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# Wireless Sensor Network LEACH Protocol: A Survey

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***Abstract***

**LEACH (Low Energy Adaptive Clustering Hierarchy) is one of popular cluster-based structures, which has been widely proposed in wireless sensor networks. LEACH uses a TDMA based MAC protocol. The idea is to form cluster of sensor nodes based on signal strength and use the cluster-head as a router to forward data of other nodes in cluster to the base station. The data processing is performed at cluster-heads. LEACH is a dynamic clustering mechanism. In this paper we analysed the literature of LEACH related protocols using different platform like NS2, OMNET++ and then in different sections just briefing about those papers.**

***Keywords*— LEACH Protocol, Wireless Sensor Networks, Sensor nodes, Clustering.**

## I. INTRODUCTION

Wireless Sensor Network is a popular area for research because now a days due to its vast potential usage in different areas. Wireless sensor network (WSN) [1,2] consists of hundreds and even thousands of small tiny devices called sensor nodes distributed autonomously to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure and motion at different locations. Micro-sensor network consist of many spatially distributed sensors, which are used to monitor various kinds of ambient conditions like temperature, humidity, etc and then transform them into electric signal. A sensor is equipped with a radio transceiver, a small microcontroller, and an energy source, usually a battery. Usually sensors are physically small and inexpensive. Small sensors are not as reliable as more expensive macro-sensors, but small size and small cost of an individual sensor, allow production and deployment in large numbers. A wireless sensor network contains hundreds or thousands of these sensor devices that have ability to communicate either directly to the Base Station (BS) or among each other. The nodes in WSNs are usually battery operated sensing devices with limited energy resources and replacing or replenishing the batteries is usually not an option. Thus energy efficiency is one of the most important issues and designing power efficient protocols is critical for prolonging the lifetime. Usually, sensor nodes are scattered in the sensing field, being the area where we want to monitor some ambient conditions. Sensor nodes have to coordinate among themselves to get information about the physical environment. The information collected by sensor nodes is routed to the Base Station either directly or through other sensor nodes. The Base Station is a fixed node or mobile node, which is capable to connect the sensor network to an infrastructure networks or to the Internet where users can access and process data. Application of WSNs exists in variety of fields including environmental applications, medical monitoring, home security, surveillance, military applications, etc [3]. Sensors in WSNs are generally equipped with data processing and communication capabilities [4]. But there are many challenges for implementation of WSNs due to different constraints like limited battery power, heterogeneity of sensor nodes, mobility of nodes, dynamic network topology, etc. In addition to these challenges, the network must be scalable and must have the ability to withstand harsh environmental conditions.

## II. LITERATURE SURVEY

Mortaza Fahimi Khaton Abad *et al.* [10]"Modify LEACH Algorithm for Wireless Sensor Network" using NS2. They analysed:

LEACH protocol is suitable for the WSNs under the following assumptions:

1. All senor nodes are static, identical and charged with the same amount of initial energy. All nodes consume energy at the same rate and are able to know their residual energy and control transmission power and distance.
2. Every node can directly communicate with every other node, including the sink node.
3. The Sink node is fixed and far away from the wireless network. Thus we can ignore the energy consumed by the sink node.
4. Every node has data to transfer in every time frame. The data transferred by sobering nodes are related and can be fused.

WSNs are autonomous networks. Sensor nodes are independent with each other. The coordination between nodes is done through wireless communication, which costs much. This is one of the major reasons that the LEACH protocol selects cluster heads randomly. This approach may cause the waste of energy because of unbalanced cluster head distribution. To solve this problem, they proposed a new approach to selecting cluster heads by assuming these parameters:

1. The network satisfies the pre-conditions of applying LEACH protocol.

2. After deployment, sensors are able to know their positions through GPS, or before deployment, their positions are accurately decided.
3. All nodes are able to adjust data transmission power. If necessary they can communicate with the base stations to acquire the initial setting information of the network.

As shown in Fig. 1, the network is divided into three parts. Nodes in region G1 will compete for being a cluster head. When a node is selected as a cluster head, it will broadcast the information to nodes nearby. Nodes in region G2 will receive the message. Thus, when nodes in this region compete for being cluster head, the location information of the cluster head in region G1 will taken into consideration. If a node in G2 is close to the cluster head in G1, the node will be discarded. The cluster heads in all other regions will be generated in the same way.

The cluster heads generated with this approach will not be close to each other. However, because some nodes quit the competition for cluster head, the total number of cluster heads can be reduced, which is not good for saving the network energy. Our approach to solving this problem is when a node is excluded in the cluster head selection, a message is broadcast to other nodes and $T(n)$ will be modified to increase the probability of others nodes being selected as cluster heads.

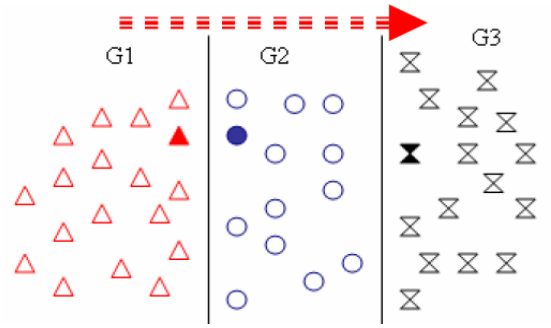

Fig.1 Selecting Cluster-heads

The modified $T(n)$ is:

$$T(n) = \begin{cases} \dfrac{P}{1 - P(r \bmod (1/p)) - pk} & n \in G \\ 0 & \text{others} \end{cases}$$

$K$ is the number of nodes that are excluded from the cluster head selection due to the location reason, with an initial value of 0. When $k$ increases, $T(n)$ increases as well, which will ensure sufficient number of cluster heads will be generated by the progressive algorithm.

They evaluated the performance of My LEACH protocol implemented with NS2. 100 sensor nodes are randomly distributed in an area of 100 m × 100 m. BS is put at the location with $x$ = 175, $y$ = 50. The bandwidth of data channel is set to 1 Mbps, the length of data messages is 500 bytes and packet header for each type of packet was 25 bytes. The number round is set to 500s. When a node uses energy down to its energy threshold, it can no longer send data and is considered as a dead node.

Results of Total Network Energy comparison is shown in Fig. 2 and Total Dead Nodes are compared in Fig. 3.

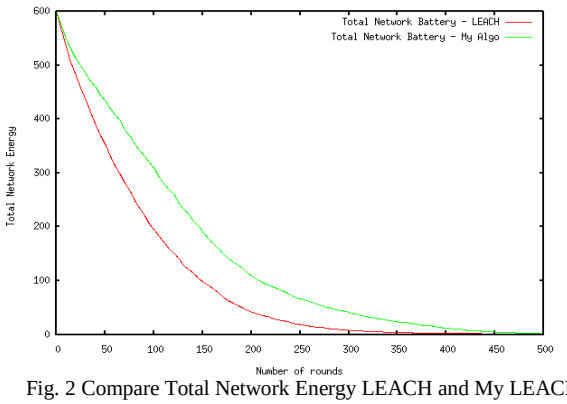

Fig. 2 Compare Total Network Energy LEACH and My LEACH

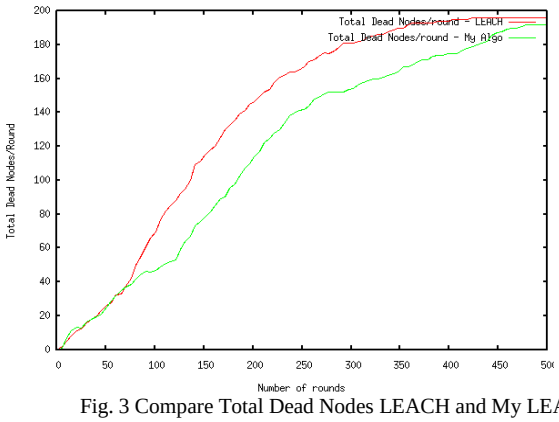

Fig. 3 Compare Total Dead Nodes LEACH and My LEACH

M. Bani Yassein *et al.* [6] "Improvement on LEACH Protocol of Wireless Sensor Network (VLEACH)" using OMNET++.

In this they propose a new version of LEACH protocol called VLEACH (Fig.4) which aims to reduce energy consumption within the wireless network. We evaluate both LEACH and V-LEACH through extensive simulations using OMNET++ simulator which shows that VLEACH performs better than LEACH protocol.
In new version of LEACH protocol, 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 CH dies. By doing this, cluster nodes data will always reach the BS; no need to elect a new CH each time the CH dies. This will extend the overall network life time.
Simulation is performed using OMNET++ as a simulation platform. OMNET++ is an object oriented modular discrete event network simulator, it has been developed by Andras Varga [5].

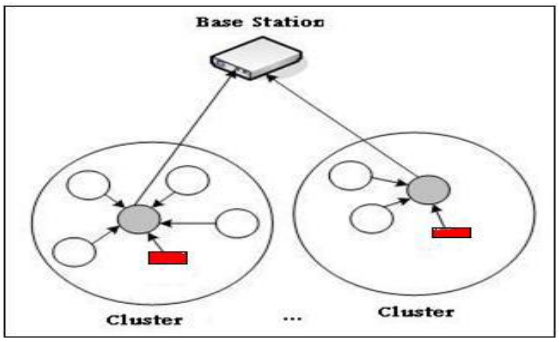

Fig. 4 VLEACH

TABLE 1
SUMMARY OF THE PARAMETERS USED IN THE SIMULATION

| Parameter | Value |
|---|---|
| Simulation time | 900 sec |
| Topology size | 900×900 $m^2$ |
| Number of node | 25, 50, 100, 115 nodes |
| CH probability | 0.2, 0.5, 0.1 |
| Number of trials | 20 trial |
| Initial node power | 1 joule |
| Nodes distribution | Nodes are randomly distributed |
| BS position | Located at 1000×450 |

They concluded number of messages created by the V-LEACH is less than the messages created by the original LEACH and if messages created by the new version are less that mean the network energy remaining using V-LEACH is more than the remaining network energy using the original LEACH as proved in table1.That mean the new version of LEACH outperforms the original version of LEACH protocol.
The results are shown in Fig. 5-Fig. 7 based on CH probability and the result of Consumed Network Energy is shown in Fig. 8.

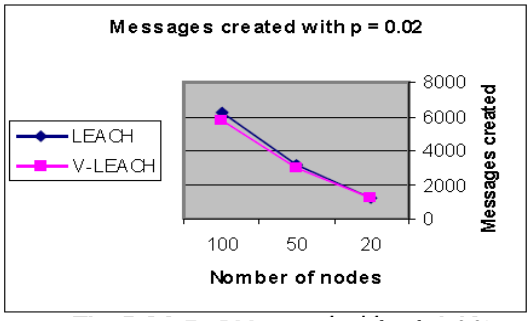

Fig.5 Messages created with p=0.02

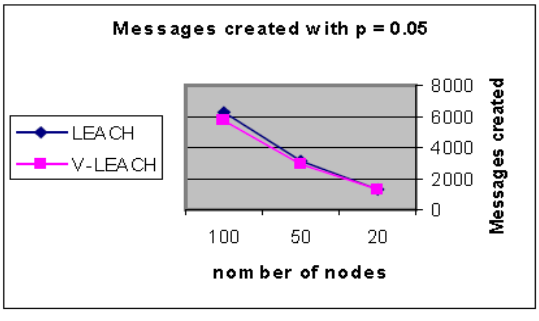

Fig. 6.Messages created with p=0.05

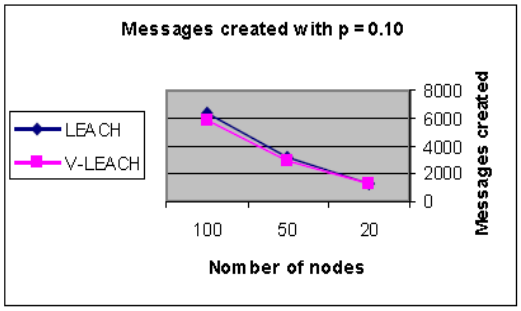


Fig. 7 Messages created with p=0.10

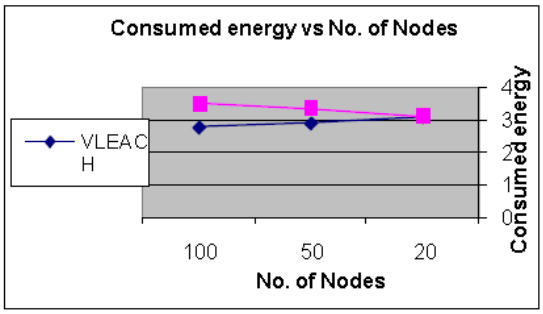


Fig. 8 Consumed Network Energy

Jyoti R. Patole *et al.* [11] "Design of MAP-REDUCE and K-MEANS based Network Clustering protocol for Sensor Networks" proposed a new method for clustering the WSN and selection of cluster head to each cluster. The approach is based on MAP-REDUCE and K-MEANS algorithms. They tried to exploit the advantages of both MAP-REDUCE and K- MEANS algorithms in order to form energy efficient sensor network with optimal number of clusters. Main aim is to extend the lifetime of the network by efficient use of energy and reduced overlapping of clusters. This method divides clustering process into two phases as Mapping and Reducing. The MAP protocol performs mapping or assigning of sensor nodes to clusters and REDUCE protocol optimizes this clustering by making some changes.
MAP-REDUCE computing model consists of two functions, Map and Reduce. The Map and Reduce functions are both defined with data structure of (key, value) pairs. Map function is applied to each item in the input dataset according to the format of the (key), value) pairs; each call produces a list (keY2' value2). All the pairs which have the same key in the output lists are put to reduce function which generates one value3 or an empty return. The results of all calls form a list, list (value3). This process of MAP and REDUCE is illustrated in Fig. 9.

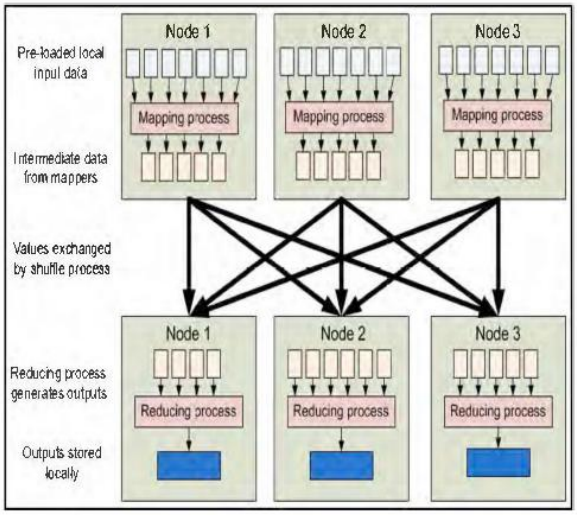


Fig. 9 MAP Reduce Illustration

K-MEANS is the simplest algorithm used for clustering which is unsupervised clustering algorithm. This algorithm partition the data set into k clusters using the cluster mean value. This algorithm is iterative in nature. Fig.10 illustrates the original K-MEANS algorithm based on algorithm steps.

Cluster Setup Phase
The cluster set up phase is divided into two sub clustering phases. In first sub clustering phase, the base station has to cluster the sensor nodes and assign the proper roles to them. This operation is referred as MAP protocol. In second sub clustering phase, only the overlapping clusters are newly formed, in which the normal node may get changed to cluster head node or the cluster head node may get changed to cluster node. This phase is referred as REDUCE protocol.

**A. Map / First-clustering Phase**
Fig.11 shows the process of a Mapper. Input to the Mapper is list of initial set of randomly selected k cluster heads as $key_1$ and list of all other nodes along with their location information and energy level as $value_1$ By using Mapper ($key_1$, $value_1$) protocol, the Map phase would produce list of new set of k cluster heads as $key_2$ and list of all other nodes with their cluster heads known to them as $value_2$.

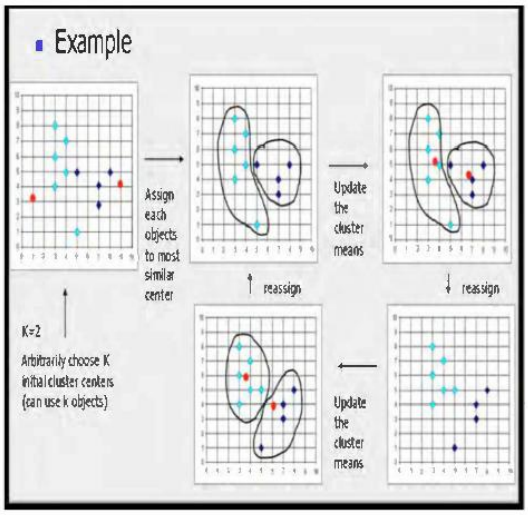


Fig10. Original K-MEANS Algorithm

1. BS → N sensor nodes: requesting node's position and energy level.
2. BS: KMEANS(***key$_1$, value$_1$***)
3. BS assigns role (Cluster Head/member) to each sensor node.
4. Each cluster head sends one hop communication about the cluster head and its energy level to other nodes;
5. Generates output ***(key$_2$, value$_2$)***

Fig. 11 MAP Operation with K-MEANS

**B. Reduce / second-clustering Phase**

Fig.13 shows the process of a Reducer. The intermediate results produced by Map protocol are given as input to the Reducer i.e. list of new set of k cluster heads as key$_2$ and list of all other nodes with their cluster heads known to them as value2. By using Reducer (key$_2$, value$_2$) protocol, the Reduce phase would produce final clusters with their cluster heads and other nodes in that cluster as value$_3$. The term reduce is used in Reduce phase, which is meant for optimizing the output and not for reducing the size of the output. Original Map is parallel in nature. We use a centralized MAP algorithm at BS but REDUCE is parallelized to optimize the final clusters. This parallization reduces the time of clustering the sensor network.

KMEANS(key$_1$, value$_1$)

1. BS arbitrarily chooses k nodes from N nodes as initial cluster heads having maximum energy level and closer enough to each other to form optimal clustering.
2. Repeat
   - I. (Re) assign each node to the cluster with the nearest CH;
   - II. Updates the CH i.e. calculate the mean value for each cluster;
3. Until no change;

Fig. 12 K-MEANS Protocol

6. Protocol reducer (key2, value2)
7. (a)
8. Read (value2); /* Build second clustering * /
9. Place k' (k'<=k) nodes represented as initial cluster heads;
10. Repeat
11. If the member node is losing the energy below the threshold, it starts searching for better CH;
12. Else, if cluster head is running out of energy new CH will be assigned to the node;
13. K-MEANS(key2, value2 );
14. Updates the CH i.e. calculate the mean value for each cluster;
15. Until no change;
16. Produce value3;

Fig. 13 Reduce Operation with K-MEANS

In Original MAPREDUCE model, REDUCE gets executed immediately after the energy of the cluster head or cluster member is falling below some threshold. It helps us to optimize the clusters.

Also it helps to reduce the packets drop. Even though the BS is a single point failure, but as the MAP protocol is run by only BS, energy required for computation at the other sensor network nodes is heavily reduced. Also sensor node's

interaction is limited to its cluster, so redundant message exchanges are reduced, resulting into saving of energy of a sensor network.

## III. CONCLUSION

In this work modification adds feature to LEACH to reduce the consumption of the network resource in each round. On simulation the modified protocol results show a significant reduction in network energy consumption compared to LEACH. When MAPREDUCE programming model and K-MEANS clustering algorithm is used clustering phase itself is divided into two sub phases as MAP and REDUCE it is expected to get the energy efficient clusters. From the simulation results of VLEACH it concludes number of messages created by the V-LEACH is less than the messages created by the original LEACH and if messages created by the new version are less that mean the network energy remaining using V-LEACH is more than the remaining network energy using the original LEACH.

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