A Study of LEACH and PSO algorithm in Wireless Sensor Networks
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Abstract— Wireless Sensor Network (WSN) consists of low cost and small sized motes known as sensor nodes. The use of sensor nodes depends upon the need of an application. Various challenges of WSN affect the performance of the network. Limited energy and power are the main issues in WSNs due to this different routing protocol are designed to improve the energy efficiency of the whole network. Low Energy Adaptive Clustering Hierarchy (LEACH) is one of the best energy efficient protocol falls under the category of hierarchical routing protocol. This works on the concept of cluster formation. Different algorithms are used for cluster setup. This paper explains the working of LEACH in detail with some advantages and disadvantages. Also highlights some improvement over LEACH and analyze the Particle Swarm Optimization (PSO) algorithm for cluster setup.

Keywords: Energy Efficiency, LEACH, PSO, WSN.

I. INTRODUCTION
The Wireless Sensor Network (WSN) is the network consisting of a large number of sensing nodes. The nodes are of small size and are densely deployed in an ad-hoc manner. Sensor node consists of four basic components i.e. sensing unit, processing unit, transmission unit and power unit. Sensor node has the capability of sensing the different types of conditions, perform some processing on sensed condition and communicating with other nodes in the network or with sink. In WSNs sensor nodes are battery-powered and needs to operate for a long period. In some applications recharging or replacing batteries is difficult or nearly impossible once the nodes have been deployed [1].

There are some other issues in the design of sensor network which are as follows:

- Dense deployment of sensor nodes in an ad-hoc manner.
- Limited resources such as memory, power and energy.
- Scalable to different network sizes.
- Transmission media should be easily available.
- Fault Tolerance to maintain network functionality in case of failure of node(s).
- Secure the data from unauthorized access.
- Coverage of the whole network.
- Data Aggregation to reduce the number of transmissions.
- Quality of Service (QoS).

But out of these the most challenging issue faced by the sensor network is a limited energy. A communication takes place between the nodes in network and the sink or base station. Energy is used in communication at the time of sensing, transmitting, processing and receiving the information from other nodes. Therefore, less energy of node may affect the performance of the whole network. Sometime energy depletion of sensor nodes fails the mission of application.

Routing protocols are used for communication and route the data to the sink. Various energy efficient routing protocols have been proposed and are classified into different categories depending upon the nature of their work. Energy efficient protocols lower the use of energy and hence increase the lifetime of the whole network. These are categorized into different categories as: Data Centric protocols, Hierarchical protocols and Location Based protocols.

One of the best energy efficient protocols is LEACH. This comes under the category of hierarchical routing protocols. The rest of the paper is organized as follows: Section II gives a description about energy efficient protocol, LEACH with its advantages and disadvantages. Section III gives the working of LEACH. Improvements over LEACH are highlighted in section IV. In section V cluster setup algorithm known as PSO is described. Finally, conclusion is presented in section VI.

II. LOW ENERGY ADAPTIVE CLUSTERING HIERARCHY (LEACH)
Low-Energy Adaptive Clustering Hierarchy (LEACH) is a hierarchical clustering routing algorithm used in wireless sensor networks and first proposed by Wendi B. Heinzelman of MIT in 2002. This works on the concept of clustering. The whole network is divided into clusters and there is one cluster head (CH) in each cluster to communicate directly with the base station. Cluster head is selected randomly from the available nodes. This is the most popular energy efficient routing protocol. For a LEACH protocol following are the two basic assumptions: [2]

- The base station or sink is situated at distance from the sensors and is fixed.
- All nodes in the network are homogeneous and are energy-constrained.

It reduces the energy consumption which leads to increase in the network lifetime. In LEACH, the role of cluster head is to collect the data from the other nodes belong to that particular cluster. It acts as an intermediate in the communication between cluster nodes and the base station. CH performs data aggregation and data compression on the collected data to reduce the amount of data and transmit the aggregated data packet to the base station (BS). The energy of CH is used more as compared to the cluster nodes. Hence, to balance the energy load evenly, cluster head changes randomly in the network after some defined interval of time. Figure 1 shows the architecture of LEACH in which CH collects the data from nodes and transmits it to the base station.

Some basic properties of LEACH are as:

- Clustering based protocol in which cluster head keeps on rotating to save energy of one node.
- Application specific data processing protocol.
- To enable scalability, localized coordination is performed.
- Cluster head use data aggregation and compression techniques to reduce amount of data.
- Increase lifetime of network by reducing energy consumption.
- Maximize the network coverage.

A. Advantages of LEACH protocols
- Due to data aggregation, amount of traffic generated is limited.
- It reduces the energy consumption. Hence, an energy efficient protocol.
- Saves energy by using single hop routing from nodes to cluster head.
- It does not require the information of location of the sensor nodes in the network to create the clusters.
- It gives the dynamic clustering approach.
- The selection of Path is simple process as sensor nodes do not need to store large amount of routing information.

B. Disadvantages of LEACH protocols
- Failure of cluster head affects the working of whole network.
- The process of change of cluster head creates some overheads.
- Requirement of high range of transmission power as CHs directly communicate with the sink.
- Randomly selects the cluster head without considering energy consumption.
- It is suitable for small size network as it does not work well with the applications that require large area coverage.
- CH will consume more energy if it is located farther away from the sink.

III. WORKING OF LEACH

The LEACH protocol works in rounds and each round have two major phases known as Setup phase and Steady phase. As shown in Figure 2, setup phase works before the creation of schedule and after the schedule is created, the steady phase. After the steady phase next round starts.

A. Setup phase
This phase is further divided into three parts i.e. Advertisement Phase, Cluster Setup Phase and Schedule Creation. In the beginning of each round, a cluster head is elected randomly. To increase the network lifetime cluster head keeps on rotating among the nodes of the cluster [6]. Cluster head is selected using the formula (1). Initially a random number between 0 and 1 is generated by the node. The node is elected as a cluster head for one round if the number generated is less than a threshold $T(n)$. The threshold value is calculated as:

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

Where $P$ is the suggested percentage of node to be selected as cluster heads, $r$ is the round for which cluster head is selected, $n$ is the number of nodes and $G$ is the set of nodes that have not been accepted as cluster-heads in the last $\lfloor 1 / P \rfloor$ rounds.

An advertisement message is broadcast by the elected cluster head to the remaining nodes. The non-cluster head nodes decide on the basis of signal strength that to which cluster head they join. In this way clusters are formed in this phase. The basic purpose of this phase is to organize the whole network into different intra-clusters. After the creation of clusters, cluster head creates a schedule for all the nodes and then steady phase begins.

B. Steady phase
In this phase, data is transmitted to the base station. Only during respective schedules non-cluster head nodes send messages to their cluster heads and remaining nodes will sleep. After receiving the data from all nodes in its cluster, it performs data aggregation and transmits data to the base station. Data compression and data aggregation is done in this phase before transmitting data to the base station or sink. Steady phase is longer as compared to set up phase to minimize the overhead.

IV. RECENT IMPROVEMENTS ON LEACH

Recently there has been increased interest in focusing on energy-efficient clustering algorithms in the field of both ad hoc and sensor networks. The main aim of clustering protocols in ad hoc networks is to generate the minimum number of clusters while maintaining network connectivity. Some of the recent researches done on the LEACH protocol are mentioned as:

Limited energy directly affects the lifetime of the sensor network. Lifetime can be improved by adding some spare nodes. LEACH-SM is proposed by [3] which modifies the LEACH protocol by managing the spare nodes. A new phase is added to LEACH known as spare selection phase before the steady phase. Spare selection is performed by the technique known as Decentralized Energy-efficient Spare Selection Technique (DESST). In LEACH the selection of cluster head is random based on probability model. This makes the clusters of unequal sizes due to which energy consumption is not balanced. In [4], a new algorithm is proposed to maintain uniform size clusters known as Equalized Cluster LEACH.
(C-LEACH). In this, a cluster has an equal number of cluster nodes. This extends the set-up phase. A new concept is introduced in C-LEACH in which orphaned nodes of cluster are adopted by the neighboring clusters.

In [5], a cluster-cell based routing protocol known as cell-LEACH is proposed. To reduce energy consumption clusters are further divided into 7 parts known as cells. Every cell contains sensor nodes and from these nodes one is selected as a cell head. Communication takes place between cell heads and cluster heads. Cell head transmits data to the cluster head after performing data aggregation. Cell-LEACH increases the lifetime of the network.

On the basis of LEACH protocol LEACH-R is designed in [6]. This protocol works on the cluster head selection. A node having higher remaining energy has more chance to become a cluster head. Also selects a relaying node R from the cluster head on the basis of remaining energy and distance from the sink node. The selected relay node aggregates the received data and sends it to the base station. This saves the energy by 20% in comparison to LEACH and extends the lifetime of network.

A new energy efficient protocol called Energy Efficient Extended LEACH (EEE LEACH) protocol is proposed in [7]. Energy efficiency is increased by minimizing the distance of communication between the nodes. This works on the concept that Communication distance is inversely proportional to the number of clusters. Due to this a multilevel clustering is introduced in which there is a Master cluster heads to receive data from the cluster heads.

In [8], authors proposed MH-LEACH which shows some improvements over the original LEACH protocol. This algorithm saves energy by allowing sensor nodes to establish a multi-hop communication. Cluster head sends a data packet to other cluster head which is nearest. Results show that improvement in average power consumption is approximately 9% than original LEACH and also have a more coverage time. This also increases the lifetime of network.

To balance the energy and increase the lifetime of the whole network a new algorithm is proposed named as LEACH-TLCH (LEACH Protocol with Two Levels Cluster Head) [9]. In original LEACH energy distribution is not balanced because of random selection of cluster heads. In LEACH-TLCH, secondary cluster is received the data from member nodes and send it to the cluster head after aggregation. Cluster head is used only to transmit data to the base station.

In [10], authors proposed a new algorithm V-LEACH to improve the energy efficiency. In V-LEACH a cluster contains cluster head, vice cluster head and member nodes. The reason of introducing the concept of vice cluster head is that if in case cluster head dies then to send the data of member nodes it will become the cluster head. In this way no data is lost after failing of cluster head. The election of cluster head and vice cluster head is based on the Distance and Remaining Energy.

V. PARTICLE SWARM OPTIMIZATION (PSO)
An efficient method to optimize a problem by improving a candidate solution with respect to a given quality measures is known as Particle Swarm Optimization (PSO). PSO is a population based algorithm. [12] In the classical PSO algorithm, each particle:
- has a position and a velocity
- knows its own position and the value associated with it
- knows the best position it has ever achieved, and the value associated with it
- knows its neighbors, their best positions and their values

PSO is a simple, effective and efficient optimization algorithm [13]. There are particles referred to as population (the swarm) of candidate solution moves around the search space over the particle’s position and velocity. Each particle's movement is influenced by its local best known position and is also guided toward the best known positions in the search-space, which are updated as better positions are found by other particles. This is expected to move the swarm toward the best solutions. The move of a particle is a composite of three possible choices:
- To follow its own way
- To go back to its best previous position
- To go towards its best neighbor’s previous or present position

The aim of PSO is to find the best position of particle to evaluate fitness function. Initially random parameters are assigned. As particles start moving in search space, particle uses two factors: previous best position and global best position for reaching towards better solution to result in better fitness. Following equation (1) is used to replace the current best fitness with the previous best fitness and Table 1 shows the list of variables used in an equation:

$$v_t = w \times v_{t-1} + c_1 \Phi_1 p_{id} - x_{id} t - 1 + c_2 \Phi_2 (p_{gd} - x_{gd} t - 1)$$

<table>
<thead>
<tr>
<th>v</th>
<th>The particle velocity</th>
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<tbody>
<tr>
<td>x</td>
<td>The particle position</td>
</tr>
<tr>
<td>t</td>
<td>Time</td>
</tr>
<tr>
<td>C1,C2</td>
<td>Learning factor</td>
</tr>
<tr>
<td>Φ1,Φ2</td>
<td>Random numbers between 0 and 1</td>
</tr>
<tr>
<td>pid</td>
<td>Particle's best position</td>
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<tr>
<td>pgd</td>
<td>Global best position</td>
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<tr>
<td>w</td>
<td>Inertia weight</td>
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Table 1: List of variables used in PSO equations

Particle Swarm Optimization Algorithm is also applied for the purpose of Cluster Setup. PSO algorithm used for cluster setup is explained in detail in [14]. This algorithm works in rounds. Initially clusters are formed and cluster head is elected on the basis of energy in setup phase. After this PSO algorithm is used to select the best n cluster heads to minimize the cost function.

VI. CONCLUSION
Energy efficiency is the basic need in wireless sensor networks. LEACH is the energy efficient routing protocol. This paper analyzed the detailed working of original LEACH protocol. Although a lot of versions of LEACH are proposed by the authors but still under research to make improvements to find more efficient scheme. PSO is an
efficient method for cluster setup and also used with LEACH protocol to make it more enhance.

REFERENCES


