LEACH and its Improved Versions

Rekha Rani[1], Harmaninderjit Singh[2]
[1]*Research Scholar,* [2]*Assistant Professor*
Department of Computer Science, Desh Bhagat University, Mandi Gobindgarh, India.

Abstract **-** Wireless sensor network is a vastly growing technology that is being used in various fields application like Health checking, Vehicular movement, military, space, etc… for sensing and transmitting data. Wireless sensor networks (WSNs) consist of sensor nodes. These sensor nodes are powered by small battery to communicate with each other. The life time of WSN can be improved with efficient use of energy. So an energy efficient routing protocol is the major concern infield of wireless sensor network. The main reason for the development of various routing protocol is wide use of WSN. LEACH is a well known hierarchical routing protocol based on cluster, along with number of advantages it also has several disadvantage about short network lifetime because of the inefficient energy consumption. In this survey paper we present some energy efficient hierarchal routing protocols, developed from conventional LEACH routing protocol. The objective of this paper is to provide brief detail of some LEACH improved versions.

Keywords **-** WSN, integrity, security, confidentiality, watermarking

I. INTRODUCTION

Sensing technology has many major components which are on the developing stage and are being used in various fields in the human world. The quick growth of technology developed a new class of distributed system known as wireless sensor network [1]. Wireless sensor network consist of thousands of nodes which are less expensive, have low processing power and multifunctioning sensor like such as seismic, low sampling rate magnetic, thermal, visual, infrared, acoustic and radar for sensing the data of environment with parameters like heat, pressure . These sensors have ability to sense the data, compute that data and then send data to base station for further process. [2, 3, 4]. These sensor nodes are having less hardware configuration like small processing power, small battery and memory [1]. Due to its small size these nodes are very cheap. In wireless sensor network battery is a single source of energy but replacement and recharging of these batteries are not possible. For handle this limitation number of routing protocol can be used. These protocols are divided into three categories [5]:-

i). Flat-based routing: All the nodes in this topology have assigned the same function to perform the sensing task.

ii). Hierarchical-based routing: In this architecture, higher energy nodes process and send the information, while low-energy nodes perform sensing in the proximity of the target.

iii). Location-based routing: Position of sensor nodes in the Wireless Sensor Network is decided the routing path for the data accordingly.

Hierarchical routing protocol is best in all which provide more energy efficiency as compare to other protocols[6][7][8]. It is a cluster based protocol which control energy consumption by decreasing the redundancy of data and performs data gathering process which decreases the network overhead and control unnecessary transmission. It divide whole the network in clusters and in every cluster a node elected as a cluster head which perform some special task in the network.

Following are advantages of a cluster based WSN[9].

- decreasing energy consumption considerably
- conserves communication bandwidth
- and improves the overall scalability of network

Leach is first hierarchical cluster based protocol. In this paper our focus on hierarchical routing protocol based LEACH and its variants. The rest of the paper is organized as follows. In section II we will discuss about LEACH protocol. Section III will discuss the protocols based on the leach. In section IV these protocols will be compared.

II. LEACH PROTOCOL

LEACH is the primary and most popular energy-efficient hierarchical clustering algorithm for WSNs which was proposed in order to reduce the power consumption. In LEACH, the task of clustering is rotated among the nodes, based on period. Direct communication allowed by each cluster head (CH) to broadcast the data to the base station (BS). It makes the use of clusters to extend the life of the wireless sensor network. LEACH is relied on an aggregation method that joins or aggregates the unique data into a small size data which have only important information to all individual sensors. LEACH divides a network into numerous clusters of sensors, which are building by using localized management and control not only to lessen the amount of data that are broadcasted to the sink, but also to create routing and data dissemination more scalable and vigorous. LEACH make use of a randomize rotation of CH that have high-energy position instead of selecting in still manner, as to provide a chance to all sensors to act as CHs and keep away from the battery reduction of an individual sensor and turned off quickly.

The function of LEACH is divided into rounds consists of two phases each namely a setup phase: In the set-up stage [15], a random number the sensor nodes produce a number between 0 and 1 arbitrarily. Compared with T(n), the node will be chosen as cluster head if the produced number is less than the threshold. The cluster head node communicates

data to nearby nodes, and the others pick the cluster to join according to the intension of the broadcast data. At that point, the cluster head utilize the approach of TDMA to disperse the time period of data transmission for members.

$$T(n)=\begin{cases}\dfrac{P}{1-P*(r \bmod \frac{1}{P})} & if\ n\in G\\ 0 & if\ n\notin G\end{cases} \quad \text{(i)}$$

Steady-state: phase for aggregation of data, firmness, and transmission to the sink[mine]

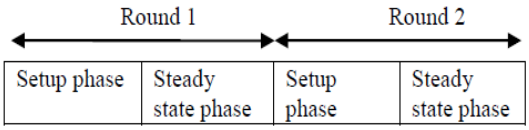

Fig.1 LEACH Phases: Setup and Steady State Phase

LEACH is totally distributed and needs no worldwide knowledge of network. It lessens energy consumption by

a) Decreasing the communication cost among sensors and their cluster heads and
b) Switching off non-head nodes as much as possible.

LEACH offers single-hop routing where each node can broadcast directly to the cluster-head and the sink. Thus, it is not valid to networks organized in large regions. In addition, the idea of lively clustering brings extra operating cost, e.g. head changes, advertisements etc., that may reduce the gain in energy utilization. Whereas LEACH assists the sensors inside their cluster disperse their energy slowly, the CHs guzzle a large portion of energy when they are placed farther away from the sink. Also, LEACH clustering finishes in a limited number of iterations, but does not give assurance good CH distribution and presumes identical energy consumption for CHs. Wireless sensor nodes recognize data and send it straightforwardly to the base station or they execute a clustering procedure as in LEACH. LEACH is known for cluster structure which consists of cluster members recognizing the data and the cluster head which accumulate the data collected in a fused manner (all the data is sent as a single packet) to the base station.

In LEACH protocol, the process is divided into fixed number of rounds, in this process each round starts with a setup phase and end with a steady-state phase. The period of a round is determined on the bases of priorityi. LEACH algorithm operate as follows:[10]

Advertisement phase: Here in this mode, nodes vote for themselves to be a cluster-heads for the present round (r) all the way through a cluster-head advertisement message. For doing cluster-head advertisement, the cluster heads make use of CSMA MAC protocol. After the achievement of this phase, and depending on the accepted advertisement signal force; the non cluster-head nodes decide the cluster to which they will fit in to for this current round (r). At every step, a node n chooses a random number k that is anything between 0 and 1.

Cluster set-up phase: Now it's time to decide for each non-cluster-head node to which cluster it belongs, it tells the cluster-head node that it will be a part of the cluster. Therefore, each node sends this information back to the cluster head using CSMA MAC protocol.

Programmed formation phase: The cluster-head node accepts all the messages for nodes that would like to be incorporated in the cluster. Based on the number of nodes in the group, the cluster-head node generates a TDMA schedule which tells each node when it can send out. This schedule is transmitting back to the nodes in the cluster.

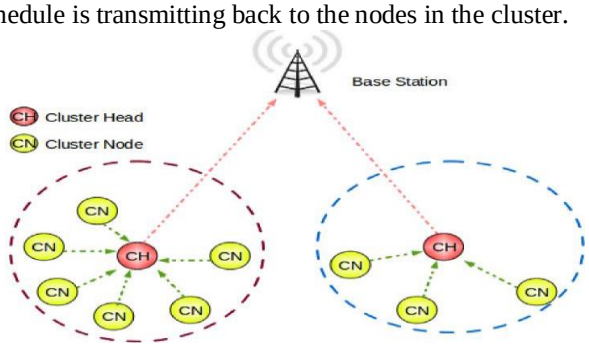

Figure 2: Depiction of Leach Protocol. Adapted from [11]

Data Transmission phase: After the formation of both the clusters and the TDMA schedule nodes in the group initiate transmitting the data they by now have during their allotted transmission time to the cluster-head. After sending all the data that have been accepted by the cluster-head node, it will execute signal processing function to reduce the data into a single signal.[10]

Advantages of LEACH Protocol - There are various advantages that the LEACH protocols possess which are as follows [12,13]:-

- It supplies with scalability in the network with the help of limiting most of the communication within the different clusters of the network.
- The head of the cluster collects or mingles the information that is been composed by the sensor nodes and this facilitates in to bound high amount of traffic generated inside the network. With this, a large-scalable network with no traffic surplus can be organized and by this also improved energy efficient network topology can be attained as compared to the flat-topology.
- Single-hop routing is probable from sensor node to head of cluster, and by this means we can able to accumulate the energy of the network.
- Property of distributing within the cluster, where it allocates the role of CH to the other cluster parts inside the cluster.
- It amplifies the lifetime of network in three stages. First, it dispenses the role of CH (that uses more energy than usual sensor nodes) to the additional nodes in the cluster. Secondly, it collects the recognized data by the CHs. Finally, by the method of TDMA, places most of the sensor nodes in the nap mode. This is done particularly in event-based applications only. With this, it is able to enlarge the network life span and also able to attain a more than 7 fold lessening of energy indulgence compared to direct communication.

- It does not need the data of location of the sensor nodes in the network to generate the clusters. Thus it is very influential routing protocol and it is very much simple also.

Disadvantages of LEACH Protocol - There are various disadvantages of the LEACH protocols too that are as follows [14,15]:-

- It appreciably believes on cluster heads instead of cluster members of the cluster for conversing to the sink. Due to this it acquires sturdiness concerns like breakdown of the cluster heads.
- It acquires additional fixed cost because of the process of cluster head modifies in each iterations of the communication of data provided. It also incurs operating cost due to computations which guides to the energy incompetence for dynamic clustering in large level networks.
- There is no communication among inter-cluster in the network since CHs directly converse with sink. This process needs high range of transmission power in the system. For this only, LEACH is not best suitable for large- scale networks that detains require single hop conversion with sink.
- In LEACH CHs are not consistently distributed inside the cluster that means CHs can be positioned at the borders of the cluster.
- In LEACH, choosing cluster head is random process that does not require energy consumption of the different nodes inside the cluster along with Cluster Head into account and these guides to re choosing of CH as the same node in much concurrent iteration of data dealing out in the network.
- It does not suit for the applications that need large area reporting along with multi-hop inter-cluster conversion.

III. VARIANTS OF LEACH PROTOCOL

Alongside the various points of interest LEACH has a few disadvantages in wireless sensor network because of limited energy capacity of nodes. along these lines the LEACH protocol was suggested that has improved energy effectiveness issue up to much enormous level. To enhance this issue some different researchers have additionally proposed the variations of LEACH protocol to encourage the performance of LEACH. Following are the a few variants of LEACH purposed by different researcher.

SLEACH (Security based LEACH) - SLEACH [16] is first protocol which added security features using SPINS protocol [17] in LEACH. This protocol uses lightweight cryptographic techniques for WSN. In WSN, providing security with the cryptographic method is a challenging task due to the limited the resources of sensor nodes. In WSN, sensor nodes have high security threats from insiders as well as outsiders. This protocol provides security only from outsiders' attacks and assumes the BS is trusted. The authors have added two important Security features to LEACH: data authentication and data freshness. In data authentication, the recipient of the message can authenticate its originator. This protocol is simple but very effective for network lifetime improvement due to its cluster maintenance and choosing the minimum distance for inter cluster communication. The main problems that needed to be improved in this protocol are finding the certain number of failed nodes in each cluster and control overheads.

LEACH-CE (LEACH-Centralized Efficient) - LEACH-CE [18], a centralized algorithm, is a modified version of LEACH-C protocol, which minimizes the problem of LEACH-C [19]. But LEACH-C protocol does not sure about the balance of energy consumption during the time of CHs selection. At the time of cluster formation, the BS choose the final CH by selecting the node which has maximum energy among the initial CHs. When CHs are elected for all the cluster, the Base station sends this information to the network. The steady state phase of LEACH-CE is similar to LEACH. The performance of LEACH-CE protocol is better than LEACH and LEACH- C protocol. Since location information is not considered in the CH selection, it results in uneven energy consumption and increases intra cluster communication cost.

LEACH-GA - LEACH-GA for Wireless Sensor Networks is purposed by Liu et.al, [20] about adaptive clustering protocol to expand the life time of sensor network dependent on having an optimal probability processing to accomplish a high level performance. LEACH-GA has both stages like LEACH, set-up and steady-state for each round in the protocol and preparation phase before starting the first round. In preparation phase, all the nodes perform CH choosing procedure and afterward send their information with the conformation of a candidate is a CH or a Cluster member, and give the physical positions and node-id to the base station. CH needs more energy as compare to cluster member then after receiving the messages from all sensor nodes, the base station select the CH dependent on node probability being CHs by utilizing a genetic algorithm for decreasing the aggregate utilization of energy required for doing each round process in the sensor region. Every one of the procedures of this protocol is same as LEACH. In simulation they demonstrate that the proposed LEACH-GA protocol productively creates efficient energy usage for the wireless sensor systems, and it results in an extension of lifespan for the network. In LEACH-GA use of the optimal probability gives up optimal energy-effective clustering.

A-LEACH (Armor-LEACH) - To resolve the energy efficiency problem of Security- LEACH, Abuhelaleh et al. [21] proposed a new secure protocol by adding the features of Security- LEACH and Time-Controlled Clustering Algorithm (TCCA) [22] named Armor- LEACH which is more secure and energy efficient as compare to LEACH. The initial keys and the distribution of IDs in the network after deployment is the same as [23]. Here, CH selection is also based on random number generation between 0 and 1 but the threshold T(n) calculation is different. Estart is the initial energy of each sensor, Eresidual.i is residual energy of node i, α is a constant and δ is the time duration for CH selection. In the second phase, a backbone tree is

constructed with the help of an energy-aware virtual backbone tree (EAVT) [24] by selecting some non-CH nodes. After the selection of EVAT nodes, the third phase starts where each CH selects its closest EVAT node as a relay node towards the BS. Cluster member Head nodes select a Cluster Head as a organizer and intra cluster communication tree are created. Finally, the data communication phase starts, where each sensor node transmits its data to the CH and sends aggregated data to the parent (root) node of the EVAT tree. This protocol uses the communication channels more efficiently and increases the lifetime of large scale networks. The drawbacks of this protocol are overhead due to tree construction and finding EVAT nodes and transmission delay.

Sec-LEACH (Security-LEACH) - Sec-LEACH [23] is a security-based LEACH protocol which mainly protects the network with many kind of attacks like sinkhole and selective forwarding attacks. At the deployment, a large number of key pools and their IDs are generated by Sec-LEACH. In pseudo-random fashion, a ring of key pools is assigned to each node with pair-wise key shared with the BS. The CH selection is similar to LEACH and selected CHs broadcast their IDs and a nonce. After the computation of CHs IDs by the other sensor nodes, they select the nearest CH and send a join request message. Cluster head transfer a TDMA schedule to their cluster members. The communication between sensors and the CH are protected by a same shared key used in the join request message generated by MAC. A value processed from the nonce is use to prevents the react including reporting cycle. The CH aggregates the decrypted message and sends it to the BS using a symmetric key shared with the BS for protection from attacks.

ME-LEACH (More Energy Efficient-LEACH) - Chen and Shen[25] extended LEACH by minimizing the communication distances among sensor nodes. They named their proposal ME-LEACH. They proposed this scheme to balance the load of sensor nodes. Thus, it become more energy efficient as compare to LEACH protocol. However, it also supports single hop communication between any nodes and the BS like LEACH. In large scale networks, this will not be feasible due to higher cost and powerful radio. So, authors further ex- tended the work to accommodate large scale net- works and named it ME-LEACH-L [26]. It tackles two major problems of previous works: channel allotment to neighbour clusters and cooperation between clusters during data collection. Each round of ME-LEACH comprises four sequential phases. In first phase, CH selection is done on the basis of a timer Ti and it is calculated with the help of Equation 7.interval win the competition to become the CH. To get the specified constant value of CHs, there is a counter. Each node generates a random number at the beginning of a round. When the timer expires, nodes check their advertisement message; if it is less than the constant value of CHs, that node announce itself as a CH and broadcasts a CH advertisement message for all cluster members by using a CDMA MAC protocol. After the selection of the CH the rest of the process is similar to LEACH. It is a totally distributed algorithm because it does not require global information for cluster formation. It provides a significant amount of improvement in energy consumption to form a constant number of clusters compared to LEACH. The authors experimentally proved that it provides longer lifetime of the network compared to LEACH. Due to direct communication between the Cluster Head and the Base Station, it is not appropriate for big networks.

TB-LEACH (Time Based-LEACH) - Junping et al. [27] presented a time based LEACH to overcome the problems of LEACH. In this protocol, the CH is selected on a time interval based threshold. The nodes which have the shortest time Where, p is the desired percentage of CHs, Tmin is the minimum threshold to avoid the remaining energy shortage, RE and Emax are residual energy and maximum energy of the network respectively. After the selection of the CH, it broadcasts an advertisement message containing CH-ID, Time to live (TTL), timestamp, nonce, remaining energy, and the advertisement message to its neighbors. Each sensor nodes replies to the CH with a request message containing sensor ID, CH-ID, join request message, original advertisement message timestamp, the remaining TTL value and sharing key ID when it receives the advertisement message. The nodes also send the encryption of sensor ID, CH-ID, sharing key ID and the nonce sent by CH to produce the message authentication code. Timestamp helps the CH to estimate the approximate distance of member nodes which helps in multi-hop data transmission. In transmission phase, each sensor sends a report message to its CH in a time slot allotted by the CH. The report message contains sensor ID, CH-ID, sensor report; the encryption of sensor ID, CH-ID, sensor report; and the nonce with its reporting cycle within the current round. The CH sends an aggregated report message to the BS containing CH-ID, BS-ID, aggregation reports of sensors, encrypted aggregation report and sharing key between the CH and the BS. In Armor-LEACH, Sec-LEACH provides a high level of security against several attacks and TCCA provides less energy consumption in the network. It protects from spoofing, jamming, replay attacks, sinkhole and selective forwarding attacks. Simulation results confirm that this protocol is give three time better result than LEACH and Sec-LEACH in terms of energy utilization and high intensity of performance. The main demerits of this protocol are bandwidth wastage due to the large number of control packets exchanged and message overhead.

T-LEACH (Threshold-LEACH) - Hong et al. in [28] have proposed a clustering protocol for replacement of the CH in WSN based on threshold energy of the sensor nodes called T-LEACH. In most of the existing protocols, the CH changes in every round, resulting in a significant amount of energy consumption as the current CHs will select the next round of new CHs in their cluster based on location information and residual energy. LEACH-H routing protocol ensures a more even distribution of CH

than LEACH and LEACH-C routing protocol. Amalgamation of the characteristics of LEACH and LEACH-C protocol gives a better solution in terms of lifetime. LEACH- H is the appropriate solution for the large scale WSN. This protocol suffers from large overhead due to the selection of a new CHs list by current CH.

ALEACH (Advanced-LEACH) - In ALEACH [29], a new technique for CH selection in every round is proposed. The technique for selection of CH depends on two terms: current state probability (CSp) and general probability (ttp). T-LEACH minimizes the CH selection and replacement process using a threshold energy scheme. In this protocol, CHs are fixed for some rounds. When the residual energy of a CH becomes lower than the threshold energy, a new CH selection process is started. It enhances the lifetime of the network by using threshold energy for changing the CH. It suffers from uneven energy consumption. The calculation of threshold energy for CH change is not clearly defined by the authors.

LEACH-H (LEACH-Hybrid) - In order to enhance the network lifetime, Wang et al. [30] exploited the advantage of LEACH and LEACH-C algorithms and proposed a new protocol named LEACH-H. LEACH-H protocol solves one main difficulty of LEACH, where the undecided number of Cluster Heads is chosen in each round. In this protocol, the number of CHs is fixed for each round. In the first round, the BS determines the optimal number of CHs set and forms the optimal cluster with the help of a Simulated Annealing algorithm. In this protocol, the selection of CHs is an iterative process. Since the CH nodes are chosen as the most appropriate nodes in terms of their current state and general probability, the network lifetime of the sensor nodes is better compared to LEACH. This protocol follows the direct communication between the CH and the BS, so it is not suitable for large scale networks.

LEACH-FL - LEACH-FL protocol takes three variables battery level, distance and node density into consideration. As LEACH protocol only depend on probability form, few CHs may be extremely near to each other and can be locate in the boundary of the WSN. These inefficient CHs could not maximize energy efficiency. A CH selection method using fuzzy logic has been introduced to overcome the defects of LEACH. In this the network lifespan can be capably long-lasting by using fuzzy variables : concentration , energy and centrality. In this approach a part of energy is spent to get the data of the three variables especially concentration and centrality [31]

Q-LEACH (Quadrant Cluster based LEACH) - Q-LEACH [32] is a quadrant-based routing protocol which combines the characteristics of Q-DIR [52] routing techniques and LEACH protocol. Q-DIR routing is the integration of location-based routing and restricted flooding. The coverage area is divided into four quadrants, and in each quadrant clusters are formed. 100m x 100m area is divided in to 4 sub networks as given in equation 1, 2 and 3[33].

$$A = a_1 + a_2 + a_3 + a_4 \quad (1)$$

$$a_n = A(X_m, Y_m) \text{ where } n=4 \text{ and } m=10 \quad (2)$$

$$\lim a_{n\,X_{m=0:50}}^{Y_{m=0:50}} + \lim a_{n\,X_{m=51:100}}^{Y_{m=0:50}} + \lim a_{n\,X_{m=0:50}}^{Y_{m=51:100}} + \lim a_{n\,X_{m=51:100}}^{Y_{m=51:100}} \quad (3)$$

The CHs of each cluster communicate with each other using route request packets (RREQ) and also determine the shortest routes between source and destination. This protocol enhanced the network lifetime but increased delay and congestion in the WSN.

In Q-LEACH, CHs are not selected on the basis of residual energy and the CH changes in every round. This limitation is further improved by a new protocol, namely Enhanced Q-LEACH [53]. It uses threshold residual energy for the CH changes. In this protocol, the CH does not change in every round. If the residual energy of the CH is less than threshold residual energy, it starts the process of new CH selection. One more protocol, Quadrature LEACH [34], published by Manzoor et al., used a similar approach Q-LEACH of splitting the entire sensing region into four quadrants. For a better coverage area of the entire sensor network, Q-LEACH uses such a partition. Each sensor node in the sensor network transmits its location information to the BS. Based on it, the BS partitions the entire network into four quadrants (a1, a2, a3 and a4) in such a way that each quadrant has an optimal number of sensor nodes for better coverage. In division, some nodes are selected as the CH on the basis of threshold. In LEACH, formation of the CH is dynamic and if member nodes are far from the CH, then more energy will dissipate. Whereas in Q-LEACH protocol clustering is performed within each quadrant and sensor nodes join the CH based on RSSI.

Q-LEACH increases the network lifespan and the constancy period of the wireless sensor network by evenly distribute energy among the sensor nodes.

U-LEACH (Unequal Clustering-LEACH) - Ren et al. [35] have proposed an unequal LEACH clustering scheme for reducing the hotspot problem in single hop communication like LEACH. In sin- gle hop clustering all CH transmit their aggregated data to the BS directly; due to this CHs distant from the BS consume more energy compared to nearer CHs. Energy consumption of the transceiver is directly proportional to distance. In this protocol, authors considered unequal sizes of concentric circles as a cluster. The size of the cluster decreases as we go far from the BS. In the CH selection phase, they have considered some extra parameters like weight factor, residual energy and distance with classical LEACH threshold function T (n). This protocol improves the network lifetime and balanced the energy but suffers from intra cluster communication in clusters near the BS.

LEACH-B (LEACH-Balanced) - LEACH-B protocol [36] resolves the issue ofvalue of r is less than T (s), based on a probability value psat, then the node is selected as CCH. In LEACH-B protocol, the value of psat is set as 0.5. After the selection of initial CCH, all nodes send their

status messages containing their node-id, location information and CCD information. Based on this information, the BS finds the optimal probability Popt for formation of optimal clusters Kopt with the help of GA. The GA searches the solution space to determine the Popt using an evolutionary optimization process including probabilistic transitions and non-deterministic rules with crossover and mutation operators. After selecting Popt using Equation 15 the BS broadcasts the value of Popt to all sensor nodes n. The set up and steady state phases are the same as in LEACH. It uses the concept of the second selection of CH for modifying the CH at set-up phase in each round. After deciding the desired percentage of sensor nodes to become the CH, LEACH-B proposes another competition for CH selection. According to LEACH-B, CHs in each round should be a constant number N P , where P is the desired percentage of CHs and N is the number of sensor nodes. In this protocol, first CHs are selected randomly based on LEACH protocol, then each CH broadcasts its status and residual energy to each sensor node. Now there are two possibilities. First, if the number of randomly selected CHs is less than N P , then some normal nodes with less time interval are selected as CHs into a CH set and these selected CHs broadcast their CH status to the network. The time interval is calculated by t = K/E where E represents residual energy of an individual sensor node and K is a constant factor. Second, if randomly selected CHs are more than N P , then exclude some CHs with low energy to maintain the CH set equal to N P . To achieve this, all the CHs are arranged in descending order based on their residual energy.

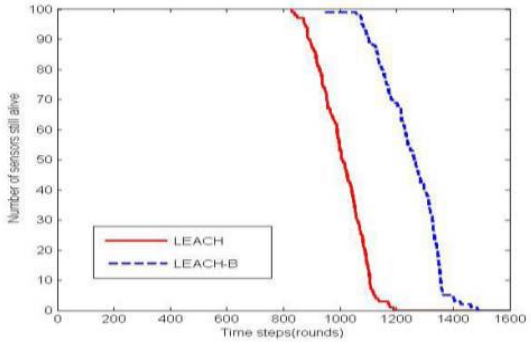

Figure 3: System lifetime using LEACH and LEACH-B [37]

The CHs that are ranked lower than N P convert into normal nodes. LEACH-B is a distributed protocol, which improves the energy-load balance problem of the cluster and reduces the energy consumption of sensor nodes in WSN compared to LEACH. The message overhead, scalability and complexity are the main demerits of this protocol.

W-LEACH (Weighted-LEACH) - W-LEACH [38] is a new data aggregation algorithm presented by Abdulsalem et al. for WSNs that can handle uniform and non-uniform networks.

FT-LEACH (Fault Tolerance LEACH) and IB-LEACH (Intra Balance LEACH) - Fault tolerance is an important issue which negatively affects the performance of LEACH and its variants [39]. To reduce the fault tolerance issue in LEACH, Cheraghlou et al. [40] have proposed a fault tolerance LEACH called FT-LEACH. The main improvement of FT-LEACH considered as each sensor node send its remaining energy as a packet header to the cluster head, members of cluster does not send same data in two repeated rounds to the CH. Hence, CHs are always aware of falsified nodes and living nodes, and not send duplicate data to saves a significant amount of energy. LEACH follows only global re-clustering but FT-LEACH uses both a Local and global re-clustering mechanism based on the CH's energy. Re-clustering reduces the network partition in every round which minimizes energy consumption. On the basis of the energy value sent by the sensor nodes to the CH and the CH to the sink, this protocol detects the fault. If a cluster member is faulty, then it can be traced back to its energy and remaining energy. By deleting this node from the cluster, the network minimizes the energy gap between the CH and cluster members of LEACH called intra-balanced LEACH (IB-LEACH) Salim et al. [41]. The main objective of IB-LEACH is to minimise intra cluster communication costs and reduce the load of CH by separating the process among the head and members. The process of IB-LEACH protocol consists of several rounds and each round is split into three phases: set-up, pre-steady and the steady state. The set-up phase is similar to basic LEACH. In the pre-steady state phase, sensor nodes of a cluster are divided into three categories: CH, sensing nodes and aggregators. Sensing nodes sense the environment and send sensed data to the aggregators. The aggregators are used to aggregate the received data and send it to the base station. This reduces the energy consumption of CHs. CHs maintain and manage the cluster activities. They create and generate a TDMA schedule to all cluster members. CHs also select the aggregator nodes in a frame and broadcast its list to all cluster members. The steady state process is divided into frames. Every cluster member send their data in each frame according to their time slots. The aggregator aggregates this data and sends it to the BS. Due to the uniform energy distribution in the cluster, the performance of this protocol is significantly increased. The simulation results show that it performs better than LEACH, E- LEACH, T-LEACH, VR-LEACH [42] and LEACH-Bin terms of energy consumption and network lifetime. There are two major problems in this protocol. The first one is control message overhead for selecting aggregators and CHs. Other problem is scalability due to direct communication from aggregators and the BS.

LEACH-SM - LEACH-SM is purposed by Bilal and Lilien for expanding life time by Management of Spare Nodes of the wireless sensor network its rely upon operational life spam of its energy assets. Accessible outcomes release that essential upgrade in WSN lifetime can be achieve by making WSNs redundant[43], that is, by signifying WSNs

additional nodes that are at first asleep but they are prepared to be exchanged on when any fundamental node expend up its energy. LEACH expands the WSN lifespan through randomized rotation of CHs. However, LEACH allow for wasteful aspects due to excess repetive area coverage, when observing regions for a few nodes are totally covered by different nodes. LEACH-SM protocol is an alteration of LEACH protocol. It adds the Spare Selection stage to LEACH with three principle points. From the part of WSN nodes that offer outmoded target coverage, with the optimal gathering of spares which will be utilized to maximum WSN lifetime. Initially spares are kept asleep while at the same time keeping up the unusual observed target coverage. As detecting ranges for nodes can cross limits of cluster, race conditions and deadlocks could occur during the spares selection process. Their second purpose for LEACH-SM is to settle on: For how much time the spares ought to stay inactive, and which of the spares ought to be utilized as substitutes for essential nodes that spent their energy.

LEACH-IMP - Hu et.al[44], have proposed LEACH-IMP dependent on LEACH. In this protocol all nodes are isolated into fixed clusters. As indicated by the detachment from the cluster head individuals from cluster nodes adaptively join cluster. In LEACH-IMP algorithm, the whole area is isolated into 9 sections and area of the cluster head is near the geometric canter of each segment, so they have picked 9 CHs by this means. The additional nodes unite different cluster as indicated by the separation from the 9 CHs, and pick the closest one to join. At that point the communication radius is decreased to some extent, and reduce the transmit control. By growing the lifetime of network and dropping energy usage, the stack of the whole network is more adjusted than the load of LEACH-IMP algorithm.

LEACH-C - LEACH-C[45] have connected evolutionary protocol in centralized clustering. LEACH-C is known as the essential parameters in network life span rely upon energy using value protocol. Innovation of their strategy is in proper demonstration of chromosomes and furthermore is to discover appropriate fitness function according to problem features based on energy measure. In their work they have proposed two new fitness procedures. The impact of applying these procedures on four various types of sensor networks are proposed and contrasted with the result of the Simulated Annealing technique. As per the attributes of the issue, in their algorithm is to discover most favourable CHs and the best clustering in Wireless Sensor Network. In algorithms fitness function utilizing of distances to intensity of two, since of the direct relationship among the utilized energy for information sends in nodes and the distances to intensity of two. By upgrading the hunt capacity they have increment Wireless Sensor Network lifetime. Furthermore, achieved by appropriate meaning of selection, mutation and crossover operators, and furthermore the sort of survival choice that is (μ+ λ). On contrasting with simulated annealing, their proposed algorithm passed local minimal and reached global minimal.

LEACH-HEFA - LEACH-HEFA (LEACH-Head Expected Frequency Appraisal) algorithm was presented by Li et.al [46] for enhancing the performances, based on the thought of cluster-head expected frequency appraisal. If the node has superior residual energy, it will have more chances to be selected as cluster-head, which stables node energy effectively.. This routing protocol is appropriate to water regime monitoring systems. The present routing protocols typically have problems such as formerly selected cluster-head, unbalancing energy loads and short existence of network. Thus, it cannot be applied to the water regime system, but LEACH-HEFA is real-time system with a huge range to gather, transmit, analyze and process water regime parameters.

FZ-LEACH - Katiyaret[47].al," have proposed FZ-LEACH to reduce the problem creating by Far-Zone. Far-Zone is a cluster of sensor nodes which are positioned at locations where their energies are less than a threshold. They have proposed FZ-LEACH algorithm, which is based on the original protocol and considers a Far-Zone inside a large group. They finally conclude that a Simulation result confirms the improvement in the performance in the original LEACH protocol in terms of energy indulgence rate and network lifetime. It is observed that FZ-LEACH protocol saves around 30% energy of sensor network in comparison to LEACH.

LEACH-MF LEACH-C - This protocol adopt technique of multi-layer clustering in order to reduce redundant information and saves the energy of CHs. Cluster heads form clusters between them called as super cluster heads and they send data to base station. LEACH-MF improves lifetime of network with increase in scale of network [48].

LEACH-GA (Genetic algorithm based LEACH) - LEACH-GA proposed by Liu et al. [49] is a genetic algorithm (GA) based adaptive clustering protocol with an optimal probability for cluster formation and CH selection. Initially, all sensor nodes participate in the candidate CH (CCH) selection process by generating a random number r and comparing this r with threshold T (s). The performance of this protocol is compared in two scenarios based on the BS position. In the first case, the BS is located in the centre of the network and in the second case; it is situated outside of the network. LEACH-GA gives better result in both cases than LEACH in terms of energy efficiency. But LEACH-GA suffers from message overhead and scalability.

MG-LEACH - MG-LEACH is use similar redundant nodes present in the network that place in the similar region for enhancing lifespan of the whole network. This is a classical idea which can further enhance the network life time by addressing other shortcomings of LEACH. We use this idea on LEACH frame work as it is classical distributed clustering based routing protocol that contains hundreds of variants. [50]

Solar ware-LEACH - In sLEACH, nodes that are equipped by solar power acts as CHs depending upon their solar status. CHs are selected using improved central control algorithm via BS. The nodes transmit solar status to BS

along with their energy and nodes with higher energy are selected as CH. Lifetime of the network depends on sun duration and CH handover is performed if sun duration is small [51].

MH- LEACH (Multi hop LEACH) - MH-LEACH protocol makes further development in LEACH to save energy by using nodes that lies on the way to base stations [52]. MH-LEACH uses same practice of LEACH to select the cluster-heads and cluster formation. Role of cluster-head is also same i.e. performing data fusion to the received packets so as to reduce the transmitting and forwarding data in the network[53][54]. But, multi-hop LEACH possesses more life-span of nodes. This is because, during inter-cluster communication, cluster- head sends data packets to nearby cluster-head that lies on way to base station instead of sending it directly to base station and hence saves energy of cluster-head. In addition, in intra-cluster communication, nodes instead of sending data packets directly to cluster-head, it sends data to neighbour nodes that lies on way to cluster-head and saves energy.

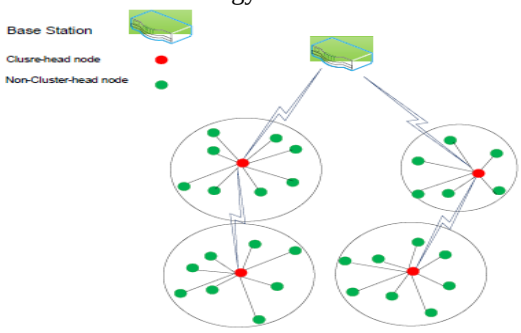

Figure 4: Multihop LEACH

Intermediate cluster-head or node makes a decision at its own depending upon their energy level whether to accept data packets or not. So, if a cluster-head or node did not accept data packets, sensor node try to locate another cluster-head or node as per its routing table entry. Multi hop LEACH protocol operates in two phases. In phase 1, all the cluster-heads broadcast an announcement message and construct their routing table depending upon level of signal (RSSI) received. Then, they make their route to base station via closest cluster-head. In phase 2, each cluster-head sends these initial routes (from routing table) to the base-station. The performance of MH-LEACH is investigated by designing a network of 200 m X 200 m consisting of 100 nodes with sink at a distance of 50 m from the network [55]. It is reported that the designed network considered cluster-head probability of 10%, packet size of 4000 bits, Efs of 10pJ, ETX of 50 pJ, ERX of 50 pJ, and EDA of 5 pJ. Each node is fed by initial energy of 0.5J. The first node of simulated MH-LEACH died after 70-80 rounds as compared to LEACH because MH-LEACH saves energy by instead of transmitting data directly to base station uses intermediate node or cluster head for communication. Also, this is reason behind the 25-30 percent more network life time of MH-LEACH as compare to LEACH for varying packet size (between 1000- 10000 bits).

LEACH-SWDN (LEACH with Sliding Window and Dynamic Number of Nodes) - LEACH-SWDN is an variant of LEACH, proposed by Wang et. al. [56] using a sliding window on the current cycle of nodes that have not already been cluster heads, and dynamically changing the number of nodes in the threshold calculation model. In this algorithm the node that is not a CH in the current round sends its residual energy information to the CH in the last slot allotted to it. The frame received by the CH with residual energy information is transmitted to the BS for average energy calculation EAveragen . Before the beginning of the next round the BS calculates the EAveragen and the number of nodes alive in the network, and distribution and energy efficiency directly depends on the selection of the CH.

LEACH-TLCH - An Energy Balanced Algorithm of LEACH Protocol in WSN was examined by the Jiang et.al [57] . They break down to WSN, as of the inadequacy of energy of nodes. Energy efficiency in WSN is a critical factor which ought to be estimated at the time of protocol design by protocol designer. In energy efficiency LEACH has play a crucial job. In reply to the not smooth allocation of energy that is caused by the mediation of CHs creation , Jiang et.al propose in their work through another improved algorithm of LEACH named LEACH-TLCH. To enhance the life time of the sensor network, this protocol balance the use of energy of all the nodes of network. They simulate this algorithm with the help of Matlab simulator and found in results the lifetime of the sensor network is obviously better than LEACH Protocol.

K-LEACH - K-LEACH is a another protocol purposed by Bakaraniya et.al [58] which enhanced the life time of LEACH Protocol in WSN, , as above discussed wireless sensor network is work from gathering of little sensor nodes so these networks are exceptionally sensitive against energy. Thus Bakaraniya et.al have proposed another routoing protocol named Kmedoids-LEACH (K-LEACH) [59]. The principle point of this algorithm is to expand the lifespan of WSN with proper utilization of energy of the hubs, they additionally simulate this algorithm with LEACH on MaTLab simulator and find better results of K-LEACH as compared to LEACH protocol.

Simulation results of this protocol are compared with LEACH BY [58]

Protocol	FND (First Node dies)	HND (Half nodes Die)	LND(Last node dies)/(5% alive nodes)
LEACH	1	25	35
K-LEACH	15	27	35
Improvement	41.17%	5.88%	0%

Network Lifetime Improvement[33]

MODLEACH -MODLEACH[60] another cluster based algorithm differs from LEACH mainly on two points. One, there is no need to change cluster-head until and unless it has more energy than the certain required threshold. Second,

MODLEACH did not amplify all the signals to same level. In MODLEACH cluster head replace only in case when current cluster head energy is not less than required threshold. It saves energy consumed in cluster formation and forwarding the routing packets for searching another new cluster-head [61]. In each round, if the residual energy of current cluster-head finds to be more than the minimum threshold value, then the current cluster- head will remain cluster-head for new round. MODLEACH categorized communication into three categories: 1) Intra cluster communication 2) Inter cluster communication 3) Data transmission from cluster-head to base station.

EMODLEACH - In EMODLEACH, if the energy level of a cluster head drops below the determined threshold value, then only that cluster head can be replaced resulting minimization of energy dissipation in overall functioning of the protocol. Again using two threshold values such as hard threshold and soft threshold minimizes the energy dissipation in redundant value sensing. As a result of which the longevity of the sensor nodes increases due to optimal transmission. But if the sensed value is not greater than or equal to the thresholds, the nodes will never transmit the data; as a result of which the user will not receive any single data from the communication network and eventually all the nodes will die without transmit a single data packet. So, this approach cannot be applied effectively where the user wants the sensed data on a periodic manner [62].

TL-LEACH (Two level LEACH) - TL-LEACH solves the uneven energy distribution problem of LEACH that occurs due to random selection of cluster-heads. Earlier, cluster-heads were selected randomly, so different cluster-heads had different residual energy. If a low energy node or node far away from BS becomes cluster-head, cluster-head dies quickly. TL-LEACH solves this problem by dividing task of collection cum aggregation of data from nodes within cluster and transmission of collected data to base station into secondary and primary cluster-heads respectively[63][64][65]. Secondary cluster-head is responsible for collecting and aggregating data collected from member nodes and then forwarding to primary cluster-head; primary cluster-head is responsible for transmitting received data from secondary cluster-head to base station. TL-LEACH adheres to cluster-head selection and cluster formation process of LEACH protocol. TL LEACH evaluates following two conditions:

- Current Cluster-head (E_{cur}) energy less than the average energy (E_{avg}) i.e, $E_{cur} < E_{avg}$ where $E_{avg} = \sum_{n=1}^{n} E(i)_{cur}$.
- Distance (d) between cluster-head and base station is larger than the average distance (d_{avg}) i.e, $d > d_{avg}$ where $d_{avg} = \sum_{n=1}^{n} d_i$.

If primary cluster-head has either lesser energy as compare to average energy or have distance more than average distance, then another node is chosen having maximum energy in the cluster to act as secondary cluster-head. Secondary cluster-heads creates and distributes TDMA schedule among their member nodes. If there did not exist any secondary node, then it is responsibility of primary cluster-head to create and distribute TDMA schedule among the member nodes.

I-LEACH - I-LEACH [66] protocol suggested a new idea for selection of the CH. The CH in I-LEACH protocol is selected by considering residual energy, the number of neighbouring nodes and position of the node from the BS. A sensor node can calculate the number of its neighbours with neighbourhood radius Rch, after receiving the information, nodes updates their random number interval and the number of nodes alive. They showed through simulation that in terms of FND and HNA there is a 41% and 36%, 17% and 26%, and 22% and 21% improvement over LEACH, LEACH-DCSH and ALEACH respectively. Due to sending residual energy information I-LEACH increases network load, it is a big problem.

EP-LEACH (Energy potential-LEACH) - EP-LEACH [67] has improved the lifetime of rechargeable battery and battery power is harvested from the environment. The EP-LEACH operation is similar to LEACH, except the CH selection process. It has two modifications over LEACH. In the first modification, sensor nodes with more energy harvesting potential should have more chance to become a CH. According to the second modification, a node can become a CH any number of times. The steady state phase is similar to LEACH. EP-LEACH with EH-WSN outperforms LEACH with respect to network lifetime. Due to the energy harvesting sensor nodes, cost will be a matter of concern in this type of network. The protocol performs poorly in terms of complexity and message overhead compare to LEACH.

EC-LEACH (Enhanced Centralized-LEACH) - EC-LEACH is a new variant of LEACH proposed by Bsoul et al. [68] using a centralized and multi- hop clustering approach. The main improvement of EC-LEACH over LEACH protocol is in selection procedure of CH. In this algorithm, all the nodes of a cluster not needed to activate and take part in each round of communication, like LEACH. In this way, authors increase the average lifetime of sensor nodes and enhance the network lifetime. In [69], authors have extended their work by introducing a dynamic W-LEACH using CH density dCH . These algorithms improve the network lifetime as well as average lifetime of individual sensor nodes. The main problems with these protocols are scalability and control message overhead.

LEACH-G - In order to minimize the deficiency of LEACH that is the uncertain number of CHs and their position, authors in [70] have proposed a protocol called LEACH-G, which ensures a certain number of CHs and their even distribution. LEACH-G routing protocol adopts a centralized as well as a distributed approach for the selection of CH and for the formation of clusters. Due to the random selection of CHs and clusters, LEACH does not guarantee the optimal number of CHs and the optimal position of CHs. According to the LEACH- G protocol, the optimal number of energy efficient nodes. The residual energy avoids selecting a low energy node as a CH. LEACH-G outperforms the classical LEACH in terms of

network lifetime and energy consumption. It suffers from scalability and hotspot problems.

DESST(Decentralized Energy-efficient Spare Selection Technique): Bilal and Lilien[71] purposed DESST, the one constituent of spare management is spare selection performed at the season of the spare choice stage by the Decentralized Energy-efficient Spare Selection Technique (DESST). DESST extends WSN lifespan since the nodes that become unused go asleep, while the WSN as the entire maintains the need above-threshold target coverage. As a reaction, DESST lessons time of the active interval for Cluster Heads. This out comes in condensed energy utilization by CHs. DESST is completely distributed algorithm so nodes can pick in parallel which of them should remain active and which ought to become inactive. DESST deals with race conditions by utilizing tiebreakers, and deals with deadlocks by total ordering of sensor nodes.

O-LEACH - Optical-LEACH (O-LEACH) was introduced in [72] as a clustering hierarchy, an optical and adaptive protocol that minimizes energy consumption. In this reference, the node should have a current energy greater than ten percent to become a CH. The reference [73] calculates a new threshold which is based on node energy, distance between sensor node and BS, distance between CH and BS. In the reference [74], authors propose a new algorithm that firstly calculates the optimal cluster number by considering location adaptability and data aggregation rate. Secondly, they present a new threshold based on remaining energy, initial energy, average energy consumption, and node degree to select CH. Thirdly, a self adaptive uneven clustering algorithm is proposed that takes node degree into consideration and solve the "hot spot" problem. And finally, they propose a solution to solve "isolated nodes problem".

CogLEACH (Cognitive LEACH) - The literature [75] presented a spectrum aware algorithm for the cognitive radio sensor network (CRSN), called cognitive LEACH (CogLEACH). Recovery of the CH is similar to that of member nodes by replacing the CH using local re-clustering. The rest of the work is similar to FT-LEACH outperforms LEACH in terms of fault tolerance and energy consumption. It has some limitations, such as how the energy level detects the faulty nodes, which is not clearly explained by the authors. Local re-clustering is also not clear and how duplicate data is managed by using a threshold is not discussed clearly [76].

LEACH-CM - LEACH-CM [77] protocol is proposed by extending LEACH-C protocol with two modifications. The first modification is that non-CH nodes decide to transmit their data directly to BS or through CH whichever is energy efficient, but in the second one node is to elect as a CHs in the network from the only pending alive nodes and leave dead nodes of the network. The first approach allows individual member node to save its energy by transmitting to either BS or CH whichever is nearest to it. The second approach reduces the number of CHs over a period of time as dead nodes increase in the network. Both of these approaches help to reduce the energy expenditure of a network. LEACHCM is energy efficient protocol and improves the network lifetime, including stability period.

EHA-LEACH (Energy Harvested Aware LEACH) - Lang et al. [78] have improved the performance of LEACH by using energy harvested sensor nodes and presented a new protocol, named energy harvested aware LEACH (EHA-LEACH). They have formulated a max-min optimization problem for maximizing the minimum energy conservation, it can be derived that the higher energy consumption nodes have more chance to become a CH. After the selection of CHs, the rest of the process is similar to LEACH. Due to using energy harvesting nodes and energy consumption rate it outperforms LEACH and EP- LEACH in terms of energy efficiency and network lifetime. As compared to EP-LEACH and LEACH, EHA_LEACH achieve 18.41% and 29.19% more rounds. Higher cost and complexity are the main problems of this protocol.

V-LEACH - Yassein. M.B et.al, [79] have proposed an enhanced version of LEACH named V-LEACH. The main purpose of this V-LEACH algorithm is to decrease the energy consumption of nodes in the wireless sensor network. They have improve first most significant cluster based LEACH protocol of wireless sensor network and with the help of OMNET++ simulator they have simulate both protocol LEACH and V-LEACH and find in simulator result, that the performance of V-LEACH is better than LEACH routing protocol.

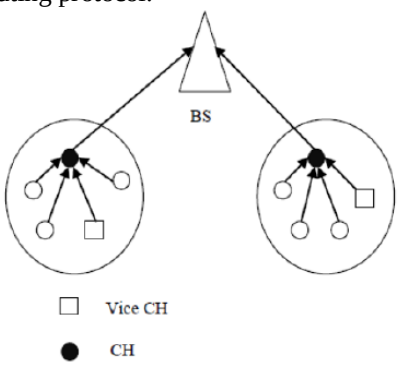

Figure 5: V-LEACH[80]

After model outcome they close V-LEACH is discharges less number of messages as contrast with LEACH protocol. They accommodate on the off chance that the less messages are conveyed by the new side that signifies the network energy left over utilizations V-LEACH which is more in utilizing by LEACH. At long last they guaranteed that V-LEACH give best results as compare to LEACH.

LEACH-MAC (LEACH-Medium Access Control) - Most of the LEACH variants use dynamic, randomness and distributed approaches for clustering and thus an optimal number of clusters does not form in the network. LEACH-MAC [81] protocol is designed to mitigate the randomness problem by restricting the number of cluster head advertisements. In the threshold function, nodes select a uniform random time from the time interval [0 to total adv time], where total adv time is the time required for the CH

transmission and reception. In successors of LEACH with multi-hop communication, researchers have mainly focused on inter and intra cluster communication, CH selection, cluster formation and scalability. These improvements achieve energy efficiency and scalability in WSN.

Stable Election Protocol (Heterogeneous LEACH) - In LEACH, every sensor node is initialized to same energy level but in Stable Election Protocol (SEP) there are two different types of nodes called as normal nodes and advanced nodes. These nodes have different initial energy. There are m numbers of advance nodes in network with α additional energy. Advance node have energy Eo* (1+α) where Eo is energy of normal nodes [82].

Variants of LEACH Protocol	Clustering	Over-head	Energy Efficiency	Security
LEACH	Distributed	High	Moderate	No
SLEACH	Distributed	High	Very High	Yes
LEACH-CE	Centralized	Need	Very High	No
LEACH-GA	Distributed	High	High	No
A- LEACH	Distributed	High	High	No
Sec- LEACH	Distributed	Very High	Low	Yes
ME- LEACH	Residual Energy	Low	Moderate	No
TB- LEACH	Distributed	High	Moderate	Yes
T- LEACH	Distributed	Need	High	No
LEACH-H	Hybrid	High	High	No
LEACH-FL	Distributed	Low	Low	No
Q- LEACH	Distributed	High	High	No
U- LEACH	Distributed	High	High	No
LEACH-B	Distributed	Low	High	No
W- LEACH	Distributed	High	High	No
FT- LEACH	Distributed	High	Moderate	No
LEACH-SM	Distributed	High	High	No
LEACH-C	Centralized	Low	High	No
FZ- LEACH	Distributed	Need	High	No
LEACH-MF	Distributed	High	High	No
MG- LEACH	Distributed	High	High	No
Solar aware LEACH	Hybrid	Need	Very High	No
MH- LEACH	Distributed	High	High	No
LEACH-SWDN	Distributed	High	Low	No
K- LEACH	Distributed	High	Very High	No
MOD LEACH	Distributed	High	High	No
EMOD LEACH	Distributed	High	High	No
TL-LEACH	Distributed	High	High	No
I- LEACH	Distributed	Very High	High	No
EP- LEACH	Distributed	High	Very High	No
EC- LEACH	Centralized	Need	High	No
O- LEACH	Distributed	High	High	No
Cog LEACH	Distributed	High	Moderate	No
EHA-LEACH	Distributed	High	Very High	No
v- LEACH	Distributed	High	Very High	No
LEACH-MAC	Distributed	Very High	High	No
IB- LEACH	Distributed	High	Moderate	No

IV. CONCLUSION

In wireless sensor network , sensor nodes have small battery for providing energy, so proper utilization of energy is main issue related prolonging lifetime of sensor network. In this paper we have discussed the first energy efficient routing protocol LEACH along with their advantages and disadvantages. To overcome from these problems and make it more energy efficient for increasing the network lifetime of network many successors of LEACH are purposed, from some popular descendants which improve performance of sensor networks in terms of network scalability, stability, security, energy efficiency and network lifetime are discussed in this paper.

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Authors Profie

Ms. Rekha rani had done Master of computer application from *Kurukshetra University* in 2004 and M.phil from choudhary Devi Lal university in 2008. She is currently pursuing Ph.D. and currently working as Assistant Professor in Department of Computer Sciences, Guru Nanak College, Budhlada since 2005. she is a member of computer society of India since 2010. she has published more than 10 research papers in national and international reputed journals and IEEE,CSI,UGC etc. approved conferences and published three books. She is having minnor project from UGC. Her main research work focuses on wireless sensor network, Network Security, Cloud Security and Privacy. She has 12 years of teaching experience and 4 years of Research Experience.

Dr. Harmaninderjit singh is an Assistant Professor and has more than 12 years of academic experience. He has done MCA degree from Punjabi University Patiala, Punjab, India and received the P.hd Degree in Computer Science from Desh bhagat university, Mandi gobindgarh, Punjab, India. He had published more than 17 papers in different Journals and conference proceedings. His research interest is in the areas of Open Source Software and Algorithm Design and is presently working on it.