# An Improved LEACH for Wireless Sensor Network

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***Abstract*—**Wireless Sensor Networks have become immensely popular due to their ability to monitor environmental conditions like temperature, humidity, pressure, position, vibration, sound etc. at a low cost, compared to other networks. They can potentially be applied in almost every field of life-from smart home monitoring to forest fire detection or even battleground surveillance. Thus the study of wireless sensor networks has become an emerging trend. In this paper, we precisely studied cluster based routing in wireless sensor networks. We studied and modified one of the most prominent routing protocols used in wireless sensor networks- "EACH" by introducing efficient cluster head replacement scheme and dual transmitting power levels. Simulation results show that our modified LEACH, compared to LEACH performs better in terms of throughput and network lifetime. Finally, a brief performance analysis of LEACH and our proposed routing protocol is undertaken considering metrics of throughput and network life.

***Keywords* -** Cluster, Cluster Head, LEACH, Network Life, Routing Protocol, Throughput, Wireless Sensor Networks, WSN's.

## I. INTRODUCTION

A Wireless Sensor Network is a kind of wireless network which consists of a huge number of spatially distributed devices called sensors/sensor nodes, to monitor physical or environmental conditions. These sensors are networked to collect, process, and transfer data to the operators. Nodes jointly work to form the networks. WSNs have widespread applications in the fields of medicine, public safety, geology, environment, battle surveillance, industry etc. Sensor nodes are often deployed in complex and extreme environments which are prone to high temperature, high humidity etc.. The sensors are autonomous small devices with several constraints like limited battery power, computation capacity, communication range and memory. They are embedded with transceivers to gather information from their environment and pass it on up to a certain base station, where the measured parameters can be stored and made available to the end user. In most cases, the sensors forming these networks are deployed randomly and left unattended to. As a result of this random deployment, the WSN has usually varying degrees of node density along its area. Sensor networks are also energy constrained since the individual sensors, which the network is formed with, are extremely energyconstrained as well. The communication devices on these sensors are small and have limited power and range. Power consumption is one of the key challenges in wireless sensor networks. To perform sensing, computing and transceiving operations with limited power is a challenging aspect. Hence for optimum performance of the network optimizing the nodes' life is of utmost importance. In this paper, we are concentrating on such a protocol that can make maximum out of limited power source of nodes. Another problem that persists in a wireless sensor network is to handle bulk of information sensed and passed over by every node. For that purpose, data aggregation and data fusion algorithms are introduced. However for efficient working of a wireless sensor network, we need an efficient routing protocol that has low routing overhead and well organized data aggregation mechanisms to increase throughput of the network and to make sure that sensor nodes do not exhaust their power much ahead of their expected lifetime.

In the subsequent sections, we present a brief overview of the work done so far on cluster based routing of wireless sensor networks along with areas which need modifications to enhance efficiency. Following that, some modifications are made in one of the most prominent routing protocols (LEACH). Finally, experiments along with comparisons are made and discussed briefly.

## II. LITERATURE SURVEY

Any application usually requires hundreds of nodes to be deployed in a network, for scalability issues and efficiency. These sensor nodes have a limited power which must be utilized in very precise manner to increase node's life. Although efficient circuit is necessary for efficient use of energy, however, routing protocol running on the network plays a vital role in bandwidth consumption, security and energy conservations as well (considering WSN's). To cop with these constraints, initially direct transmission approach was discussed [1]. In direct transmission, a node senses data from its environment and transmits it straight to base station. Although this method ensures data security, however, we have to compromise on node's life time due to excessive power consumption (if the base station is far away). Hence, using direct transmission technique, nodes that are far away from the base station die early as they require more power to propagate their signal. To solve this problem, minimum transmission energy (MTE) emerged. In this technique, data is transmitted to base stations via multi-hop. This gives birth to almost the same problem as in direct transmission except that in minimum transmission energy algorithm, far away nodes remain alive

longer with respect to the nodes nearer to BS. This is due to routing of all data traffic to base station by the nearer nodes. Moreover, transmitting bulk of sensed data from each node uses much energy. To overcome this problem, the concept of Directed Diffusion was introduced that involves data processing and dissemination. [2] Estrin [3] worked on an hierarchical clustering mechanism dealing with asymmetric communication for power saving in sensor nodes. M. Jiang, J. Li presented a cluster based routing protocol (CBRP). [4] According to this mechanism, all participating nodes of a network are distributed in 2-hop cluster. Though this protocol is not much energy efficient for wireless sensor nodes, however, it gives way to hierarchical clustering algorithms. Clustering for energy conservation is proven to be an efficient mechanism for wireless sensor networks [5], [6]. When a sensor network is deployed, nodes establish clusters and nominate one node from each cluster as a cluster head. These cluster head nodes are responsible for receiving data from other nodes of cluster, perform data aggregation/ fusion of received data and transmit it to base station. In this way, bandwidth consumption and life time of network is optimized. [7] In [8] authors give concept of inter cluster communication. They prove that regardless of transmitting fused data direct from cluster head to base station, if data is transmitted in multiple hops i.e. from one cluster head to another and finally to base station, it would further enhance network life time. Considering cluster based algorithms, today numerous protocols are developed, each having different attributes and enhancements, mainly in cluster head selection algorithms. Though one thing is common, all protocols focus on energy conservation and data aggregation. Authors of [9] preserve energy in WSN's by differentiating idle and operational mode of a sensor node. Authors of [10], [11] states that nodes having high initial energy will be selected as cluster heads (in case of heterogeneous sensor networks). While according to [12], [13], [14] any node that lie within network can be elected as a cluster head. Stable Election Protocol (SEP) gives weighted probability to each node of becoming a cluster head [12]. In DEEC [13] existing energy in node is election criteria of a node to become a cluster head. LEACH [1], TEEN [15], SEP [12], DEEC [13] and PEGASIS [16] are prominent routing techniques for wireless sensor networks. Main procedure of electing a cluster head was given by LEACH and that is further enhanced by SEP and DEEC. TEEN introduces the concept of thresholds that gives good results in network life time by showing reactive nature. These thresholds can be implemented in any routing protocol to enhance its performance with respect to utility or application. Based on LEACH, SEP and DEEC, numerous protocols are proposed. Q-LEACH [17] optimize network life time of homogenous wireless sensor network. [18] gives a detailed comparison analysis on different variants of LEACH as A-LEACH, SLEACH and M-LEACH in terms of energy efficiency and applications.

## III. MOTIVATION

LEACH (Low-energy adaptive clustering hierarchy) is a self-organizing, adaptive clustering protocol that uses randomization to distribute the energy load evenly among the sensor nodes in the network. In this technique, the nodes organize themselves into local clusters, with one node acting as the cluster-head. Sensors elect themselves to be local cluster-heads at any given time with a certain probability. These cluster head nodes broadcast their status to the other nodes in the network (advertisement phase). Each sensor node determines to which cluster it wants to belong to by choosing the cluster-head that requires the minimum communication energy. Once all the nodes are organized into clusters, each cluster-head creates a schedule for the nodes in its cluster (setup phase). This allows each noncluster-head node to be active only during it's transmit time. Each cluster node transmits its sensed data to the clusterhead node (steady phase) which in turn aggregates the data and then transmits the compressed data to the base station.

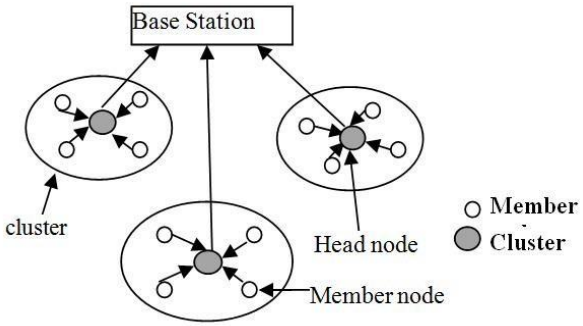


Fig.1: Clustering in LEACH protocol

A drawback of this protocol is that it requires new cluster head to be elected for every round, i.e., new cluster formation is required. This results in unnecessary routing overhead causing excessive use of limited energy. A cluster head node may not have utilized much of its energy during the previous round, and there is probability that some low energy node may replace it as a cluster head in the next round. The LEACH protocol doesn't take into account the residual energy of nodes when choosing the cluster heads, which may result in the node with rather low energy to be chosen as a cluster head. Naturally, such node would die quickly. Thus, there is a need to limit change of cluster heads at every round. Hence for conservation of energy, an efficient cluster head replacement algorithm is required.

Another shortcoming of LEACH is that it uses same amplification energy for the nodes to transmit data regardless of distance between transmitter (node or cluster head) and receiver (cluster head or base station). The transmission mechanism should specify required amplification energy for communicating with cluster head or base station in order to preserve energy. One way of accomplishing this would be to

have a global knowledge of the network and then nodes would decide how much they need to amplify signal. However, locating and calculating distances within the network would require lot of routing and excessive loss of energy. To solve the aforementioned problems, we propose two mechanisms. I.e. efficient cluster head replacement and dual transmitting power levels.

## IV. PROPOSED SCHEME

The LEACH protocol changes the cluster head at every round and once a cluster head is formed, it cannot become the cluster head for the next 1/*p* rounds, i.e., cluster heads are replaced and the whole cluster formation process is undertaken for every round. In this work, we modify LEACH by introducing "efficient cluster head replacement scheme". If the residual energy of the existing cluster head is more than required threshold, it will remain cluster head for the next round as well and the energy wasted in routing packets for new cluster head selection and cluster formation can be saved. However, if its energy is less than required threshold, then it will be replaced according to LEACH algorithm. Besides limiting energy consumption in cluster formation, we also introduce two different levels of power to amplify signals according to nature of transmission. Basically in a cluster based network, there can be three modes of transmission:

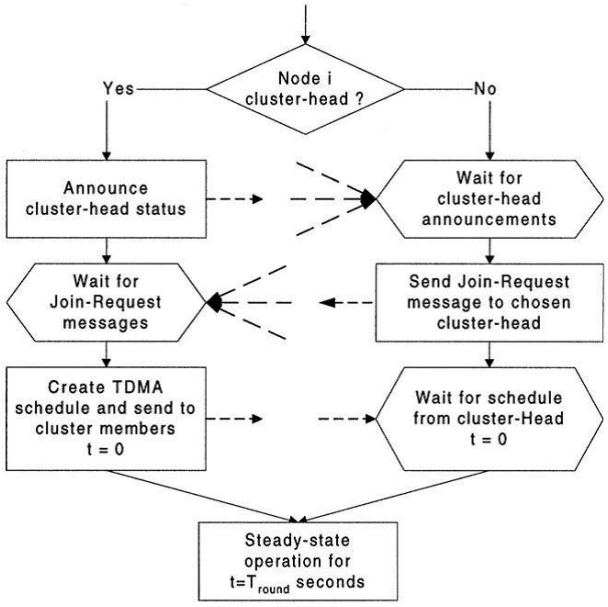


Fig.2: Flowchart of LEACH protocol

1) Inter Cluster Transmission
2) Cluster Head to Base Station Transmission
3) Cluster Head to Base Station Transmission

Intra Cluster Transmission deals with the transmission of data from the cluster members to the cluster head. Inter cluster transmission deals with the transmission/ reception of data between two cluster heads. Cluster head to base station transmission deals with the transmission of data from a cluster head to the base station. LEACH uses the same amplification energy for all kinds of transmissions. In order to save energy, intra cluster transmissions should be carried out at a low energy level compared to cluster head to BS transmission. Thus the proposed algorithm can be summarized in the following steps:

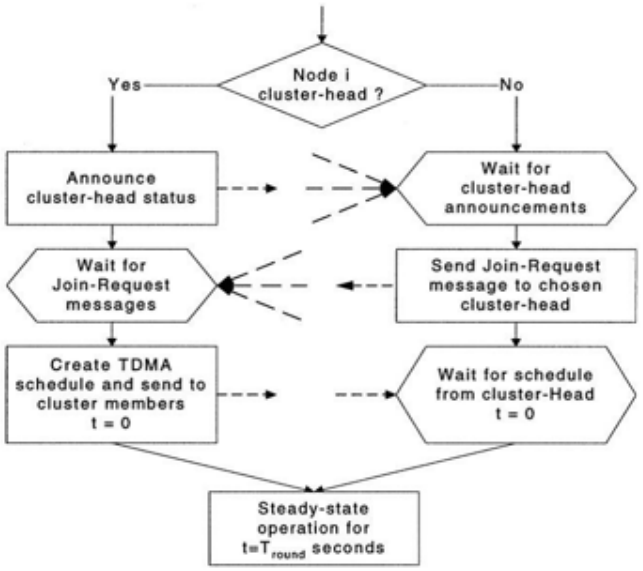


Fig.3: Cluster Formation of LEACH protocol

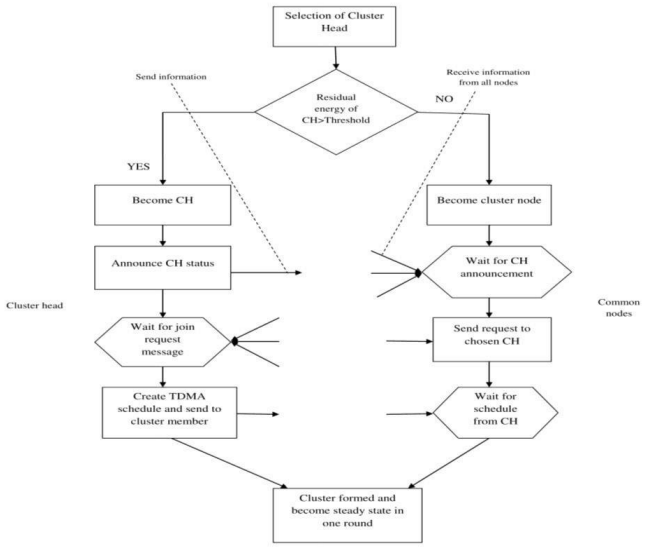


Fig.4: Flowchart of PROPOSEDLEACH protocol

1) First, we deploy the WSN by initializing the parameters.
2) Next the cluster head is selected and cluster formation is initiated in the sensor network.
3) Communication among the nodes is initialized by sending the data packets to the cluster head.
4) Cluster head collects the data, compresses (aggregates) it and sends it to the base station.
5) Now the residual energy (remaining energy after each round) is checked of the current cluster head. If it is less than a defined threshold, then the election process initiates and cluster formation takes place again. Otherwise the current cluster head continues working as CH for the next round as well.

## V. SIMULATION RESULTS

Simulations are conducted using GNU Octave 3.8.2 [19] with parameters defined at Table 1. The results show that PROPOSEDLEACH outperforms LEACH in terms of throughput and network life time.

1) Network Life Time: LEACH exhibits lower network life time comparatively. PROPOSEDLEACH exhibits longer stable period due to its efficient cluster head replacement scheme and dual transmitting power level for different communication modes. The simulated results depicted in figure '5 and figure '6 represent network life time by showing number of alive and dead nodes respectively.
2) Throughput: Another factor which determines efficiency of a routing protocol is its throughput. A base station receiving more data packets shows the efficiency of a routing protocol. The simulated results depicted in figure '10 show that maximum throughput is achieved by PROPOSEDLEACH. This is due to increased network life time and better cluster head replacement scheme undertaken in PROPOSEDLEACH. Another reason is dual transmitting power levels within the network which reduces packet drop ratio resulting in higher throughput.

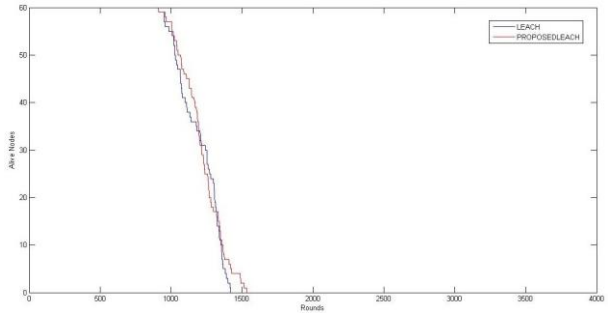


Fig.5: Comparison of number of alive nodes,for 60 nodes and 4000 rounds.

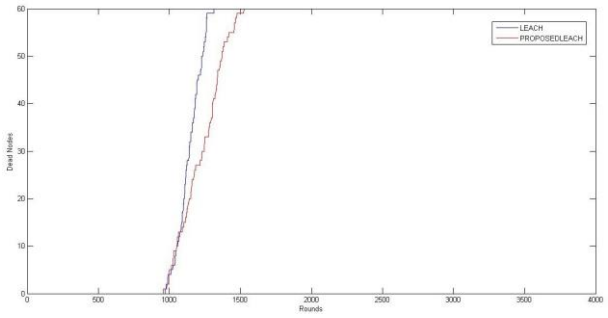


Fig.6: Comparison of Dead nodes,for 60 nodes and 4000 rounds.

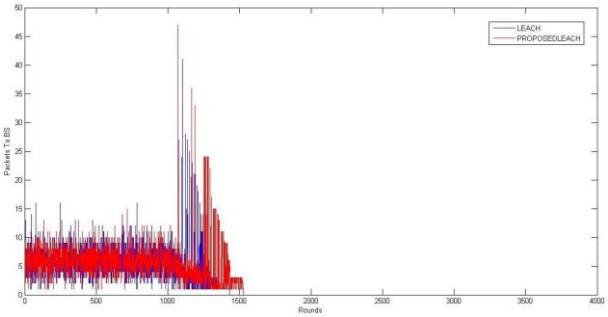


Fig.7: Comparison of Number of packets transmitted to base station, for 60 nodes and 4000 rounds.

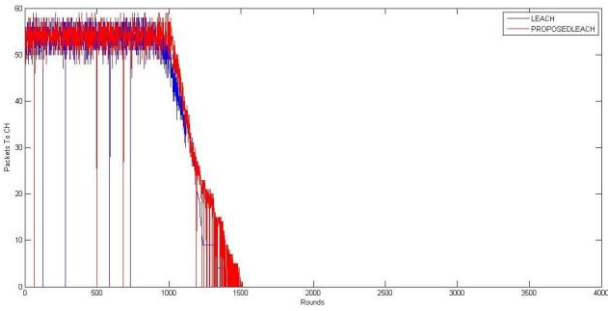


Fig.8: Comparison of number of packets transmitted to cluster head, for 60 nodes and 4000 rounds.

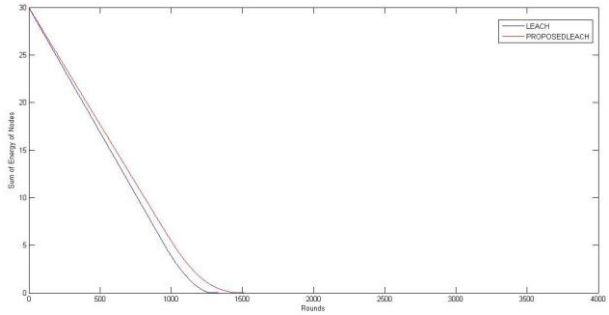


Fig.9: Comparison of sum of energy,for 60 nodes and 4000 rounds.

| Parameters | Value |
|---|---|
| Network size | 100×100 $m^2$ |
| Initial Energy | 0.5 J |
| Packet Size | 4000 bits |
| Transceiver idle state energy consumption | 50*nJ/bit* |
| Data Aggregation or Fusion Energy consumption | 5*nJ/bit/report* |
| Amplification Energy (Cluster to BS) $d \geq d_0$ | 10*pJ/bit/*$m^2$ |
| Amplification Energy (Cluster to BS) $d \geq d_0$ | 0.0013*pJ/bit/*$m^2$ |
| Amplification Energy (Intra Cluster Comm.) $d \geq d_1$ | *Efs*/10= *Efs*1 |
| Amplification Energy (Intra Cluster Comm.) $d \geq d_1$ | *Emp*/10= *Emp*1 |
| Location of Sink | 50,50 |
| Number of Rounds | 4000 |

Table 1. Network Parameters

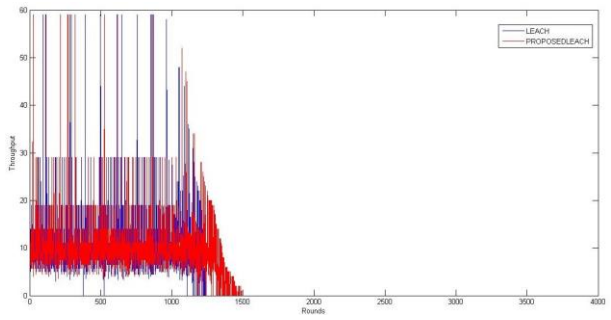


Fig.10: Comparison of throughput, for 60 nodes and 4000 rounds.

## VI. CONCLUSION

In this work, we give a brief discussion on emergence of cluster based routing in wireless sensor networks. We also propose PROPOSEDLEACH, a new variant of LEACH that can further be utilized in other clustering routing protocols for better efficiency. PROPOSEDLEACH tends to minimize network energy consumption by efficient cluster head replacement after very first round and dual transmitting power levels for intra cluster and cluster head to base station communication. In PROPOSEDLEACH, a cluster head will only be replaced when its energy falls below certain threshold minimizing routing load of protocol. Hence, cluster head replacement procedure involves residual energy of cluster head at the start of each round. Thus, we can conclude that our proposed scheme, PROPOSEDLEACH is a more energy efficient protocol compared to the existing LEACH.

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