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An Analysis of Low Energy Adaptive Clustering Hierarchy (LEACH) Protocol for Wireless Sensor Networks

Arshdeep Kaur[1] and Satbir Singh[1*]
[1]*Research Scholar, Dept. of ECE, GNDU, RC, GSP, Punjab, India (143521)*
[1*] *Assistant Professor, Dept. of ECE, GNDU, RC, GSP, Punjab, India (143521)*

Abstract:- Wireless sensor network is an emerging field leading to the various applications worldwide. Small nodes being used are capable enough to sensing, computation, collection and forwarding the data to the Base Station. Battery source is one of the most prominent concerning issue in making the sensor network running for performing various assigned tasks. This battery source has all business with the routing strategies being employed. Here in this paper the routing protocol LEACH (Low-Energy Adaptive Clustering Hierarchy) is being reviewed to explore the advancements in clustering strategies. LEACH is being the first clustering protocol which selects the cluster head in each round and thereby balancing the energy consumption throughout the network. The work in the paper focus to discuss various variants of LEACH aiming to enhance the network life-time.

Keywords:- LEACH, Wireless Sensor Networks, Battery Source, Hierarchical Routing Protocols.

I. INTRODUCTION

A Wireless Sensor Network (WSN) is a group of sensor nodes which connects themselves to collect data and forward data to the Base Station or sink to monitor the environmental conditions. There is almost every application in which sensor network has been promising in comforting the human beings; be it an environmental application, habitat monitoring, military applications and many more [1].

The sensor node not only contains sensors but also some significant components which do the task of processing the data as well transmitting and receiving the data. These sensor nodes are battery powered in which its quixotic to replace battery once a sensor node is deployed. So it's always a concerning issue to deal with, which is the most prominent research issue for the survival of WSN.

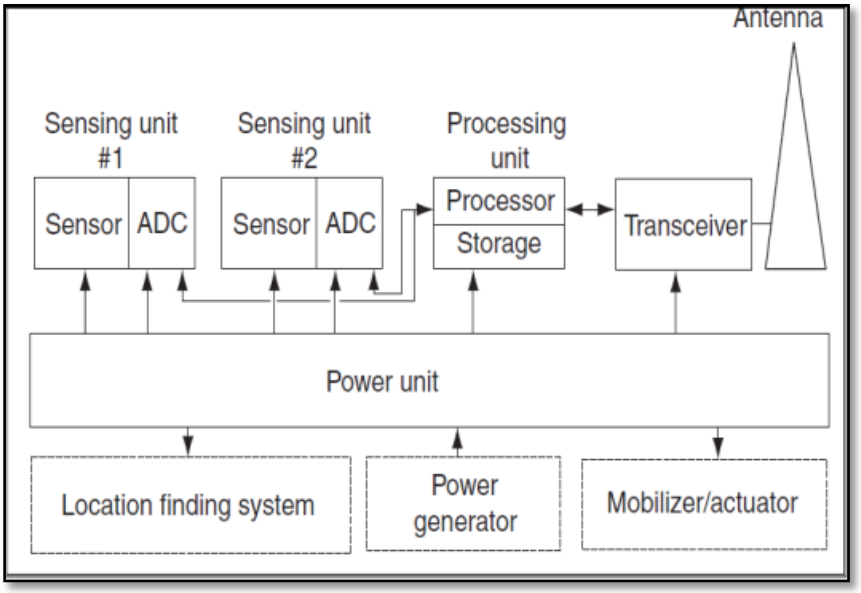

Fig.1 Architecture of Sensor Node [1]

It has been confirmed that sensor node consumes its most of energy in communication with the other members of the sensor network. Thereby routing plays an important role in handling the worrying concern of utilization of energy of sensor nodes efficiently [2]. In this aspect, various routing protocols have been brought into existence which aims to achieve the maximum network lifetime.

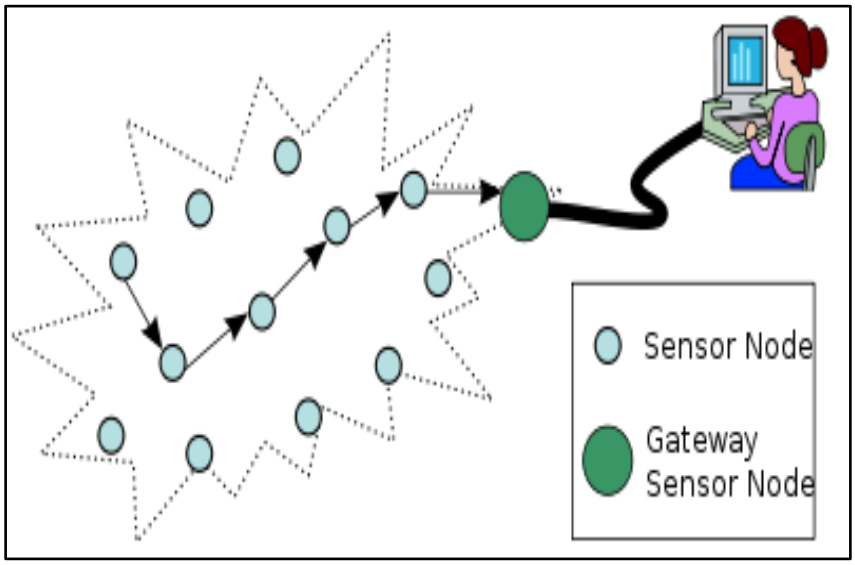

Fig. 2 WSN Architecture [2]

II. CLUSTERING IN WSN

Clustering has been the most prominent approach for enhancing the network lifetime. The sensor nodes are grouped to form a cluster in which the nodes join with the leader of group termed as Cluster Head (CH) [3].

Types of cluster communication: There are two types of cluster communication which are given as:

I. Intra cluster communication - The communication in which member nodes transmit their data to the cluster head within cluster as shown in Fig. 3. The intra cluster communication can be done in single hop or multi-hop approach. In single hop communication, the member nodes directly transmit their data to the cluster head. In multi-hop communication, the member nodes transmit their data to the cluster head through multi-hop approach.

II. Inter cluster communication - The communication in which cluster head transmit the aggregated data packets from the member nodes to the base station as shown in Fig.2. In generally inter cluster communication is done in single hop i.e. the cluster head directly transmits the aggregated data to the base station but sometimes it is beneficial to have multi-hop communication in which cluster head transmits the aggregated data to the base station through multi-hop manner and makes the system more energy efficient.

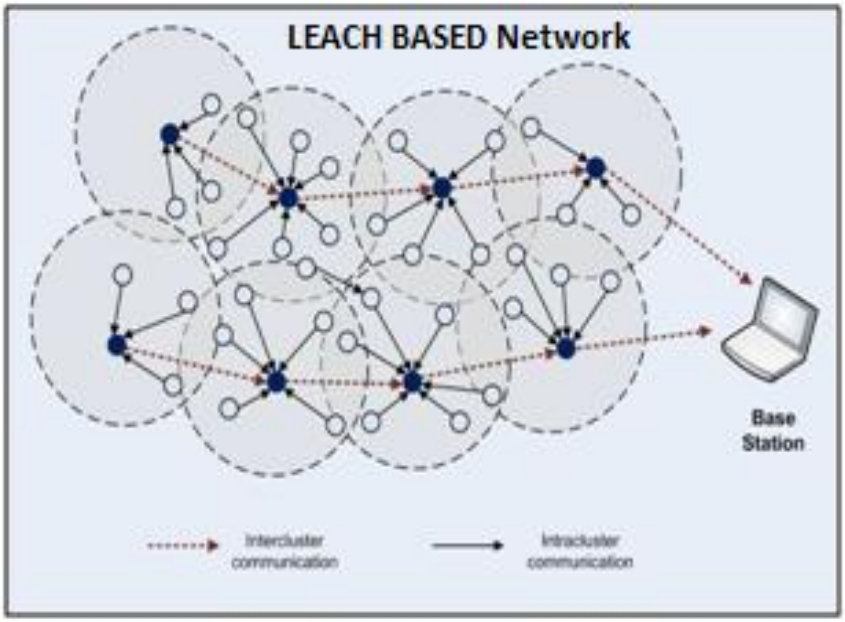

Fig.3 Cluster Communication [3]

CH collects the data from the all the cluster nodes and forward it to the Base Station. It is the process of data transmission that takes place in each round. So in every round the CH selection takes place. There have been various routing protocols aiming to enhance the network lifetime [4].

In the consideration of enhancing the network lifetime the LEACH (Low-Energy Adaptive Clustering Hierarchy) Protocol was developed which was 1st cluster based protocol aiming to achieve maximum network lifetime [5].

LEACH outperforms classical clustering algorithms by using adaptive clusters and rotating cluster-heads, allowing the energy requirements of the system to be distributed among all the sensors. Instead, when the cluster-head die, the cluster will become useless because the data gathered by cluster nodes will never reach the base station. So, there is a requirement to improve LEACH protocol to enhance the performance.

Leach is considered as the most popular routing protocol that use cluster based routing in order to minimize the energy consumption; in this paper we explore the various advancements in the LEACH protocol in the form of its variants that further enhance the network life-time.

III. LEACH PROTOCOL FRAMEWORK

Low Energy Adaptive Clustering Hierarchy (LEACH) is the first hierarchical cluster-based routing protocol for wireless sensor network which partitions the nodes into clusters, in each cluster a dedicated node with extra privileges called Cluster Head (CH) is responsible for creating and manipulating a TDMA (Time division multiple access) schedule and sending aggregated data from nodes to the BS where these data is needed using CDMA (Code division multiple access**)**. Remaining nodes are cluster members. Only cluster-head can directly communicate to sink and member nodes use cluster-head as intermediate router in case of communication to sink. Cluster-head collects the data from all the nodes, aggregate the data and route all meaningful compress information to Sink.

Because of these additional responsibilities Cluster-head dissipates more energy and if it remains cluster-head permanently it will die quickly as happened in case of static clustering. LEACH tackles this problem by randomized rotation of cluster-head to save the battery of individual node. In this ways LEACH maximize life time of network nodes and also reduce the energy dissipation by compressing the date before transmitting to cluster-head. LEACH routing protocol operations based on rounds, where each round normally consists of two phases. First is setup phase and second is steady state phase. In setup phase cluster-head and cluster are created.

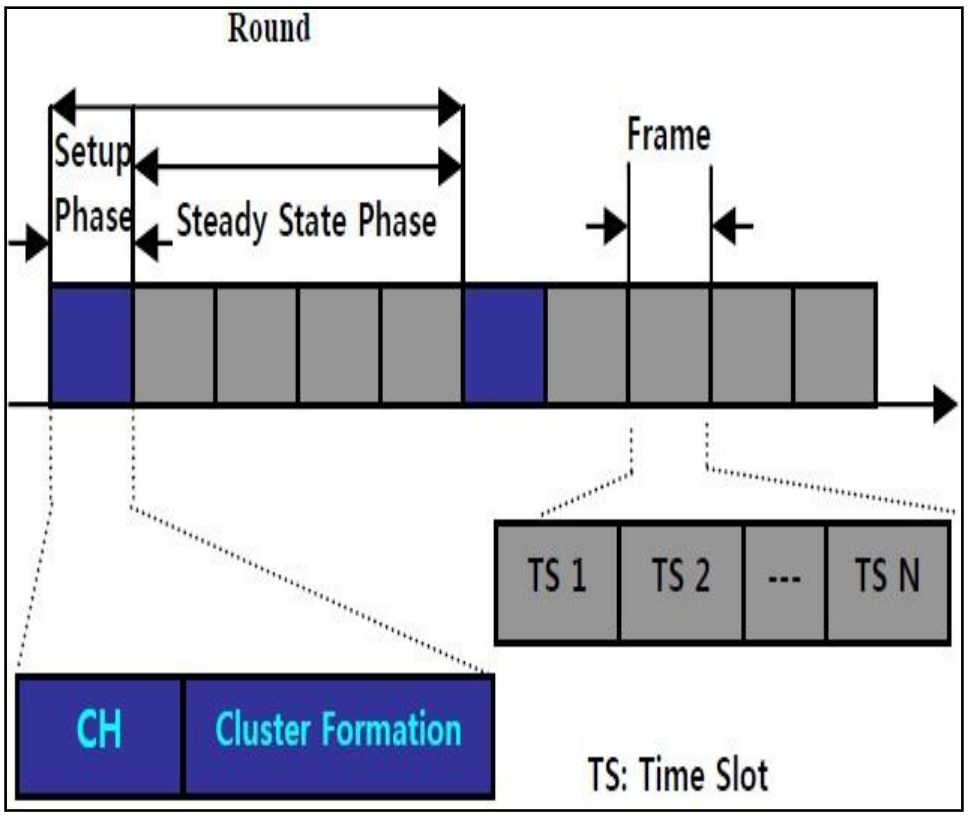

Fig.4: LEACH protocol phases [5]

This protocol is divided into rounds; each round consists of two phases;

Set-up Phase

(1) Advertisement Phase

(2) Cluster Set-up Phase

Steady Phase

(1) Schedule Creation

(2) Data Transmission

Setup Phase

Each node decides independent of other nodes if it will become a CH or not. This decision takes into account when the node served as a CH for the last time (the node that hasn't been a CH for long time is more likely to elect itself than nodes that have been a CH recently).

In the following advertisement phase, the CHs inform their neighborhood with an advertisement packet that they become CHs. Non-CH nodes pick the advertisement packet with the strongest received signal strength. In the next cluster setup phase, the member nodes inform the CH that they become a member to that cluster with "join packet" contains their IDs using CSMA. After the cluster-setup sub phase, the CH knows the number of member nodes and their IDs. Based on all messages received within the cluster, the CH creates a TDMA schedule, pick a CSMA code randomly, and broadcast the TDMA table to cluster members. After that steady-state phase begins.

Steady-state phase

Data transmission begins; Nodes send their data during their allocated TDMA slot to the CH. This transmission uses a minimal amount of energy (chosen based on the received strength of the CH advertisement). The radio of each non-CH node can be turned off until the nodes allocated TDMA slot, thus minimizing energy dissipation in these nodes. When all the data has been received, the CH aggregate these data and send it to the BS.

LEACH is able to perform local aggregation of data in each cluster to reduce the amount of data that transmitted to the base station. LEACH is able to perform local aggregation of data in each cluster to reduce the amount of data that transmitted to the base station. Although LEACH protocol acts in a good manner, it suffers from many drawbacks such like;

I) CH selection is randomly, that does not take into account energy consumption.

II) It can't cover a large area.

III) CHs are not uniformly distributed; where CHs can be located at the edges of the cluster.

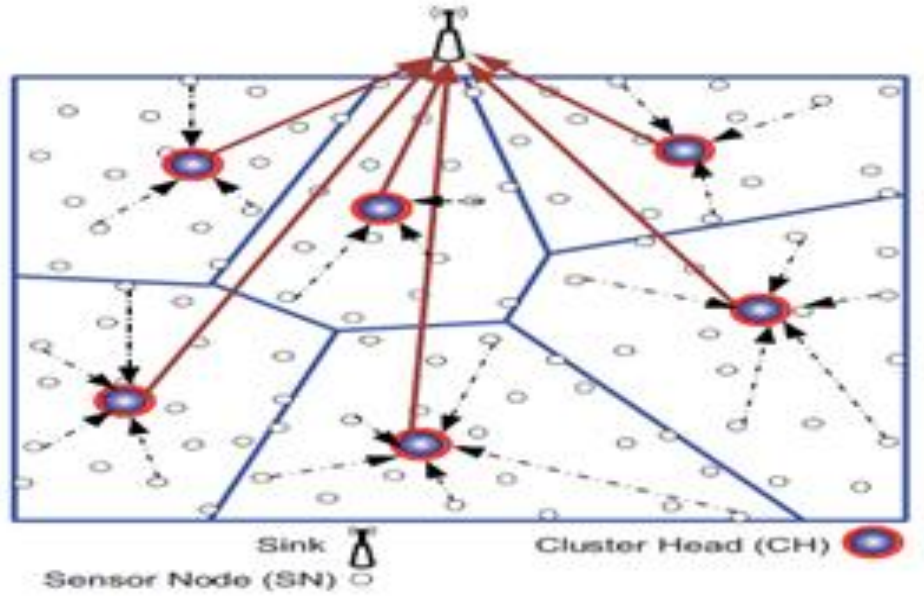

Fig. 5 LEACH Protocol Architecture [5]

IV. ADVANCEMENTS IN LEACH PROTOCOL

There have been various advancements in developing the energy efficient routing protocols in the form of LEACH variants [6-7]. They are discussed in brief down under.

TL-LEACH

In LEACH protocol, the CH collects and aggregates data from sensors in its own cluster and passes the information to the BS directly. CH might be located far away from the BS, so it uses most of its energy for transmitting and because it is always on it will die faster than other nodes.

A new version of LEACH called Two-level Leach was proposed. In this protocol; CH collects data from other cluster members as original LEACH, but rather than transfer data to the BS directly, it uses one of the CHs that lies between the CH and the BS as a relay station.

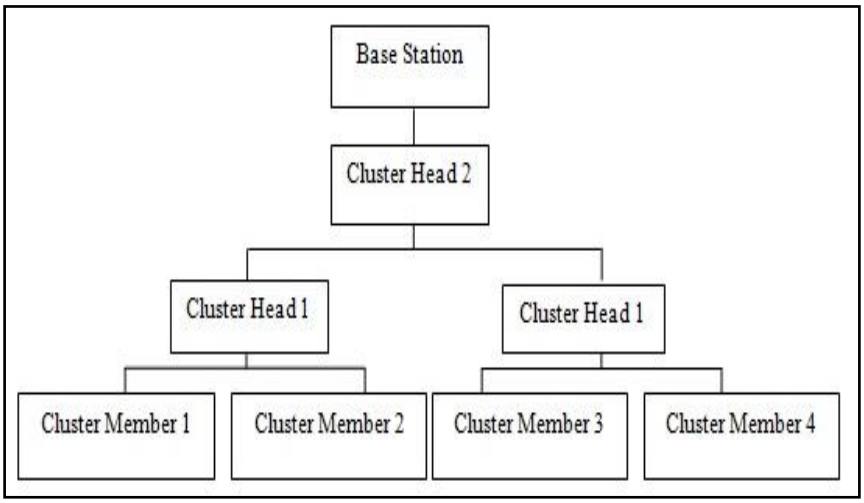

Fig. 6 TL-LEACH [8]

E-LEACH protocol

Energy-LEACH protocol improves the CH selection procedure. It makes residual energy of node as the main metric which decides whether the nodes turn into CH or not after the first round [9]. Same as LEACH protocol, E-LEACH is divided into rounds, in the first round, every node has the same probability to turn into CH, that mean nodes are randomly selected as CHs, in the next rounds, the residual energy of each node is different after one round communication and taken into account for the selection of the CHs. That mean nodes have more energy will become a CHs rather than nodes with less energy.

M-LEACH protocol

In LEACH, Each CH directly communicates with BS no matter the distance between CH and BS. It will consume lot of its energy if the distance is far. On the other hand, Multihop-LEACH protocol selects optimal path between the CH and the BS through other CHs and use these CHs as a relay station to transmit data over through them [10].

First, multi-hop communication is adopted among CHs. Then, according to the selected optimal path, these CHs transmit data to the corresponding CH which is nearest to BS. Finally, this CH sends data to BS.

M-LEACH protocol is almost the same as LEACH protocol, only makes communication mode from single hop to multi-hop between CHs and BS.

LEACH-C protocol

LEACH offers no guarantee about the placement and/or number of cluster heads. In an enhancement over the LEACH protocol was proposed. The protocol, called LEACH-C, uses a centralized clustering algorithm and the same steady-state phase as LEACH. LEACH-C protocol can produce better performance by dispersing the cluster heads throughout the network. During the set-up phase of LEACH-C [10], each node sends information about its current location (possibly determined using GPS) and residual energy level to the sink. In addition to determining good clusters, the sink needs to ensure that the energy load is evenly distributed among all the nodes. To do this, sink computes the average node energy, and determines which nodes have energy below this average.

Once the cluster heads and associated clusters are found, the sink broadcasts a message that obtains the cluster head ID for each node. If a 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 sleep until its time to transmit data. The steady-state phase of LEACH-C is identical to that of the LEACH protocol.

***V-LEACH* Protocol**

In new version of LEACH protocol, the cluster contains; CH (responsible only for sending data that is received from the cluster members to the BS), vice-CH (the node that will become a CH of the cluster in case of CH dies), cluster nodes (gathering data from environment and send it to the CH).

In the original leach, the CH is always on receiving data from cluster members, aggregate these data and then send it to the BS that might be located far away from it. The CH will die earlier than the other nodes in the cluster because of its operation of receiving, sending and overhearing.

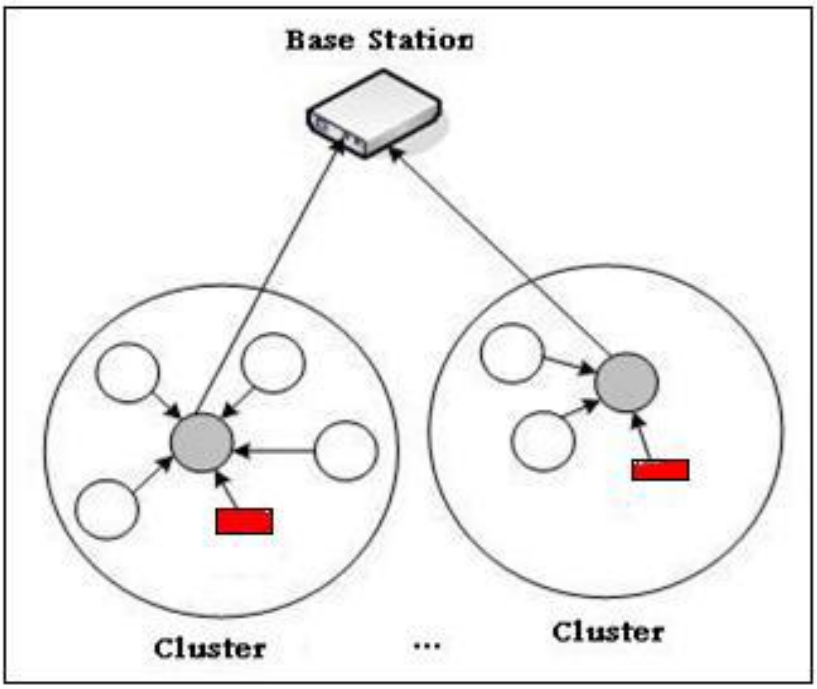

Fig.7 V-LEACH Protocol [11]

When the CH die, the cluster will become useless because the data gathered by cluster nodes will never reach the base station. In our V-LEACH protocol, besides having a CH in the cluster, there is a vice-CH that takes the role of the CH when the CH dies because the reasons we mentioned above.

By doing this, cluster nodes data will always reach the BS; no need to elect a new CH each time the CH dies. This will extend the overall network life time.

LEACH-F

LEACH-F (Fixed number of cluster Low Energy Adaptive Clustering Hierarchy): Similar to LEACH-C protocol, this protocol uses centralized approach for cluster formation. Once the cluster formation process is completed, then there is no re-clustering phase in next round. The clusters are fixed and only rotation of cluster head nodes within its clusters is performed. There is removal of overhead of re-clustering in LEACH-F protocol as once the fixed number of clusters is formed; they are maintained throughout the network. But this protocol has lack of flexibility of adding or removing the nodes once clusters are formed and nodes cannot adjust their behavior on node dying [12].

V. CONCLUSION AND FUTURE WORK

The routing techniques have always been responsible for the longer running of network lifetime. Studying LEACH protocol with its variants makes it easy to explore various clustering strategies. Clustering not only balance the network in energy consumption but also provides scalability to the network. After doing the retrospective survey on LEACH it can be concluded that since the time LEACH came into picture, there has been development of various efficient variants of LEACH which has enhanced network lifetime at much higher level. As discussed in the paper, where E-LEACH selects the cluster head on the residual energy basis, TL-LEACH work on the two levels of cluster head. These different selections of cluster head still leave a margin of improvement for the getting optimized cluster head selection. So in the future work, we would extend our review to the energy efficient optimization techniques.

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