LEACH: Energy Efficient Routing Protocol for WSNs along with its Enhancements

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Abstract- Wireless Sensor networks are a standout in the midst of the many recent and rousing research disciplines of our time. They comprise impending to be employed for a variety of mission-critical applications. The biggest and most imperative challenge that wireless sensor network is facing these days is energy. There are numerous constraints in the minute sensor nodes like limited memory, power, bandwidth and processing capability. Since the nodes are deployed in an unattended area it makes the energy requirements of these nodes a big concern. Lot of investigation is done in command to formulate proficient routing algorithms which make nominal use of energy giving energy efficient routing protocols for WSNs. This paper gives a concise introduction to wireless sensor networks and its routing schemes classified on the root of network structure. The key focus of this study is on LEACH which is a cluster based routing protocol for sensor networks and several modifications made to LEACH resulting in Modified LEACH (MODLEACH) that boasts the performance even more. MODLEACH is further enhanced to improve energy efficiency for routing protocols in WSNs resulting in EMODLEACH. Finally a comparison is carried out among the different variants of LEACH routing protocol taking several metrics like network lifetime, throughput and cluster head replacements under consideration.

Keywords-Wireless sensor networks, Routing protocol, Cluster Head, LEACH, MODLEACH, Threshold, MODLEACHHT, MODLEACHST, and EMODLEACH.

I INTRODUCTION

Wireless sensor networks (WSN) are built up of a huge amount of tiny, low-cost sensor nodes that are densely deployed in hostile areas. They are mainly developed for real-time compilation and study of sensed data in belligerent environments [1]. To list just a few grounds, sensor networks are widely used in environment and habitat monitoring, infrastructure security, military applications, industrial sensing, traffic control, fire detection, wildlife monitoring, intelligent communications, smart buildings, distributed robotics and patient monitoring applications etc.

A sensor node is competent of performing gathering, processing and communicating the sensed information to the sink node or to the other nodes in the network. These sensor nodes are scattered in a special sector called a sensor field. The sensor node has communication interfaces and wireless links, to neighbouring spheres. These nodes continuously monitor the physical environmental conditions in their neighbouring domains and gather in depth information and then convey the composed data to the base station.

Base station is a doorway from sensor networks to the external world. It has a very large storage and data processing capabilities.

Fig. 1 shows the general wireless sensor network model where the sensor nodes are represented by the blue color and the gateway is shown in green. Base station transmits the data it gathers from sensor nodes further to the server from where end-users can access the sensory information for analysis and decision making. So, the sensor nodes may be deployed in an open space; on a battlefield, inside industrial machinery; at the bottom of a water body; in a biologically and/or chemically polluted field; in a commercial building; in home appliances; or even inside or on a human body. Any innovation that is in procedure of its improvement, gives an immense pact of difficulties.
Similarly, sensor networks do. Detecting, processing and gathering by small sized sensors with energy limitation is not a straightforward thing. This thus is the significant concern toward researchers and analysts. To advance sensors life time, researchers have to concentrate on such calculations, conventions and physical hardware that can make most extreme out of restricted power source. In any system particularly wireless sensor networks for productive execution, its protocols must be extremely proficient. Various protocols are created that address power issue.

The remaining document is ordered as follows. Section 2 describes diverse routing techniques for sensor networks. Section 3 describes energy aware LEACH routing protocol. Section 4 describes the modifications made to LEACH routing to optimize this protocol. Section 5 will further enhance the MODLEACH to Enhanced MODLEACH routing protocol. Section 6 describes comparison of these protocols and section 7 concludes the study.

II ROUTING TECHNIQUES IN WSN

The design of routing protocols for sensor networks must observe the power and resource limitations of the nodes, the quality of the wireless channel, and the prospect for delay and packet loss.

To mark these propose requirements, numerous routing strategies have been projected for WSNs. All main routing protocols are classified on the foundation of network structure into three main categories as shown in Fig. 2:

One class of routing protocols embrace a flat network architecture in which all nodes are well thought-out peers. In flat routing protocols, all sensor nodes in the network have equivalent capabilities and roles in gathering information [2]. They all have the similar information regarding the state of the network. Sensor Protocols for Information via Negotiation (SPIN) and Directed Diffusion belong to the class of flat network routing protocols.

A subsequent class of routing protocols imposes a network model that achieves energy efficiency, stability, and scalability by using clustering technique.

In this class of protocols, networks divided into fixed or variable sized clusters with each cluster having a cluster head which assembles the data coming from non-cluster-head nodes and transmits the assembled data to the sink. Several energy efficient algorithms can be used for deciding the cluster head for each round. The cluster head is liable for synchronizing activities and communicating within the clusters and forwarding the sensed information between clusters and the base station. Clustering has potential to lessen energy utilization and lengthen the life span of the network which is the pivotal requirement of sensor nodes in WSNs. For example: LEACH routing protocol.

A next class of routing protocols uses location information to address a sensor node. In Location-based routing protocol route discovery, route maintenance, data forwarding all the tasks stands on the location it means that instead of flooding the complete network with the sensed data, the data is only send to specific areas which are relevant to the query issued by the source node in the network. For example: Geographic and Energy Aware Routing (GEAR).

III LEACH ROUTING PROTOCOL

LEACH stands for Low Energy Adaptive Clustering Hierarchy. It is the key cluster based hierarchical routing protocol worn out for wireless networks. This protocol uses a clustering technique to pass on data in command to procure advantage on minimization of energy consumption [3].

In clustering complete network is broken up into a number of groups known as cluster and each cluster is governed by a cluster head (CH).

Usually, initial assignment of cluster head is done randomly on the bases of energy levels of the nodes and then for every next round the task of cluster head is spins so that each node will operate as a cluster head at least once in its lifetime.

The other non-cluster head low energy nodes senses the information from adjoining neighbours and transmit it to the cluster head. Cluster head will further aggregate the incoming data and pass on it to base station or the sink.

This technique minimizes the energy utilization as transmission will merely be made by cluster head rather than all the devices sending sensed data individually. As this protocol dissipates the energy in low level it is widely used in WSNs.

The algorithm works in two phases i.e. setup phase and the steady state phase. These phases are described below:

![Routing Protocols in WSN](image-url)
A. Setup Phase

In this phase Cluster and the Cluster head are created. At first the cluster head is elected at random among the nodes whose energy enervation is not as much as of all the other nodes in the network. During this phase all the nodes select an arbitrary number between 0 and 1. Sensor node, whose number is smaller than the pre-defined threshold $T(n)$, is going to become a cluster head. Threshold value is obtained by equation (1) specified beneath:

$$T(n) = \begin{cases} \frac{p}{1 - P(r \mod p)} & \text{if } n \in G \\ 0 & \text{Otherwise} \end{cases}$$

(1)

Where $T(n)$ is pre-defined threshold value, $P$ is probability of a node $n$ being selected as cluster head, $r$ represent the present round number, and $G$ is the set of nodes that are not selected as cluster head in last $1/p$ rounds [4]. In this manner every node has an identical probability to be selected as a cluster head.

B. Steady State Phase

In this phase the selected cluster head from setup phase will advertise a message to all the nodes in the network and provide section of time for a reply from sensor nodes. Now the nodes assemble data from surrounding and pass on it to cluster head in a given time period and remaining time they stay in a sleeping mode. This results in improved network lifetime and reduced energy consumption. The data aggregated by cluster head is processed, compressed and sent to the base station which further transmits the data to the intended end user.

Leach also makes use of CDMA (Code Division Multiple Access). By using CDMA each cluster will have a dissimilar set of CDMA a code which further helps to reduce collision among clusters, reduce delay and is efficient in sending real time data [5].

In Fig. 3 the cluster nodes are represented by blue colour and the cluster head is shown in green. It represents structure of the cluster of nodes in a wireless network. Cluster member nodes pass on the data to the correspondent cluster head furthermore the cluster head onwards the data to the base station successive to performing data fusion [6]. Cluster head allots time slots to the cluster member nodes so that cluster members can pass on the data to the bases station in the assigned scheme.

C. Unique Features of Leach Protocol

Some unique characteristics of LEACH protocol [7] are:

1) The synchronization and organization in the clusters is confined in the set up stage.
2) The part of the cluster head is pivoted and randomized to distribute the energy prerequisites among the nodes of the system.
3) To lessen the aggregate sum of information transmission, local compression techniques are utilized in the CH.
4) LEACH is appropriate for homogeneous systems.

D. Limitations of Leach Protocol

1) Initially the selection of cluster head is done arbitrarily and does not consider the utilization of the energy. The likelihood of selecting a node as a cluster head is equivalent to every single node.
2) LEACH clustering does not cover the entire network zone.
3) Dispersion of the cluster head is not uniform. A portion of the clusters may have cluster head at the edge of the cluster.
4) In LEACH for each round, new cluster head is selected and therefore new cluster formation is necessary which leads to redundant use of limited resources and pointless routing overhead.
5) LEACH doesn’t take account of residual energy of a node.
6) The nodes in LEACH use equal amplification energy to pass on data for some kind of transmission in spite of the distance between transmitter and receiver.

To address the above mentioned problems some amendments are made to the LEACH routing protocol and the resulting protocol is termed as modified LEACH (MODLEACH).

Now we will take a glance on the enhancements to LEACH algorithms taken into concern for this study.

IV MODLEACH ROUTING PROTOCOL

There are several variants of the LEACH routing protocol. They are developed by applying several enhancements and modifications to the existing LEACH protocol. The criteria for such enhancements in LEACH can be the modification of cluster head election algorithm, use of energy aware routing algorithm or by optimizing the cluster head election. So, MODLEACH is a modified cluster head selection routing algorithm developed by extending the fundamental LEACH protocol for wireless sensor network to increase network lifetime and throughput [8].
The motivation behind modifying LEACH is that in LEACH protocol for each round new cluster head is selected, as a result a new cluster formation is necessary which leads to redundant routing overhead and too much use of limited energy resources. As a result, there is a need to edge change of cluster head at each round by taking into report the left over energy of active cluster head. Hence, in command to save energy in energy constrained environment like WSNs we need to have an efficient cluster head replacement algorithm.

Secondly in LEACH the sensor nodes use the equivalent amplification energy to pass on the data irrespective of the gap between the transmitter and the receiver. So, in command to diminish the energy utilization there should be some mechanism that specifies required amplification energy for communicating with the cluster head or the base station [9].

To solve these problems two techniques known as efficient cluster head replacement and dual transmitting power levels were added in the MODLEACH algorithm. The LEACH protocol changes the cluster head at each round, and once a node is selected as a cluster head it will not get one more chance for subsequently 1/p rounds. For each round the cluster heads are replaced and the cluster formation process is undertaken.

In MODLEACH the cluster head replacement was done by checking the energy of existing cluster head with the threshold value. If the left over energy of the existing cluster head is larger than the threshold, then the cluster head remains unchanged for the next round as well. If cluster head has less energy than the required threshold then there is a requirement for cluster head replacement and it will be done according to the LEACH algorithm. This scheme saved the energy of fresh cluster head selection and cluster formation process.

Besides minimizing the energy utilization during cluster formation we also require to initiate different levels of power to amplify the signal based on the mode of transmission. Basically in a cluster based network there can be three modes of transmission:

1) Intra cluster transmission.
2) Inter cluster transmission.
3) Cluster head to base station transmission.

Intra cluster transmission refers to the communications within a cluster itself i.e. cluster member nodes sense the data and report the sensed data to the sink. The transmission and reception of the sensed data between two cluster heads is known as inter cluster transmission and when the cluster head transmits its data straight to the sink then this falls under the class of cluster head to base station transmission. In LEACH same amplification energy levels are used for all these type of transmissions. MODLEACH uses multi power levels which reduces the energy consumption and reduces packet drop ratio, collisions to a greater extent.

MODLEACH can further be improved by using the concept of hard and soft threshold as introduced by TEEN protocol.

V ENHANCED MODLEACH ROUTING PROTOCOL

Now we point out EMODLEACH protocol which is an improved version of the modified LEACH protocol. The motivation behind proposing this protocol is that number of packets transmitted to cluster head in EMODLEACH is comparatively less than LEACH and MODLEACH which further needs some improvement.

Enhanced Modified LEACH (EMODLEACH) is a reactive protocol which is implemented for homogeneous networks. In this protocol we have implemented the concept of efficient cluster head replacement and Dual transmitting power level technique of MODLEACH all along with the concept of efficient intra cluster transmission scheme of TEEN in LEACH. The concept of effective cluster head replacement technique and dual transmission power levels are already discussed in MODLEACH now this section will present efficient intra cluster transmission scheme.

A. Efficient Intra Cluster Transmission Scheme

1) The value sensed by every sensor node is stored in an internal variable known as sensed value (SV).
2) On every cluster replacement time, the cluster head broadcasts two threshold values to its members:
   a) Hard Threshold (HT): It is the absolute value of the attribute ahead of which, the node sensing this value should switch on its transmitter and account to its cluster head.
   b) Soft Threshold (ST): This is a little change in the value of the sensed attribute which trigger the node to transmit.

Using these two threshold values reduces the energy dissipation in redundant value sensing.
3) The sensor nodes continuously monitor the environment around them. Whenever the attribute value touches its hard threshold value, the node sends the sensed data. The nodes will then transmit data in the existing cluster period, only when both the below mentioned state of affairs are true:
   a) The current value of sensed attribute is greater than the hard threshold.
   b) The current value of the sensed attribute differs from the former sensed value by a number equivalent to or greater than the soft threshold.

This protocol tends to lengthen network lifetime, throughput, energy consumption and number of packets transmitted to sink and also reduces the energy loss per node resulting in longevity of the sensor nodes which increases due to optimal transmission. However, this approach cannot be applied effectively where the user wants the sensed data on a periodic manner.

On the basis of above discussion we conclude that EMODLEACH outperforms LEACH and MODLEACH protocol on the grounds of homogeneous networks. Hence this protocol will be effective for applications those are time critical by nature.
VI COMPARATIVE STUDY
Comparison among the various variants of LEACH routing protocol i.e. LEACH, MODLEACH, MODLEACHHT AND MODLEACHST are done by taking into account the following three performance metrics:

1) Network Lifetime
Considering network lifetime of LEACH, MODLEACH, MODLEACHHT and MODLEACHST, LEACH has least performance amongst all these protocols. MODLEACH has greater stable period due to the two techniques used by this protocol i.e. efficient cluster head replacement and the use of dual transmission levels for transmission.

MODLEACH is further improved by using the concept of soft and hard thresholds. MODLEACHST gives the maximum performance amongst all the variants. MODLEACHHT performs the second best in conditions of network lifetime [10].

2) Throughput
Another metric which is used to test the efficiency of a routing protocol is its throughput. Sometimes throughput is based on the network lifetime but this is not the case always. MODLEACHST achieves the maximum throughput among all. Comparing MODLEACH and LEACH, MODLEACH gives better throughput due to efficient cluster head replacement strategy and use of different amplification energies.

Another factor for this gain in throughput in MODLEACHST and MODLEACHHT is the fact that these protocols being reactive in nature have greater throughput in comparison to the proactive routing protocols such as LEACH and MODLEACH.

3) Cluster head formation
As all these protocols use the same algorithm for cluster head election so there is no major difference in the cluster head formation however, in MODLEACH initially the measure of cluster head stay steady and then its behaviour becomes like that of LEACH routing protocol.

So the above assessment shows that MODLEACHST performs the best amongst all in terms of network lifetime, throughput and cluster head formation performance metrics.

VII CONCLUSION
This paper gives a brief introduction on wireless sensor networks (WSN) and its routing techniques classified on the grounds of network structure. Then one of the most extensively used energy efficient cluster based routing protocol i.e. LEACH is discussed.

Then this paper introduces a new alternative of LEACH protocol i.e. modified LEACH (MODLEACH). This is done by introducing two new techniques namely efficient cluster head replacement and dual transmission power levels to the existing model. In MODLEACH, a cluster head will simply be replaced when its energy falls under certain threshold value and not in each round as in case of LEACH protocol. Hence, cluster head replacement method involves left over energy of cluster head at the beginning of each round resulting in reduced routing load of protocol. MODLEACH is further improved by using the concept of hard and soft threshold resulting in MODLEACHHT and MODLEACHST respectively. Further, some more modifications were made to MODLEACH by commencing efficient intra cluster transmission scheme resulting in an improved protocol named as enhanced modified LEACH (EMODLEACH). Finally a comparison is carried out among LEACH, MODLEACH, MODLEACHHT and MODLEACHST by taking network lifetime, throughput and cluster head formation under consideration. The comparison shows that MODLEACHST outperforms all the variants of LEACH compared in this paper.

REFERENCES