Optimal LEACH: Optimal Energy Efficient Routing Method for Wireless Sensor Network

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Abstract- In this paper, we propose variant of LEACH which is well-known routing algorithm in the field of wireless sensor networks. The proposed algorithm works on the principle of mutual nearest neighbor, a distinguished concept in the field of machine learning. The basic LEACH algorithm is modified in terms of identifying the cluster head and thereby increasing the energy efficiency of the nodes in a wireless sensor network. The major problems with neighbor relationship based clustering is the closeness relationship with respect to the other points from a given point and not vice-versa. Hence, we have explored a method which possess mutual relationships rather than nearest neighboring relationship of points. The computation of pairwise closeness relationship for every node point and comparing every node point with another node point is performed in order to find mutual neighbors. The simulation results were provided and comparative analysis is made with the basic LEACH algorithm and promising results are reported due to the proposed methodology.

Keywords –LEACH, Optimal-LEACH, Routing Methods, Wireless Sensor Networks.

I. INTRODUCTION

In the field of wireless communication, the wireless sensors are deployed in different locations in dense structure in order to address limited bandwidth, energy depletion, random movement of nodes etc. The field of wireless sensor network (WSN) is growing exponentially due to the vast number of applications integrated with internet of things area. Hence, several research works are being carried out in WSN field in order to address the problems related to routing the data. Since the sensors are operated in a battery mode, due to the computations that are being performed at node level, optimal utilization of energy resource is one of the critical issue and hence much research is focused on devising an energy efficient routing techniques and hence to have a continued communication among the nodes. However, routing is quite challenging due to the existence of thousands of nodes in the region of interest and hence maintaining the routing table is quite complex too. In this context, there is huge demand in WSN field to develop energy efficient routing techniques. In this work, we have made an attempt to explore the benefit of fuzzy clustering technique integrated with LEACH algorithm and the proposed process does comparatively better than the basic LEACH algorithm. The details are brought out in the following sections.

II.REVIEW OF LITERATURE

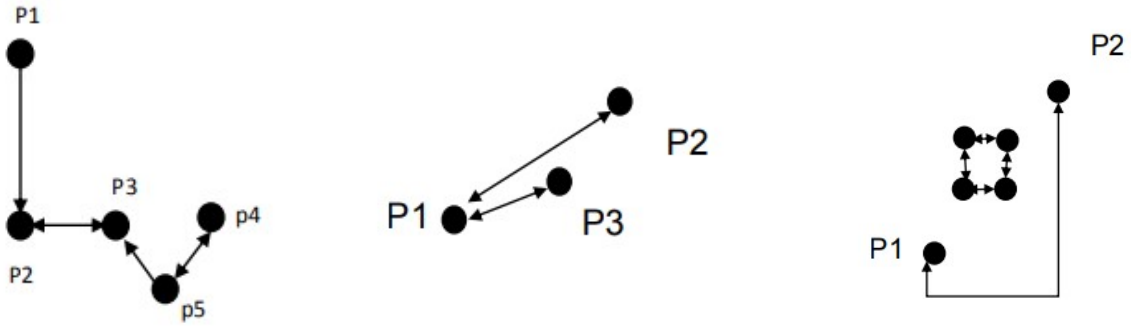
Due to the voluminous research works in the field of electronics and communication, we have been witnessing the enormous growth of IT industry where many of the societal problems are solved using the computing devices. The research works in the field of cyber-physical systems enable us to dream the smart home, smart cities, smart agricultural works, smart manufacturing etc. Hence, the sensor technology has become so popular not only because of its desirable properties like low cost and less power consumption, the wireless sensor networks helps in solving battle field situations, under water or geographically dangerous locations where people do not have an easy access to such locations. A sensor network contains many sensors and the location of a sensor in the network is insignificant. Because of this reason sensors can be put in areas where people do not have easy access. It also implies that a WSN can organize the sensors in an order on the need basis. There are many advantages of having WSN. They are applied in battle fields, fraud detection, pollution monitoring and control, traffic control, health care monitoring, wildlife habitat monitoring and many more [2]. The sensor node in a WSN can communicate with other nodes or to an external computer. In a large geographical area, the larger the sensor nodes used, the greater is the accuracy gained in sensing. Sensing, processing, communicating and a power unit are the major component of a sensor [2].
Different techniques have been developed to address energy efficiency issue, but it is required to know about the consumption of energy by the sensor nodes during different activities such as start-up power, sampling rate, signal

conversion etc. The communication load reduction is achieved by performing node-level process and thus proposed fusion of information based approach in [11]. The collaborative routing strategy has been explored in [4].
The energy conversion is achieved using handoff method [12]. The frequency hopping method is introduced in [16]. In this work, a unit time was used to transmit in a given frequency and switching is made to save energy. In [18], attention is made on sensing an environment and detection of events rather than energy saving issue. The hand-off strategy for reservation of resources is proposed in [19]. The histogram of energy is explored by Schurgers and Srivastava [15] where streams of packets are aggregated in a robust manner. The opportunistic communication based topology regulator is developed in [10].
A Voronoi diagram based method is introduced in [17] for efficient energy supervision in WSNs. The criterion is based on identification of nodes which are to be turned on/off using Voronoi diagram based representation. An adaptive routing mechanism is developed in [6] which is based on power awareness in the set of nodes under consideration.
The authors in [20] proposed power consumption model based on cluster heads balanced energy and hence to select them for transferring the data. The LEACH protocol developed in [7] achieves best energy efficiency exploring clustering strategy which selecting the sensor nodes to transmit the data from one node to another node. At the time of routing, energy management strategy is introduced in [1] and simulation study has been conducted to justify the suitability of the method.
Thus, we have seen many methods which addresses energy efficiency in wireless sensor networks and there are continuous attempts made by the research community to improve the energy efficiency of the nodes. In this direction, we have made an attempt to explore mutual nearest neighbor relationship in clustering process and thereby increasing the better energy utilization of clustered nodes. The details are presented in the following section.

III. Proposed Methodology

Due to the deployment of large number of nodes to ensure quality service, it is challenging part to have proper routing strategies and securing the nodes with sufficient energy for data transmission. The authors in [7] and [9] respectively proposed a hierarchy oriented protocols called LEACH and PEGASIS. The cluster based principle is employed in LEACH protocol in order to save energy. The LEACH protocol basically has two major phases namely set-up phase and steady phase. The set-up phase takes care of choosing the cluster head which is having maximum energy in the cluster, whereas the steady-phase deals with transmission of data to the base station.
In the LEACH algorithm, the local clusters are created and cluster head is selected based on the remaining energy which is supposed to be maximum among the nodes in the cluster. The cluster head acts as data transmitting node by collecting the data from the nodes belong to its group. The cluster head sends the signal to join its group and based on the nearness, the nodes are allowed to form the groups. After formation of clusters and having the cluster head, the transmission takes place among the nodes through cluster heads.
The different phases of LEACH include advertisement; cluster formation; scheduling and data broadcasting phases. In the advertisement phase, based on the random value chosen by the nodes within a cluster decides the headship of the node. The signal strength decides the cluster head and it is achieved in cluster set-up stage. The schedule to broadcast the data is achieved in schedule creation stage where Time Division Multiple Access is set among the nodes within a cluster to transit the data. During data transmission, the head of the cluster receives the data from its group members and it is supposed to wait till it receives the data from all its members. Since the number of nodes in a cluster are not uniform in nature across all the clusters, there is a possibility that the delay in communication would be occurred and as well as energy depletion would also happen. The nodes within a cluster may not be near to the cluster head also and there is also a possibility that a node may be nearer to many other cluster heads and in such cases, the number of members within a cluster is to be looked into before joining the group. In the proposed work, we basically address these issues and hence the proposed work is referred as optimal which balances the number of nodes in a cluster and as well maintain energy to a moderate level. The closeness of nodes is observed from either ends and hence decides the cluster formation.
In the proposed method which we refer as OPTIMAL LEACH (O-LEACH), is defined during the setup phase. The base station has the data about the residual energy of nodes and also the location of the nodes. The cluster heads are the ones which are having maximum residual energy. There may be more number of cluster heads having more amount of residual energy and in such cases, the cluster heads are chosen which are having more number of nodes nearer to the designated cluster head. While deciding the membership of a node to a particular cluster, the number of nodes within a cluster is also considered such that the balancing among the clusters is achieved in terms of number of nodes in a group. In the proposed methodology, unlike conventional clustering technique, we have explored an un-conventional clustering strategy in order to identify the cluster head and the details are given below.

The main limitation of the conventional clustering method is the relationship computation among the nodes in a network. The cluster is formed based on the distance from the node head to other nodes in the network and not vice-versa. In particular, in the case of k-nearest neighbor based approach, the relationship is from a node to another node and not among the nodes. This approach does not suitable to the nodes having varying energy values. It is necessary to consider the mutual relationship among the nodes and hence Hu and Bhatnagar [8] developed a method that consider the relationship among the nodes mutually. We have explored this idea in this work. The distance relationship is estimated based on the energy information among the nodes and as well as every node distance is estimated to form the clusters and thereby choosing the cluster head. The design details and implementation of Mutual k-Nearest Algorithm are presented here. The algorithm is based on the notion of mutual k-nearest neighbor relationships between data points and uses an efficient message passing system to figure out two-way nearest neighboring relationships. The difference between the conventional clustering and mutually nearest neighbor based clustering is illustrated here for more clarity. Let the point p_1 selects p_2 as its nearest neighbor and it does not study the relationship of p_2 with p_1. The mutually nearest neighbor approach estimate the both-way relationship as well. That means, p_1 and p_2 can only become a mutually nearest neighbor pair if both p_1 has p_2 and p_2 has p_1 as their nearest neighbor. The following figure illustrate the process.



(a) (b) (c)

Fig.1. a. Nodes to understand mutual nearest relationship;
Fig.1. b, c Node points with number of neighbors set to 2.

In Fig.1 (a), the one-sided arrow signifies nearest neighbor relationship and bi-directional arrows signifies mutual relationships between the points. We can see that points P_1 has P_2 as its neighbor in its Euclidean space but the same is not true with point P_2. Similarly, points P_5 has P_3 as its neighbor but point P_3 has already selected point P_2 as its mutual nearest neighbor. This clustering process is adopted in the O-LEACH algorithm to group the nodes and hence to select the cluster heads. The mutual nearest neighborhood based clustering algorithm is given below:

1. Let there be $p_1, p_2,\ldots,p_n$ number of sensor nodes. Let n be the initial clusters where cluster weight is set to 1.
2. Find the k-width neighborhood sensor nodes for each sensor node by computing the proximity values using modified procedure as presented above in identifying the neighbor between all pairs of nodes coming under the region of interest. Compute the mutual nearest value for every pair of nodes.
3. Set MNV threshold $MNV_{th} = 2$.
4. Recognize all pairs of nodes with MNV = MNV_{th}. Join every such pair into a cluster in ascending proximity values, and reduce the total number of clusters by 1 after each combines.
5. If all the pairs of nodes with MNV = MNV_{th}, have been merged and if still MNV_{th}, < 2n, then MNV_{th} = MNV_{th} + 1, GOTO the above step, otherwise STOP.

IV. Experimental Results

In this section, we present the experimental results conducted and also provide a comparative analysis with the basic LEACH algorithm. The algorithm is developed using MATLAB tool and LEACH code which is available as open-source is used in the experimentation. The network settings are presented in Table 1.

Table 1. Simulation Parameters.

Parameter Name	**Parameter values**
Number of nodes	100
Experimental area	200
Initial energy	0.5
Relative position of the base station	100, 250
Proportion of cluster head nodes	0.05

Performance Evaluation Index: The number of survival nodes represent the length of network time. The improved method is developed with an aim to balance the energy consumption of all the nodes, increasing the network survival time with an increased data traffic network. Hence, the following metrics are used to estimate the performance of the proposed method.

- "The survival nodes of network: in the life cycle of network, the more of the surviving nodes, the longer survival time of network.
- Residual energy of nodes: remaining energy of all nodes in the current round of number. The higher the residual energy of nodes, the slower speed nodes die, which prolongs the survival time of the network".

We have shown in Fig.2, the deployment of wireless sensor nodes in certain region of interest.

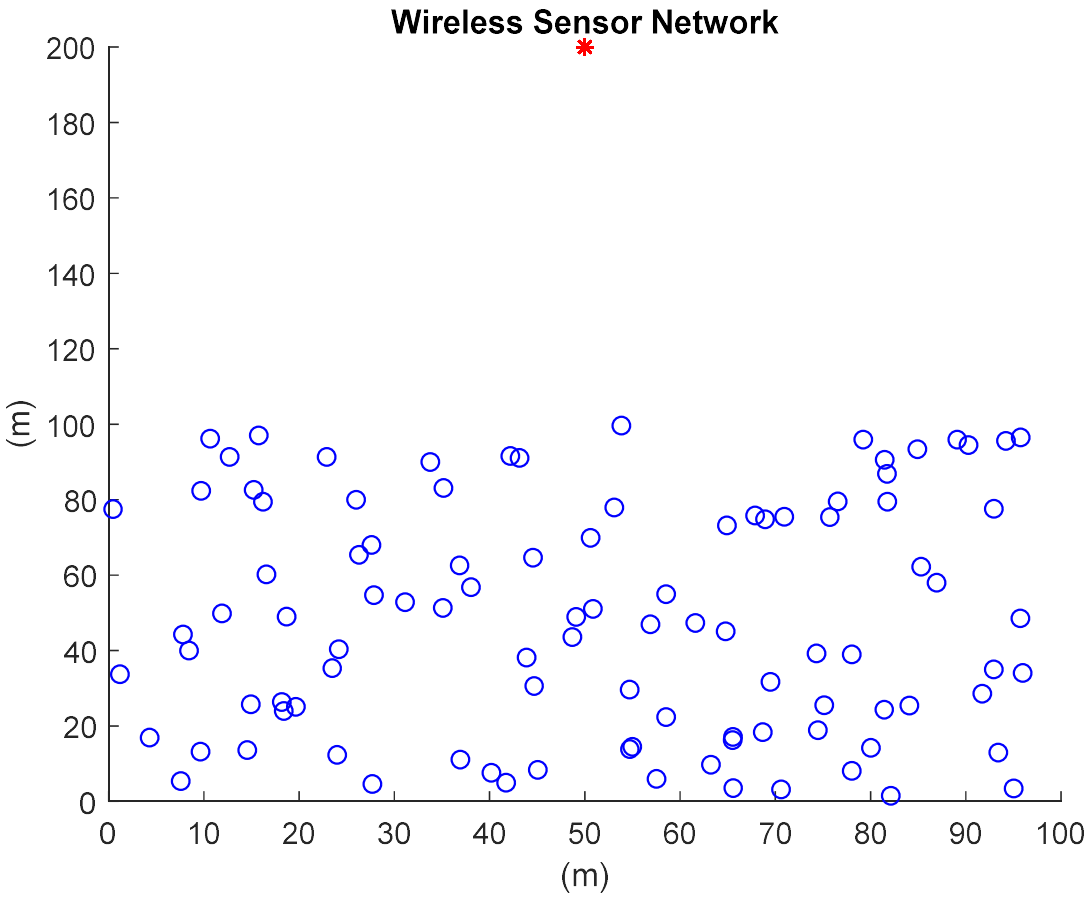


Fig.2. Wireless sensor network in a region of interest.

Experimentation on the survival nodes of network: Fig. 3 illustrates the situation which depicts the number of remaining nodes with the LEACH, and OPTIMAL-LEACH. It shall be observed from Fig.3 that the LEACH algorithm performance decreases approximately after 230 nodes whereas in the proposed technique, the number of remaining nodes is around 470 and the energy is carried upto that point. It is observed that the efficiency loss of

improved algorithm OPTIMAL-LEACH nodes is slow, which increases the efficiency of the network energy, increases the existence time of network.

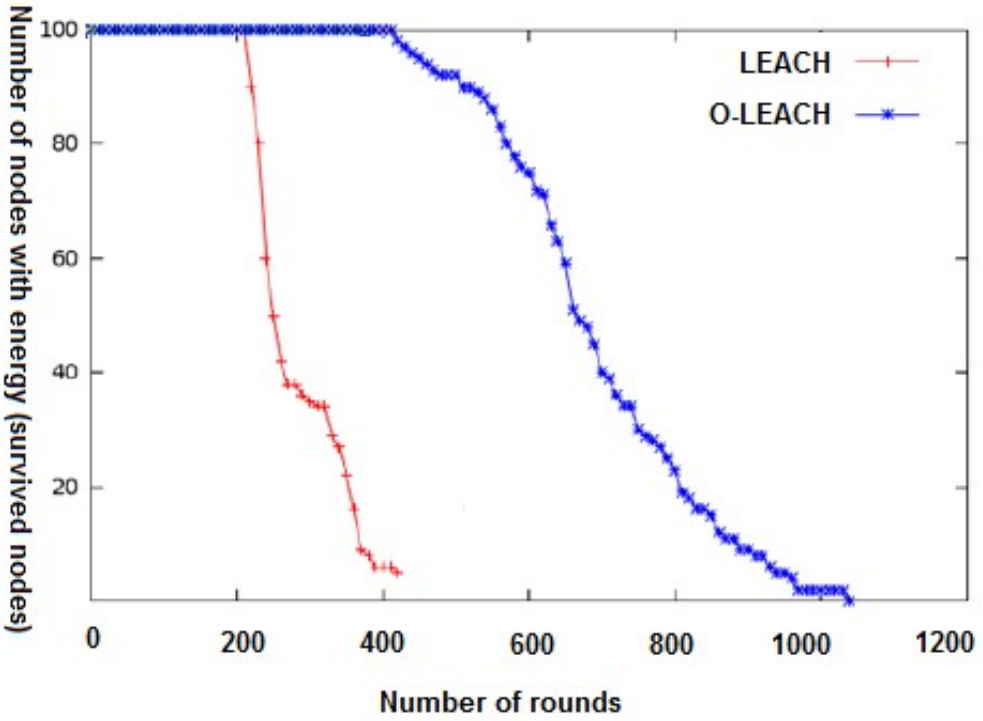


Fig. 3. Remaining number of nodes with energy.

Experimentation on the residual energy: In Fig. 4, we have provided the residual energy of each node and it is noted that the residual energy of the proposed algorithm OPTIMAL-LEACH is better when compared to the basic LEACH algorithm. ,

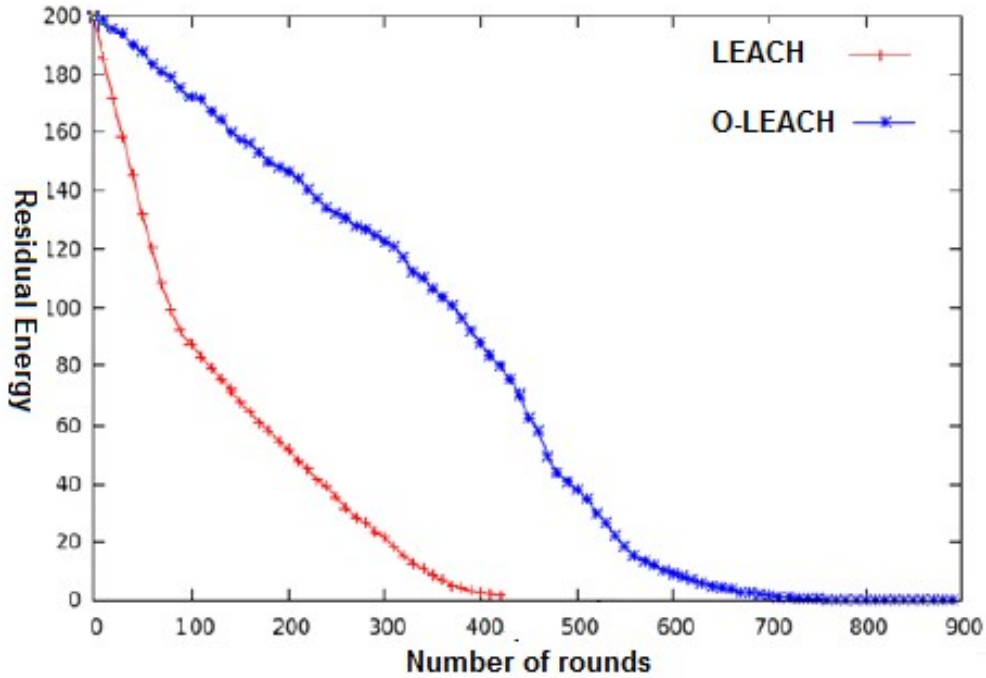


Fig. 4. Residual energy of each node.

V. CONCLUSIONS

In this work, we have made an attempt to modify the basic and well-known LEACH algorithm. The concept of mutual nearest neighbor is explored for estimating the cluster head and thereby increasing the energy efficiency of the nodes in a network. We have integrated a method which possess mutual relationships rather than nearest neighboring relationship of points. The computation of pairwise closeness relationship for every node point and comparing every node point with another node point is performed in order to find mutual neighbors. The simulation results and the comparative analysis with the basic LEACH algorithm justifies the significance of the proposed methodology.

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