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A Survey on Secured and Energy Efficient Hierarchical Routing Based Protocols for Wireless Sensor Networks

Harish N J[1], H S Manjunatha Reddy[2]
[1]Asst. Prof., Department of ECE, VTU, Belagavi, Global Academy of Technology, Bengaluru, Karnataka, India
[2]Prof. and Head, Department of ECE, VTU, Belagavi, Global Academy of Technology, Bengaluru, Karnataka, India

ABSTRACT

Wireless Sensor Networks (WSNs) domain is one of the most emergent fields in today's smart world with plenty of applications such as defense, environment and wildlife monitoring, healthcare etc. A basic wireless sensor network is consisting of number of randomly deployed sensor nodes to collect and transmit the data to base station. Since charging and replacement of batteries is not feasible in wireless network, hence designing of energy efficient routing protocols along with better network lifetime is area of interest for researchers. Low Energy Adaptive Clustering Hierarchy (LEACH) was the basic routing protocol which was proposed around 17 years ago. This routing scheme has been further enhanced in order to optimize the network parameters as per the requirement. In this paper, we have surveyed different hierarchical routing protocols which are enhanced versions of standard LEACH algorithm. We have also presented a comparative analysis for the surveyed routing schemes. This survey paper finally makes inroads for further researches in the domain of hierarchical routing protocols for wireless sensor networks.

Keywords : Wireless Sensor Network, Hierarchical Routing, LEACH, Cluster Head, Energy Efficiency, and Network Lifetime.

I. INTRODUCTION

The domain of Wireless Sensors Networks (WSNs) is known as one of the most promptly emerging, challenging and fascinating fields in the modern era. In today's smart world, the upgrading in the arena of both micro-electronics and communication technologies is going to serve the advancement of micro devices or circuitries used in smart devices.

This advancement turns out to be a key aspect for evolution of Wireless Sensor Networks (WSNs); which are optimal in terms of energy consumption, network lifetime, cost effectiveness and high throughput. A generic Wireless Sensor Network (WSN) is a complete package of huge numbers of sensor nodes which are subjected to limited sensing, communication, computing competencies and are not only cost effective but also the energy efficient with multi-functionality. Furthermore, these sensors nodes of the designed network are going to be installed over a big area with multiple number of Base Stations (BS). Sensor nodes deployed in the area in order to design network are of several types depending upon the application such as radar, acoustic, security surveillance, infrared, temperature, humidity, visual, thermal, seismic, pressure, health monitoring etc. [1-4]. The designed Wireless Sensor Networks (WSNs) are used for several applications both military and civilian such as traffic control, battlefield surveillance, health monitoring, and tracking etc. Security of network, network lifetime, memory, energy, reliability and bandwidth are the

key parameters which need to be taken in consideration while designing the networks [5].

Wireless Sensor Networks (WSNs) have variety of constraints and characteristics. The deployment of sensor nodes in coverage area is random. However, they further organize themselves to constitute a wireless network which is going to execute the particular task. Furthermore, all the designed wireless network applications are powered using batteries hence the recharging and replacement of batteries after deployment of the sensor nodes becomes a key challenge. In addition to this, data redundancy is another constraint which brings down the efficiency of the deployed sensor nodes due to redundant data availability from neighborhood nodes in a highly dense deployed area. Moreover, security of nodes inside the network is also a serious issue. This is mainly due to unidentified topology, physical attacks occurring on idle nodes, resource limitation over the nodes, node density in region of interest and size. Hence, the selection of routing schemes becomes a significant concern in order to design wireless network with efficient energy consumption in order to obtain better network lifetime along with the efficient and secured communication.

The rest of the paper is planned as follows. Section 2 presents the different routing protocol schemes for designing wireless sensor networks. Section 3 presents the different hierarchal routing protocol schemes presented in last few years. Section 4 presents a comparison of different hierarchal routing protocol schemes discussed in section 3. Sections 5 present the conclusion of the paper.

II. DIFFERENT ROUTING SCHEMES FOR DESIGINING WSNs

Routing protocols can be broadly classified in four different schemes: Reliable Routing Scheme, Topology Based Scheme, Network Structure Scheme, and Communication Model Scheme [6]. However on the basis of the node deployment in the designed network, these network structure schemes can be further classified into two schemes: Hierarchical routing scheme and Flat routing scheme. In flat routing protocol scheme, the functionalities and key roles for the entire deployed sensor nodes are similar in the designed wireless network. Since these schemes are useful only for small area networks, the major limitation for these techniques is scalability. Negotiation based [7], Rumor [8], Directed diffusion [9], Gossiping [10] etc. are the commonly used flat routing protocol schemes.

On the other hand, hierarchical routing provides the efficiency in terms of both energy and scalability as a result of its architecture. In hierarchical routing of protocol, the entire network is going to be divided into clusters. Also based on some certain criteria, few nodes are selected as distinctive nodes. These distinctive nodes are known as cluster heads (CHs). The main tasks of these cluster heads are collection, aggregation and compression of the received data or information from the nodes which are in neighborhood to them, and finally transmission of this collected and compressed data or information to the nearby base station. Since these cluster heads are responsible for number of tasks for a particular cluster, hence they consume more energy in comparison of rest of the nodes available in that cluster. However, a general technique of cluster rotation is employed in order to balance the consumption of energy inside any cluster. A general model for hierarchical routing is as shown in Figure - 1. The very first hierarchical routing protocol scheme proposed is commonly known as Low Energy Adaptive Clustering Hierarchy (LEACH) [11].

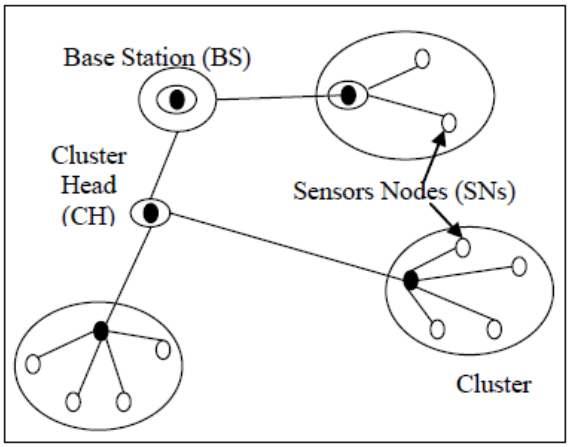

Figure 1. Basic Model of Hierarchical Routing

In basic LEACH algorithm on the basis of received signal strength, clusters are formed from the available sensor nodes. Then he available local cluster heads (CHs) are used as routers from the deployed individual sensor node to base station. Since in this type of routing only cluster heads are involved during transmission instead of all the deployed sensor nodes, hence this technique becomes efficient in terms of energy consumption. With consideration of this LEACH algorithm as basis, a variety of hierarchical routing protocol schemes have been evolved. TEEN [12], PEGASIS [13], EEMC [14], HEED [15], PANEL [16], etc. are some popular examples of hierarchical routing technique. One of the main objectives of this paper is to discuss various hierarchical routing schemes and to compare them for different parameters in order to start the research work in the same domain to evolve a new algorithm which is both energy efficient and more secured than existing algorithms.

III. 3. DIFFERENT HIERARCHICAL ROUTING SCHEMES

A. Low Energy Adaptive Clustering Hierarchy (LEACH) [11]

LEACH is the very basic and the first clustering algorithm used in wireless sensor networks in order to enhance the network lifetime. LEACH is a hierarchical clustering protocol which is self-organizing and adaptive in nature. It familiarizes the early concept of several rounds. In this type of clustering the assumption is taken as base station is stationary and located at a very distance from the deployed sensor nodes. Furthermore, it is also assumed that all the deployed sensor nodes are homogenous in nature and are having limited energy source. Here, the deployed sensor nodes communicate not only among each other but also with base station and sensing the environment at static rate. The basic idea of LEACH algorithm is to form clusters from the available deployed nodes and to allocate the energy among them for the designed wireless sensor network and further selection of a special node which is known as cluster head (CH) on the basis of a threshold value which is set for this. For selection of cluster head, each node within the cluster contributes by generating a random priority value between 0 and 1. If the generated random number of the particular deployed sensor node is less than the threshold value T(n) then that particular node will become the cluster head for that round. The threshold value T(n) is calculated using Equation 1.

$$T(n) = \begin{cases} \dfrac{p}{1 - p * \left(r \bmod \frac{1}{p}\right)} & \text{if } n \in C \\ 0 & \text{Else} \end{cases} \quad (1)$$

Where, p is the probability of any node becoming cluster head, r is the round number for current round and C is the group of nodes other than the cluster head in previous rounds (these nodes only are eligible to become cluster head for current round or future rounds). Once all the rounds are completed, the threshold value T(n) becomes unity, hence now all the deployed nodes of that cluster get eligibility to become cluster head again. LEACH is a complete distributed routing protocol in nature.

LEACH algorithm has several advantages such as enhanced network lifetime, less energy consumption

and hence energy efficient, enhanced battery lifetime due to minimized intra clusters collisions and high throughput etc. However, there are few disadvantages of using LEACH algorithm such as robustness of network is severely exaggerated and hence network lifetime is tainted when low energy node is selected as cluster head, increased intra cluster communication due to change in location of cluster head and hence resulting in more energy dissipation, etc. Also, the LEACH routing is not feasible for multi hop communication due to uneven energy dissipation among the farthest and nearest sensor nodes to base station over the cluster. Moreover, dynamic clustering becomes another extra overhead. In addition to these issues, assumptions of LEACH like initialization of nodes with same energy, static nature etc. further make inroads to enhance the LEACH algorithm.

B. Power Efficient Gathering in Sensor Information Systems (PEGASIS) [13]

PEGASIS is a sequential or chain structured hierarchical routing protocol. This is an improved version of LEACH which is having enhanced network lifetime for designed wireless sensor network. Similar to LEACH, in this algorithm first the sensor nodes are deployed randomly in the given network area. The communication is different here than standard LEACH algorithm. The deployed sensor nodes transmit the information to the other sensor nodes which is in the closest neighborhood for that particular node with proper adjustments in transmission power. The distance among the particular sensor node and the neighborhood nodes is calculated on the basis of the signal strength. In this way the entire sensor nodes are connection in a chain fashion with the extensive use of Greedy Algorithm and finally only one node will be connected to the base station which is in the closest proximity of base station. Furthermore, at random a node is selected as cluster head (CH) for completing the transmission of data or information among the sensor nodes and base station. This technique lowers not only the overhead issue but also the bandwidth problem from the base station. As a result, the individual deployed sensor node is responsible for transmission and receipt of only single packet in each round and at least once will be selected as cluster head (CH) in 'n' number of rounds where 'n' is number of nodes in designed wireless sensor network.

C. Threshold Sensitive Energy Efficient Sensor Network protocol (TEEN) [12]

TEEN hierarchical routing protocol technique is mainly designed for both to provide quick response and to sense the attributes immediately. This technique is useful in real time critical applications such as detection of explosives and trespasser. Data centric methodology along with the hierarchical approach is used extensively in order to design this routing technique. This technique is also an extension of standard LEACH algorithm. The only difference is during data transmission from cluster head (CH) to base station. In this technique instead of sending data directly from cluster head to base station, the data is sent from lower level cluster head to next level cluster head which is up in hierarchy and kept on transmitting among inter level cluster heads and finally transmitted to base station. Here instead of single threshold, two different threshold values soft threshold and hard threshold are used. The soft threshold is used to shrink the volume of transmissions whenever there is trivial or no deviation in the sensing trait. While the hard threshold is used to shrink the volume of transmissions with the permissions given to deployed sensor nodes to transmit the data only to the sensing nodes available in the range of region of interest. In addition to this, the data is accelerated from deployed sensor node in the current round only if the available sensor node is having the threshold value more than the hard threshold value along with the available sensor node threshold value being altered from the

value available in last round by an amount greater than or equal to soft threshold value.

D. Distributed Energy Efficient Clustering protocol (DEEC) [17]

In DEEC hierarchical routing protocol technique the cluster heads (CHs) are selected in different fashion. Instead of on the basis of threshold value, the cluster heads are selected on the basis of a generic probability equation. Here, the probability value is depicted as ratio of residual energy for each and individual sensor node and the average energy for the designed wireless sensor network. Hence owing to different residual and initial energy, the rotational iteration each and individual deployed sensor node is also not same. Furthermore, the cluster head selection is also solely based on the residual and initial energy if the sensor nodes. Hence, higher the residual and initial energy of the sensor node means higher the probability of becoming cluster head for that particular node. As a result, DEEC based hierarchical clustering scheme provides the enhanced network lifetime which further results in stable period. This routing technique also uses the average energy of the designed wireless sensor network as the reference energy with the extensive use of adaptive techniques in order to bear out and control all the energy expenses for the deployed sensor nodes. Consequently, this routing scheme does not have any need of any type of universal information of the energy available on the deployed sensor node after performing every selection round for cluster head. This technique further enables to design multi-level heterogeneous wireless sensor network and the data transmission over it.

E. Modified LEACH (MOD-LEACH) [18]

MOD-LEACH protocol is the enhanced and modified version of standard LEACH algorithm. Here both inter and intra cluster communication take place by using two particular types of signal amplification schemes instead of same signal amplification which is performed in standard LEACH algorithm. The high signal amplification is used for inter cluster communication and low signal amplification is used for intra cluster communication. This leads us to save a considerable sum of energy which is consumed in simple LEACH. In addition to this, in MOD-LEACH cluster head (CH) is changed. Here as soon as any round is completed, residual energy of cluster has is checked. If this residual energy is found to be less than the predefined threshold energy, cluster head is changed and new evaluation for new cluster head begins for next round. While if residual energy is found to be greater than the predefined threshold energy, cluster head is not changed for next round. Hence with this addition in algorithm, overall energy saving and better network lifetime are achieved. The key issue for this hierarchical routing algorithm is the signal amplification in two particular type of manners and furthermore their corresponding synchronization.

F. Cognitive LEACH (COG-LEACH) [19]

A spectrum sensitive COG-LEACH hierarchical routing protocol was proposed for the cognitive radio sensor network (CRSN). In this algorithm during selection of cluster head, number of idle channels is used as weight in order to evaluate the probability of each corresponding node to be selected as cluster head. The probability P_k is evaluated using Equation 2. In addition to this the total number of available channels in particular band C_t is obtained using Equation 3.

$$P_k = \min\left(N\frac{C_k}{C_t}, 1\right) \qquad (2)$$

$$C_t = \sum_{k=1}^{n} C_k \qquad (3)$$

Where, N denotes the number of cluster heads available for particular round of designed wireless sensor network. Also n represents the number of available deployed sensor nodes in the network and $C_k$represents the number of idle channels is used as weight in order to evaluate the probability in k^{th}

node. On the basis of this evaluated probability P_k, decision is made for each deployed node whether it will become as cluster head or not. Once cluster head is created rest of the technique of inter and intra communication is similar to standard LEACH algorithm. COG-LEACH hierarchical routing protocol enhances both the throughput and the network lifetime in comparison of basic LEACH algorithm. The major issue with this algorithm arises due to not caring for residual energy for individual nodes at the time of cluster head selection. This results in irregular load balancing and energy consumption issues.

G. Prediction based Cluster LEACH (P-LEACH) [20]

Prediction based cluster LEACH hierarchical clustering algorithm is advancement over LEACH in WSN by enabling the facility of dynamic or mobile base station. An empirical cluster based prediction scheme is used in order to reduce the energy consumption. This technique further activates few nodes out of available deployed nodes during the tracking of base station. For implementation of this protocol routing, the whole network area is virtually categorized into three sub areas: a Communication Quadrangle (CQ), a Partition Cluster (PC), and a basic structure with four Partition Clusters. A basic partition cluster is area which is circular in shape whose radius is given by r and having a Cluster Centre (CC) along with four numbers of Gate Nodes (GNs) and four numbers of Partition Nodes (PNs). Cluster centre is taken as the node with maximum energy and situated at the centre of the partition cluster. While all the four gate nodes and all the four partition nodes are situated at the periphery or the perimeter of the partition cluster circle. Both transmissions of data collected from deployed nodes and monitoring of mobile or dynamic base station presence is controlled by gate nodes. This protocol was found to be superior in terms of saving energy consumption and stability over basic LEACH algorithm. However, the increased message overhead and complexity due to mobility of base satiation put constrain on this routing protocol scheme.

H. Energy Efficient LEACH (EE-LEACH) [21]

Energy efficient LEACH routing protocol technique was proposed to overcome the issues of single hop communication and arbitrary method of cluster head selection in standard LEACH algorithm. In order to save considerable energy consumption, an efficient data aggregation and the most favorable cluster formation this technique proves out to be an optimistic solution. The basic theorem of conditional probability is used for achieving an efficient data aggregation and Gaussian distribution scheme is used in order to obtain the superior coverage of designed wireless network. However, residual energy of neighborhood nodes enables to form the most favorable cluster. This optimal probability which is used for selection of cluster head is found to be a function of spatial density. This further helps us to enhance the reliability during data transmission, network lifetime, throughput, and data rates. In order to perform the quality transmission from deployed nodes to base station, selection of the highest residual energy nodes is done to perform energy efficient routing. The issue with this technique is increased complexity and deficiency in terms of data integrity and scalability.

I. Vice Cluster Head LEACH (V-LEACH) [22]

Vice Cluster LEACH routing algorithm was proposed in order to overcome the issues of selection of low energy nodes as cluster head and becoming dead even before the completion of ongoing round. Here, the proposal was about the role of a vice Cluster head which comes into the picture when the originally selected cluster head is having very low energy and is dead even before the completion of ongoing round. However, the cluster head selection technique is same as before. In addition to this, the sensor node with the highest residual energy is selected as vice cluster head (VCH). Hence, in this technique there

are three different types of nodes namely the cluster head node which is responsible for receiving data from the deployed nodes within cluster, vice cluster head node which is acting as cluster head once the cluster head is dead and the remaining deployed cluster nodes which are going to sense the data from surroundings. Since in this technique there are two cluster heads available, hence this enables a more successful data transmission. The issue in this scheme arises due to extra cluster head and single hope communication which result in increased complexity and scalability.

J. Cross Layer LEACH (CL-LEACH) [23]

In order to improve the network lifetime, cross layer LEACH hierarchical routing algorithm was proposed with manipulation of cross layer techniques. There are four basic steps involved in this technique namely

- ✓ Formation of cluster
- ✓ Establish the routing for communication
- ✓ Perform the Cross Layer Leach algorithm
- ✓ Maintenance of the routing

During formation of cluster, first the cluster heads are selected among the deployed nodes within the cluster. Selection of cluster head is done on the basis of their distance from the base station and residual energy. In second step of routing the process is performed in two steps. First the routes are discovered and then the distance is calculated for them. The distance is calculated with the help of standard distance formula from mathematics of coordinate geometry. In this scheme threshold value and residual energy for the deployed node is input. For multi hop communication the relay node is configured, which is defined as the node which is having its residual energy greater than the threshold value. Maintenance of routing discovers the damaged links in addition to both source and destination nodes. These broken paths are replaced by other available new paths in available routing in order to provide maintenance to them. This scheme proves out to be energy efficient and with better network lifetime in comparison to standard LEACH algorithm. Complexity and message overheads are two major concerns of this scheme.

K. Orphan LEACH (O-LEACH) [24]

Orphan LEACH hierarchical routing scheme was proposed to facilitate greater connectivity rate while covering the vast area of wireless network. In this scheme, the nodes which are not under regulation of any cluster head are named as orphan nodes. This routing scheme is discussed for two different types of situations. In first case, orphan nodes within a cluster are regulated and find a gateway using one of the deployed nodes within the same cluster. Gateway node is joined by the corresponding orphan nodes and their data is sent to this gateway. Furthermore, this data is aggregated and sent to base station similar to cluster head via single hop communication. However in second case, orphan nodes are defined as the nodes which are existing inside any uncovered region of wireless network. Furthermore, these nodes are going to form another cluster and a cluster head is selected inside this cluster only on the basis of the minimal distance to the available gateway nodes. Next, the selected cluster head collects the data from the nodes available in this cluster and transmits to gateway nodes after aggregation. This routing scheme enables superior connectivity rate, energy efficiency, scalability and better coverage area in comparison to standard LEACH algorithm. The major issue for this technique was to locate the orphan nodes and collecting their information. In addition to this, control overhead and delayed data delivery also put more constraint on this scheme.

L. Medium Access Control LEACH (MAC- LEACH) [25]

There were different versions of LEACH algorithms available. But most of these were found to be using random, dynamic and distributed techniques for clustering. These techniques do not provide the ideal

number of clusters within the network. Medium Access Control based LEACH hierarchical routing algorithm puts a restriction over number of cluster heads getting selected under advertisement in order to alleviate the issue of randomness. Hence, the ideal numbers of cluster heads are obtained. During the selection of cluster head, a dynamic cluster head group variable is going to be initialized with zero value and is added with unity if it is able to receive the message of cluster head advertisement. If the value of this dynamic cluster head group variable is found to be less than the ideal number of clusters, it is declared as cluster head and it transmits a cluster head advertisement else it will be considered as an ordinary node. This routing protocol provide better network lifetime in comparison of standard LEACH. Complexity and message overheads are two major concerns of this scheme.

M. Dual-hop Layered LEACH (DL- LEACH) [26]

Dual-hop Layered LEACH hierarchical routing scheme overcomes the issue of dual-hop transmission with the use of two layers during multi-hop scheme for standard LEACH algorithm. The nodes are segregated on the basis of distance. Hence the nodes which are situated near to base station are considered in lower layer. The selection of cluster head is completed similar to standard LEACH algorithm. However on energy consumption basis, the network can be categorized into various layers. During transmission cycle, the distance from cluster head to base station is compared for nodes available in lower layer. If this distance is found to be smaller than the distance of cluster head, they directly communicate to base station else the data is communicated via cluster head. However for the nodes situated at very far distance, the communication is carried out through cluster head, then cluster head to relay nodes or to base station. This technique saves a lot of energy consumption rather than standard LEACH. The only issue with this technique is inferior node lifetime.

N. Energy Harvested Aware LEACH (EHA-LEACH) [27]

Energy Harvested Aware LEACH hierarchical routing algorithm uses energy harvested nodes in order to enhance the performance of standard LEACH. In this scheme, optimization techniques were employed. The objective function was to maximize the minimum conserved energy for every deployed node in wireless network. Hence, this scheme is based on solving a ma-min scenario. The selection of cluster head is done on the basis of both energy consumption and energy harvesting capacity. Hence any node which is having the lowest energy consumption and the highest energy harvesting capacity is having the highest probability of becoming the cluster head. This provides an enhancement over the standard LEACH algorithm. Since this technique uses the feature of energy harvesting nodes and due to rate of energy consumption, Energy Harvested Aware LEACH dominates over standard LEACH in terms of all the aspects such as network lifetime and energy consumption etc. The only issues with this scheme are complexity and higher cost of design.

IV. COMPARISON OF DIFFERENT HIERARCHICAL ROUTING SCHEMES

Table-I presents a comparative analysis of various versions of LEACH discussed and surveyed in this paper. The basic idea for selection of cluster head and functionality for these protocols along with their pros and cons are listed in this table. They are arranged in chronological order in this table. The selection of protocol depends on the choice of network performance parameters such as cluster formation, selection of cluster head, cost effectiveness, scalability, network lifetime, throughput, mobility, energy efficiency, complexity etc.

V. CONCLUSION

This paper has presented a widespread and up to date survey on hierarchical routing schemes with different version of LEACH too. Since, consumption of energy is the most challenging issue during the wireless sensor network designs and specially routing protocols. Moreover, the aliveness of deployed sensor nodes i.e. network lifetime is also equally significant. It is also necessary to check the feasibilities of both single hop and multi hop transmissions along with both homogeneous and heterogeneous environment. In addition to this, the selection criterion for cluster head is also responsible for quality of network parameters. The summarized table presented in section 4 covers the description along with the pros and cons for various routing schemes. The increased energy efficiency and enhanced network lifetime creates the issues like increased complexity, overhead and cost.

Another major issue with wireless sensor networks is security as they are used in defense and hostile situations. But the wireless networks designed especially from security perspective were found to have very high energy consumption and poor lifetime. Hence, this trade-off puts a challenge for researchers in order to improve both energy efficiency and security simultaneously. This survey paper is done to understand the various network parameters for existing routing protocols and to make the path for research in same domain to design a routing protocol which is both energy efficient and having good network lifetime along with the security.

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Table 1. Comparison of Different Hierarchical Routing Schemes

Routing Scheme	Description	Advantages	Disadvantages
LEACH [11]	CH selection is done using threshold based probability. Single hope communication and used for homogeneous networks.	Delay is less Low complexity Cost effective	Poor scalability Not energy efficient Moderated stability and load balancing Poor lifetime
PEGASIS [13]	CH selection is done randomly. Single hope communication with multi level hierarchy and used for homogeneous networks.	Good lifetime Moderated energy efficiency	Delay is large Low stability High complexity Moderated load balancing
TEEN [12]	Data is sent from lower level cluster head to next level cluster head. Works on soft and hard threshold.	Very good lifetime Energy efficiency is good High stability	High complexity Poor scalability Calculation of dual threshold
DEEC [17]	Custer head is selected by ratio of residual and average energy. Works in multi level heterogeneous networks.	High stability Better lifetime Lower complexity	Moderated energy efficiency Advanced nodes die rapidly
MOD-LEACH [18]	Both inter and intra cluster communication take place by using two particular types of signal amplification	Low overhead Energy efficiency is better Good load balance	High complexity Different signal amplification and synchronization
COG-LEACH [19]	During selection of cluster head, number of idle channels is used as weight to evaluate the probability	Better lifetime High throughput High scalability	High complexity Bad load balancing Energy efficiency is low
P-LEACH [20]	Cluster centre is taken as the node with maximum energy. Empirical prediction based clustering scheme.	Energy efficiency is very high Better lifetime Superior stability	Extremely high overhead and complexity
EE-LEACH [21]	Conditional probability and use of Gaussian distribution scheme. Spatial density is useful for CH selection.	Energy efficiency is good Better lifetime High data rates	High overhead and complexity Low data integrity
V-LEACH [22]	Vice cluster head selection	Energy efficiency is	Low scalability

	along with cluster head. If cluster head is dead VCH acts as CH.	very high Good load balance	High overhead and complexity
CL-LEACH [23]	Threshold value and residual energy for the deployed node is input. Uses relay nodes.	Energy efficiency is very high Good load balance Better lifetime	High overhead and complexity Poor data rates Less throughput
O-LEACH [24]	Nodes which are not under regulation of any cluster head are named as orphan nodes.	Energy efficiency is very high Good load balance Better coverage	High overhead and complexity Less throughput
MAC-LEACH [25]	Puts a restriction over number of cluster heads getting selected under CH advertisement.	Energy efficiency is very high Good load balance High throughput	High overhead and complexity
DL-LEACH [26]	Nodes are segregated on the basis of distance. Direct communication between nodes and gateway if less distance without CH.	Less complexity and moderated overhead Good load balance	Moderated data rates Inferior network lifetime
EHA-LEACH [27]	Maximizing the minimum conserved energy. CH Selection is based on energy consumption and energy harvesting capacity.	Energy efficiency is very high Good load balance High throughput	Very high overhead and complexity Higher cost