult, particularly in those areas where the human intervention is not possible. In WSN, the network after establishment keeps on sensing the data and the power of nodes continues dissipating when they obtain some data and deliver it further to other nodes or base station. Various types of routing protocols have now been proposed to make sensor nodes more power efficient. As the sensor nodes are densely distributed, energy of the sensor nodes gets dissipated quickly when redundant information is transferred to the base station. To alleviate these troubles various clustering algorithms have been proposed. In clustering algorithms, whole network is divided into clusters and data aggregation is performed within these clusters and then transmitted to the base station. Clustering reduces the data redundancy and improves the network lifetime. Different clustering algorithms are LEACH, HEED, DEEC, SEP, GSTEB etc. In this paper, we choose two important hierarchical protocols, LEACH and GSTEB for their performance comparison.

The rest of the paper is organized as follows: Section II reviews the related work in this field. Section III depicts the energy dissipation model used by sensor nodes. Section IV contains simulation results to compare both protocols under various performance metrics. Finally Section V concludes the paper.

II. REVIEW OF HIERARCHICAL ROUTING PROTOCOLS FOR WSN

The key goal of hierarchical routing protocols [3] is to effectively maintain the power utilization of sensor nodes by means of multi-hop communication within a particular cluster and by performing data aggregation and combination in order to lower the quantity of transmitted messages to the base station. Cluster formation is usually based upon power saved by sensors as well as the proximity of sensors towards the cluster head (CH). The cluster head selection is based on following parameters:

- **Initial Energy:** initial energy of all sensor nodes.
- **Remaining Energy:** Remaining energy of every node after every round.
- **Average energy consumption rate:** energy dissipated by sensor nodes while operation along with energy related to cluster formation.
- **Average energy of network**

We explore two important hierarchical routing protocols in this section.

A. LEACH

Low energy adaptive clustering hierarchy (LEACH) is a popular hierarchical routing protocol for sensor networks proposed by W. Heinzelman *et al.* [4]. LEACH is a hierarchical protocol where most nodes transmit to cluster heads, and the cluster heads compress and aggregate the information and forward it to the base station. LEACH assumes that every node features a radio powerful enough to directly reach the base station or the nearest cluster head, but by applying this radio at full power constantly would waste energy. Nodes which were cluster heads cannot become cluster heads again for P rounds. At the end of every round, each node that is not a cluster head selects the closest cluster head and joins that cluster to transmit its data. LEACH depends on two basic assumptions: (a) base station is fixed and located far from the sensors. (b) all nodes in the network are homogeneous and energy constrained.

The concept behind LEACH is to make clusters of the sensor nodes with respect to the received signal strength and use local cluster heads as routers to route data to the base station. The architecture of LEACH is shown in figure 1. LEACH algorithm [5] works as follows:

a) Advertisement phase

In this phase, nodes elect themselves to be always a cluster-heads for the present round I through a cluster-head advertisement message. With this cluster-head advertisement, the cluster heads use CSMA MAC protocol. Following the completion of the phase, and with respect to the received advertisement signal strength; the non cluster-head nodes (their receivers must certainly be maintained in this phase to hear the advertisements of most cluster-heads) determine the cluster to which they belong to for this current round I. At each round, a node n selects a random number k that's between 0 and 1. If k is less than the usual threshold T (n), then your node becomes a cluster-head for the present round I.

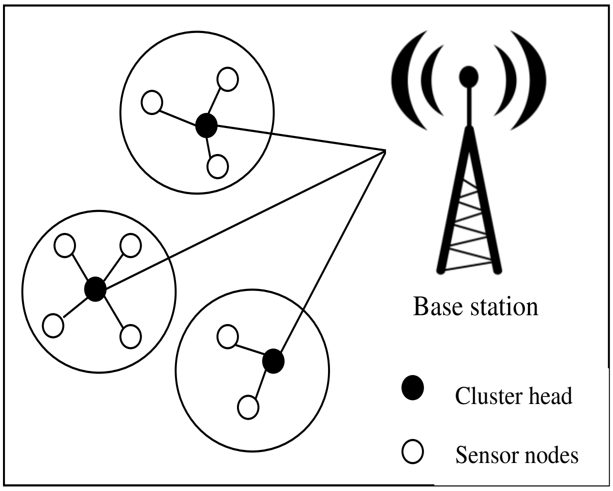

Fig. 1. Architecture of LEACH protocol

$$T(n) = \begin{cases} \dfrac{P}{1-P\left(r \bmod \left(\frac{1}{p}\right)\right)}, & if\ n \epsilon S \\ 0, & otherwise, \end{cases} \quad (1)$$

Where P is the desired percentage of cluster-heads, r is the current round, and S is the set of nodes that have not been cluster heads in the last $1=P$ rounds. Since k is randomly selected, the number of cluster heads may not be fixed.

b) Cluster set-up phase

After each non-cluster-head node will have chosen to which cluster it belongs, it informs the cluster-head node so it will be a member of the cluster. So, each node transmits these details back once again to the cluster head using CSMA MAC protocol.

c) Schedule Creation phase

The cluster-head node receives all the messages for nodes that wish to be contained in the cluster. Based on the quantity of nodes in the cluster, the cluster-head node makes a TDMA schedule telling each node if this can transmit. This schedule is broadcast back towards the nodes inside the cluster.

d) Data Transmission phase

After the creation of both the clusters and the TDMA schedule (TDMA is fixed), nodes in the cluster start transmitting the data they currently have throughout their allocated transmission time to the cluster-head (cluster-head node keeps its receiver on all the time to receive the sent data). Once all the data (sent by nodes in the cluster) have been received by the cluster-head node, it will perform signal processing functions to compress the data into a single signal (the steady-state operation of LEACH networks).

Advantages of LEACH protocol are:

- LEACH is entirely distributed, hence doesn't require control information from base station.
- It provides scalability in the network by restricting most of the communication within the cluster.
- It is powerful and simple protocol as it doesn't need location information of the nodes to create clusters.
- It is an energetic clustering protocol suitable for applications where regular tracking is necessary and information collecting develops regularly to the centralized place.
- It improves energy efficiency in comparison to flat-topology protocols.

Although, LEACH has shown good features to the sensor networks, yet it suffers from the following drawbacks:

- It can't be put on time-inhibited application as it results in a long latency.
- The nodes on the route a hotspot to the sink could drain their power fast. This issue referred to as "hotspot" problem.
- It can't be put on large sensor networks.
- It extremely depends upon the cluster head (CH) thus experienced robustness problems such as failing of cluster head.
- Selection of CH is random due to which energy consumption is not taken into account.

B. GSTEB

The key aim of General Self-Organized Tree-Based Energy-Balance Routing Protocol (GSTEB) [6] is to reach an extended network lifetime for different applications. The BS allocates a root node and broadcasts its ID and coordinates to all or any sensor nodes in each round. Then network computes the route either by transmitting the route

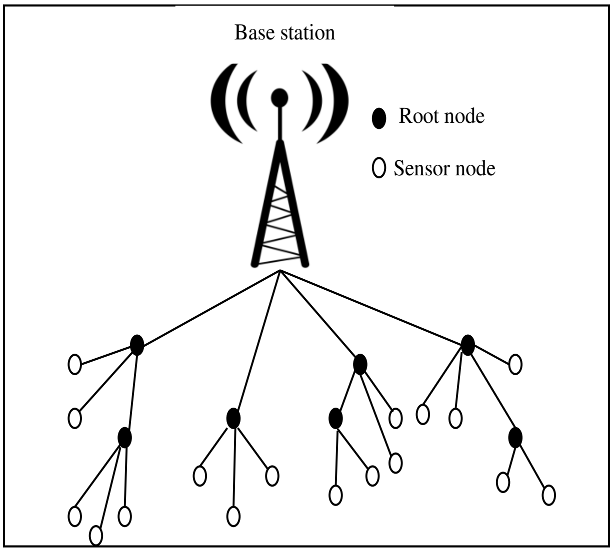

Fig. 2. Architecture of GSTEB protocol

information from BS to sensor nodes or with the same tree structure being dynamically and individually built by each node. In both cases, GSTEB may change the basis and reconstructs the routing tree with a short delay and low energy consumption. The architecture of GSTEB is shown in figure 2. The operation of GSTEB is divided in Initial Phase, Tree Constructing Phase, Self-Organized Data Collecting and Transmitting Phase, and Information Exchanging Phase.

a) Initial Phase

When Initial Phase begins, base station broadcasts a packet to all or some of the nodes to share with them of creation time. Each node sends its packet in a group with a particular radius during a unique time slot. Each node sends a packet which contains all its neighbors' information during a unique time slot. Then its neighbors can receive this packet and record the info in memory. Initial Phase has been just a significant preparation for other phases. After Initial Phase, GSTEB operates in rounds. In a round, the routing tree may be rebuilt, and each sensor node generates data packet that really needs to be provided for base station. When base station receives the information of most sensor nodes, a round finished.

b) Tree Constructing Phase

BS assigns a node as root and broadcasts root ID and root coordinates to any or all sensor nodes. In each round, a node with the greatest residual energy is chosen as root. The root collects the data of most sensors and transmits the fused data to base station over long distance. Each node tries to choose a parent in its neighbors using vitality. The nodes will compute their energy level by using the function,

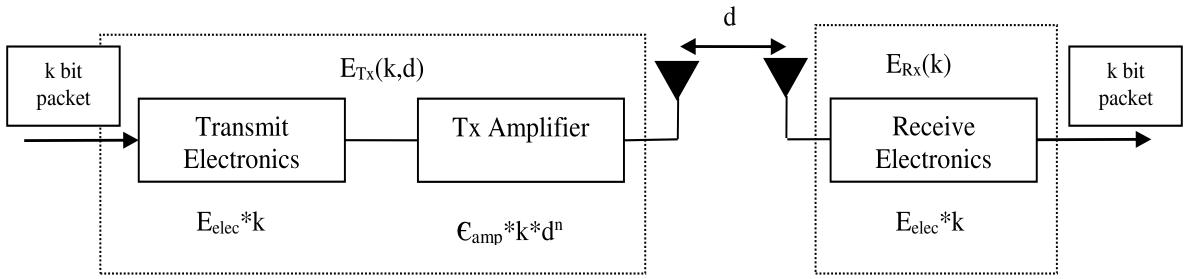

Fig. 3. Radio energy dissipation model

$$EL = \frac{Residual\ energy(i)}{\alpha} \quad (2)$$

In the equation 2, where '*i*' may be the ID of every node, and α is a constant which reflects the minimum energy unit and may be changed predicated on our demands. The length between a parent node and the primary needs to be shorter than that between its and the root. Because every node selects the parent from its neighbors and every node records its neighbors' information in the table. Each node is fully aware of all its neighbors' parent nodes by computing, and additionally, it knows all its child nodes. In case a node does not have any child node, it defines itself as a leaf node from that data transmission begins.

c) Self-Organized Data Collecting and Transmitting Phase

Once the routing tree is constructed, each sensor node gathers information to develop a data packet which must be transmitted to base station. After having a node receives every piece of information from its child nodes, this node itself functions as a leaf node and tries to send the fused data in the next time slot. The initial segment is required to examine if you have communication interference for a parent node. During this segment, each leaf node sends a beacon that contains its ID to its parent node at the same time. Each node chooses its parent by considering not the length but the entire energy consumption.

d) Information Exchanging Phase

Each node must generate and transmit a data packet in each round, before it drains its energy and dies. The dying of any sensor node can persuade the topography. So the nodes that are likely to die need to share with other nodes. The process can also be split into time slots and in every time slot, the nodes whose energy will probably be exhausted will compute a random delay helping to make only 1 node broadcast in a new slot. Once the delay is ended, these nodes will make an effort to broadcast a package to the complete network. While all the nodes are monitoring the channel, they'll receive this packet and perform an ID check. So, the cluster head is selected on the basis of the degree of energy in order that information may be transferred securely.

Advantages of GSTEB protocol:

- GSTEB is a self organized protocol, thus it reduces energy consumption in each round for balancing energy consumption.
- It provides longer network lifetime for different applications.
- In GSTEB, transmission delay is short as all the leaf nodes transmit data in the same slot.
- It reduces routing overhead as compared to any other hierarchical routing protocols.
- It provides improved and efficient packet delivery ratio.

III. ENERGY MODEL ANALYSIS

In this paper, we are analyzing LEACH and GSTEB on the basis of energy dissipation model [4] as shown in figure 3. In this model, energy is dissipated by both transmitter and receiver during data transmission. Power control can be utilized to reverse the multipath fading loss by proper setting of power amplifier and if the exact distance is less when compared to a threshold d_o, the free space (fs) model can be utilized; if not, then multipath (mp) method is used. The energy spends by the transmitter to transmit k-bit message at distance d is given by

$$E_{Tx}(k,d) = \begin{cases} E_{elec}*k + \epsilon_{fs}*k*d^2, & d<d_o \\ E_{elec}*k + \epsilon_{amp}*k*d^4, & d\geq d_o \end{cases} \quad (3)$$

and the energy spends during receiving the message is given by:

$$E_{Rx}(k) = E_{elec}*k \quad (4)$$

where E_{elec} is the electronics energy i.e. energy dissipated to run the electronics circuits, which depends upon factors such as digital coding, modulation, filtering and spreading of the signal, whereas amplifier energy $\epsilon_{fs}d^2$ and $\epsilon_{amp}d^4$ depends upon the distance to the receiver and the acceptable bit error rate. The energy is also dissipated by the CH due to data aggregation, which is given by E_{DA}.

IV. SIMULATION RESULTS

We have carried out different experiments and used them for making comparison between LEACH and GSTEB for various performance parameters. Simulation is carried using MATLAB.

A. Network Settings

We used a 100×100 region having N=100 sensor nodes, which are randomly distributed. The data packet size is K=4000 bits. The various parameter values which are taken for the experiments are shown in table I.

TABLE I. Simulation Parameters

Parameter	Value
E_{elec}	50nJ/bit
E_{fs}	10pJ/bit/m^2
E_{mp}	0.0013pJ/bit/m^4
E_{DA}	5nJ/bit/packet
E_o	0.5J
P_{opt}	0.1
r_{max}	3000
K	4000bits
N	100
Network size	100×100
Base station location	(50,100)

a) Performance Metrics

- Stability period: It is the round up to which all nodes are alive. This period lies between round 1 and the round at which the first node lies.
- Instability period: It is the period between first dead node and last dead node. This period should be as small as possible.
- Data packet transferred to base station: It is the total amount of data received by the base station during network lifetime.
- Average remaining energy: It is the amount of available energy after the data transmission to the base station.

b) Performance analysis of LEACH and GSTEB

We have done our simulations using MATLAB to compare LEACH and GSTEB. The results of the simulation are shown below:

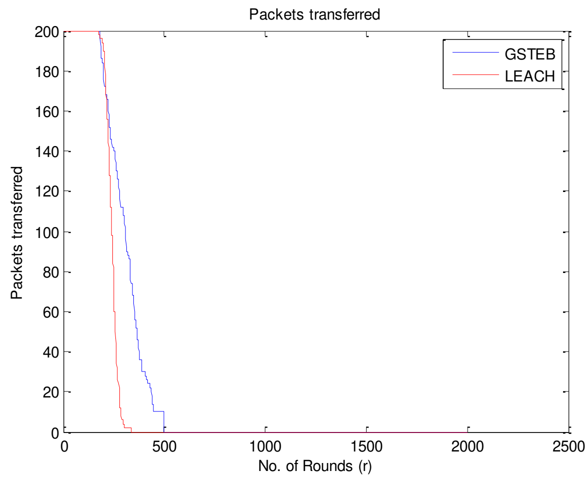

Fig. 4. Number of packets transferred to base station Vs Number of rounds

Figure 4 shows that the number of packets transferred to the base station is large in GSTEB as compare to LEACH. As GSTEB uses tree based data transmission model due to which only those nodes which are in close proximity of base station act as root nodes, which allow direct transmission to the base station and lower transmission delay, hence more data packets get transferred to the base station. Whereas in case of LEACH data is transmitted to base station only through the cluster head, which can be at any distance from base station which results into more energy wastage and longer transmission delay, hence less data packets transferred to base station.

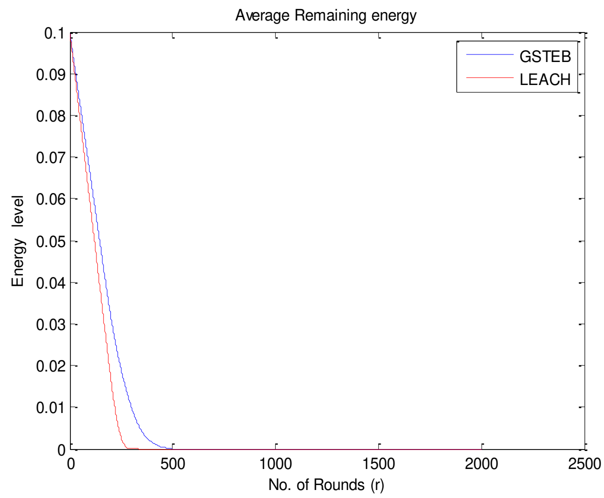

Fig. 5. Average remaining energy Versus Number of rounds

Figure 5 shows that average remaining energy with GSTEB protocol is more as compared with the LEACH protocol because GSTEB is a self organized protocol, thus it consumes small amount of energy in each round as it changes its topography for balancing energy consumption. Hence we can say that GSTEB protocol provides energy efficiency for the WSN network as compared to that with LEACH.

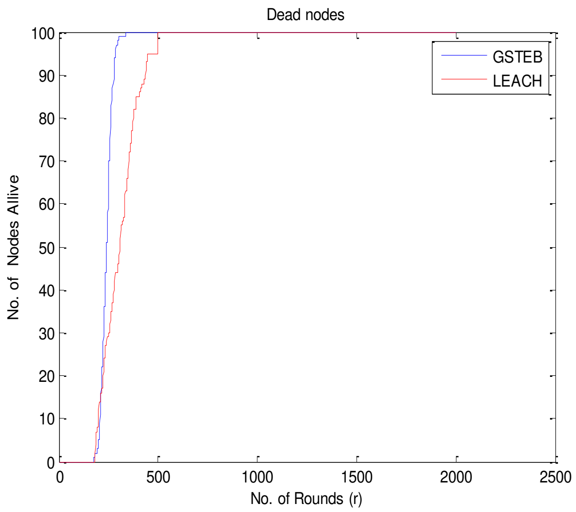

Fig. 6. Number of nodes alive Versus Number of rounds

Figure 6 shows that the number of nodes alive at particular round is more in case of GSTEB as compare to LEACH protocol this shows that the stability period of GSTEB is more as compared to LEACH protocol. As in case of GSTEB protocol the first node becomes dead after longer time as compared to LEACH protocol due to lesser energy consumption. Thus we can say that GSTEB protocols increases the lifetime of the WSN network as compare to LEACH protocol. Table II shows the comparison between these two protocols under various performance metrics.

TABLE II. Comparison table for LEACH and GSTEB

Performance metrics	**LEACH**	**GSTEB**
Data Transmission Model	Cluster Head	Tree Based
Network lifetime	Low	Prolong
Packet Transferred	Low	High
Stability	Low	High
Power Consumption	High	Low

V. CONCLUSION

We have compared the LEACH and GSTEB protocol under different performance metrics using MATLAB simulation tool. The simulation results show that GSTEB performs better than LEACH in terms of data packet transfer to base station, average remaining energy and number of nodes alive. In GSTEB, a tree topology is constructed to transfer the information and the topography is kept on changing for balancing energy consumption of the WSN network. As WSN needs more reductions in energy consumption to increase the network lifetime, so we conclude that GSTEB proves better in increasing the network lifetime when compared with LEACH. In the near future, we plan to apply attacks on LEACH and GSTEB and compare their performances under attacks using different performance metrics.

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