ABSTRACT

One of the important issues in wireless sensor networks is the inherent limited battery power of the sensor nodes. The battery power in the sensor nodes plays an important role in increasing the lifespan of the nodes. Hierarchical routing protocols are the best known protocols to minimize the energy consumption. Leach is one of the fundamental protocols in the clustering technique hierarchical routing protocols that can be used for minimizing the energy consumed in collecting and disseminating. We have surveyed the state-of-art of different hierarchical routing protocols that have been developed from the LEACH. This paper highlights some of the drawbacks and issues in LEACH and discuss how these issues are overcome by the descendants of LEACH. This paper also compare the features and performance issues of all hierarchical routing protocols.

Keywords: Hierarchical routing, LEACH, Disseminating ,clustering.

INTRODUCTION

Routing in wireless sensor networks differs from conventional routing in fixed network in various ways: There is no infrastructure, wireless links are unreliable, sensor nodes may fail, and routing protocols have to meet strict energy saving requirements. Routing protocols for wireless sensor Networks have to ensure reliable multi-hop communication under these conditions. In general, routing in WSNs can be divided into flat-based routing, hierarchical-based routing, location based routing and network flow and QOS aware routing protocol depending upon the network structure. Clustering involves the grouping of nodes into clusters with a cluster head which has the Responsibility of routing from the cluster to other cluster heads or base stations.

II. HIERARCHICAL ROUTING PROTOCOLS

In hierarchical routing protocols, clusters are created and a head node is assigned to each cluster. In this context, the LEACH[7] protocol is discussed. Description and the comparison of the descendants of LEACH protocol is discussed in the next subsections.

2.1 LEACH (Low Energy Adaptive Clustering Hierarchy)

Leach was proposed for the reduction of the power consumption. Leach involves the data aggregation (fusion) process which combines the original data into a smaller sized data[3].

Figure 1: Leach clustering hierarchical model

Leach is completely distributed which requires the global knowledge about the network. In order to achieve the design goal the key tasks performed by Leach are as follows[1]:

- Randomized rotation of the cluster heads and the corresponding clusters
- Global communication reduction by the local compression
Localized co-ordination and control for cluster setup and operation
Low energy media access control
Application specific data processing

The Leach operation is classified into rounds each of which has mainly two phases namely:

a) Setup phase
   - for organizing the network into clusters
   - advertisements of the cluster heads
   - transmission schedule creation

b) Steady state phase involves
   - the data aggregation
   - compression
   - transmission to the sink

The main drawbacks in Leach are as follows:

- The time duration of the setup phase is non-deterministic and the collisions will cause the time duration too long and hence the sensing services are interrupted. Due to that Leach may be unstable during the setup phase that depends on the density of sensors.
- Leach is not applicable to networks that are deployed in large region as it uses single hop routing where each node can transmit directly to the cluster head and the sink
- The cluster heads used in the LEACH will consume a large amount of energy if they are located farther away from the sink
- Leach does not guarantee good cluster head distribution and it involves the assumption of uniform energy consumption for the cluster heads.
- Leach uses dynamic clustering which results in extra overhead such as the head changes advertisement that reduces the energy consumption gain

2.2 LEACH-C (Centralized Low Energy Adaptive Clustering Hierarchy)

It involves a centralized clustering algorithm. The steady state will remain the same whereas the setup phase of the Leach-C contains each node sending information about the current location and also the energy level to the base station. The base station thus by utilizing the global information of the network produce better clusters that requires the less energy for data transmission[3]. It needs GPS or the other location tracking method. The base station has to make sure that only nodes with enough energy are allowed to participate in the selection of the cluster head. The base station then broadcasts the information to all nodes in the network. Leach-C has a deterministic threshold algorithm which takes into account the amount of energy in the node and/or whether or not the node was recently a cluster head. The number of cluster head nodes and its placement cannot be guaranteed. The central control algorithm can be used to form the clusters which may produce better clusters through the distribution of the cluster head nodes throughout the network.

2.3 MULTI-HOP LEACH

The distance between the clusterhead and the base station is increased enormously when the network diameter is increased beyond a certain level in which the scenario is not suitable for Leach routing protocol[9].

The energy efficiency of the protocol can be increased by using multi-hop communication within the cluster. Multi-hop-Leach is a complete distributed clustering based routing protocol. The multi-hop approach is utilized inside the cluster and outside the cluster

2.4 LEACH-F (Fixed no. of clusters Low Energy Adaptive Clustering Hierarchy)
In Leach-F, once the clusters are formed, they are fixed and there is no setup overhead at the beginning of each round. It uses the same centralized cluster formation algorithm as Leach-C for deciding the clusters. In Leach-F, new nodes cannot be added to the system and do not adjust their behaviour based on nodes dying. Furthermore, the node mobility cannot be handled by the Leach-F. Only the cluster head position is rotated among the nodes within the cluster. Leach-F may or may not be provided energy saving. A stable cluster and rotating cluster head concept is used by Leach-F in which cluster once formed is maintained stable throughout the network lifetime in order to avoid re-clustering [11].

2.5. LEACH-L (Energy Balanced Low Energy Adaptive Clustering Hierarchy)

Leach-L is an advanced multihop routing protocol and considers only the distance. It is suitable for large scope wireless sensor network and the optimum hop counts are deduced. The cluster heads can communicate directly to the base station when they are located close to it. When they are located far away from the base station, they can communicate by the method of multi-hop way and the shortest transmission distance is limited. In this, the sensors are allowed to use different frequencies and gaps to communicate with base station. The clusters are re-established in each round consisting of the setup and steady state phase. And in each round new cluster heads are elected and the load is distributed and balanced among the nodes in the network. Since Leach-L makes power equally distribute among all sensors, in the pre-period, the network’s activity nodes and cover areas of Leach-L are greatly larger than that of Leach-M.

2.6. LEACH-E (Energy Low Energy Adaptive Clustering Hierarchy)

LEACH-E is the enhancement of LEACH. It involves a cluster head selection algorithm which have non-uniform starting energy level among the sensors having global information about the other sensors. In order to minimize the total energy consumption, the required number of cluster heads has to scale as the square root of the total number of sensor nodes and this can be determined by Leach-E. By making the residual energy of the sensor node as the main factor, it decides whether the sensor nodes turn into the cluster head or not in the next-round [11].

2.7. LEACH-B (Balanced Low Energy Adaptive Clustering Hierarchy)

Leach-B uses the decentralized algorithms of cluster formation where each sensor node only knows about its own position and the final receiver and does not know about the position of all the sensor nodes. Leach-B involves the following techniques: Cluster head selection algorithm, Cluster formation and data transmission with multiple access. By evaluating the energy dissipated in the path between final receiver and itself, each of the sensor node chooses its cluster head. Efficiency of Leach-B is better than Leach [11].

2.8. LEACH-A (Advanced Low Energy Adaptive Clustering Hierarchy)

In Leach protocol the head node consumes more energy than others. Hence the energy saving and reliable data transfer is improved LEACH-A. In this, the data is processed using mobile agent technique based on Leach. Advanced Leach, a heterogeneous energy protocol is proposed for the purpose of decreasing the node’s failure probability and for prolonging the time interval before the death of the first node which can be referred to as stability period [10].

By using a synchronized clock, each sensor knows the starting of each round. Let n be the total number of nodes and m be the fraction of n that are equipped with a time more energy than others. These nodes are called CAG nodes, the nodes selected as cluster heads or gateways and the rest...
(1-m) x n as the normal nodes. The CAG nodes will become the cluster head for the data aggregation and transmit to the sink. The Leach-A protocol offers the following advantages:

- The merging of the data is done to reduce the amount of information that are transmitted to the base station.
- More energy can be saved by using TDMA/CDMA techniques that allows hierarchy and makes clustering on several levels.
- The CAG nodes continue to send data to the sink when all normal nodes death.

Functions performed by the gateways:

- Reduction in the energy consumption.
- Extension of the lifetime of the cluster head.
- Decrease in probability of failure nodes.
- Prolonging the time interval before the death of the first node.
- Increasing the lifetime in heterogeneous WSNs.
- Self configuration of clusters is independent of the base station.

2.9 LEACH-M (Mobile - Low Energy Adaptive Clustering Hierarchy)

Mobility support is an important issue in Leach routing protocol. Leach-M is proposed to mitigate this issue. Leach-M involves the mobility of non-cluster head nodes and cluster head during the setup and steady state phase. The nodes in Leach-M are assumed to be homogeneous and have their location information through GPS. The cluster head can be selected based on the minimum mobility and lowest attenuation mode. The selected cluster heads then broadcasts their status to all nodes in transmission range.

2.10.1 LEACH-S (SOLAR AWARE CENTRALIZED LEACH)

In Leach-S, the base station selects the cluster head with the help of improved central control algorithm. Base station select solar powered nodes having maximum residual energy. In Leach-S, the solar status is transmitted by the nodes to the base station along with the energy and the nodes with higher energy are selected as the cluster head. When the number of solar-aware nodes is increased, the performance of sensor network is also increased. The sunduration increases the lifetime of the sensor network. The cluster head handover takes place if the sunduration is smaller [8].

2.10.2 (SOLAR AWARE DISTRIBUTED LEACH)

In this LEACH-S, the solar driven nodes are given choosing the preference of cluster head probability of solar driven nodes which is higher than the battery driven nodes [8].

III. COMPARISON OF LEACH AND IMPROVED VERSION OF THE LEACH ROUTING PROTOCOL

A number of protocols that are the enhanced version of the conventional LEACH routing protocol have been compared and is shown in the TABLE 1. All these protocols showed better performance than the conventional LEACH routing protocol.

IV. SIMULATION SETTINGS

We use a network size of 100 x 100 m with BS location x, y 50, 170 by taking 150 nodes, the processing delay is 50µs, radio speed 1Mbps and a data size of 500 bytes for the simulation.

V. SIMULATION RESULTS

The network lifetime of the protocols has been compared and shown in Figure 4 and 5. Solar-aware has better network lifetime than others as they have the ability to re-energise themselves.
Among that LEACH-S(distributed) is better than centralized as it uses the distributed localized clustering formation.

![Graph](image)

**Figure 4 : Dead nodes**

<table>
<thead>
<tr>
<th>Clustering Routing protocol</th>
<th>Classification</th>
<th>mobility</th>
<th>Scalability</th>
<th>Self organisation</th>
<th>Randomized Rotation</th>
<th>Distributed</th>
<th>Centralised</th>
<th>Hop count</th>
<th>Energy efficiency</th>
<th>homo geneous</th>
<th>Use of location information</th>
<th>Data aggregation</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEACH</td>
<td>Hierarchical</td>
<td>Fixed BS</td>
<td>Limited</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Single hop</td>
<td>High</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>LEACH-S</td>
<td>Hierarchical</td>
<td>Fixed BS</td>
<td>Good</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Single hop</td>
<td>Very high</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Multi-hop LEACH</td>
<td>Hierarchical</td>
<td>Fixed BS</td>
<td>Very good</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Multi hop</td>
<td>Very high</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>LEACH-M</td>
<td>Hierarchical</td>
<td>Mobile BS and nodes</td>
<td>Very good</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Single hop</td>
<td>Very high</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>LEACH-A</td>
<td>Hierarchical</td>
<td>Fixed BS</td>
<td>good</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Single hop</td>
<td>Very high</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>LEACH-C</td>
<td>Hierarchical</td>
<td>Fixed BS</td>
<td>good</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Single hop</td>
<td>Very high</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>LEACH-B</td>
<td>Hierarchical</td>
<td>Fixed BS</td>
<td>good</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Single hop</td>
<td>Very high</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>LEACH-F</td>
<td>Hierarchical</td>
<td>Fixed BS</td>
<td>limited</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Single hop</td>
<td>Very high</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>LEACH-L</td>
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<td>Fixed BS</td>
<td>Very good</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Multi hop</td>
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<tr>
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<td>Fixed BS</td>
<td>Very good</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Single hop</td>
<td>Very high</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**TABLE1: PERFORMANCE COMPARISON OF DIFFERENT LEACH PROTOCOLS**
From the above analysis, it has been shown that all the descendants of the LEACH protocol are proved to be better than the LEACH and they overcome the drawbacks and issues related to LEACH which is the hierarchical clustering routing protocol.

V. CONCLUSION

In this survey, the drawbacks and issues addressed by the LEACH protocol and how these issues are overcome by the descendants of LEACH are discussed. Each of the routing protocol has its own advantages compared to the fundamental LEACH routing protocol. This paper also compares the features and performance of each hierarchical clustering routing protocol. Finally, it can be concluded from the given survey that for an energy efficient and prolonged wireless sensor networks, still it is needed to find more efficient, scalable and robust clustering scheme.

REFERENCES

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