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A Review on Different Types of LEACH Protocol for Wireless Sensor Networks

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ABSTRACT

In wireless sensor networks (WSNs), due to the limitation of nodes' energy, energy efficiency is an important point should be considered at the time of designing of protocols. Low Energy Adaptive Clustering Hierarchy (LEACH) is one of the elementary protocols in this class. As a quintessential representation of hierarchical routing protocols, LEACH Protocol plays an critical role. In addition to exaggerate the lifespan of cluster nodes, it is preferable to dissipated energy throughout the wireless sensor network. Hierarchical routing protocols are best known in regard to energy capability. The asset of LEACH protocol is that each node has the equal probability to be a cluster head, which makes the energy distribution of each node be balanced. In LEACH protocol, time is divided into many rounds, in each round, all the nodes contend to be cluster head according to a predefined criterion. In this paper, we study different LEACH protocol architectures and its functions.

Keywords : LEACH, Clustering, Wireless Sensor Networks

I. INTRODUCTION

Wireless sensor network is a network of small and low power sensor nodes having limited memory. These cluster nodes are deployed to monitor environmental conditions such as temperature, noise, vibration, pressure, moment or pollutants. Each network has at least one base station where these sensor nodes send their raw data which they collect by sensing. A base station acts like an alloy between users and the network. Low Energy Adaptive Clustering Hierarchy (LEACH) is the popular hierarchical routing protocols for WSN. The idea is to form clusters of the cluster nodes based on the received signal strength and use cluster heads as routers to the Base station. This will consume less energy since the transmissions will only be done by such cluster heads rather than all cluster nodes. Classical network protocols, such as direct transmission, low transmission energy, multi-hop routing, and clustering all have defects that don't allow them to achieve all the desirable qualities. LEACH includes distributed cluster formation, local processing to reduce global communication, and randomized rotation of the CH. Together, these features allow LEACH to achieve the desired requirements.

The big problem with the LEACH protocol is that it needs the user to specify probability for use with the threshold function. Because the network performance is highly sensitive to this probability, and it is very difficult to find an optimum setting from available knowledge.

In this paper firstly we study LEACH protocol architecture then in the third section we will discuss the operations of LEACH protocol. In the fourth section we will discuss various LEACH protocols.

II. LEACH PROTOCOL

LEACH is an adaptive clustering routing protocol proposed by Wendi B. Heinzelman, et al. The main goals of LEACH are: increasing network lifetime, low network energy consumption, reducing number of communication messages by data aggregation. Leach is called "Energy efficient Adaptive protocol for clustered Wireless sensor networks". This protocol facilitates the nodes with more residual energy have more chances to be selected as cluster head. In order to extend the lifetime of the whole sensor network, energy load must be evenly distributed among all sensor nodes so that the

energy at a single sensor node or a small set of sensor nodes will not be drained out.

Low Energy Adaptive Clustering Hierarchy (LEACH) is the first energy efficient routing protocol for hierarchical clustering. It reduces the energy significantly. The LEACH protocol forms clusters in the sensor networks and randomly selects the Cluster-heads for each cluster. Non cluster-head nodes sense the data and transmit to the cluster-heads. The cluster-heads aggregate the received data and then forward the data to the base station.

Design: LEACH organizes nodes into clusters with one node from each cluster serving as a cluster-head (CH) shown in figure 1. It randomly selects some predetermined number of nodes as cluster heads.

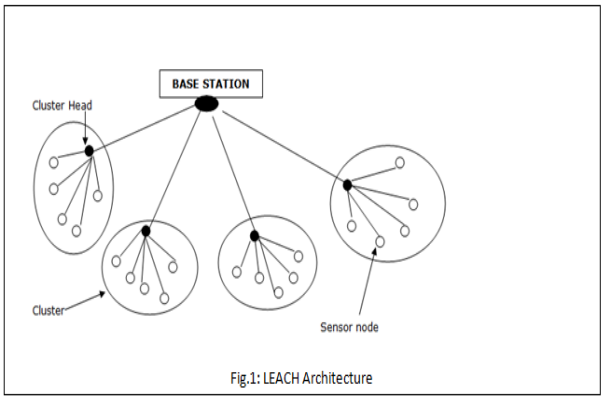

Fig.1: LEACH Architecture

LEACH Protocol is a typical representative of hierarchical routing protocols. It is self adaptive and self-organized. LEACH protocol uses round as unit, each round is made up of cluster set-up stage and steady-state stage, for the purpose of reducing unnecessary energy costs, the steady state stage must be much longer than the set-up stage. The process of it is shown in Figure 1.

III. LEACH OPERATION

The operation of LEACH is divided into several rounds. Each round begins with a set-up phase when the clusters are organized, followed by a steady–state phase.

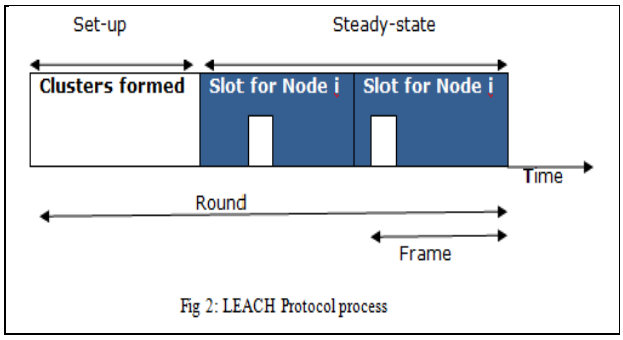

Fig 2: LEACH Protocol process

A. SET-UP PHASE

During this phase, each node decides whether or not to become a cluster head (CH) for the current round. This decision is based on choosing a random number between 0 and 1, if number is less than a threshold T(s), the node become a cluster head for the current round.
The threshold is defined as follows [1]:

$$T(s) = p/1\text{-}p\ (r \bmod (1/p)) \qquad \text{if } s \in G \qquad (1)$$

Where p is the desired percentage of cluster heads (e.g. 0.05), r is = the current round, and G is the set of nodes that have not been cluster heads in the last 1/p rounds.

The cluster head node sets up a TDMA schedule and transmits this schedule to all the nodes in its cluster, completing the setup phase which is then followed by a steady-state operation.

B. STEADY-STATE PHASE

Each cluster-head waits to receive data from all nodes in its cluster and then sends the aggregated or compressed result back to a BS.

IV. LEACH PROTOCOLS

1. LEACH (Low Energy Adaptive Cluster Head):

Several cluster-based routing algorithms are proposed that among them, LEACH algorithm is the most famous algorithm. This algorithm uses a random model to selects CH nodes then, non-CH nodes join to the clusters using one-hop transmissions with Time-Division Multiple Access (TDMA). LEACH algorithm does not consider the remaining energy and geographical position of sensor nodes in the CH selection process. This leads to the early death of sensor nodes and the decrease of WSN lifetime.

2. PEGASIS ALGORITHM:

PEGASIS algorithm forms chains of sensor nodes rather than clusters to transfer information packets to the BS, so that each sensor node sends receives data from its close neighbor.. Under the PEGASIS algorithm, all nodes need to have a general knowledge

of the network to form chains and greedy algorithms are used. This increases PEGASIS algorithm spent cost and makes it difficult to implement it in real applications.

3. HEED:

HEED algorithm extends the basic idea of LEACH algorithm by incorporating residual energy and sensor node proximity to its neighbors in the CH node selection; but it does not pay any attention to the distribution or density of sensor nodes. In HEED algorithm, unlike LEACH, CH nodes are well distributed in the network. But, this algorithm does not consider any assumptions about the sensor node capabilities, such as geographical position.

4. LEACH-C (Centralized Low Energy Adaptive Cluster Head):

A modification over the LEACH protocol that uses a centralized clustering algorithm and the same steady state phase protocol [8] same as LEACH is called as centralized low energy adaptive cluster head (LEACHC) protocol. During setup phase of LEACH-C, each node sends the current location and remaining energy of itself to the base station. The location can be determined by GPS system or any other tracking method. In addition to determine good cluster head the base station will elect only those nodes which have energy above Average level and ensure that the energy load is evenly distributed among all the nodes. Once the cluster heads and linked clusters are found, the BS broadcasts a message that contains the cluster head ID for each node. If a node's cluster head ID matches its own ID, the node is a cluster head; otherwise, the node determines its TDMA slot for data transmission and goes to sleep until it is time to transmit data. The steady-state phase of LEACH-C is same as that of LEACH.

5. LEACH-F (Fixed number of cluster Low Energy Adaptive Clustering Hierarchy):

In 2000, Heinemann proposed LEACH-F a modified version of LEACH with fixed clusters and rotating cluster heads [10]. This protocol uses centralized approach for cluster formation as that of LEACH-C. Once the cluster formation process is done, then there is no re-clustering phase in next round. The clusters are fixed and only rotation of cluster head nodes within its Clusters. The steady-state is same as classical LEACH.
The overhead of re-clustering in basic LEACH is removed by LEAC-F protocol as once the fixed number of clusters is formed; they are maintained throughout the network. But this protocol provides no flexibility of adding or removing the nodes once clusters are formed and nodes cannot adjust their behavior on node dying.

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

Mu Tong and Minghao Tang proposed LEACH-B algorithm to balance the number of cluster heads based on the residual energy of the sensor nodes. LEACH-B uses decentralized approach of cluster formation in which each sensor node knows about its own position and position of final destination irrespective of position of rest of the nodes in the network. LEACH-B works in three stages: Cluster head selection, Cluster formation and data transmission with multiple accesses. According to energy dissipated in the path between a node and final receiver, each node chooses its cluster head. LEACH-B has better energy efficiency than basic LEACH protocol.

7. TL-LEACH (Two level Low Energy Adaptive Clustering Hierarchy):

TL-LEACH protocol proposed by V. Loscrì, G. Morabito, S. Marano, unlike LEACH protocol where cluster heads send data to the base station directly in a single hop, TL-LEACH protocol works in two-level hierarchy. The aggregated data from each cluster head is collected by a cluster head lies between cluster heads and the base station, instead of sending directly to the base station.

Advancement of this protocol reduces data transmission energy. Cluster head nodes die early compared to other nodes, far away from base station and TL-LEACH improves energy efficiency by using a cluster head node as relay node in between cluster head nodes .

8. MH-LEACH (Multi-Hop Low Energy Adaptive Clustering Hierarchy):

In LEACH protocol, the cluster head nodes send data to the base station directly irrespective of distance between them. This will cause high energy dissipation of cluster head node if base station is located far away from it. As the network diameter increases, the distance between base station and cluster head nodes increases and this is disadvantages of LEACH protocol. To increase energy efficiency of the protocol, multi-hoping communication is introduced. Firstly cluster member nodes send data to their respective cluster head nodes which further transfer data to cluster head rather than base station directly. This protocol adopts an optimal path between cluster head and the base station.

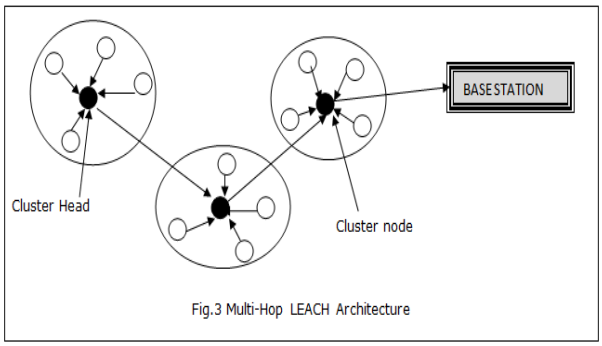

Fig.3 Multi-Hop LEACH Architecture

9. LEACH-E (Energy Low Energy Adaptive Clustering Hierarchy):

In LEACH-E protocol, initially all nodes have same energy and same probability of becoming the cluster head. After the first round, energy level of each node changes. Then the amount of residual energy of each node is used to select cluster head nodes. The nodes with highest residual energy are preferred on rest of the nodes. LEACH-E enhance lifetime of network by balancing energy load among all nodes in the network.

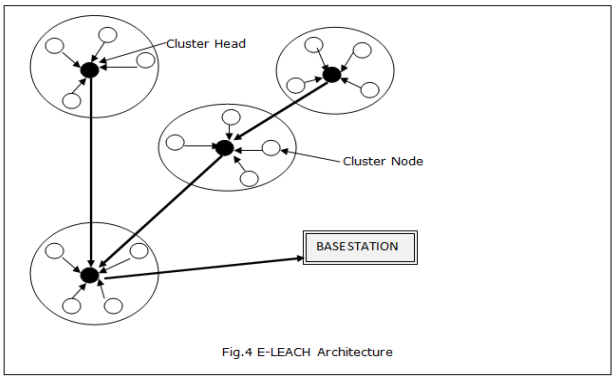

Fig.4 E-LEACH Architecture

10. LEACH-M (Mobile Low Energy Adaptive Clustering Hierarchy):

Mobility issue in LEACH protocol was resolved by introducing LEACH-M protocol. This protocol provides mobility to the both non-cluster head nodes and cluster head nodes while the set-up and the steady state. Nodes are homogeneous and location of each node is calculated by GPS. The nodes with minimum mobility and the lowest attenuation are being selected as cluster head nodes and the role of cluster head nodes is broadcasted to all nodes within its transmission range.

11. I-LEACH (Improved Low Energy Adaptive Clustering Hierarchy):

Authors Zahra Beiranvand, Ahmad Pathology, and Mahdi Fazeli have proposed I-Leach. It has three phases. During cluster head selection phase this protocol has modified the threshold value by considering various properties of sensor nodes such as their current energy level, number of neighbor nodes, and their distances to base station. It also considers average energy of the network, average number of neighbor nodes in the network, average distances of nodes from base station. In cluster formation phase nodes take into account the distances of cluster heads from the base station. In Data transmission phase cluster heads transmit data to the base station after collecting data from their local cluster members. Nodes which are very nearer to base station they are allowed to transmit data to the base station directly, it has reduced extra transfers. Therefore average consumed energy reduces and prolonged the WSN lifetime.

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

This protocol proposed a heterogeneous energy protocol for decreasing the node's failure probability and for prolonging the time interval before the first node dies which called as stability period. By the use of a synchronized clock, each sensor node would about to know the starting of each round for transferring of information. The maximum energy nodes are selected as cluster head for each cluster and these nodes are called as CAG node.

13. V-LEACH (Vice Cluster Head Low Energy Adaptive Clustering Hierarchy):

In classical LEACH protocol, the cluster head node consumed more energy as compared to normal nodes in sending aggregated data to the base station (located far away). Therefore the cluster head node dies early and the whole cluster will become useless, results data loss . V-LEACH improves this drawback having vice cluster head in each cluster that takes the role of cluster head when cluster head dies. In this way, this protocol reduces overhead of selecting new cluster head each time when a cluster head dies and the data will always reach to the base station. Hence network lifetime increases.

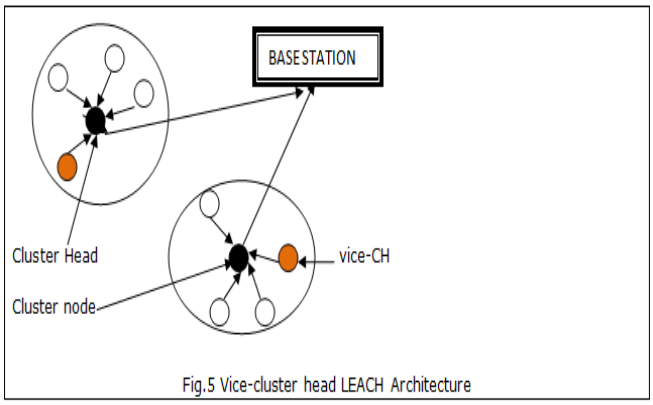

Fig.5 Vice-cluster head LEACH Architecture

V. CONCLUSION

In this paper, a well-known protocol in wireless sensor networks called LEACH is described. LEACH is first low energy protocol introduced in WSN which save energy and increase lifetime of the sensor networks. With the number of advantages of LEACH protocol it also comes with some drawbacks. To overcome those drawbacks and make LEACH more efficient many descendants of LEACH protocol are introduced and some of them like E-LEACH,LEACH-B,HEED,LEACH-F,TL-LEACH, MULTI-HOP LEACH, LEACH-C,LEACH-M,I-LEACH, CELL-LEACH and V-LEACH are described in this paper that how these protocol overcome the disadvantage of the LEACH protocol and make the sensor networks more efficient.

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