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Mobile Sink based Low Energy Adaptive Clustering Hierarchy Routing Algorithm in Wireless Sensor Networks

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Abstract*-Wireless Sensors Network consists of small electro-mechanical devices called sensor nodes which are capable of sensing, computing and communicating data packets from harsh physical environments like a battle field. These sensor nodes consist of batteries for energy, which get discharged at a faster rate because of the operations like computation and communication they have to perform. Mainly routing protocols are designed for efficient utilization of energy resources. However, sensor networks with one fixed sink node often suffer from a hot spots problem since nodes near sinks have more traffic burden to forward during a multi-hop transmission process. The use of mobile sinks has been shown to be an effective technique to enhance network performance features such as latency, energy efficiency, network lifetime, etc. In this paper, a modified Low Energy Adaptive Clustering Hierarchy (LEACH), which employs a mobile sink, has been proposed for WSNs with non-uniform node distribution. The decision of selecting cluster heads by the sink is based on the minimization of the associated additional energy and residual energy at each node. Simulation results demonstrate that our algorithm has better performance than traditional routing algorithms, such as LEACH.*

Keywords: *Wireless Sensor Networks (WSN), Cluster Head (CH), Routing Protocol, Layered Sensor, Stability Period, Network Lifetime, Residual Energy.*

I. INTRODUCTION

Wireless Sensor Networks (WSNs) became one of the most interesting areas for researchers for communication. Routing techniques are the most important issue for these networks as resources like energy are limited. Mostly sensor nodes are battery operated as they are used in physical environments where replacement of battery is not possible. Also they are mostly limited processing power and sensing ability. Lots of research is ongoing to find new application of WSN and few current military applications like battle field surveillance, monitoring the enemy territory, detection of attacks [1]. Other applications of WSN are in the medial sectors where doctors can use small sensors to collect physiological data from patients and in deployment in natural disaster prone areas for environmental monitoring. There is need to maintain a reliable data packets delivery, data aggregation and information fusion that is necessary for streamlined and effective communication between these sensor nodes. Only processed and brief information should be delivered to the base station to reduce transmission energy, prolonging the effective network life-time with optimal data delivery. A wasteful use of the available energy leads to poor performance and short lifetime of the network. To this end, energy in these sensors is a valuable resource and must be managed in an efficient manner [2].

Hierarchical routing protocols [3-6] which use clustering approach have been proved more energy efficient routing protocols than previous routing protocols. Several hierarchical protocols are designed for homogeneous networks. LEACH [1] is one of the very first clustered based routing protocols for homogeneous network. LEACH assigns same probability for all sensor nodes to become cluster head.

Clustering has characteristics such as scalable, energy-efficient, lower latency, *etc.* which make it a popular technique for WSNs. The idea is to select a set of cluster heads from the set of nodes in the network, and then cluster the remaining nodes with these heads [5]. The data gathered are transmitted through cluster heads to remote base stations or sink nodes. However, sink nodes are always fixed, which could result in the neighboring nodes to dying much faster and causing network partition as well as isolated sensors. A typically clustered sensor network is illustrated in Figure 1.

Moreover, the sensor nodes near the static sink act as relays for sensors that are far from it and thus will deplete their energy very quickly, resulting energy holes in the sensor field. The energy hole problem [7–12] leads to a premature disconnection of the network and thus sink gets isolated from the rest of the network due to the death of its neighbors, while most of the sensor nodes are still alive and fully operational. Exploiting the mobility of the sink has been widely accepted as an efficient way to alleviate the energy hole problem in WSNs and further prolong the network lifetime by avoiding excessive transmission overhead at nodes that are close to the sink. An unbalanced energy assumption phenomenon occurs when the one-hop neighboring sensors deplete their battery power, and those sensors far away may still have more than 90% of their initial energy unused [5–7]. When comparing with sensors far from the sink, nearby sensors are shared by more sensor-to-sink paths, thus they have heavier message relay loads, and consume more energy [8]. To solve this problem, many energy efficient routing algorithms and protocols have been proposed in recent years, including clustering based routing protocols, mobile sink based routing protocols, power-aware routing and multi-level transmission radii routing.

The use of mobile sinks can potentially provide energy-efficient data collection with well-designed networking protocols for WSNs [13]. When using the mobile sink in practice, the sink nodes can be attached to vehicles, animals or people that can move inside the region of interest. Usually, static sink nodes are not very efficient [14]. Although single hop data collection is feasible in networks deployed in small regions, the multi-hop transmission manner is more commonly used in large sensor areas. Intuitively, mobile sinks gain advantages by mitigating the so-called hot spot problem, balancing energy among sensor nodes, prolonging network lifetime, reducing transmission latency, and improving network performance by periodically accessing some isolated nodes into the network.

In this research, we design a proposed new protocol named Mobile sink based improved algorithm for Low Energy Adaptive Clustering Hierarchy (MS-LEACH). In this improved algorithm, the different trajectories of mobile sinks are set and experimented by the used of different positions in the sensing field. Sink nodes move back and forth along the designed trajectory. The network is divided into several clusters based on the Low Energy Adaptive Clustering Hierarchy Protocol. Each cluster head collects data and feeds it to the mobile sink.

The remainder of the paper is organized as follows. Section II presents related work and motivation for this research is given. Section III tells the network and radio model used for MS-LEACH. In Section IV, we provide the details of MS-LEACH algorithm.

Performance evaluation of MS-LEACH with LEACH on the basis of stability period and network lifetime and other performance metrics is given in Section V. Finally, the conclusion and future scope of this research are elaborated in Section VI.

II. RELATED WORK AND MOTIVATION

Hierarchical routing protocols are designed to deal with management of energy of sensor nodes in WSNs. Low Energy Adaptive Clustering Hierarchy (LEACH), a clustering based protocol that uses randomized rotation of election of cluster heads among nodes, hence distributing the energy load among the sensors nodes in the network field was proposed in Ref. [4]. LEACH protocol is basically used in homogeneous network in which these sensors nodes have equal chance of becoming cluster head by probabilistic rule. However, LEACH protocol is not used for heterogeneous network as this protocol is not able to take advantage of sensor nodes with extra energy. LEACH protocol operation are broken into rounds where every round starts with a set-up phase in which clusters are formed, followed by next phase named steady state phase in which data packets are transferred from sensor nodes to base station. In real life scenario it is hard for the sensor nodes to preserve their energy uniformly, thus, introducing energy imbalances between sensors. LEACH takes that the energy usage of each sensor node with respect to the overall energy of the network is homogeneous. Classical protocols such as Direct Transmission (DT) and Minimum Transmission Energy (MTE) [3] do not also assure a balanced and uniformly use of the sensor nodes respective energies as the network evolves.

However, LEACH-type protocols have some disadvantages. First, the algorithm offers no guarantee about the placement and number of cluster head nodes. Second, if the cluster head dies in round *n*, the whole cluster is unable to transfer its data to the base station until the next round. This intermittent failure of clusters could be a disaster when monitoring a region in real-time. Third, the individual sensor nodes transfer their data to the cluster head through single-hops, which is not suitable for large-scale networks. Therefore, further research has been undertaken into some of these issues.

The main idea in Power-Efficient GAthering in Sensor Information System (PEGASIS) is to make the energy load distribution more even among sensors for WSNs. Each node will receive from and transmit to close neighbors and take turns being the leader for transmissions to the base station [12]. It assumes that all nodes have global knowledge of the network; the base station is fixed at a far distance from the sensor nodes; the sensor nodes are homogeneous and energy constrained with uniform energy; and the energy cost for transmitting a packet depends on the distance of transmission. PEGASIS builds a chain to ensure that all nodes have close neighbors. When a node dies, the chain is reconstructed to bypass the dead node.

III. NETWORK AND RADIO MODEL

In this section we present network and radio model for our proposed protocol which is extension of LEACH. Further we elaborate the optimal number of cluster heads for our algorithm.

A. Network Model

In this proposed protocol, we assume that sensor nodes are randomly deployed in the circular network field. We assume that sensor network and sensor nodes possess following attributes.

- All sensor nodes are stationary after the initial deployment and each one knows its locations via GPS module [15].
- Sensor nodes can use power control to tune the amount of send power in accordance to the transmission distance.

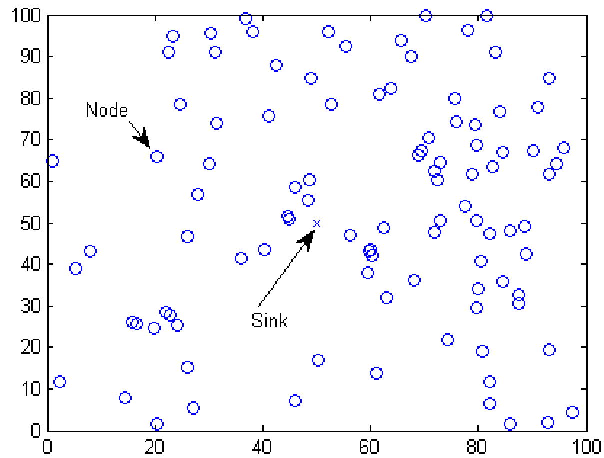

Figure 1. Network Phase

B. Radio Model

Our radio model is similar to the previous protocols LEACH [4]. Discussion over radio model is important because assumptions about the radio characteristics including energy dissipation in transmit and receive mode will have an impact on the performance of a particular routing protocol in contrast of other protocol. We also assume that path loss exponential is d^2 power loss provided transmitter and receivers are within certain threshold distance d_0 otherwise it is d^4. If a node wants to transmit 'k' bits of data over a distance 'd' then following equation will give us transmission energy requirements[16].

$$E_{T_x}(k,d) = \begin{cases} k.E_{elec} + k.\varepsilon_{fs}.d^2 & if\ d < d_0 \\ k.E_{elec} + k.\varepsilon_{amp}.d^4 & if\ d \geq d_0 \end{cases} \quad (1)$$

$$E_{R_x}(k) = k.E_{elec} \quad (2)$$

In above equation E_{elec} is the per bit energy dissipations for transmission. We use the free-space and two-ray models according to the distance between the transmitter and receiver. d_0 is a threshold transmission distance and $d_0=\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{amp}}}$. If $d_0 < d$, the free-space model will be used for transmission; otherwise, the two-ray model will be employed. ε_{fs} and ε_{amp} are the amplifier parameters of transmission corresponding to the free-space and the two-ray models respectively.

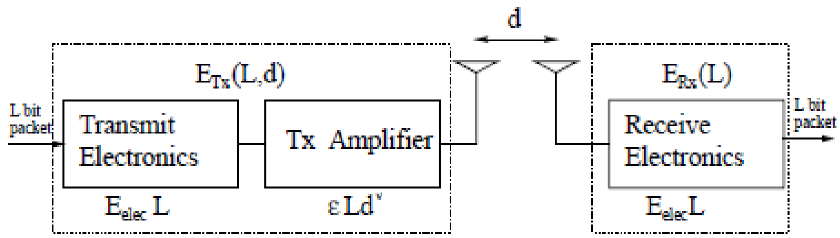

Figure 2. Radio Model

IV. MS-LEACH ALGORITHM

The operations that are carried out in the MS-LEACH protocol are divided into three stages, which are given below:

- Cluster Formation.
- Proposed Mobile Sink path patterns
- Transmission of aggregated data by cluster heads to the mobile sinks.

A. Cluster Formation

The cluster formation phase is same as of LEACH set-up phase, all the sensors within a network field form some cluster regions by electing cluster-heads through the weighted election probability according to their initial energy level [2]. p_{nrm} is defined as the optimal number of cluster-heads that are selected per round and $T(s_{nrm})$ is defined as threshold for sensor nodes which is defined by the following formaula.

$$T(s_{nrm}) = \begin{cases} \frac{p_{nrm}}{1-p_{nrm} \times (r \bmod \frac{1}{p_{nrm}})} & if\ s_{nrm} \in G' \\ 0 & otherwise \end{cases} \qquad (3)$$

After the election of cluster heads, the non-cluster head nodes choose to join those cluster heads to form clusters on the basis of signal strength of the messages sent by the cluster heads. Nodes interested in joining a particular cluster reply back to their respective cluster heads through response signal indicating their acceptance to join. Figure 3 below shows phase of election of cluster heads from nodes in a MS-LEACH protocol. All the sensors form as cluster members to the cluster heads.

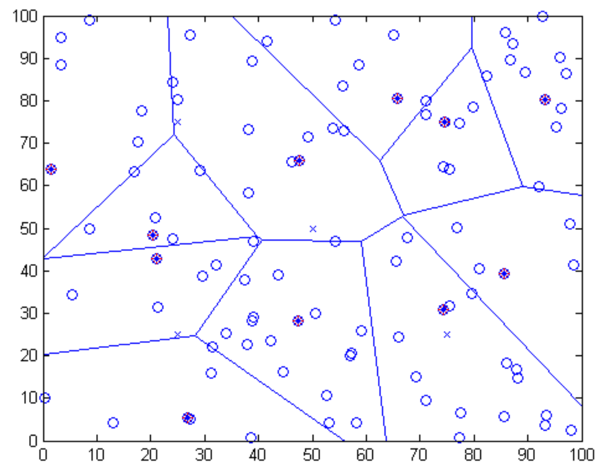

Figure 3. Selection of Cluster-heads and Cluster Formation

B. Proposed Mobility Path Patterns

In our protocol, we use a controlled mobile sink that guided based on minimizing the dissipated energy of all sensor nodes. The sensor field is divided into R equal size regions to conserve energy since data is transmitted over fewer hops. This reduces the number of dropped packets and delay that packet needs to reach to the sink because the mobile sink moves along the sojourn path and stops at the sojourn location closer to the sensor nodes in each region in the sensor field. Moreover, dividing the sensor field into small regions requires sensors with small communication range in contrast to the whole sensor field which requires sensors with large communication range to ensure the connectivity between the nodes and the sink. Here, we consider two sojourn path patterns for the mobile sink. These patterns are rectangular paths with 4 and 8 sojourn locations as illustrated in Figure 4 and 5 respectively.

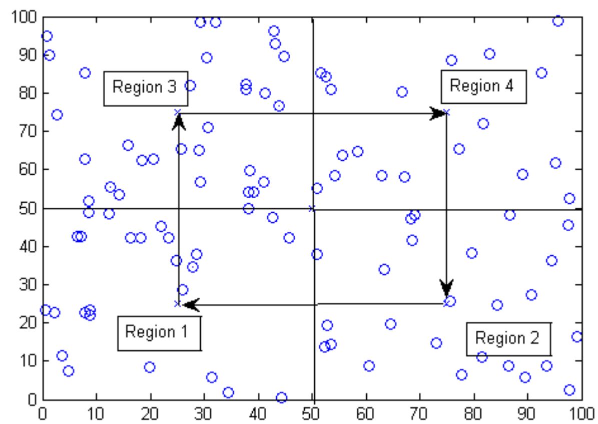

Figure 4. Sink Mobility Patterns for Four region rectangular path

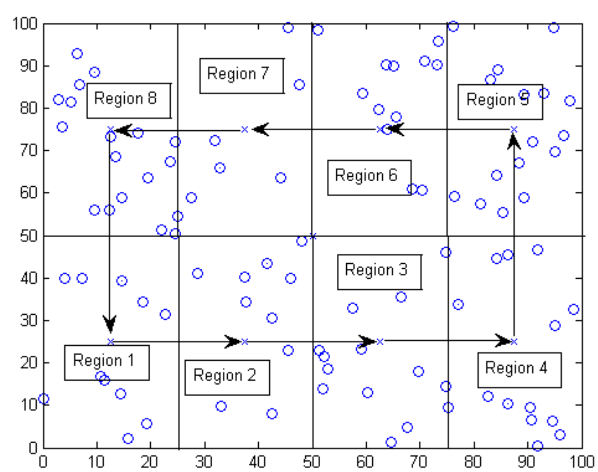

Figure 5. Sink Mobility Patterns for Eight region rectangular path pattern

C. *Transmission of aggregated data by cluster heads to Base Station through Multi-hop routing.*

After finding the locations of the CHs and the sojourn location of the mobile sink in a region r, the sink moves to its sojourn location and wakes up the sensor nodes in this region, while the rest nodes in other (R-1) regions are sleep. The nodes start sensing the data; then each sensor sends its data to its CHs or the sink if it is close to the sink than CH according to the

TDMA schedule. Each cluster communicates using different CDMA codes in order to reduce interference from nodes belonging to other clusters. Once each CH received the sensed data from its member nodes, it performs signal processing functions to aggregate the data into a single packet. Then, CHs send their packets to the sink. After certain time called sojourn time, the sink moves at a certain speed along the mobility path to the next region (r+1) to perform clustering and collects data from the sensors in this region. This process is repeated until the sink visits all R regions in the sensor field to guarantee complete data collection. When the sink finishes its round, it again goes back to first region to begin a new round. For example, when mobile sink enters the region 1, all the cluster heads present in region send their data to the sink, while other cluster heads wait for mobile sink to reach their region.

The following figure 6 illustrates this last phase of the protocol in which the four-rectangular path is followed by the mobile sink and cluster heads transfer their data to the mobile when it enters their region.

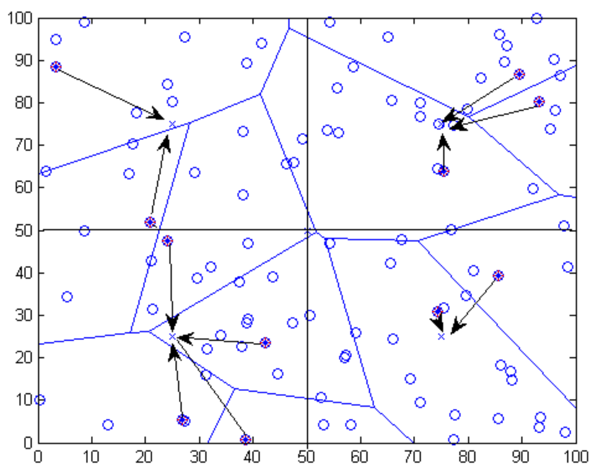

Figure 6. Illustration of transmission of data by cluster heads to the mobile sink when it enters their region

V. SIMULATION RESULTS

In this section various parameters and performance metrics are considered for the simulation results.

A. Parameters for the Simulation

We simulate proposed algorithm MS-LEACH and LEACH clustering algorithm for WSN. Results from many runs of each algorithm are recorded for random distribution of nodes. The basic parameters used are listed in Table 1

Table 1. Parameter for the MS-LEACH algorithm

Parameter	Value
Number of Nodes	100
Network Field	100*100
Size of data packet	4000 bits
Initial energy of normal node	0.1 J
ε_{fs}	10pJ/bit/m^2
ε_{amp}	0.0013pJ/bit/m^4
E_{elec}	50nJ/bit
E_{DA}	5nJ/bit/signal
d_0	87m

We use following metrics to analyze and compare the performance of the algorithm MS-LEACH and LEACH

- The stability of networks [16], namely the first node dead round from the start of network.
- The networks life time, namely the total energy dissipation and survival round, is the key metric of evaluation.
- Throughput
- Energy Dissipation

B. Stability Period & Network Lifetime

We have calculated the stability period and Network Lifetime for proposed algorithm and LEACH algorithm over the 100 simulation. The table 2 shows the results of Stability period and Table. 3 shows the result of Network Lifetime for both algorithm

Table 2. Comparison of stability period for LEACH and MS-LEACH

Stability Period for LEACH	167 Rounds
Stability Period for MS-LEACH (Path1)	262 Rounds
Stability Period for MS-LEACH (Path2)	306 Rounds

Table 3. Comparison of Network Lifetime for LEACH and MS-LEACH

Network lifetime for LEACH	324 Rounds
Network lifetime for MS-LEACH(Path1)	403 Rounds
Network lifetime for MS-LEACH(Path2)	457 Rounds

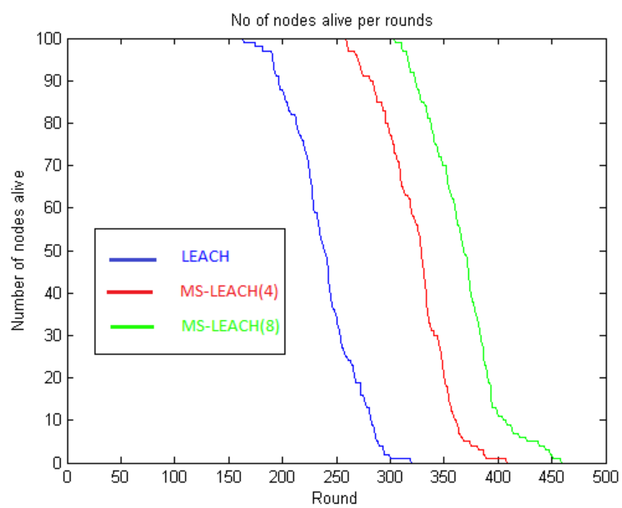

Figure 7. Stability Period & Network Lifetime Result

C. Throughput

There are total two types of communication in clustering protocols i.e. intra-cluster communication and inter cluster communication. In intra-cluster communication, the non cluster head nodes transfer data packets to their respective cluster-heads whereas in inter cluster communication, each cluster head transfer its aggregated data to the mobile sink when it arrives at their respective region. Finally, throughput is total of both of these communication i.e. packets to cluster heads and packets to the sink.

Through figure 8, it is clearly illustrated that our protocol improves the throughput of the network significantly.

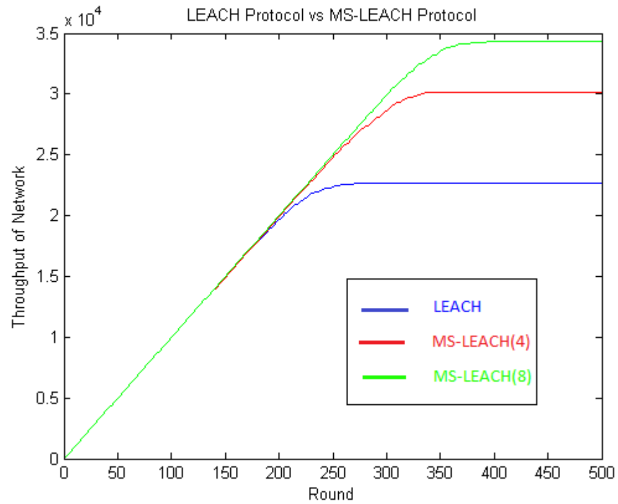

Figure 8. Comparison of throughput of both protocols

D. Energy Dissipation of the Network

Energy Dissipation is important parameter to determine how the energy of the network is consumed with rounds. By figure 9, it is clearly evident that our protocol conserves the energy of the network better than LEACH protocol which proves its superiority.

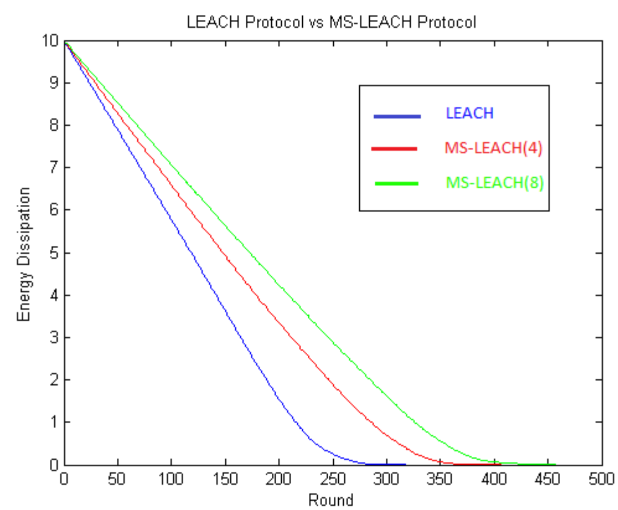

Figure 9. Energy Dissipation

VI. CONCLUSION AND FUTURE SCOPE

In this paper, Mobile Sink based Low Energy Adaptive Clustering Hierarchy (MS-LEACH) is proposed to minimize the energy consumption of sensor nodes. MS-LEACH introduces the concept of mobile sink which collects the data from the cluster heads by following the pre-defined paths. With minimizing the energy hole issue, MS-LEACH algorithm provides better stability period and network lifetime than original LEACH. The simulation results have proved that MS-LEACH performs well compared to similar approaches.

This MS-LEACH algorithm has been tested only for the homogenous environment. The better result could be found with the introduction of heterogeneity. Also MS-LEACH can further be extended to deal with clustered sensor networks with more than two levels of hierarchy and more than two types of nodes. In the end, multi-hop routing can also proved to be more beneficial in further conservation of energy of the network.

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