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Descendant of LEACH Based Routing Protocols in Wireless Sensor Networks

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Abstract

Due to the advancement in wireless communication, Wireless Sensor Network (WSN) is used in different areas like: civilian, military, and industrial applications. A WSN is a network formed by large number of sensor nodes which are randomly deployed in a region. There is an issue of limited source of power in a node and in fact battery of node can not be replaced. The life time of WSN is very much dependent on the life of each sensor node. As node does the task of sensing and forwarding the data to sink from environment, in wsn routing schemes for data forwarding has to be efficient and efficiently utilize the battery power of sensor node to increase the network lifetime. An energy efficient routing protocol is the major concern in field of WSN. Researchers have been working to develop routing techniques that enhances the WSN lifetime among which is the hierarchical routing. In this paper, we present a recent survey of descendant of LEACH hierarchical routing protocol and its timeline. Furthermore, a comparison of these protocols on various assumptions is being done.

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Keywords: Cluster head; LEACH; hierarchical routing; Clustering; CH selection; Energy consumption; Network lifetime;

1. Introduction

In recent years, a new wave of wireless communications labelled, Wireless Sensor Network (WSN) has attracted a lot of attention from researchers in both academic and industrial communities. A WSN consists of a collection of sensor nodes and a base station (BS) connected through wireless channels with sensing, wireless communications and computational capabilities. Due to adhoc nature of WSN can be used for many applications such as military application, air traffic control, traffic observation, physical security, video surveillance, industrial and manufacturing

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automation, environment monitoring, building monitoring, hospital and health care monitoring [1],[2],[3],[4],[5]. The advantages of WSN are ease of deployment, low installation cost, distribution over a wide region and high fault tolerance [6]. A WSN is deployed for collecting environmental data in region of interest (ROI) and for sending it to a BS. In WSN, how nodes will be deployed, is application specific and totally dependent on environment. The node deployment option affects the performance of routing protocol in terms of energy consumption. There are three ways in which tiny sensor nodes can be deployed in a WSN environment: Regular Deployment-Sensor nodes can be deployed in a fixed manner and data is routed through a predefined path. This deployment is used in medical, industrial sector, home networks, etc. Random Deployment – Sensor nodes are deployed over finite area in scatter manner. This deployment is generally used in rescue operations like, environmental and habitual monitoring. Sensor Nodes with Mobility – node can move to compensate for deployment shortcomings; can be passively moved around by some external force (wind, water, and vehicle). This deployment is used in battle field surveillances, emergency situations (fire, volcano, and tsunami), etc. In above given categories, once sensor nodes are deployed, WSN performed a specific job. In WSN, energy is a big challenge because nodes are powered by batteries. This energy can be very expensive, difficult or even impossible to renew. So saving energy to maximize network lifetime is one of the critical problems in WSN.

In WSN, nodes dissipate energy in processing and transmitting/receiving messages. In addition to this energy, there is a great amount of energy required in states that are useless from the application point of view, such as: Idle listening, overhearing, interference and collision. Another constraint that reduces the efficiency of deployed nodes is data redundancy since nodes in most cases are densely deployed in a ROI, and that causes a redundant data from nearby nodes in the region. Based on these energy constrained of wireless nodes many energy efficient techniques are designed, to minimize the energy consumption and maximize network lifetime [7]. One of the interesting techniques is the hierarchical routing, which introduces the concept of cluster creation and assigning special tasks to selected sensor node within the cluster called cluster head (CH). Researchers agreed that clustering of nodes in WSN is an effective program of energy conservation [8]. Clustering is defined as the grouping of similar objects or data [9]. In WSN it is used to minimize the number of nodes that take part in long distance data transmission to a BS, what leads to lowering of total energy consumption of the system [10]. Clustering reduces the amount of transmitted data by grouping similar nodes together and electing one node as a CH, where aggregation of data is performed to avoid redundancy and communication load caused by multiple adjacent nodes, then sending the aggregated data to the next CH or to the BS, where it is processed, stored and retrieved. The main target of hierarchical routing or cluster based routing is to efficiently maintain the energy usage of sensor nodes by involving them in multi-hop communication within a particular cluster. The first hierarchical protocol is the Low Energy Adaptive Clustering Hierarchy (LEACH) that was introduced in [11]. Many hierarchical protocols were emerged from LEACH.

Our work is organized as follows. Section 2 presents the basic concepts of hierarchical routing protocol. Section 3 presents detail about LEACH protocol. Sections 4 survey various descendants of LEACH and give its timeline of descendant protocols. Section 5 provides summary table that compares some protocols and finally conclude the survey in section 6.

2. Hierarchical Routing Protocols

In WSN, the consumption of energy is one of the most important issues. The traditional routing protocols for WSN may not be optimal in terms of energy consumption [34]. Hierarchical routing protocols (HRP) are more energy efficient than other protocols [12]. HRP follows the clustering mechanisms; clustering techniques can be efficient in terms of energy and scalability [13]. By the use of a clustering technique they minimize the consumption of energy greatly in collecting and disseminating (fusion and aggregation) data. HRP minimizes energy consumption by dividing nodes into different clusters. In each cluster, higher energy nodes i.e. the CHs can be used to process and send the information to the BS while low energy nodes i.e. the cluster members can be used to perform the sensing in the proximity of the target and send to its CH. This means that creation of clusters and assigning special tasks to CH can greatly contribute to overall system scalability, lifetime, and energy efficiency, reduces the size of the routing table by localizing the route setup within the clusters, and conserves communication bandwidth of network [14]. Fig.1 has shown a hierarchical cluster based approach divides the network into different clustered layers. Different sensor nodes are grouped into clusters with a CH that has the responsibility of routing

from the cluster to the other CHs or to the BS. Clustering mechanism provides inherent optimization capabilities of sensed information at the CHs. In the cluster-based hierarchical model, data is first aggregated in the cluster then sent to higher-level CHs or to the BS. In cluster based hierarchical model only the CH have to perform the data aggregation process, but in case of the multi-hop model every intermediate node performs data aggregation process also presents benefits and challenges of clustering. The major benefits of clustering in WSN are present here [15]. Clustering provides the spatial reuse of resources to increase system capacity. For example, if the clusters are not neighbours, they can use the same frequency for wireless communication; secondly routing information of a cluster is shared with only other CH. This restriction reduces the number of transmissions performed for distributing routing information. By using this advantage of clustering, more energy efficient routing protocols have been implemented. In WSN, clustering faces several deployment challenges, such as ensuring connectivity, selection of CH and clusters, real-time operation, synchronization, data aggregation and quality of service (QoS).

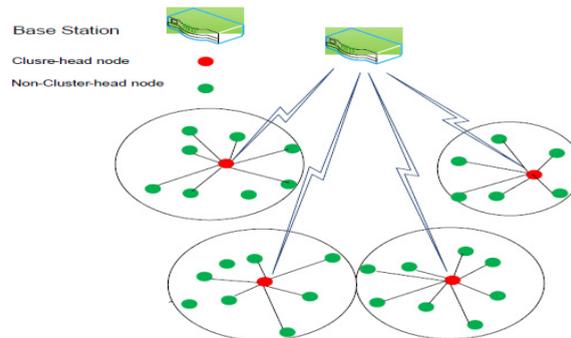


Fig.1. Hierarchical Clustering Model [13]

3. Cluster Based Hierarchical Routing Protocol: LEACH

3.1. LEACH: Low Energy Adaptive Clustering Hierarchy

It is the most popular energy-efficient hierarchical routing algorithm proposed by W.R.Heinzelman et.al. [11], for WSN to reduce power consumption. In LEACH, direct communication is used by each CH to forward the data to the BS. LEACH divides the network into several clusters. Since energy dissipation of the sensor depends on the distance, LEACH attempts to transmit data over short distances and reduce total number of transmission and reception operations [16]. In order to achieve the design goal the key tasks performed by LEACH are as follows. Randomized rotation of the CH for corresponding clusters after that local aggregation of data to reduce global communication and finally localized coordination and control cluster setup and operation.

3.2. The Working Process of LEACH

The working of LEACH is managed through the rounds. In each round, the operation of LEACH is divided into two stages, the setup stage and the steady state stage. In setup stage, CHs are elected, clusters are created and then cluster communication schedule is determined. Firstly, sensor nodes choose a random number m between 0 and 1. If this number m is less than threshold value $T(n)$, then sensor node becomes the CH. Since the number m is randomly selected, that's why the number of CH cannot be fixed. $T(n)$ is calculated by the following equation, where p is desired percentage of cluster head nodes, r is the current round number and G is the set of nodes that have not been CH in the last $1/p$ rounds.

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

The decision to change the CH is probabilistic; it is possible that the node with low energy may be selected as CH. When this low energy node dies the whole cluster becomes dysfunctional. It is assumed that the CH has a long communication range so that the data can reach the BS directly. But this assumption is not always true because the network is deployed in large region and therefore all the CHs may not communicate directly. After the selection of CH nodes, each CH node will send information via CDMA code to other nodes and normal nodes will join the corresponding CH nodes. Then the CH nodes use TDMA to provide data transmission time for every node connected to them. The steady state: this stage is for data transmission where normal nodes sense data and send this sensed data to their respective CH node. The processing of received data (data aggregation and data fusion) is done by CH node and processed data will be sent to the BS.

3.3. Radio Energy Dissipation Model

In LEACH, authors use a simple radio model which describe the energy dissipation through the electronic devices, transmitter, power amplifier and the receiver. Fig.2 shows the radio model used to simulate the LEACH and LEACH based protocols.

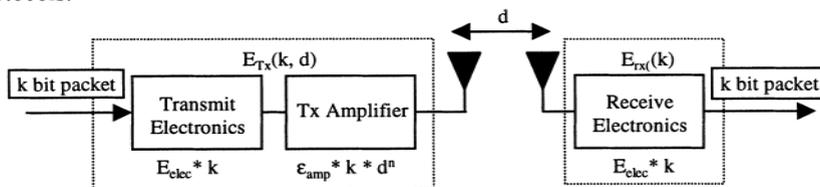


Fig.2. Radio energy dissipation model [11]

3.4. Merit of LEACH Protocol

It confines most of the communication inside the clusters, and thus provides scalability in the network. The CH aggregates the data composed by the nodes and this leads to a limit on the traffic generated in the network. Hence, a large-scale network without traffic overload could be deployed and improved energy efficiency compared to the flat-topology could be achieved.

LEACH is a completely distributed approach and requires no global information of network, so it is powerful. Network lifetime can be increased by the rotation of CH, aggregating the data by CHs, TDMA assigned to cluster members by the CH, so that most of the nodes in sleep mode and localized co-ordination and control for cluster setup and operation and the CHs aggregates the data collected by the nodes and this leads to a limit on the traffic generated in the network. Hence, a large-scale network without traffic overload could be deployed and better energy efficiency compared to the flat-topology could be achieved.

3.5. Demerit of the LEACH Protocol

Although LEACH protocol prolongs the network lifetime in contrast to plane multi-hop routing and static routing, it still has problems.

- The CHs are elected randomly, so the optimal number and distribution of CH cannot be ensured and the nodes with low energy have the same priority to be a CH as the node with high energy. Therefore, those nodes with less energy may be chosen as the CHs which will result that these nodes may die first.
- The CHs communicate with the BS in single-hop mode which makes LEACH cannot be used in large-scale WSN for the limit effective communication range of the sensor nodes.
- Failure of CH leads to lack of robustness. LEACH uses dynamic clustering which results in extra overhead such as the head changes, advertisement that reduces the energy consumption gain and it is not suited for the applications that cover a large area that support multihop routing [17].

4. Descendant of LEACH Routing Protocols

4.1. LEACH-B (Balanced)

Dopedri.A.et.al.[18] proposed a new algorithm called LEACH-B. LEACH-B protocol is based on decentralized algorithms of cluster formation in which sensor node only knows about its own position, position of final receiver and not the position of all sensor nodes. LEACH-B operates in following phases: CH selection algorithm, cluster formation and data transmission with multiple accesses. Each sensor node chooses its CH by evaluating the energy dissipated in the path between final receiver and itself. It provides better energy efficiency to the network than LEACH, but the CH energy gets drained out quickly. In [18] LEACH-B outperformed LEACH-A, Direct and MH in terms of system lifetime, finally authors present improvements of LEACH-B over LEACH, which can be briefly described as follows: they proposed a new adaptive strategy to choose CH and to vary their election's frequency considering the dissipated energy and also proposed a new idea for cluster's formation, which considers the total path energy dissipation between the node and the final receiver also considered the energy dissipated by CH to send their broadcast packets.

4.2. LEACH-C (Centralized)

Heinzelman.W.et.al. [19] present first centralized routing protocol is called centralized Leach (LEACH-C), basically LEACH using distributed cluster formation algorithm, and this protocol offers no guarantee about the placement and/or number of CH nodes. Since the clusters are adaptive, obtaining a poor clustering setup during a given round will not greatly affect overall performance. However, using a central control algorithm to form the clusters may produce better clusters by dispersing the CH nodes throughout the network. This is the basis for LEACH-C, a protocol that uses a centralized clustering algorithm and the same steady-state protocol as LEACH. In other way we can say LEACH has no knowledge about the CHs places. However, centralized LEACH protocol can produce better performance by distributing the CH throughout the network. During the setup phase, each node sends remaining energy and location to the BS. The BS then runs a centralized cluster formation algorithm to determine the clusters for that round. However, since this protocol requires location information for all sensors in the network, it is not robust. In [19] simulation result show LEACH-C deliver the most data per unit energy, achieving both energy and latency efficiency. A routing protocol such as LEACH and MTE does not enable local computation to reduce the amount of data that needs to be transmitted to the BS. Graph shows that LEACH-C is more efficient than LEACH. This is because the BS has global knowledge of the location and energy of all the nodes in the network, so it can produce better clusters that require less energy for data transmission.

4.3. LEACH-E (Energy Low Energy Adaptive Clustering Hierarchy)

LEACH-E protocol improves the CH selection process compared to LEACH protocol. The LEACH-E is divided into different round that is same as LEACH protocol. In the first round, all the sensor nodes would have the same probability to be CH of the cluster. After the first round of transmission, the residual energy of each node would get different and based on this, the node who would have the high residual energy would be chosen as CH of the cluster and other nodes in the cluster would became the cluster member who would have the less energy [20]. Authors give the simulation results of E-LEACH improvement over LEACH and multi hop-LEACH with the energy consumption due to the enhanced way of the CH selecting process.

4.4. LEACH-F (Fixed number of cluster Low Energy Adaptive Clustering Hierarchy)

The basic concept of cluster formation in LEACH-F is beginning of the network setup and after that is being fixed. The CH position rotates among the nodes within the cluster that is same as LEACH. The advantage of this process compared to LEACH is that, there is no setup overhead at the beginning of each round like LEACH. For clusters formation, LEACH-F uses centralized cluster formation algorithm that is same as LEACH-C. The disadvantage of this protocol is that the fixed clusters in LEACH-F do not allow new nodes to be added to the

network and do not adjust their behaviour when any node dies in the network [21]. The overhead of re-clustering in basic LEACH is removed by LEACH-F protocol as once the fixed number of clusters is formed; they are maintained throughout the network.

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

Authors proposed algorithm known as I-LEACH [22]. I-LEACH employs the distributed clustering approach as compared to LEACH protocol. The total sensor field is divided into equal sub-region. The choice of the CH from each sub-region is determined by the threshold approach as in LEACH protocol. In simulation, authors analysis the performance of the proposed I-LEACH is compared with basic LEACH protocol in terms of average energy consumption. I-LEACH gives better performance as compare to LEACH in terms of energy.

4.6. K-LEACH (Kmedoids-Low Energy Adaptive Clustering Hierarchy)

The proposed protocol K-LEACH [23] uses the K-medoids clustering algorithm to obtain highly uniform clustering of nodes and very good choices of CHs and it is a very well known fact that energy retention of a WSN is highly dependent on the grouping or clustering of transmitting and receiving nodes for the first round of communication, in setup phase. K-LEACH considers least distant from the centre of cluster as a criterion for a node to be chosen as a CH during CH selection procedure (from second round onwards), K-LEACH is divided into many rounds, and each round contains cluster formation phase and steady state phase. In [23] results show the nodes are started to die in LEACH from the initial few rounds whereas in K-LEACH, 1st node died at round 15 that is after almost 50% of the network lifetime.

4.7. L-LEACH (Energy Balanced Clustering Algorithm Based on LEACH Protocol)

Authors [24] proposed improved protocol of LEACH is called energy balanced clustering algorithm named L-LEACH. The basic concept to design this improved protocol over traditional LEACH is proposes an energy balance algorithm optimizing CHs election. This algorithm comprehensively considers the residual energy and distance factors, improves CH election and the strategy of non-CH node selecting the optimal CH. Authors in [24] present simulation result, the energy consumption in L-LEACH is less than in LEACH algorithm at any time. The causes are as follows: the improved algorithm selects CH based on residual energy and node coordinates information, enables each node to consume energy in a relatively balanced way, the early death of low-energy nodes is avoided, the network energy dissipation is saved and the amount of data transmission is enhanced considerably.

4.8. LEACH-M (Mobile) and LEACH-ME (Mobile Enhanced)

Authors in [25] proposed a improved version of LEACH with a mobility scenario is called LEACH-M. LEACH-M uses the same threshold formula of the original LEACH to calculate the threshold, but LEACH-M takes into consideration the mobility of nodes during data transfer phase, which LEACH does not. The mobility itself is a challenge because mobile node can leave cluster while it is transmitting data to a CH. LEACH-M solves this problem by confirming whether a mobile node still able to communicate with CH or not according to TDMA schedule. At the beginning of each TDMA slot, the CH transmits the message req-data-transmission. If the mobile node is unable to receive the message, the CH waits for the request in the next TDMA slot. If the node misses two successive TDMA frames, it considers itself out of range, and the CH will remove unreachable nodes from its member list. Further improvement over LEACH-M is known LEACH-ME [26] as an enhanced version of LEACH-M. LEACH-ME was proposed to enhance LEACH-M by selecting the less mobile nodes relatively to its neighbours to be CHs. Each node contains CH transitions it has made during the steady state phase while transmitting data. Nodes transmit a transition count to its CH during the TDMA slot. The CH calculates the average transition count of its members for the few last cycles. The amount of energy dissipations for the data packets transmitted for both LEACH-M and LEACH-ME protocols and LEACH-ME saves more energy than LEACH-M.

4.9. LEACH-P (Performance)

Authors [27] introduced the other improved protocol called LEACH-P protocol which considers the probability selection of EAMR (Energy Aware Multipath Routing) into LEACH algorithm and makes a better choice of selecting CHs and optimizing the chance of cluster rebuilding. In [27] simulation result shows that LEACH-P has improved network lifetime compared with LEACH. It means LEACH-P longer network lifetime than LEACH.

4.10. LEACH-S (Solar aware Centralized & Distributed Low Energy Adaptive Clustering Hierarchy)

Authors [9] proposed another version of LEACH, which called solar-aware LEACH (S-LEACH). Using solar power in WSN has increased the lifetime of networks. In S-LEACH some nodes are facilitated by solar power and these nodes will act as CH mainly depending upon their solar status. Both LEACH and LEACH-C are extended by S-LEACH. The concept of solar scheme is applied to centralized and non-centralized LEACH protocol. Solar-aware centralized LEACH: In centralized LEACH-S, the sink node would select the CH with the help of improved central control algorithm. In LEACH-S, the solar status along with the energy of the sensor nodes is being transmitted to the sink and the nodes with having the higher energy are selected as the CH. When the number of solar-aware nodes is getting increased, the performance of sensor network is also getting increased and by this the lifetimes of the network also get increased. The sunduration increases the lifetime of the sensor network. The cluster head handover takes place if the sunduration is smaller [28]. Solar-aware Distributed LEACH: In solar-aware distributed LEACH, choosing preference of CH is given to solar-driven nodes. Probability of solar-driven nodes is higher than battery-driven nodes, more information about this paper so reader is advised to see [28].

4.11. T-LEACH (Threshold-based LEACH)

Authors [29] present T-LEACH protocol, which is a threshold-based cluster head replacement scheme for clustering protocols of WSNs. T-LEACH minimizes the number of CH selection by using threshold of residual energy. Lifetime of the entire networks can be extended compared with the existing clustering protocols by reducing the amount of head selection and replacement cost. In [29] simulation result shows that T-LEACH outperformed LEACH in terms of energy consumption and network lifetime.

4.12. V-LEACH (Vice)

Authors in [30] proposed new version of LEACH protocol in which the cluster contains CH (responsible only for sending data that is received from the cluster members to the BS), vice-CH (the node that will become a CH of the cluster in case of CH dies), cluster nodes (gathering data from environment and send it to the CH). In V-LEACH protocol, besides having a CH in the cluster, there is a vice-CH that takes the role of the CH when the original CH dies. By doing that, data collected by the cluster nodes will always reach the BS. Therefore, no need to elect a new CH each time the CH dies. This will extend the overall network lifetime [31], simulation result show V-LEACH consumes less energy compared with LEACH, as result of that the network lifetime is enhanced. That mean the new version of LEACH outperforms the original LEACH protocol [31].

4.13. W-LEACH (Weighted Low Energy Adaptive Clustering Hierarchy Aggregation)

Authors in [32] proposed a new version of LEACH is called W-LEACH; W-LEACH is a centralized data aggregation algorithm. W-LEACH consists of a setup phase and a steady state phase similar to traditional LEACH. In the setup phase, W-LEACH first calculates a weight value, W_i , and assigns it to each sensor S_i . Authors modify the definition of p to be the percentage of the maximum number of CHs instead of the actual number of CH as it is defined in the original LEACH. A maximum of $p\%$ of alive sensors are, then, selected to be CH based on the calculated weights, such that the higher the weights the better the chance for them to be CH. Note that unlike LEACH, W-LEACH does not take into consideration whether or not this sensor was a CH for previous near rounds. After all CHs are chosen, clusters are formed such that each sensor is assigned to its nearest CH. Author's simulate

LEACH and W-LEACH with all its modification using C-Language. In simulation, it is assumed that all sensors can directly reach each other's and they also can directly reach to BS. Due to this reason, no need to use a routing method because data can be directly sent from sender to receiver. This concept makes W-LEACH a general aggregation algorithm that can be used with any routing method. In [32], simulation result show that W-LEACH extends the network life time.

4.14. W-LEACH (Decentralized Algorithm)

Authors in [33] present improved model of W-LEACH to a new protocol called W-LEACH decentralized to increase network lifetime without the use of maps. Working of W-LEACH decentralized algorithm is similar to LEACH, W-LEACH decentralized algorithm is divided into rounds, where each round begins with a setup phase in which CH are selected and clusters are formed. Then comes the steady-state phase in which the data transmitted to the BS. Just before the beginning of data transmission, each node determines its neighbours according to a well-determined distance which organizes the density of nodes so the neighbouring nodes do not transmit the same data. According to the number of neighbours, the node members decide their status as being in an active state or they remain in a sleep state during this round, so a sensor with low densities (has a lot of neighbours) stays alive as long as possible. In this way, the allocations of sensors densely send data to their CHs have probably led to minimize redundant data CH and they always share in sending data with their CH. Thereafter the total energy consumption of the network is minimized, so we increase lifetime of network. During each round in the network, there are member nodes which are selected into two groups: sleeping nodes and active nodes. In [33] a result show, W-LEACH decentralized saves more energy compares to LEACH protocol, finally in this paper we give the time line of LEACH and its descendant protocols in table 1.

Table 1: Time line of LEACH and its Descendant

S.No.	LEACH & its Descendant	Author's	Abbreviation	Year
01	LEACH[11]	Heinzelman. W.R. et al.	Low Energy Adaptive Clustering Hierarchy	2000
02	LEACH-B[18]	Depedri. A.et.al.	Balanced Low Energy Adaptive Clustering Hierarchy	2003
03	LEACH-C[19]	Heinzelman.W.et.al.	Centralized Low Energy Adaptive Clustering Hierarchy	2002
04	LEACH-E[20]	Fan. X. N.et.al.	Energy Low Energy Adaptive Clustering Hierarchy	2007
05	LEACH-F[21]	Manimala.P.et.al.	Fixed number of cluster Low Energy Adaptive Clustering Hierarchy	2013
06	LEACH-I[22]	Dembla.D.et.al.	Improved Low Energy Adaptive Clustering Hierarchy	2013
07	LEACH-K[23]	Bakaraniya.P.,et.al.	Kmedoids-Low Energy Adaptive Clustering Hierarchy	2013
08	LEACH-L[24]	Qian .L.,et.al.	Energy Balanced Clustering Algorithm Based on LEACH Protocol	2013
09	LEACH-M[25]	Kim. D. S.et.al.	Mobile Low Energy Adaptive Clustering Hierarchy	2006
10	LEACH-ME[26]	Kumar G. S.et.al.	Mobile Enhanced Low Energy Adaptive Clustering Hierarchy	2008
11	LEACH-P[27]	Zhu.D.et.al.	Low Energy Adaptive Clustering Hierarchy Performance	2010
12	LEACH-S[28]	Thiemo .V.et.al.	Solar aware Low Energy Adaptive Clustering Hierarchy	2004
13	LEACH-T[29]	Jiman .H.et.al.	Threshold-based Low Energy Adaptive Clustering Hierarchy	2007
14	LEACH-V[30][31]	Bani Y.M.et.al.	Vice Low Energy Adaptive Clustering Hierarchy	2009
15	LEACH-W[32]	Hanady. M.et.al.	Weighted Low Energy Adaptive Clustering Hierarchy Aggregation	2013
16	LEACH-WD[33]	Abdelhalim.H.et.al.	Weighted Decentralized Low Energy Adaptive Clustering Hierarchy	2014

5. Comparison of LEACH and its Descendants Protocols for WSNs

In this survey, LEACH based routing protocols are described. LEACH protocol enhances the life time of a WSN and saves the energy by random rotation of CH and assigns the TDMA schedule to each cluster members to avoid collision. Selection of CH is random, even though LEACH improves energy efficiency but it does not work well in

large coverage area which need multihop transmission, does not support mobility, reliability, etc. To overcome these drawbacks, to develop more efficient descendant of LEACH are developed which are summarize on various assumptions, shown in table 2. From this survey, it can be finalized that to make WSN more efficient and to extend the lifetime, still needs more improvement in clustering protocol.

Table 2: Survey on LEACH and its Descendant protocols based on selected features

LEACH Descendant	Clustering Method	Data Aggregation	Mobility Type	Scalability	Advantages	Disadvantage
LEACH[11]	Distributed	Yes	Static	Limited	Load distribution in network	CH are not uniformly
LEACH-B[18]	Distributed	Yes	Static	Good	Network lifetime increase	Overhead increase
LEACH-C[19]	Centralized	Yes	Static	Good	Achieves more rounds in n/w	Overhead on the BS
LEACH-E[20]	Distributed	Yes	Static	Very good	Improves CH selection	CH is always in active
LEACH-F[21]	Centralized	Yes	Static	Limited	Delay is small	Cover larger region
LEACH-I[22]	Distributed	Yes	Static	Very good	Equally divide field	Periodically updates
LEACH-K[23]	Distributed	Yes	Static	Good	Prolonged stability period	Needs load balancing
LEACH-L[24]	Distributed	Yes	Static	Very good	Balanced network load	Needs storage capacity more
LEACH-M[25]	Distributed	Yes	Mobile	Good	Mobility of CH node	Overhead increase
LEACH-ME[26]	Distributed	Yes	Mobile	Limited	Supports nodes mobility	Extra overhead
LEACH-P[27]	Distributed	Yes	Static	good	Increase network lifetime	Introduced extra overhead
LEACH-S[28]	Centralized	Yes	Static	Very good	Power gain from solar	Centrally controlled
LEACH-T[29]	Distributed	Yes	Static	Good	Reducing the CH selection	CH based on threshold
LEACHV[30][31]	Distributed	Yes	Static	Very good	Introduce vice CH	Extra processing for vice CH
LEACH-W[32]	Centralized	Yes	Static	Good	Increase lifetime of network	CH selection is random

6. Conclusion

Due to scarce energy resources in sensors, the main challenge has been the energy efficiency of network. Even while design the routing protocols for WSN, the aim of least energy consumption holds its top priority because energy resources are very limited. The first objective behind the routing protocol design is to keep the sensors in operation for as long as possible, thus extending the network's lifetime. The energy consumption of the sensors is dominated by data transmission and reception. Therefore, routing protocols designed for WSN should be as energy efficient as possible to prolong the lifetime of individual sensors and hence the network's lifetime. In this paper various LEACH-based protocols has been discussed in brief. Furthermore, the timeline and surveyed summary table of LEACH and its descendant routing protocol has been presented. Due to the drawbacks of LEACH, many protocols have been come to solve these problems. However, more work is still needed to find more efficient, scalable and robust clustering scheme to enhance energy consumption and enhance networks lifetime in small and large WSN.

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