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A LEACH and its variants in Wireless Sensor Network – A Review

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Abstract : *Wireless sensor network is a collection of sensor node which are low weight, cheap processor and low battery power. Each node have low limited energy resources. Energy efficiency is the vital design issue in wireless sensor network. Therefore wireless sensor network needs to be boosted in order to increase the life time. There are many protocol are designed for that to increase the lifetime with restricted energy. Hierarchical routing or Clustering is best solution for reducing energy consumption in WSN. LEACH (Low Energy Adaptive Clustering Hierarchy) is good hierarchical protocol. This paper is review on LEACH protocol and provides best detail of some LEACH improved version. Finally this paper describes some features of LEACH protocol variants and describes how they try to overcome the LEACH.*

Keywords :*Energy Efficient, Hierarchical clustering, LEACH (Low Energy Adaptive Clustering Hierarchy), Wireless Sensor Network (WSN)*

I INTRODUCTION

A WSN is a collection of sensor node with limited battery power[8]. They are located randomly on a dynamically changing environment which is spread over the specific area [1]. Nodes in WSN are compact size, light weight devices. Through these special characteristics all the sensor nodes are communicate with each other through wireless medium and for the purpose of close range sensing [2]. Due to these characteristics routing in WSN is challenging from other wireless network [3]. These sensor nodes are arranged randomly and can communicate with each other and make ad-hoc network. Sensor nodes have limited battery and it is not easy to replace or recharge the battery.

A Cluster network is divided into various clusters. In each cluster, one node is elected as a cluster Head (CH) among all sensor nodes and others are cluster members. In every cluster all the cluster members send their data to CH and CH aggregate that data and compress the data and send it to Base Station (BS) either directly or via multihop transmission. Cluster head utilizes more energy than cluster members. So, Cluster head is rotated among the all the cluster members. Energy saving of sensor nodes is a major design issue. Since sensor nodes are usually battery-operated devices. Sensor network's lifetime can be prolonged by minimizing the energy consumption. Hierarchical routing is an efficient routing technique to reduce energy consumption [5]. LEACH (Low Energy Adaptive Clustering Hierarchy) is the first hierarchical protocol [5].

II LEACH PROTOCOL

LEACH (Low Energy Adaptive Clustering Hierarchy): LEACH is the most popular energy efficient hierarchical routing algorithm proposed by W.Heinzelman [5] for WSN to reduce the energy consumption. LEACH divides the network into several clusters. In every cluster one node is selected as a Cluster Head (CH). Other non Cluster Head node send their data to CH and all the CH aggregate that data and send compressed data to Base Station (BS). All CH use the direct communication to forward the data to BS. Since energy dissipation of the sensor depends on the distance LEACH attempts to transmit data over short distances and reduce total number of transmission and reception operations [6].
The key features of LEACH are:

1) Randomized Rotation of CH and corresponding clusters.
2) Local aggregation of data to reduce global communication.
3) Localize co-ordination and cluster set up operation.

In LEACH the role of a CH is rotated periodically among all the nodes of clusters to balance the load. CH rotation takes place rather than selecting one in static manner and give opportunity to all the member of clusters to become CH to reduce the energy consumptions.
The Operation of LEACH is divided into rounds, each round has mainly two phases.

1) Setup Phase is used to choose a CH, clusters are organized, and CH advertisement and transmission schedule is created. In this phase CH is selected from all the nodes of cluster based on the probability P of CHs, for the current round r, and the set of sensors that have not become CH in the past 1/P rounds. Nodes which are not selected as the CH in the last 1/P round generate the random number between 0 and 1. If it is less than the threshold T(n) then node becomes a CH for the current round. Where threshold value is set through the following formula.

$$T(n) = \begin{cases} \dfrac{P}{1-P \times (r \bmod 1/P)} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

Where n is a random number betweem 0 and 1, P is the probability of cluster head and G is the set of nodes that weren't cluster heads in the previous 1/P rounds. After its selection of each CH will broadcast an advertisement to all other nodes of cluster by using CSMA MAC protocol [7]. Now each node selects a CH based on the received signal strength of the advertisement. Each node sends its join packet to its selected CH. Then cluster are formed, each CH creates a TDMA schedule according to the number of nodes in their cluster.

2) Steady State phase for data aggregation, data compression and data transmission to the Base Station. In this phase after getting TDMA schedule all the nodes send their sensed data to CH during its allocated transmission time as per the TDMA schedule. The CH receives all the data and aggregates that data and sends these compressed data to BS. Now after certain time next round will start. Network start next round again by setup phase and steady state phase.

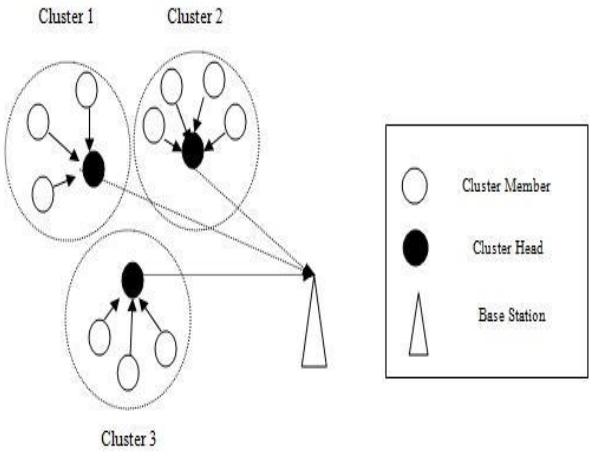

Fig. 1: LEACH Communication

Drawbacks of LEACH
Although LEACH protocol prolongs the network lifetime in contrast to plane multi hop routing and static routing but still it has problems. There are many drawbacks of LEACH.

- Each node has same priority to become a cluster head. If low energy node becomes cluster head, it would die earlier and cluster becomes incomplete.
- Non uniform distribution of cluster heads in each region. Some regions have more cluster head some regions have less number of cluster head.
- Cluster head communicate with base station by single hop routing. It becomes more energy consuming. So it is not applicable to large scale network.

III VARIANTS OF LEACH

A. LEACH-C (Centralized Low Energy Adaptive Clustering Hierarchy)

The limitation of LEACH is that number of cluster head nodes is little ambiguous to count. LEACH-C provides an efficient clustering configuration algorithm in which an optimum cluster head is selected which minimize the transmission energy between a cluster head and other nodes in a cluster. The cluster head node is selected by base station based on the residual energy and current location. Base station uses this global knowledge via GPS or other tracking methods to select the best clusters which require less transmission energy. LEACH-C causes better distribution of cluster

head nodes in the network. LEACH-C requires current location information of all nodes in cluster using GPS and this is not robust **[5] [9].**

B. LEACH-F (Fixed number of cluster Low Energy Adaptive Clustering Hierarchy):
For cluster formation LEACH-F use the same centralize approach like LEACH-C. Once the clusters are formed they are fixed there is no re- clustering in every round. There is no network setup overhead at the starting of each round. Only cluster head node is rotated among the nodes in the cluster. Setup phase is same as LEACH. Limitation of leach overhead of re clustering was removed in LEACH-F by fix number of clusters for entire lifetime of network. But it does not provide the flexibility of adding or removing any nodes in fix number of clusters [5] [10] [11].

C. LEACH-B (Balanced Low Energy Adaptive Clustering Hierarchy):
LEACH-B solves the problems, number of cluster heads and the ignorance of residual energy in LEACH protocol. This protocol adds a second selection of cluster heads to modify the number cluster-head in the set-up phase considering the node's residual energy per round. In order to save the energy consumption and to prolong the life span of the network, the protocol ensures that the partition of cluster is balance and uniform [12]. LEACH-B has better energy efficiency than LEACH.

D. TL-LEACH (Two level Low Energy Adaptive Clustering Hierarchy):
In LEACH protocol the CH collects and aggregates data from sensor nodes in its own cluster and sends the compressed data to base station directly. If cluster head node is far away from base station, so it is very high energy transmission and therefore CH node dies earlier than other nodes. TL-LEACH is a new version of LEACH improve the energy efficiency by using a cluster head node as relay node between the cluster head and base station [2].

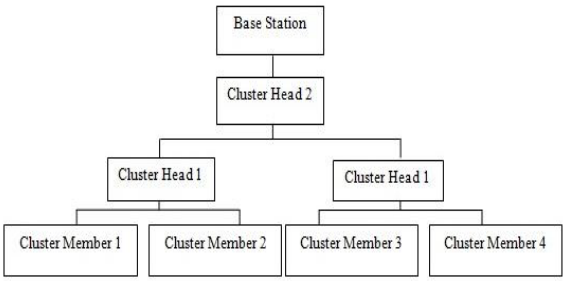

Fig 2: TL-LEACH Protocol

E. 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 [13] [14].

F. 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. 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 [10][2].

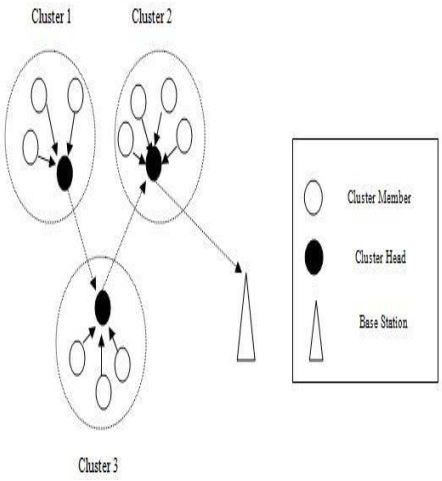

Fig 3: MH-LEACH Protocol

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

Detection of Twin nodes and assignment of Sub-Cluster Head (SCH) nodes are the two functions served by Improved-LEACH protocol. Randomly deployment of nodes results in high probability of two nodes located very close to each other called Twin nodes. It is necessary to keep one node sleep until the energy of another node depletes. Therefore I-LEACH has uniform distribution of cluster head so that it doesn't run out of energy when longer distance transmission takes place. This protocol uses threshold approach for managing number of cluster members for each cluster head in the network at a time [13] [14].

IV COMPARISON BETWEEN LEACH PROTOCOL AND ITS VARIANTS

A brief comparison among LEACH protocol and its different variants are shown in Table 1. All these variants have better performance than classical LEACH.

TABLE: 1 COMPARISION OF LEACH AND ITS VARIANTS PROTOCOLS [8]

Protocol	CH Selection	Improvement Over LEACH
LEACH-C	Centralized Low Energy Adaptive Clustering Hierarchy	BS is Responsible for making Clusters for each round by Running Centralized Cluster Algorithm by Getting Remaining Energy and Position of each Sensor Node
LEACH-F	Fixed number of cluster Low Energy Adaptive Clustering Hierarchy	The clusters are fixed and only rotation of cluster head nodes within its clusters.
LEACH-B	Balanced Low Energy Adaptive Clustering Hierarchy	LEACH-B works in three stages: Cluster head selection, Cluster formation and data transmission with multiple accesses.
TL-LEACH	Two level Low Energy Adaptive Clustering Hierarchy	CH sends the Data to BS through Other Ch that lies between the CH and BS.
LEACH-E	Energy Low Energy Adaptive Clustering Hierarchy	Selection of CH based on Residual energy
MH-LEACH	Multi-Hop Low Energy Adaptive Clustering Hierarchy	Cluster member nodes send data to their respective cluster head nodes which further transfer data to cluster head rather than base station directly.
I-LEACH	Improved Low Energy Adaptive	uniform distribution of cluster head so that it doesn't run out of

	Clustering Hierarchy	energy when longer distance transmission takes place

V CONCLUSION

In this paper a hierarchical clustering protocol LEACH of Wireless Sensor Network is described. LEACH is First hierarchical protocol which is energy efficient protocol and increase lifetime of the sensor networks. In this paper we describe LEACH protocol which has drawbacks also describe. To overcome those drawbacks and make more energy efficient many variants of LEACH protocol are introduced and some of them are LEACH-C, LEACH-B, LEACH-F, TL-LEACH, LEACH-E, MH-LEACH, I-LEACH and V-LEACH are briefly described in this paper and make the sensor networks more efficient.

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