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A Comparative Study on Advances in LEACH Routing Protocol for Wireless Sensor Networks: A survey

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Abstract: The Wireless Sensor Network (WSN) is composed of a collection of sensor nodes, which are small energy constrained devices. The efficient use of energy source in a sensor node is most desirable criteria for prolong the life time of wireless sensor network. So designing efficient routing for reducing energy consumption is the important factor. In this paper, a brief introduction to routing challenges in WSN along with some basic designing issues related to routing protocols have been mentioned. This paper also reviews the basic classification of routing protocols in WSNs along with the most energy efficient protocol named LEACH along with its advantages and disadvantages. This paper also give light on some of the improve version of LEACH protocol along with its advantageous routing compared to the fundamental LEACH protocol. Finely this paper concludes with some comparison of descendents of LEACH with LEACH protocol.

Keywords: Wireless sensor network, hierarchical routing, cluster based routing protocol, LEACH

I. INTRODUCTION

In the advancement of Micro-Electro-Mechanical System (MEMS) has highly influenced the development of miniaturized sensor nodes [13]. These tiny nodes collaborate with each other via RF communication in ISM (Industrial, Scientific and Medical) band to form Wireless Sensor Network (WSN) [13]. In the twenty-first century Wireless Sensor Networks (WSNs) are being widely considered as one of the most important technologies for many real time applications [2].

Wireless Sensor Networks consist of tiny sensor nodes that and these sensor nodes are consist of sensors (temperature, light, humidity, radiation, and more), microprocessor, memory, transceiver, and power supply [7]. These smart sensor nodes are deployed in a physical area and networked through internet and wireless links, which provide unprecedented opportunities for a variety of civilian and military applications, for example, environmental monitoring, battle field surveillance, and industry process control [2]. Sensors are deployed in an ad-hoc manner in the area of interest to monitor events and gather data about the environment. They have the ability of sensing, data processing and communicating with each other in the network environment. Multi-hopping in the WSNs can cause a sensor node to communicate with a node with is far away from it. This allows the sensor nodes in the network to expand the monitored area and hence proves its scalability and flexibility property [8].

If the node is not able to communicate with other through direct link, i.e. they are out of coverage area of each other, than the data can be sent to the other node by using the nodes in between them. This property in WSNs is referred as multi-hoping. A network can be divided into several clusters with the help of a property called clustering. Within each cluster, one of the sensor nodes is elected as a cluster head (CH) and other are called as with cluster members (CM). All sensor nodes work cooperatively to serve the requests within each cluster. Cluster head collects the data locally from the cluster members and with the help of fusion and aggregation it drops the redundant data and then transmits the aggregated data either directly or via multi-hop transmission to the sink. Since the cluster heads spend more energy than the non-cluster heads so to distribute the workload of the cluster heads among the wireless sensor nodes their role is rotated among all nodes in order to equalize energy consumption [12]. This process is called the cluster head (CH) rotation.

These networks (WSNs) are unique as compared to traditional wired and wireless networks because they having the seal-healing and self-organizing property which differentiate them from other networks. Regardless of their unique characteristics, they (WSNs) are highly limited to resources. The sensor nodes are very small in size and therefore energy is a limited resource. Apart from energy, these nodes are low on battery power, memory, processing capabilities, security features and available bandwidth. These sensor nodes are capable of delivering the captured phenomena (information) of interest to the base station via multi-hop or single hop link. However, multi-hop links are preferred mode of communication in order to reduce the consumption of energy [2].

The fundamental goal of a WSN is to produce information from raw local data obtained (sensed data) by individual sensor mode by prolonging the life time of WSN as much as possible. The resource constrained nature of sensor nodes pose the unique challenges to the design of WSNs for their applications. The limited power

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of sensor nodes mandates the design of energy-efficient communication protocol in WSNs [2].

WSNs are not a centralized network scenario as there is possible of peer-to-peer communication between the nodes. Therefore there is no requirement of prior established infrastructure to deploy the network. WSN gives flexibility of adding nodes and removing the nodes as required. But this gives rise to many drastic changes to deal with in the network topology such as updating the path, or the network tree, etc. In a WSN the node that gathers the data information refers to sink. The sink may be connected to the outside world through internet where the information can be utilized within time constraints. The main problem in using these networks is limited battery life. This is due to fact that the size of a sensor node is expected to be small and this leads to constraints on size of its components i.e. battery size, processors, data storing memory, all are needed to be small. So any optimization in these networks should focus on optimizing energy consumption in the network [12].

An efficient and beneficial solution from overcoming this problem is to implement routing protocols that perform efficiently and utilizing the less amount of energy as possible for the communication among nodes within the network and along with between the networks. Sensor devices in WSNs monitor the same event and report on them to the base station. Therefore, one good approach is to consider that sensors located in the same region of the network will transmit similar values of the attributes. This fact notices inherent redundancy in the node transmissions that may be used by the routing protocol. Sensor networks need protocols, which are specific, data centric, capable of aggregating data and optimizing energy consumption. The sensor nodes are usually programmed to monitor or collect data from surrounding environment and pass the information to the base station for remote user access through various communication technologies [6].

The basic goals of WSNs are as follows [11],

a) Determine the value of physical variables at a given location.
b) Detect the occurrence of events of interest, and estimate parameters of the detected event or events.
c) Classify a detected object and also track an object.

1.1 Routing challenges and design issues in WSNs

There are different parameters are there which provides a very challenging criterion in routing for WSN and they are as follows [14]

- Node deployment in the sensor network.
- Energy Consumption in the network should occur without losing of accuracy of the network.
- Data Reporting Method should be configured in the network.
- Node/Link Heterogeneity of the network.
- Scalability of the network.
- Network Dynamics.
- Transmission Media should be fault tolerance.
- Coverage area of different sensor nodes in the network.
- Data Aggregation process within the clusters in the network.
- QOS policies of the network.

This paper reviews the following subjects. In Section 2, we mentioned about classification of routing protocols in WSNs. In Section 3, we discuss a brief about hierarchical routing protocol along with cluster based hierarchical model along with some difficulties arise in hierarchical cluster based routing. In Section 4, we discuss about LEACH protocol along with its advantages and disadvantages. In Section 5, we discuss some improvement of LEACH protocols in an energy efficient way. In section 6, we discuss the comparative study of different improved version LEACH with LEACH routing protocol based on different criteria. In Section 7, we finally conclude the paper with an efficient way.

II. ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORK

A WSN can have network structure based or protocol operation based routing protocol .Routing protocols in WSNs might differ depending on the application (Protocol-Operation-based) and network architecture (Network-Structure-based) [11, 2].

Depending on protocol operation WSN can be classified into,

a. Multipath-based routing

It uses multiple paths rather than a single path in order to enhance network performance. For instance the fault tolerance can be increased by maintaining multiple paths between the source and destination at the expense of increased energy consumption and traffic generation.

b. Query-based routing

The destination nodes propagate a query for data from a node through the network. A node with this data sends the data that matches the query back to the node that initiated it.

c. Negotiation-based routing

This negotiation based routing is done in order to eliminate redundant data transmissions. In this communication decisions are also made based on the resources available in the network scenario.

d. QOS-based routing

When delivering process of data in ongoing with the help of this routing, balances the network in between energy consumption and data quality through certain QOS metrics such as delay, energy or bandwidth.

e. Coherent-based routing

The entity of local data processing on the nodes is being distinguished between the coherent (minimum processing) and the non-coherent (full processing) routing protocols. Depending on the network structure Routing Protocols can also be classified into,

f. Flat-based routin:

In this routing protocol each node plays the same role and sensor nodes collaborate to perform the sensing task.

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g. Hierarchical-based routing:

In this type of routing, the nodes having the higher-energy are used to process and send the information, while the nodes having the low-energy are used to perform the sensing in the proximity of the target. The process of creation of clusters and assigning special tasks to cluster heads can efficiently increase the overall system scalability, lifetime, and energy efficiency. Hierarchical routing is an efficient way to lower the energy consumption within a cluster with the help of performing data aggregation and fusion within the different clusters in order to decrease the number of transmitted messages to the sink node.

h. Location-based routing:

In this type of protocol sensor nodes are addressed by means of their locations. The distance between neighboring nodes can be estimated on the basis of incoming signal strengths from the source nodes. Relative coordinates of neighboring nodes can be obtained by exchanging such information between neighbors or by communicating with a satellite using GPS. To save energy, some location-based schemes also suggest that nodes should go to sleep if there is no activity to perform in a definite time.

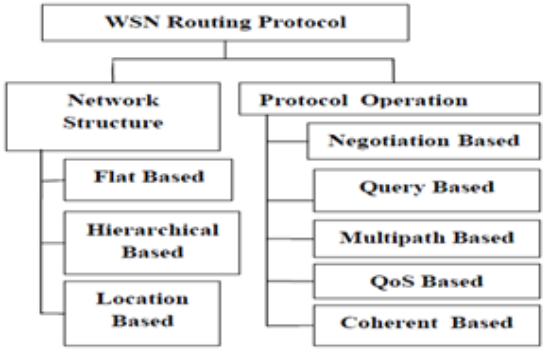

Fig.1. Routing protocols classification for WSNs

III. HIERARCHICAL ROUTING PROTOCOL

Among the issues in WSN the consumption of energy is one of the most important issues [11]. Traditional routing protocols for WSN may not be optimal in terms of energy consumption [paper Energy]. Hierarchical routing protocols are found to be more energy efficient than other protocols [11]. Hierarchical routing follows the clustering mechanisms. Clustering techniques can be efficient in terms of energy and scalability [14]. By the use of a clustering technique they minimize the consumption of energy greatly in collecting and disseminating data [11]. This is neither but the process of fusion and aggregation process. Hierarchical routing protocols minimize energy consumption by dividing nodes into different clusters. In each cluster, higher energy nodes i.e. the cluster head (CHs) can be used to process and send the information to the base station while low energy nodes i.e. the cluster members can be used to perform the sensing in the proximity of the target and send to its cluster head. This means that creation of clusters and assigning special tasks to cluster heads can greatly contribute to overall system scalability, lifetime, and energy efficiency, reduces the size of the routing table by localizing the route setup within the clusters, and conserves communication bandwidth of network [11, 15].

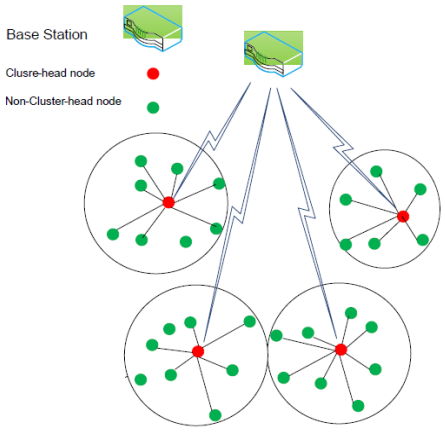

Fig.2. Clustering Model Hierarchical routing

3.1 *Cluster Based Hierarchical Model*

As shown in Fig. 2, a hierarchical cluster based approach divides the network into different clustered layers. Different sensor nodes are grouped into clusters with a cluster head that has the responsibility of routing from the cluster to the other cluster heads or to the base stations. Clustering mechanism provides inherent optimization capabilities of sensed information at the cluster heads. In the cluster-based hierarchical model, data is first aggregated in the cluster then sent to a higher-level cluster-head or to the base station. In cluster-based hierarchical model only the cluster-heads have to perform the data aggregation process, but in case of the multi-hop model every intermediate node performs data aggregation process. As a result of this process, the cluster-based model is more suitable for time-critical application. However this cluster based approach having a disadvantage of, as the distance between clustering level increases, the energy spent in processing and communicating is directly proportional to the square of the distance between the cluster levels.

Advantages of clustering over different classes of algorithms are [14],

- Minimization of energy consumption of intra-cluster and as well as inter cluster network.
- Scalability of the network.
- Network life time prolonging.
- Reduction of information packet delay.
- Handling heterogeneity of network.

3.2. *Challenges in Hierarchical Cluster based hierarchical algorithm*

We have to face various challenges while transmitting of sensed information in the network or outside the network while using of cluster based routing protocols. Some of the challenges are as follows [14],

- Some of the cluster based routing algorithms are only efficient to small region or small number of nodes (LEACH) only.
- Some of the cluster based routing is suitable only for deployment of nodes in a static manner and it

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degrades its performance in the case of mobile nodes.

- In some of the cluster based routing algorithm distribution of the cluster heads is concentrated to one area only.
- Some cluster based routing algorithms are not efficient for time critical application.
- All available Cluster based routing algorithms are top down approach, which interns requires re-clustering when deployed in some mission critical application.
- Some cluster based routing algorithms allows all the CHs to send the aggregated information to base station that leads to more energy dissipation in the network.
- Few of the cluster based routing algorithms uses probabilistic approach while processing and communicating of information in the network which does not consider residual energy in the network nodes and that results in early dyeing of CHs.

IV. CLUSTER BASED HIERARCHICAL ROUTING PROTOCOL – LEACH

Low-Energy Adaptive Clustering Hierarchy (LEACH) is a clustering based protocol that uses a randomized rotation of local cluster base stations [8]. LEACH is one of the most popular distributed cluster-based routing protocols in WSNs [11]. LEACH is the first and most popular energy efficient hierarchical clustering algorithm for WSNs that was proposed for reducing power consumption and also to increase the lifetime of the network [2, 7].

It is an application-specific data dissemination protocol that uses clusters to prolong the life of the wireless sensor network [2]. LEACH performs self-organizing and re-clustering functions for every round. Sensor nodes organize themselves into clusters in LEACH routing protocol [10]. 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 very soon [12]. In every cluster one of the sensor node acts as cluster-head and remaining sensor nodes as member nodes of that cluster. Only cluster-head can directly communicate to sink and member nodes use cluster-head as intermediate router in case of communication to sink [10]. 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 [7]. 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 [9],

- 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 different rounds and each of these rounds having mainly two phases and these are called [2, 7, 9],

a) Setup phase

- For the process of organizing the whole network into different intra-clusters
- Advertisements of the cluster heads to its different individual cluster members
- Transmission of the schedule that has been created during the setup phase only

b) Steady state

- The process of data aggregation within the different clusters of the network
- Compression of the sensed information that is being sensed by the sensor node into its different cluster head within the cluster only
- Transmission of the compressed data to the sink via different cluster heads

4.1 *Advantages of LEACH protocols*

The different advantages that the LEACH protocols having are as follows [12, 8],

- It provides scalability in the network by means of limiting most of the communication inside the different clusters of the network.
- The cluster heads aggregates or fuses the information that is been collected by the sensor nodes and this helps in to limit high amount of traffic generated within the network. By this means, a large-scalable network without traffic overload can be deployed and by this also better energy efficient network topology can be achieved as compared to the flat-topology.
- Single-hop routing is possible from sensor node to cluster head, and by this means we can able to save the energy of the network.
- Distributiveness property within the cluster, where it distributes the role of CH to the other cluster members within the cluster.
- It increases the lifetime of network in three phases. First, it distributes the role of CH (which consumes more energy than normal sensor nodes) to the other nodes in the cluster. Second, it aggregates the sensed information by the CHs. Finally, by the process of TDMA, (which is been assigned by the CH to its members) puts most of the sensor nodes in the sleep mode. This is done especially in event-based applications only. By

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this means, it is able to increase the network lifetime and also able to achieve a more than 7-fold reduction of energy dissipation compared to direct communication.

- It does not require the information of location of the sensor nodes in the network to create the clusters. Therefore it is very powerful routing protocol and it is very much simple also.
- It gives the dynamic clustering approach. It is well-suited for applications where constant monitoring of the environmental information is needed and data collection process occurs periodically to a centralized location of the network.

4.2 *Disadvantages of LEACH protocol*

The different disadvantages that the LEACH protocols having are as follows [6, 9],

- It significantly relies on cluster heads rather than cluster members of the cluster for communicating to the sink. Due to this it incurs robustness issues like failure of the cluster heads.
- It incurs additional overheads due to the process of cluster head changes in each iterations of the communication of information. It also incurs overhead due to calculations which leads to the energy inefficiency for dynamic clustering in large scale networks.
- There is no inter-cluster communication in the network because CHs directly communicate with sink. This process requires high range of transmission power in the network. For this only, LEACH is not best suited for large- scale networks that interns require single hop communication with sink.
- In LEACH CHs are not uniformly distributed within the cluster that means CHs can be located at the edges of the cluster.
- In LEACH, CH selection is random process, which does not take energy consumption of the different nodes within the cluster along with CH into account and this leads to reselecting of CH as the sane node in many simultaneous iteration of data processing in the network.
- It does not work well with the applications that require large area coverage along with multi-hop inter-cluster communication.

V. IMPROVEMENT OF LEACH

There are many protocols that have been proposed by many authors that described the improvement of the efficient protocols called LEACH in many factors to overcome from the disadvantages which are there in the LEACH clustering protocol. Some of the improvement of LEACH protocol are mentioned below which have been surveyed in the survey period [5].

5.1 A-LEACH (Angled Low Energy Adaptive Clustering Hierarchy)

The main motivation of developing the A-LEACH is to reduce the amount of traffic that is generated at the base station. The first phase that is cluster formation and cluster head selection is assumed to be same as LEACH in this protocol. This protocol also assumes that some of the nodes in the network may not belong to any of the cluster that is being formed in the network. These nodes would transfer their sensed data to the sink directly which would caused high amount of traffic at the sink node and intern it affects load balancing at the sink and it also affects the energy efficiency factor also. A-LEACH protocol calculates the angles among the nodes in such a way that, the nodes would be transferring the data to their respective cluster heads should be lies at an angle less than or equal to 45° to the cluster head. This process would reduce the overall traffic in the network and hence energy utilization is being done very effectively. The angles of the nodes to their respective cluster heads and the sink node is been calculated by the dot product of the position of the nodes, cluster heads and the sink [9, 11, 14, 15].

5.2 *LEACH-A (Advanced Low Energy Adaptive Clustering Hierarchy)*

In LEACH-A, the data is been processed using mobile agent technique which is based on LEACH protocol. 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. Leach-A protocol having the following advantages compared to LEACH [7, 11, 14, 15],

a. The fusion of the data is done to reduce the amount of information that been transmitted to the base station.
b. Maximum energy can be saved by using TDMA/CDMA techniques that allows hierarchy and makes clustering on several levels.
c. The CAG nodes continue to send data to the sink after the death of other normal nodes also.

5.3 *LEACH-B (Balanced Low Energy Adaptive Clustering Hierarchy)*

In LEACH-B for the cluster formation purpose it uses the de-centralized algorithms in which each sensor node only knows about its own position and the destination node position where actually the information will going to receive, and it does not know about any other sensor node position. In LEACH-B, Cluster formation and data transmission are done with the help of multiple accesses to different nodes. After this how much the energy is been dissipated in the path between destination node and originating node is being calculated and based on this only each of the sensor nodes would choose its own cluster heads. Compared to LEACH efficiency of LEACH-B is much higher [9, 11, 14, 15].

5.4 *LEACH-C (Centralized Low Energy Adaptive Clustering Hierarchy)*

LEACH-C uses a centralized clustering algorithm and same steady-state protocol as LEACH. In the set-up phase of LEACH-C, each node would send its current location

position and energy level information to the sink node. Based on this information from the sensor nodes the BS will determine the different clusters along with CH node and non-CH nodes of each and every cluster. The BS would able to produce better clusters by utilizing its global information of the whole network and by this process less energy is being consumed for data transmission purpose. In LEACH-C the number of CHs in each round is equals to a predetermined optimal value, whereas in LEACH the number of CHs would varies from round to round because of the lack of global coordination between different nodes in the network [2, 6, 7, 8, 9, 11, 12, 13, 14, 15].

5.5 C-LEACH (Cell Low Energy Adaptive Clustering Hierarchy)

In C-LEACH sensor network would divided in different sections called as cell and each cell includes several sensors. One sensor node in the cell is selected as cell head. Cluster is being formed by combing seven nearby cells, and each cell would have a cluster-head (CH). The cell-heads and CHs would change dynamically in every round of transmission of information in the network. Cell-head would allocate a time to each sensor nodes on the basis of TDM (Time Division Multiplexing), and each cell should transfer its data to the cell-head in this sliced time only. The same would apply for transferring of data from cell-head to cluster-head also. In the time of transmission of information in the network, the entire cell will remain off except the node which has been given the slice time for transmission of information to the cell-head. The cell head will aggregate the information and it send to its respective CH, and process would repeated in the CH also [4, 6, 11, 12, 15].

5.6 LEACH-E (Energy Low Energy Adaptive Clustering Hierarchy)

LEACH-E protocol would improve the CH selection process compared to LEACH protocol. The LEACH-E is divided into different round that is same as LEACH protocol. In the first round all the sensor nodes would having the same probability to be CH of the cluster. After the first round of transmission the residual energy of each node would got different and based on this, the node who would have the high residual energy would be chosen as CH of the cluster and other nodes in the cluster would became the cluster member who would having the less energy [8, 9, 11, 14, 15].

5.7 E-LEACH (Enhanced Low Energy Adaptive Clustering Hierarchy)

E-LEACH would able to improve the LEACH protocol in two main aspects of routing and transmission of information in the network. E-LEACH would choose a cluster head for the clusters in the sensor networks that having non-uniform starting energy level among all the sensor nodes. It also able to determine that the required number of cluster heads has to scale as the square root of the total number of sensor nodes to minimize the total energy consumption in the network. All the other aspects rather than these two above mentioned aspects of E-LEACH are the same as LEACH protocol [2, 6, 11, 12, 14, 15].

5.8 LEACH-F (Fixed no of cluster Low Energy Adaptive Clustering Hierarchy)

In LEACH-F clusters are formed at the beginning of the network setup and after that are being fixed. The cluster head position rotates among the nodes within the cluster that is same as LEACH. The advantage of this process compared to LEACH is that, there is no set-up overhead at the beginning of each round. For clusters formation, LEACH-F uses centralized cluster formation algorithm that is same as LEACH-C. The disadvantage of this protocol is that the fixed clusters in LEACH-F do not allow new nodes to be added to the network and do not adjust their behavior when any node dies in the network [2, 9, 11, 14, 15].

5.9 I-LEACH (Improved Low Energy Adaptive Clustering Hierarchy)

In I-LEACH protocol two main functions it serves are, a) Detection of Twin nodes and b) Assignment of Sub-Cluster Head (SCH) nodes. The two nodes closes to each other in the network are called as Twin node. These kinds of node would sense the same information. Therefore it is necessary to keep one of the two twin nodes in sleep mode until the first node would run out of energy. I-LEACH addresses the uniform distribution of CH in the network so that it does not run out of energy for longer distance of transmission. It also addresses the matter of managing the threshold no of cluster members by every CH [3, 11, 13, 14, 15].

5.10 LEACH-L (Energy Balanced Low Energy Adaptive Clustering Hierarchy)

LEACH-L is an advanced multi-hop routing protocol. It is suitable for large area covered WSNs. In this, the cluster heads can able to communicate directly to the sink node when these sensor nodes are located close to the sink. When sensor nodes are located too far from the sink, they can communicate to the process of multi-hop way. In LEACH-L, the sensor nodes are allowed to use different frequencies and also different frequency gaps to communicate to the sink node. The clusters would re-establish in every round of transmission of information in the network which consists of both setup phase and steady state phase. In every round new CHs would elect for every cluster and the network load would be distributed among every node and thus balanced among the nodes would remain perfect in the network [9, 11, 14, 15].

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

LEACH-M is been proposed to overcome from the mobility issue which is an important issue in LEACH protocol. During the setup and steady state phase, LEACH-M provides mobility to the non-CH nodes along with CH. In LEACH-M the nodes' location assumed to be gain by the GPS process along with the characteristics of the nodes to be assumed to be homogeneous. The CHs are being chooses on the basis of minimum mobility of the node and lowest attenuation mode of the node. After this process the status of the CHs are being broadcasted within its transmission range [9, 10, 11, 14, 15].

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5.12 M-LEACH (Multi-hop Low Energy Adaptive Clustering Hierarchy)

When the network diameter is increased beyond a certain level, the distance between the CHs and the sink node would get increased and this is disadvantage of the LEACH protocol. This can be overcome by the help of M-LEACH in which the CH sends the data to the sink using the other CHs as relay stations. M-LEACH is a complete distributed clustered based routing protocol. The approach can be utilized inside or outside the clusters [2, 6, 7, 8, 11, 12, 13, 14, 15].

Clustering Routing protocol	Classification	Mobility	Scalability	Self organization	Randomized Rotation	Distribution Used	Hop count	Energy Efficiency	Homogeneous	Use of location Information	Data aggregation
LEACH	Hierarchical	Fixed BS	Limited	Yes	Yes	Yes	Single Hop	High	Yes	No	Yes
A-LEACH	Hierarchical	Fixed BS	Good	Yes	Yes	Yes	Single Hop	Very High	Yes	Yes	Yes
LEACH-A	Hierarchical	Fixed BS	Good	Yes	Yes	Yes	Single Hop	Very High	No	No	Yes
LEACH-B	Hierarchical	Fixed BS	Good	Yes	Yes	Yes	Single Hop	Very High	Yes	Yes	Yes
LEACH-C	Hierarchical	Fixed BS	Very Good	Yes	Yes	No	Single Hop	Very High	Yes	Yes	Yes
C-LEACH	Hierarchical	Fixed BS	Very Good	Yes	Yes	Yes	Single Hop	Very High	Yes	Yes	Yes
LEACH-E	Hierarchical	Fixed BS	Very Good	Yes	Yes	Yes	Single Hop	Very High	No	Yes	Yes
E-LEACH	Hierarchical	Fixed BS	Good	Yes	Yes	Yes	Single Hop	Very High	Yes	Yes	Yes
LEACH-F	Hierarchical	Fixed BS	Limited	Yes	Yes	No	Single Hop	Very High	Yes	Yes	Yes
I-LEACH	Hierarchical	Fixed BS	Very Good	Yes	Yes	Yes	Single Hop	Very High	Yes	Yes	Yes
LEACH-L	Hierarchical	Fixed BS	Good	Yes	Yes	Yes	Multi Hop	Very High	Yes	Yes	Yes
LEACH-M	Hierarchical	Mobile BS and Nodes	Good	Yes	Yes	Yes	Single Hop	Very High	Yes	Yes	Yes
M-LEACH	Hierarchical	Fixed BS	Very Good	Yes	Yes	Yes	Multi Hop	Very High	Yes	Yes	Yes
LEACH-S	Hierarchical	Fixed BS	Very Good	Yes	Yes	Yes	Single Hop	Very High	Yes	No	Yes
TL-LEACH	Hierarchical	Fixed BS	Very Good	Yes	Yes	Yes	Single Hop	Very High	Yes	Yes	Yes
V-LEACH	Hierarchical	Fixed BS	Very Good	Yes	Yes	Yes	Single Hop	Very High	Yes	Yes	Yes

TABLE 1 Comparison of LEACH and advance LEACH

5.13 LEACH-S (Solar aware Centralized and Distributed Low Energy Adaptive Clustering Hierarchy)

In Centralized LEACH-S, the sink node would select the CHs with the help of improved central control algorithm. In Leach-S, the solar status along with the energy of the sensor nodes is being transmitted to the sink and the nodes with having the higher energy are selected as the CHs. When the number of solar-aware nodes is getting increased, the performance of sensor network is also get increased and by this the lifetime of the network also get increased.

In Distributed LEACH-S, the solar driven nodes are given more preference than the battery driven nodes for choosing CHs [9, 10, 11, 14, 15].

5.14 TL-LEACH (Two level Low Energy Adaptive Clustering Hierarchy)

In LEACH protocol, the CH sends the aggregated data to the sink directly. Due to this process CHs would die very early compared to the other sensor nodes due to energy loss for transmission of information to the sink because sink node may be located too far away from the CHs might be located far away from the BS. To overcome from this TL-LEACH was been proposed. In this CH collects information as LEACH protocol, but for transmission to the sink it uses one of the CHs that lies between the CH and the sink as a relay station [8, 11, 12, 14, 15].

5.15 V-LEACH (Vice Cluster level Low Energy Adaptive Clustering Hierarchy)

When a CH dies the cluster would become useless, because the information collected by the cluster members will not able to transmit to the sink. To overcome from this protocol V-LEACH was been proposed. In V-LEACH protocol, along with CH in the cluster, there is a vice-CH that comes to act as a CH when the CH dies. The other working of this protocol is same as the LEACH protocol [1, 8, 11, 12, 14, 15].

VI. COMPARISON OF EXPLORED ADVANCES LEACH PROTOCOL WITH LEACH PROTOCOL

Brief comparisons of a numbers of protocols that are the enhanced version of the conventional LEACH routing are shown in Table 1. All these hierarchical routing protocols have showed better performance than the conventional LEACH routing protocol.

VII. CONCLUSION

In Wireless Sensor Networks the main purpose of designing energy efficient routing protocol is to efficiently use the energy of the network so that the network lifetime get increased. In WSNs many energy efficient routing protocols are available now-a-days. One of the most efficient routing algorithms everyone uses is the LEACH routing protocol. In our survey period we studied briefly about LEACH protocols and we able to distinguish various disadvantages of this protocol along with its advantages. During our survey we also studied various improved version of LEACH protocol which gives various advantageous result in many ways which we are able to learn when we do the comparative study of various improve version of LEACH with the fundamental one. 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 for better result.

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