H-LEACH: Modified and Efficient LEACH Protocol for Hybrid Clustering Scenario in Wireless Sensor Networks

Vishal Gupta and M.N. Doja

Abstract Wireless sensor networks consist of independent sensors that sense and monitor the area of deployment and distributedly communicate this information to base station. The desirables of WSN are to have long longevity and high reliability along with maximized coverage. LEACH is one of the most discussed hierarchical, cluster-based routing protocols for sensor networks owing to its load-balancing characteristics. In this paper, we have presented a hybrid approach (H-LEACH) in which the clusters are fixed, but the cluster heads are chosen dynamically. The approach shows an improved performance that is duly supported by the simulation results using MATLAB. The paper concludes with the limitations and further scope for improvement in the proposed protocol.

Keywords Wireless sensor network/s · LEACH · H-LEACH · Cluster · Lifetime · Skewness · Base station (BS) · Cluster head (CH)

1 Introduction

In wireless sensor network (WSN), the sensor nodes mostly employ distributed algorithms to collect the information and wirelessly communicate this information to the base station, from where this information may be processed and analyzed.

Out of these responsibilities, the communication amongst nodes is considered to be the major energy consumption area in WSN [1]. The main approaches used in the literature to reduce this are either to limit the amount of data to be communicated or to minimize the distance between the source and sink of the data to be transported.

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Different types of routing protocols and algorithms have been proposed by different researchers for WSN. The hierarchical protocols are the category of protocols that has got the most concern in this field. The characteristic of these protocols is to cluster the field nodes, thereby reducing the overhead for transmissions. In this approach, the nodes in the particular cluster talk to the cluster head of the respective cluster. The cluster head in turn communicates this received information to base station. Clustering significantly improves the network lifetime by minimizing the number of nodes participating in long-distance transmission to base station [2].

"Low-Energy Adaptive Clustering Hierarchy protocol" (LEACH) [3] is the widely discussed protocol with clustering hierarchy. However, the issues of the number of cluster heads and the cluster members cannot be controlled by LEACH [4].

In present day scenario, where we have very cheap and effective coordinate finding techniques like GPS, we can use this technological improvement to enhance the performance of basic LEACH protocol. In this paper, we have utilized this concept that if we have this information, we can modify the basic leach protocol to enhance its performance.

The paper organization is as follows: Section 2 presents the brief idea of the basic LEACH protocol. Section 3 summarizes some work done by different researchers to enhance the performance of the basic LEACH protocol. In Sect. 4, we have explained our proposed protocol H-LEACH with the simulation results supporting our claim. The paper lists the limitations and assumptions of this work in Sect. 5. Finally, the conclusion and future scope are presented in Sect. 6.

2 LEACH Protocol

LEACH [3] is the most popular clustering strategy for WSNs where the sensor nodes make autonomous decisions for dynamic cluster formation.

The protocol works in rounds, and the different rounds consist of two phases each: the set-up phase and the steady-state phase as shown in Fig. 1.

The cluster heads are chosen in the set-up phase on the basic of the following function (known as candidate/threshold function):

$$T(n) = \begin{cases} \frac{P}{1-P\left(r.\mathrm{mod}\frac{1}{P}\right)}, & \text{if } n \in G \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

where the meaning of symbols used is

P percentage of the cluster head nodes;
r number indicating the current round;
G set of nodes those were CH node in the previous $1/P$ rounds.

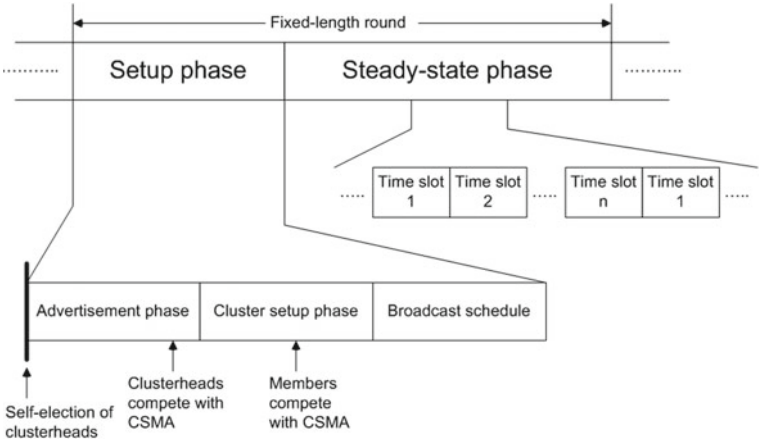

Fig. 1 LEACH protocol

The selected CH list is broadcast in the area, and the different member nodes pick the CH as one that is nearest to them and convey this to the selected CH with the join request. The CHs then create TDMA schedule for the different member nodes in the respective clusters for data transmission. In steady-state phase, the sensed data are transmitted by the different member nodes as per their time slot to the CH. The CH may aggregate this collected data (if desired) and then forwards this to the base station for further processing.

After this, the whole process is repeated over again marking the beginning of the next round.

3 Literature Survey

Much work has been done to enhance the performance of the basic LEACH protocol. In this section, we summarize some work by different researchers in this area.

LEACH-C [5] considers the residual energy when the clusters are formed. Muruganathan et al. in [6] have proposed a centralized protocol "Base station-controlled dynamic clustering protocol (BCDCP)" that claims to uniformly distribute the dissipation of energy amongst all the deployed sensor nodes.

In BN-LEACH [7], the author propose to select the CH using the Bayesian network (BN) model based on three factors distance to base station (BS), remaining energy and density. Wang and Zhu et al. in [8] have proposed LEACH-R routing scheme to improve the cluster head selection using the relaying node. WEEC [9] utilizes the location of each node for calculating the probability of CH-selection.

Kumar et al. [10] have proposed a heterogeneous model in which the selection of cluster head is based on weighted probability. Wang and Yong in [11] have proposed

cluster head selection using pseudo-cluster concept. Energy Efficient Extended LEACH (EEE-LEACH) proposed in [12] is a multilevel clustering approach to improve the energy efficiency. In [13], Farooq et al. have presented a "Multi-hop Routing with Low-Energy Adaptive Clustering Hierarchy (MR-LEACH)" protocol for WSN.

Liao [14] proposed a scheme to select CHs based on the residual energy along with the location information of nodes. They also presented an optimized threshold for selecting cluster head. In [15], Ma et al. have presented an "Adaptive Assistant-Aided Clustering Protocol using Niching Particle Swarm Optimization (AAAC-NPSO)" to increase the lifespan and data delivery rate by regulating the energy dissipation in the WSN. Mehra et al. [16] have proposed a LEASE protocol to control the energy dissipation rate of the different nodes in the network to enhance the efficiency. In [17], Abhishek and Sumedha have implemented node residual energy and node distance-based algorithm for clustering of nodes to minimize the average energy consumption in WSN.

Arumugam and Ponnuchamy [18] have proposed a protocol "EE-LEACH" claiming a better packet delivery ratio, lesser energy consumption and lesser E2E delay than the EBRP and LEACH protocols. Sheta and Solaiman [19] have presented two hybrid clustering algorithms called K-Means Particle Swarm Optimization (KPSO) and K-Means Genetic Algorithms (KGAs) showing improvements over traditional LEACH. An improvement over LEACH protocol is presented by Tohma et al. [20] on the basis of number of packets, number of living nodes, etc. using the OMNet++ as the simulation environment. Li and Changdong [21] proposed an improved LEACH algorithm that considers the current position and the current energy of the node.

The proposed work is presented in the next section.

4 H-LEACH: Proposed Protocol

We have proposed a modification in the basic LEACH protocol by utilizing the area and node location coordinates and then clustering the area on the basis of this information. In essence, we first partition the complete area in as many zones as the desired number of clusters. The protocol chooses one node from each zone as the CH of that area on the basis of LEACH criteria in each round. The role of the CH is rotated amongst the nodes of the respective zones in each round to balance the energy dissipation of the nodes. The member nodes of a particular zone talk to their respective zone cluster head.

Figure 2 shows the arbitrary deployment scenario for normal LEACH showing the base station, cluster heads (as picked by the current round of the protocol) and the member nodes in the given area of (100 * 100) units. The association of the member nodes to their respective cluster head for this round is shown by Fig. 3.

Figure 4 shows the arbitrary deployment scenario for H-LEACH showing the base station, cluster heads (as picked by the current round of the protocol) and the

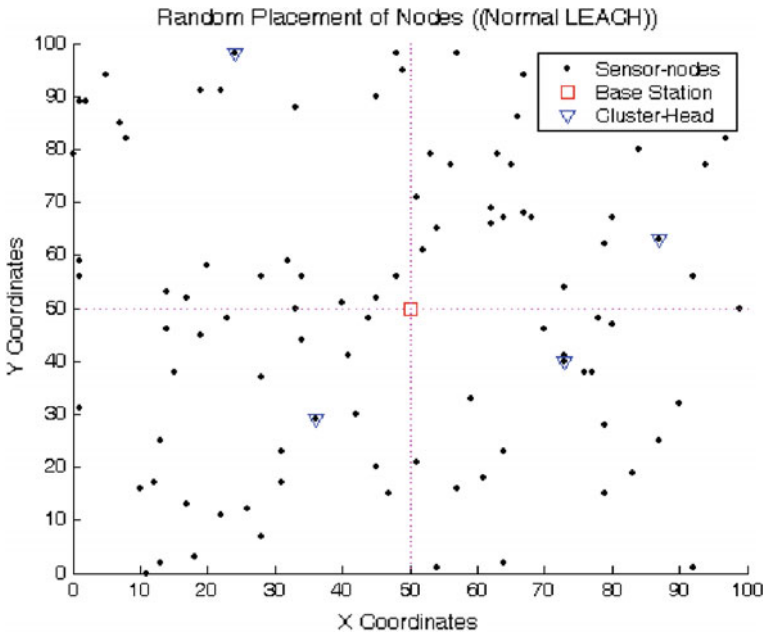

Fig. 2 Normal LEACH deployment scenario

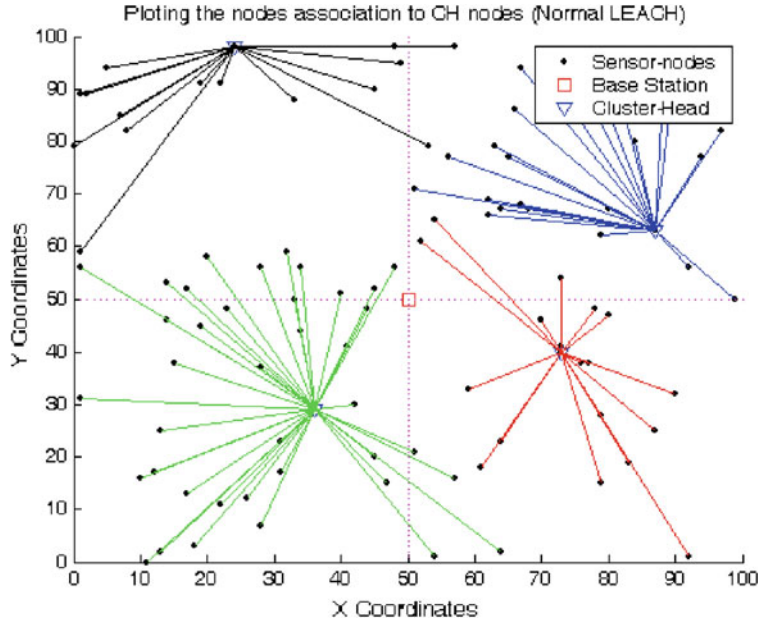

Fig. 3 Normal LEACH node association to CH

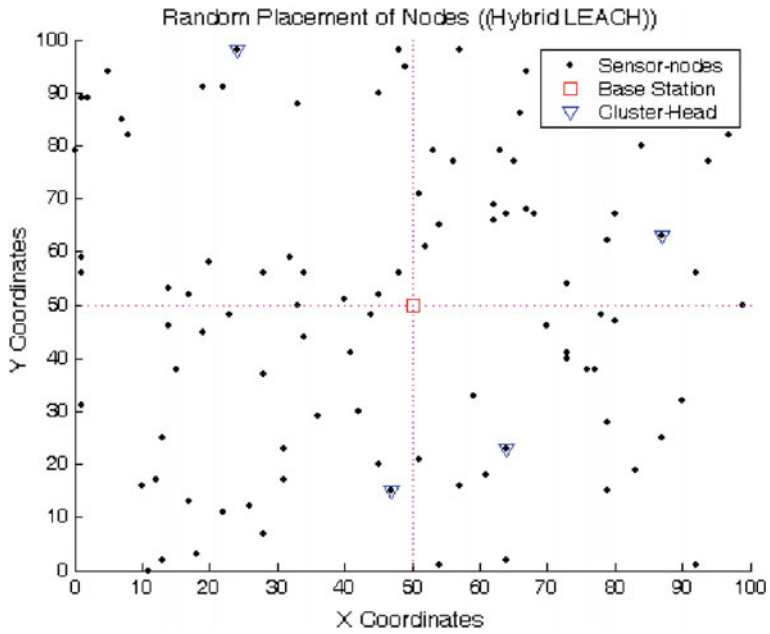

Fig. 4 H-LEACH deployment scenario

member nodes in the given area of (100 * 100) units. The association of the member nodes to their respective cluster head for this round is shown by Fig. 5.

Figure 6 presents the comparison of average energy consumed by all the member nodes in different rounds for some arbitrary deployment. Figure 7 shows the comparison of average energy consumed by all the member nodes in different deployment scenarios.

Figure 8 shows the energy gain corresponding to the difference of average energy spent by the member nodes in normal LEACH and H-LEACH protocol over different deployment scenarios.

5 Limitations and Assumptions

Comparing our protocol to the basic LEACH protocol, we have assumed that all the nodes deployed are well-aware of their location coordinates that are also shared by base station as well. Also, we have not considered the energy consumed by the CH nodes to transfer the gathered information to the base station because this will affect both the protocols roughly equally for a long run as the CH is chosen randomly in both the schemes.

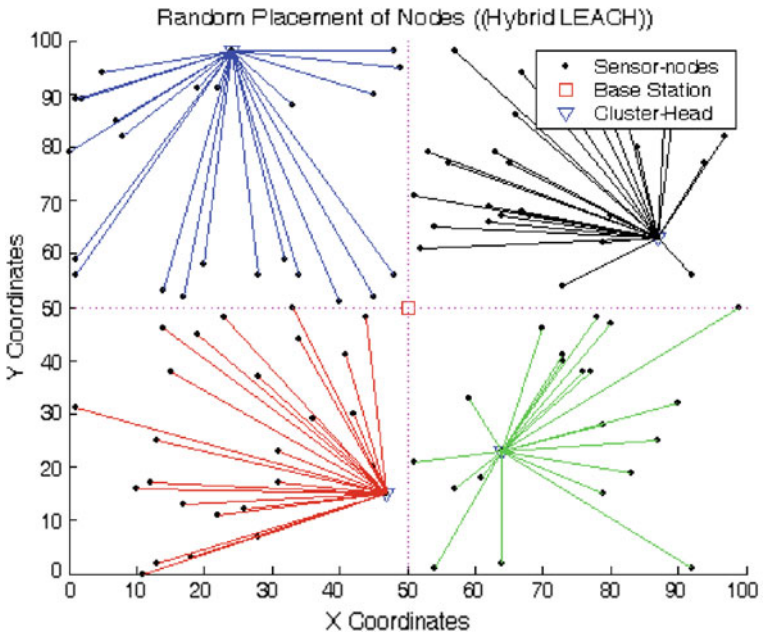

Fig. 5 H-LEACH node association to CH

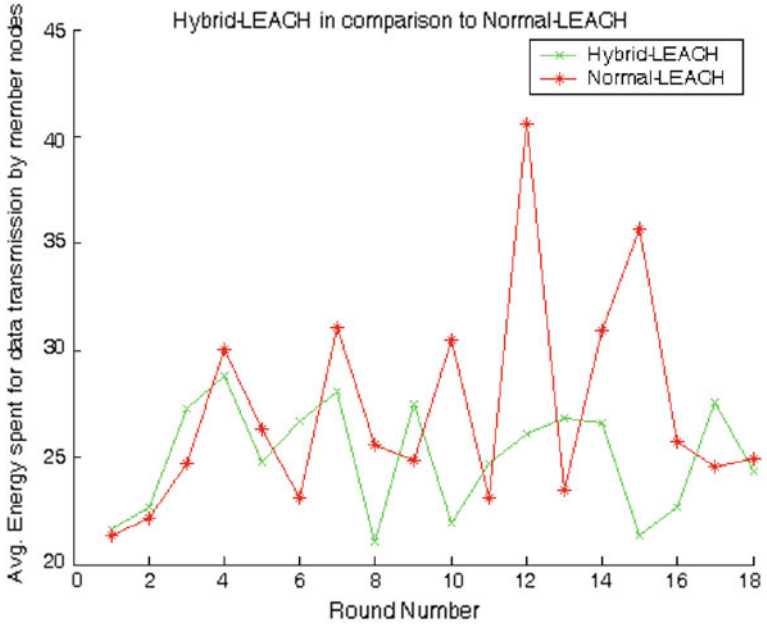

Fig. 6 H-LEACH versus normal LEACH (rounds)

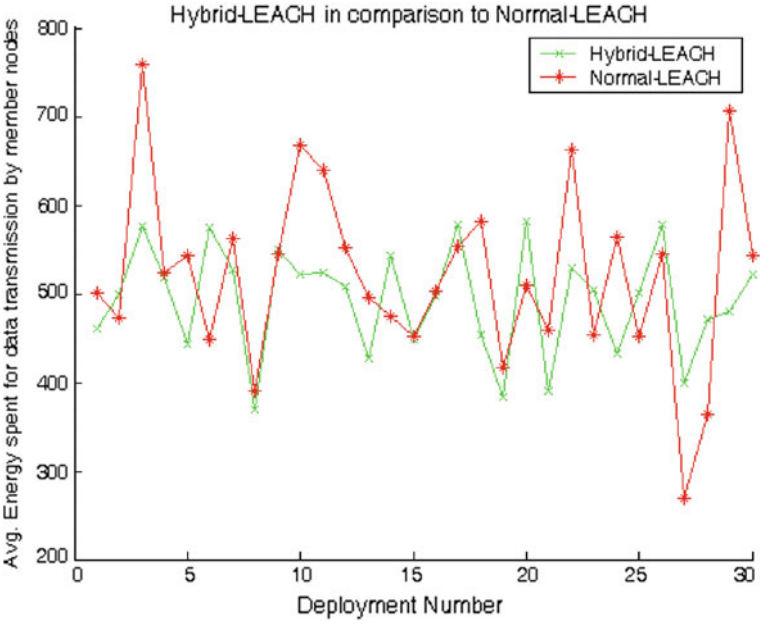

Fig. 7 H-LEACH versus normal LEACH (deployments)

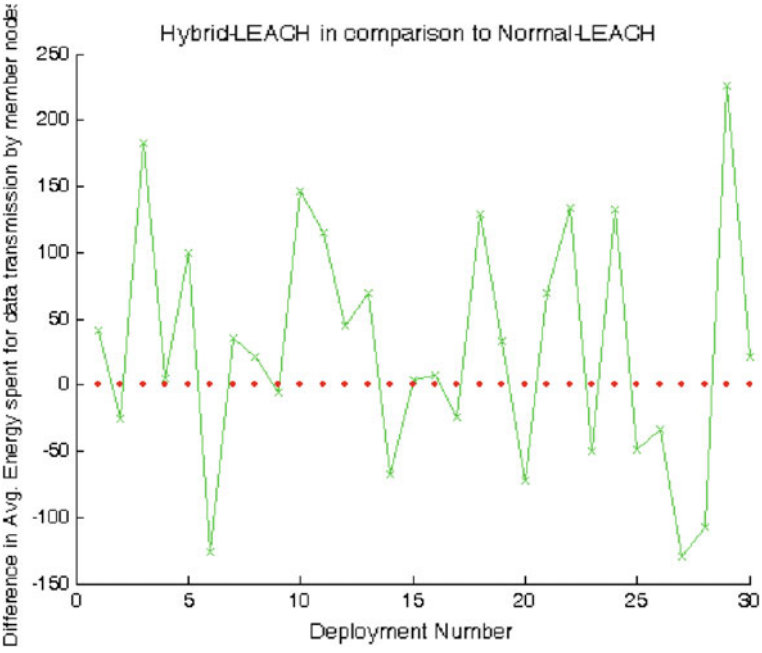

Fig. 8 Energy gain: H-LEACH versus normal LEACH (deployments)

There may be an extreme chance that some zone have very few or no nodes at all as the nodes are randomly deployed. In this case, the proposed protocol fails. But the probability of this case is negligible owing to the large scale, random but controlled deployment of the sensor nodes.

6 Conclusion and Future Scope

From the results obtained by the simulation clearly indicate that applying the available location information for nodes can result into an energy efficient design of a WSN. From Fig. 5, we conclude that the nodes in H-LEACH get associated with the CH node in the respective zone only, thereby guarding themselves to have long-distance CH association with CH nodes as shown by Fig. 3 in the case of normal LEACH.

From Fig. 6, we also observe that for some rounds, the results favour normal LEACH. These are the cases when the member nodes find this efficient to get associated with the CH nodes that are not in their zone but are nearer to them. But in long run, the Hybrid-LEACH protocol shows much energy gain as normal LEACH, thereby enhancing the lifetime of the network. Also, this is intuitive that this effect will keep on reducing as the number of zones/CHs is increased.

For future work, this will be interesting to see the effect of increasing the zones/CHs along with the number of deployed nodes on the energy gain of the given network.

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