Chapter 50
A Literature Survey on LEACH Protocol and Its Descendants for Homogeneous and Heterogeneous Wireless Sensor Networks

Anish Khan and Nikhil Marriwala

1 Introduction

WSN has become most interesting research area nowadays, due to low price, low power, flexible wireless sensor nodes that sense the desired information and forward that data to the controlling station for processing. WSN has widely utilized in everyday life because of its numerous applications in the field of healthcare, military battlefield, surveillance, intelligent highways, environment monitoring, etc. [1]. When these kinds of applications are implemented in a real-life environment, the sensors devour a lot of energy for detecting, processing, transferring the data. As the energy consumption is the major concern in the WSN so, how to effectively utilize the limited power and refines system life durability is the bottleneck of the whole scenario [2].

Various kinds of approaches are introduced in the literature by the researchers in the field of WSN to minimize the energy drainage and to enhance the lifetime of the network are either to confine the measure of information to be transmitted or to limit the distance between the sink and the source node [3]. The hierarchical protocols emphasize the concern in WSN. The fundamental quality of the various levelled/hierarchical protocol is to bunch the nodes and the nodes of a specific group converse with their group heads. Furthermore, the group head conveys the computed details to the controlling base station [3].

The paper structuring is as follow Sect. 2 briefing basic LEACH protocol. Section 3, sum up's the work carried out by other researchers to amplify the potential of essential LEACH. Section 4, describes the successors of LEACH protocol.

A. Khan (✉) · N. Marriwala
University Institute of Engineering and Technology, Kurukshetra University, Kurukshetra, Haryana, India
e-mail: anikhan0101@gmail.com

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Section 5, analyze the comparison between descendants of basic LEACH routing protocol. At last, the verdict is exhibited in Sect. 6.

2 LEACH Protocol

"Low-Energy Adaptive Clustering Hierarchy Protocol" (LEACH) is proposed by Heinzelman et al. [4] is popular weighted protocol with the clustering hierarchy. The prime benefit of this routing protocol, it improves the network duration by diminishing the energy utilization of the whole wireless sensor network. LEACH protocol, organizes sensor nodes as clusters. Clusters communicate with their respective group heads. The sensor nodes sense the details of interest and forward it to their cluster heads. In addition to this, the group head assembles information from all nodes at that point amasses and packs them to send to the base station [5]. LEACH is established in rounds and every round includes two stages. The first stage refers to the set-up stage and the second stage refers to the steady-stage. In the set-up stage, cluster head selection and cluster formation take place. It also is known as the initialization phase, every node produces an arbitrary number somewhere in the range of 0 and 1. On the off chance that the arbitrary number created by a node is under the set limit $T(n)$, the node communicates to all nodes that it's the cluster head for the current round [6]. $T(n)$ is given as:

$$T(n) = \begin{cases} \frac{p}{1-p\left[\text{rmod}\left(\frac{1}{\text{p}}\right)\right]}, & n \in G \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

where

p *the current round,*
r *the current number of rounds,*
G *the set of nodes that have not been selected as CHs in the last 1/P rounds,*
n *the threshold value*

In the steady stage, the information passes on starts. Cluster head nodes make a TDMA plan The TDMA schedule tells nodes present in the cluster when to start communicating their data. When the TDMA schedule is fixed and broadcast in the respective cluster, the nodes start transmitting their sensed data in the allocated scheduled transmission time [4].

Basic diagram of the LEACH protocol is shown in the Fig. 1.

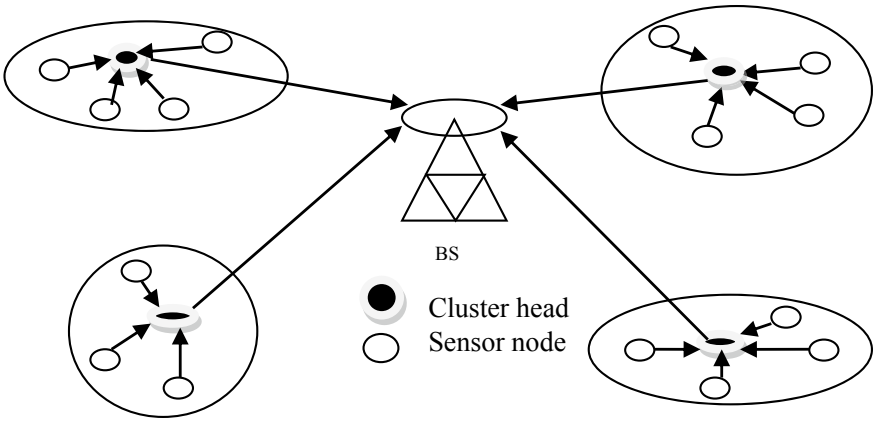

Fig. 1 Clustered framework

3 Related Work

Many researchers already did their research in the field of WSN. Nikhil Marriwala et al. [26], conclude the working of basic LEACH Protocol. Some advanced versions of this protocol are discussed in brief. Mohammad NajmudDoja et al. [3], wind up that in H-LEACH sharing location information using GPS is an important factor to improve energy efficiency. Jie Chen et al. [6], I-LEACH is introduced based upon the residual and balanced energy. The entire network works for a long time. Xu-Xing Ding et al. [7], Dynamic k value leach is proposed to optimize the cluster structure. The network is divided into an even and uneven network. Tanushree Agarwal et al. [8], this paper ensures excellent formula for extending the duration of the network. Vishal Kumar Arora et al. [9], make a survey that gives us a birds-eye view of different kinds of protocols. The main focus is on hierarchical protocols like LEACH and its variants, for example, C-LEACH, MODLEACH, Stable Election Protocol (SEP), MH-LEACH, T-LEACH, and V-LEACH. In addition to this, other hierarchical routing protocols like PEGASIS, TEEN, APTEEN are also discussed. Sudhanshu Tyagi et al. [10] gives a nitty-gritty survey on clustering and routing strategies dependent on LEACH protocol for remote sensor network.

4 Descendants of Leach Routing Protocol: Overview

Ben alla et al. [11], introduces IB-LEACH for heterogeneous WSN which decreases the probability of node failure and makes the whole network reliable, stable, and an improved lifetime of the whole network. Some more power level nodes are added in a network known as NCG nodes (Normal, cluster, gateway) nodes that will perform the role of cluster head to amass features from respective cluster nodes and forward

it to "gateways" that requires less energy to talk with BS. As the proposed protocol is a descendant of LEACH protocol, it also works in rounds as there are two main rounds [26]. In the set-up phase, gateways are elected by using gateway algorithm and groups are framed with the help of a group selection algorithm. In the steady phase, details are passed on from cluster nodes via cluster heads to gateways that utilize minimum energy to transmit data to BS. At last, a comparison is made between LEACH, SEP and IB-LEACH protocols that show higher quality results.

Guijum Chen et al. [12], introduces an improved LEACH algorithm name LEACH-HEM algorithm, which is based upon the energy heterogeneity of nodes that have identical beginning energy and transmission of messages are in multi-hop fashion among the cluster heads (CH). A new threshold value introduces the concept of current energy and standard energy of nodes. Hence, nodes with higher residual energy have more chances to be appointed as a cluster head. Cluster head election equation is described as:

$$\overline{E(r)} = \frac{1}{N} \sum_{i=1}^{N} E_i(r) \tag{2}$$

Here,

$\overline{E(r)}$ *Average network energy in round r*
$E_i(r)$ *Node Current energy for round r*

The optimal percentage of the CH, the equation becomes:

$$p_i = p_{\text{opt}} \left[1 - \frac{\overline{E(r)} - E_i(r)}{\overline{E(r)}} \right] = p_{\text{opt}} \frac{E_i(r)}{\overline{E(r)}} \tag{3}$$

Here,

p_{opt} optimal percentage of the CH
$p_i = \frac{1}{n_i}$ the average probability to become CH

In this scenario, two kinds of propagation models are used one is free space ε_{fs} and multi-path fading ε_{mp}. At last, the aftereffect of suggested calculation is contrasted with LEACH, LEACH-DCHS, ALEACH.

Naveen Kumar et al. [13], have structured rules of conduct named universal LEACH, the selection for CH's lies on prime energy and extant energy of nodes. This protocol mixed the concept of PPEGASIS and I-LEACH protocol. Exchange of messages within the cluster is done with the help of a chain, in addition to this chain begins from the farthest node in distinction to the base station. This protocol uses the concept of Master Cluster Head (MCH), CH's transmit aggregated data to the MCH which further sends it to BS. Nodes that are far off from the BS send their detected information to their neighbour nodes that are nearer to them and in the same fashion information is sent to BS. Chain formation is a very effective mechanism for energy saving because nodes need not to directly communicate with BS.

Manzoor et al. [14], introduces Quadrature-LEACH for uniform wireless sensor networks. This proposed routing protocol shows eye-catching results in terms of strength, network life existence of the network. As the network is homogeneous, the author subdivides the whole network within four equal divisions name as (a1, a2, a3, a4) for better coverage. Then two algorithms are applied, algorithm 1 defines the CH selection procedure. Algorithm 2 defines the association of nodes with their respective cluster heads. In algorithm 1, the node picks an irregular number somewhere in the range of 0 and 1. If the chosen is lower than the threshold value *T(n)* and the provision for the desideratefigure of CHs is not obtained then the node becomes CH. Algorithm 2 describes the association of nodes with their clusters which are based upon the Received Signal Strength Indicator (RSSI).

Versha Sharma et al. [15], investigates the effectiveness of single-bounce and multi-bounce LEACH protocol that consists of heterogeneous nodes. In advanced single-bounce LEACH protocol, the author takes heterogeneous nodes having different energy levels named as standard nodes and high energy nodes. The power level of high energy nodes is improved by a factor of 1 in contrast with standard nodes. Sensor nodes that are having more remaining energy will become the CH for the particular round either node is a standard node or high energy node. CH collects data, made aggregation and forwards it to the BS. Further, the whole operation is the same as the LEACH protocol. The threshold value is calculated as Eq. (1). In advanced multi-hop LEACH protocol, the transmission of details is made by opting prompt neighbour node. Multi-hop LEACH prolongs the lifetime of the network by an optimal number of clusters and the optimal number of hops to avoid overlapping and collision.

The equation for Energy depletion in CH:

$$E_{\mathrm{CH}} = \left(\frac{N}{k} - 1\right) L * E_{\mathrm{elec}} + \left(\frac{N}{k}\right) L * E_{\mathrm{proc}} + L * E_{\mathrm{elec}} + L * \varepsilon_{\mathrm{mp}} * D_{\mathrm{BS}}^{4} \quad (4)$$

where,

E_{elec} energy for electronic circuitry
L packet size
D_{BS}^{4} distance between CH to BS
$\varepsilon_{\mathrm{mp}}$ multipath energy

Equation for optimum number of hops:

$$H = \left[\left(\frac{Mk}{2T_x}\right) - 1\right] k \quad (5)$$

Average energy calculation:

$$E_{\mathrm{avg}}(r) = \frac{1}{N} E\left(1 - \frac{r}{R}\right) \quad (6)$$

Amr Amwary et al. [16], introduces a modified LEACH protocol for heterogeneous networks. In the M-LEACH protocol, the main change is done in the setup phase, only the advanced nodes turn into CH for particular spin and steady phase, in which data transmission occurs, will remain the same. Considering energy calculation, the radio energy model is adopted. Energy exhausted by transmitter:

$$E_{\mathrm{Tx}}(k,d) = E_{\mathrm{Tx-elec}}(k) + E_{\mathrm{Tx-amp}}(k,d)$$
$$E_{\mathrm{Tx}}(k,d) = k * E_{\mathrm{elec}} + k * E_{\mathrm{amp}} * d^2 \tag{7}$$

where,

k packet length in bits
E_{Tx} energy consumed in transmitting k - bit message
d distance

The threshold value is calculated as,

$$T(n) = \begin{cases} \frac{p*a}{1-a*p\left[r \bmod \left(\frac{1}{p*a}\right)\right]}, & n \in G \\ 0, & \text{otherwise} \end{cases} \tag{8}$$

where $a = \begin{cases} 1 \text{ if node is normal} \\ 5 \text{ if node is advanced} \end{cases}$

Shweta Gupta et al. [17], In this paper, a new approach introduced for the homogeneous & heterogeneous WSN name as IDE-LEACH. In this approach, IDE-LEACH utilizes the primary energy, space between cluster nodes & sink node and the enduring energy of the node for CH determination. The author takes many assumptions to design the network model as 100*100 sq. Meter area. Both networks consist of 100 sensors. In the homogenous model, the sensors are having the same energy level but in the heterogeneous model the energy level of nodes are the same but 10% of the total nodes are having the higher power. The author used a radio energy model.

Future work: we can merge both the heterogeneous and homogeneous networks enhance the existing pattern of the system.

Ahmed al-baz et al. [18], newly designed protocol entitled as NR-LEACH. Energy load is scattered in the group of nodes with the help of the node rank algorithm. Moreover, the entire activity is partitioned into cycles. In the set-up phase, CH's are elected, and in the steady phase, aggregated data is transmitted within CH and BS. Appointment of CH depends on node rank calculation; the weight of a node is affected by three main elements i.e. acquired signal quality, leftover energy of every node in the network, and connection association number among different nodes. Node Rank Score is calculated by:

$$\mathrm{NR}(n_i) = \mathrm{PO}(n_i) * \alpha * \sum_{0}^{j} \mathrm{NR}\left(n_j\right) \frac{\frac{1}{d_{\mathrm{out}}^{ji}}}{\sum_{k \in \mathrm{NH}} d_{\mathrm{out}}^{jk}} + (1-\alpha) \tag{9}$$

Here,

d_{out}^{ji} *distance of out link from node j to node i*
$PO(n_i)$ *current energy of node i*
α *damping ratio*

Performance is compared with classical LEACH protocol, LEACH-E, I-LEACH.

Mohammad NajmudDoja et al. [3], the study of this paper shows the hybrid approach in leach. The author has offered a change in the fundamental LEACH protocol by considering factors i.e. utilizing the area in which sensor nodes to be deployed and by considering area coordinates. On the bases of these factors, clustering is done. In this approach, the cluster is stabilized however the group head is picked progressively. First, the area is divided into zones according to parameters and then one node from each zone is picked as group supervisor as done in traditional LEACH.Some assumptions are taken for designing the H-LEACH protocol is as follows:-1. Nodes that are deployed in the zone are very much informed of their area correspondent and the location coordinates are shared with the BS.2. Energy exhausted by the CH to move the assembled data received from nodes to the BS is not taken into account because it will affect the protocol in long terms.

Amer O. Abu Salem et al. [5], An Enhanced LEACH protocol is recommended; Author identifies CH according to the distance between node and CH and from CH to BS to decrease the power consumption of CH node. The main change is done in the setup stage. After the node selects the CH, the node sends the message to the CH that through it the distance is minimum to the BS & hence, it will become the member of that CH. Steady-state remains the same.

Xu-Xing Ding et al. [7],This paper introduced a reformed cluster construction method recognized as Dynamic K value LEACH. The main motive to design this protocol is to diminish the energy utilization of the unequal distribution of energy in WSN. The remaining energy of the CH is considered. The node that has more residual energy is elected as CH. DK-LEACH is operated in phase's i.e. setup and steady phase.

Jie Chen et al. [6], Proposed a clustering algorithm name Improved Leach (I-LEACH). In this algorithm, the choice of CH is done on the bases of the unused energy of node and gap with other CH. The comparison is done with the Basic LEACH and P-LEACH. In the improved algorithm, advancement is done in the cluster head selection and data communication.

1. To lessen energy utilization, every node includes its remaining energy to the envelope and forwards it to the BS.
2. If the node is near to the CH, the probability of a node to become CH is very less. The threshold value of the distance is set as d0/2.
3. Data Communication between node and cluster head.
4. Data communication among the CH.

JyotiBhola et al. [19],designed an advanced variant of LEACH protocol with the use of the genetic algorithm by using its fitness function. The energy consumption rate is increased by 17.39% of the total. In this paper, the main key aspect is the

amount of CH's present in the scenario. When the amount of CH is less, they have to cover more areas, causes more energy consumption. GA selects the CH according to their remaining energy.

Ravi Kishore Kodali et al. [20], DD-TL-LEACH is invented. The simulation is done in NS-3 simulator. Comparison is done in between Direct Transmission, MTE, LEACH, Directed Diffusion protocol. To beat the constraints of the LEACH a few enhancements are done by introducing the TL-LEACH, DD-LEACH, M-LEACH. The proposed protocol is the mixture of the TL-DD-LEACH.

Abdul Razaque et al. [21], In this paper, the author designed a dynamic protocol with the help of PEGASIS. The author named this protocol as PEGASIS-LEACH Protocol (P-LEACH). The author combines basic LEACH with chain cased construction of PEGASIS. In PEGASIS protocol, a string of nodes are constructed and a chief node is chosen randomly. Chief node assembles data, fuse and forward it to BS. PEGASIS reduces power consumption, reduces traffic overload and builds the system lifetime and cost-effectiveness.

Mustafa A et al. [22], analysis new protocol that uses the basic LEACH protocol with the three layers. Every layer has individual CH's. Layers are introduced with diminishing the separation between the sink node and the CH's. Layer three came in play if the distance is larger as compared to the threshold value. The author named it as the LEACH Three (LEACH-T). The first layer nodes gather data from the sensor nodes. Further, second layer CH gathers information from first layer CH & forward it to BS. The third layer CH's are used when the distance between the second layer CH & BS is more. The proposed protocol works in the three phases.

Chinchu T Sony et al. [23], In this paper, the author introduces some improvements in the basic leach protocol for making the convention substantially more energy proficient. The advancements are done in the cluster head selection, assigning the TDMA schedule. Some new parameters are introduced i.e. node energy level for the CH selection. The primary thought is to dodge the sensor node with lessen remaining energy as the CH. If the altered limit esteem is more than the arbitrarily produced number between the extents 0 to 1, that specific node can be proclaimed itself as the CH.

Mu Tong et al. [24], the author has presented a new version known as LEACH-B (LEACH- Balanced) protocol. In this proposed algorithm the author concern basic drawbacks in the essential LEACH protocol i.e. selection of group heads is done without considering lingering vitality of hubs. Group chief selection is done in rounds. In the first round, group chief choice is identical as in basic LEACH protocol. The main change is brought in the second round. To keep up the steady number of group heads n * p, where p signifies the ideal level of the group heads and n is meant as the aggregate number of hubs. Leftover energy of hubs is advertised in the network through advertisement messages from cluster heads.

Saravanakumar et al. [25], proposed algorithm in which sensor nodes form clusters and the process of group chief selection depends on the enduring vitality of the nodes. Hub planning strategy is maintained in each group of the WSN's. In the hub arrangement plan, the concept of alive mode and snooze mode is introduced; it expands the vitality effectiveness of the system up to 50%.

Nikhil Marriwala [26], In this chapter, the author describes the meaning of routing protocols and how we can classify various kinds of routing protocols on the bases of their network structure and their mode of operations like flat routing, location-based routing, hierarchical routing. Moreover, there are many design constraints for routing in WSN's. The study gives us an idea about the constraints and how can we overcome those constraints. In addition to this, the study focuses on the LEACH protocol and various kind of Hybrid-LEACH protocols or H-LEACH. A variety of H-LEACH protocols are discussed in this chapter like PEGASIS, HEED, V-LEACH.

4.1 Performance Comparison Between LEACH Protocol and Its Descendents

See Table 1.

5 Conclusion

Extending the network lifetime by efficiently utilizing energy is the bottleneck in wireless sensor networks. As LEACH protocol is first and energy-saving hierarchical protocol which is widely used for prolonging the network life has some limitations, hence many upgraded variants are proposed to remove those limitations. Therefore a brief analysis is done on how to overcome the constraints in basic LEACH. On the bases of this analysis, the comparison is made to contrast the performance of derived LEACH protocols as shown in Table 1. The whole survey windups that for more energy-efficient and reliable network we need to model systematic, structured and well-organized energy-saving protocols.

Table 1 Comparison between various improved LEACH protocol

Clustering routing protocol	Year	Mobility	Energy efficiecy	Self oganization	Hop count	Homogeneous/heterogeneous	Use of residual energy and distance b/w nodes
IB-LEACH	2010	Fixed Bs	Improved	Yes	Single Hop	Heterogeneous	Yes
LEACH-B	2010	Fixed Bs	Improved	Yes	Single Hop	Homogeneous	Yes
I-LEACH	2011	Fixed Bs	Improved	Yes	Single Hop	Homogeneous	Yes
LEACH-HEM	2012	Fixed Bs	Improved	Yes	Multi-Hop	Heterogeneous	Yes
U-LEACH	2012	Fixed Bs	Improved	Yes	Multi-Hop	Heterogeneous	Yes
Q-LEACH	2013	Fixed Bs	Improved	Yes	Single Hop	Homogeneous	Yes
SINGLE-HOP & MULTI-HOP LEACH	2015	Fixed Bs	Improved	Yes	Single Hop & Multi-Hop	Heterogeneous	Yes
Modified LEACH & Modified Multi-Hop LEACH	2015	Fixed Bs	Improved	Yes	Single Hop & Multi-Hop	Homogeneous	Yes
DD-TL-LEACH	2015	Fixed Bs	Improved	Yes	Multi-Hop	Homogeneous	Yes
M-LEACH	2016	Fixed Bs	Improved	Yes	Single Hop	Heterogeneous	Yes
P-LEACH	2016	Fixed Bs	Improved	Yes	Multi-Hop	Homogeneous	Yes
LEACH-T	2016	Fixed Bs	Improved	Yes	Multi-Hop	Homogeneous	Yes
IDE-LEACH	2017	Fixed Bs	Improved	Yes	Single Hop	Heterogeneous & Homogeneous	Yes
DK-LEACH	2017	Fixed Bs	Improved	Yes	Single Hop	Heterogeneous	Yes
NR-LEACH	2018	Fixed Bs	Improved	Yes	Single Hop	Homogeneous	Yes
H-LEACH	2018	Fixed Bs	Improved	Yes	Single Hop	Homogeneous	Yes
Enhanced LEACH	2019	Fixed Bs	Improved	Yes	Single Hop	Homogeneous	Yes

(continued)

Table 1 (continued)

Clustering routing protocol	Year	Mobility	Energy efficiecy	Self oganization	Hop count	Homogeneous/heterogeneous	Use of residual energy and distance b/w nodes
LEAH with GA	2019	Fixed Bs	Improved	Yes	Multi-Hop	Homogeneous	Yes

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