



## Optimization of Energy Efficient Hierarchical Routing Protocol in Sensor Network

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**Abstract:** *A wireless network consisting of a large number of small sensors with low-power transceivers can be an effective tool for gathering data in a variety of environments. Wireless distributed micro sensor systems will enable the reliable monitoring of a variety of environments for both civil and military applications. In this paper, we look at communication protocols, which can have significant impact on the overall energy dissipation of these networks. Based on our findings that the conventional protocols of direct transmission, minimum-transmission-energy, multi-hop routing, and static clustering may not be optimal for sensor networks, we propose LEACH (Low-Energy Adaptive Clustering Hierarchy), a clustering-based protocol that utilizes randomized rotation of local cluster based station (cluster-heads) to evenly distribute the energy load among the sensors in the network. LEACH uses localized coordination to enable scalability and robustness for dynamic networks, and incorporates data fusion into the routing protocol to reduce the amount of information that must be transmitted to the base station. Simulations show the LEACH can achieve as much as a factor of 8 reductions in energy dissipation compared with conventional routing protocols. In addition, LEACH is able to distribute energy dissipation evenly throughout the sensors, doubling the useful system lifetime for the networks we simulated. LEACH includes a new, distributed cluster formation technique that enables self-organization of large numbers of nodes, algorithms for adapting clusters and rotating cluster head positions to evenly distribute the energy load among all the nodes, and techniques to enable distributed signal processing to save communication resources. Our results show that LEACH can improve system lifetime by an order of magnitude compared with general-purpose multi hop approaches.*

**Keyword:** *Architecture of Wireless Sensor Network, LEACH, LEACH Optimization, LEACH Architecture, LEACH Protocol.*

### I. INTRODUCTION

A Wireless Sensor Networks (WSN) is a set of hundreds or thousands of micro sensor nodes that have capabilities of sensing, establishing wireless communication between each other and doing computational and processing operations.

The components of sensor node and communication architecture of a WSN. Sensor nodes are usually scattered in a sensor field, which is an area where the sensor nodes are deployed. Sensor nodes coordinate among themselves to produce high-quality information about the physical environment. Each sensor node bases its decisions on its mission, the information it currently has, and its knowledge of its computing, communication, and energy resources. Each of these scattered sensor nodes has the capability to collect and route data either to other sensors or back to an external base station(s).

The typical configuration of such a sensor node in a WSN includes single or multiple sensing elements, a data processor, communicating components and a power source of limited energy capacity. The sensing elements of such a sensor node perform measurements related to the conditions existing at its surrounding environment. These measurements are transformed into corresponding electric signals and are processed by the processing unit. A sensor node makes use of its communication components in order to transmit the data, over a wireless channel, to a designated sink point, referred to as a base station. The base station collects all the data transmitted to it in order to act as a supervisory control processor or an access point for a human interfaces or even as a gateway to other networks.

### II. ARCHITECTURE OF WIRELESS SENSOR NETWORK

Let us look at the architecture of a generic Wireless Sensor Network, and examine how the clustering phenomenon is an essential part of the organizational structure.

- **Sensor Node:** A sensor node is the core component of a WSN. Sensor nodes can take on multiple roles in a network, such as simple sensing, data storage, routing and data processing[1].
- **Clusters:** Clusters are the organizational unit for WSNs. The dense nature of these networks requires the need for them to be broken down into clusters to simplify tasks such
- **Cluster heads:** Cluster heads are the organization leader of a cluster. They often are required to organize activities in the cluster. These tasks include but are not limited to data-aggregation and organizing the communication schedule of a cluster.

- Base Station: The base station is at the upper level of the hierarchical WSN. It provides the communication link between the sensor network and the end-user.
- End User: The data in a sensor network can be used for a wide-range of applications. Therefore, a particular application may make use of the network data over the Internet, using a PDA, or even a desktop computer. In a queried sensor network (where the required data is gathered from a query sent through the network). This query is generated by the end user. The clustering phenomenon as we can see, plays an important role in not just organization of the network, but can dramatically affect network performance. WSN creates a local network hierarchy on one or more levels represented by nodes chosen by certain criteria that are aggregating and sending data to a central base station (BS). Most times it is not necessary to identify the exact location of the node and its ID. Communication is done mostly from node to BS, the BS sends requests to obtain data from nodes. The answer of a particular node is not important, but the area of origin is. All data has to be aggregated by the cluster-head before reaching the BS. Generally, routing protocols on the basis of network structure are divided into 3 main groups:-

1. FLAT
2. Hierarchical
3. Location based

Specifically, hierarchical routing protocols have proved to have considerable savings in total energy consumption of the WSN. In hierarchical routing protocols, clusters are created and a head node is assigned to each cluster. The head nodes are the leaders of their groups having responsibilities like collection and aggregation the data from their respective clusters and transmitting the aggregated data to the BS. This data aggregation in the head nodes greatly reduces energy consumption in the network by minimizing the total data messages to be sent to BS [2].

The less the energy consumption, the more the network life time. The main idea of developing cluster-based routing protocols is to reduce the network traffic toward the sink. This method of clustering may introduce overhead due to the cluster configuration and maintenance, but it has been demonstrated that cluster-based protocols exhibit better energy consumption and performance when compared to flat network topologies for large scale WSNs.

### III. LEACH

Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol for sensor networks is proposed by W. R. Heinzelman et.al [3] which minimizes energy dissipation in sensor networks, it is based on a simple clustering mechanism by which energy can be conserved since cluster heads are selected for data transmission instead of other nodes [13]. The operation of LEACH is broken up into rounds, where each round begins with a set-up phase, when the clusters are organized, followed by a steady-state phase, when data transfers to the base station occur. In order to minimize overhead, the steady-state phase is long compared to the set-up phase.

Set-up phase: During this phase, each node decides whether or not to become a cluster head (CH) for the current round [4]. This decision is based on choosing a random number between 0 and 1. If number is less than a threshold  $T(n)$ , the node becomes a cluster head for the current round. The threshold value is set as:

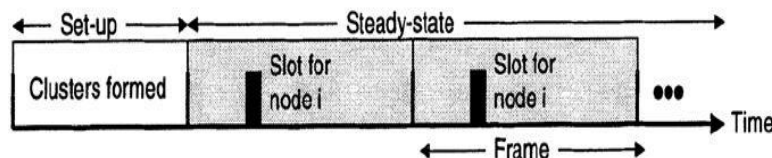


Figure: Time-Line Operation Of Leach

Once the cluster head is chosen, it will use the CDMA MAC protocol to advertise its status. Remaining nodes will take the decision about their cluster head for current round based on the received signal strength of the advertisement message. [5]

Before steady-state phase starts, certain parameters are considered, such as the network topology and the relative costs of computation versus the communication. A Time Division Multiple Access (TDMA) schedule is applied to all the members of the cluster group to send messages to the CH, and then to the cluster head towards the base station. As soon as a cluster head is selected for a region, steady-state phase starts.

### IV. LEACH OPTIMIZATION

E- LEACH: It makes residual energy of node as the main metric which decides whether the nodes turn into CH or not after the first round. Same as LEACH protocol, E-LEACH [13] is divided into rounds, in the first round, every node has the same probability to turn into CH, that mean nodes are randomly selected as CHs, in the next rounds, the residual energy of each node is different after one round communication and taken into account for the selection of the CHs. That mean nodes have more energy will become a CHs rather than nodes with less energy.

- TL- LEACH: The CH [12] collects and aggregates data from sensors in its own cluster and passes the information to the BS directly. CH might be located far away from the BS, so it uses most of its energy for transmitting and because it is always on it will die faster than other nodes. A new version of LEACH called Two-level Leach was proposed. In this protocol; CH collects data from other cluster members as original LEACH, but rather than transfer data to the BS directly, it uses one of the CHs that lies between the CH and the BS as a relay station.

• LEACH -C: LEACH [6] offers no guarantee about the placement and/or number of cluster heads. In an enhancement over the LEACH protocol was proposed. The protocol, called LEACH-C, uses a centralized clustering algorithm and the same steady-state phase as LEACH. LEACH-C protocol can produce better performance by dispersing the cluster heads throughout the network. During the set-up phase of LEACH-C, each node sends information about its current location (possibly determined using GPS) residual energy level to the sink. In addition to determining good clusters, the sink needs to ensure that the energy load is evenly distributed among all the nodes. To do this, sink computes the average node energy, and determines which nodes have energy below this average.

Once the cluster heads and associated clusters are found, the sink broadcasts a message that obtains the cluster head ID for each node. If a cluster head ID matches its own ID, the node is a cluster head; otherwise the node determines its TDMA slot for data transmission and goes sleep until its time to transmit data. The steady-state phase of LEACH-C is identical to that of the LEACH protocol.

M- LEACH: In LEACH, Each CH directly communicates with BS no matter the distance between CH and BS. It will consume lot of its energy if the distances far. On the other hand, Multihop-LEACH protocol [2] selects optimal path between the CH and the BS through other CHs and use these CHs as a relay station to transmit data over through them. First, multi-hop communication is adopted among CHs. Then, according to the selected optimal path, these CHs transmit data to the corresponding CH which is nearest to BS. Finally, this CH sends data to BS. M-LEACH protocol is almost the same as LEACH protocol, only makes communication mode from single hop to multi-hop between CHs and BS.

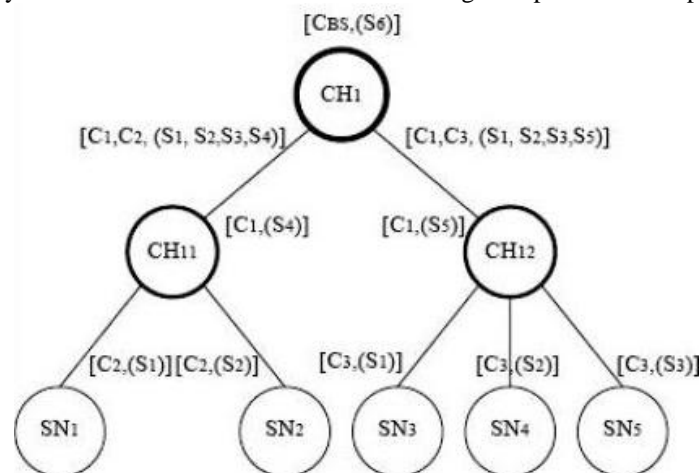


Figure: TL-LEACH

Distributed Energy-efficient Clustering Hierarchy Protocol (DECHP) [11], which distributes the energy dissipation evenly among all sensor nodes to improve network lifetime and average energy savings. DECHP uses a geographical and energy aware neighbor cluster heads selection heuristic to transfer fused data to the BS.

The two key elements considered in the design of DECHP are the sensor nodes and BS. The sensor nodes are geographically grouped into clusters and capable of operating in two basic nodes: i) the cluster head nodes ii) the sensing node.

In the sensing node, the nodes perform sensing tasks and transmit the sensed data to the cluster head. In cluster head node, a node gathers data from the other nodes within its cluster performs data fusion and routes the data to the BS through other cluster head nodes. The BS in turn supervises the entire network. Initially, the nodes organize themselves into local clusters based on their localization, with one node acting as the cluster head.

The scheme proposed [4] attains a scale-independent emergent clustering algorithm, through which it performs high uniform cluster distribution with less overlap between clusters. In the mean time, PCC requires only a small constant amount of communications overhead, and it achieves clustering despite the overall number of nodes in the network. Furthermore, a virtual migration-based rotation strategy of cluster-head node is introduced into PCC. Once a cluster head detects its inadequate power, the head will indicate unwillingness to return to the scheme. Consequently, PCC can also ensure the reliability of data transmission.

These notations are classified into three types: network layer notations, node layer notations and cluster layer notations. For the network layer notations, all nodes are scattered in a square sensing region, whose area is  $LL$ . With limited power capacity, radio ranges of all nodes are predefined as  $R$  in PCC.

As for node layer notations, all nodes located within sensing region together form the set of generic nodes  $P$ . A node in PCC can have three possible states: it can be non-clustered (not a member node of any cluster), member node or it may be a cluster-head.

Likewise, cluster layer notations reflect the subordinate relationship between cluster-head and member nodes. CH represents a set, which includes all the current cluster heads. To specify a particular cluster-head, element in CH are indexed by its sequence number.

• Hierarchical Cluster-based Routing (HCR) Hierarchical cluster-based routing (HCR) technique is an extension of the LEACH protocol. In HCR, each cluster is managed by a set of associates and the energy efficient clusters are retained for a longer period of time. The energy-efficient clusters are identified using heuristics-based approach.

Moreover, in a variation of HCR, the base station determines the cluster formation. A Genetic Algorithm (GA) is used to generate energy efficient hierarchical clusters. The base station broadcasts the GA-based clusters configuration, which is received by the sensor nodes and the network is configured accordingly. The main objective of the HCR (Sajid Hussain, Abdul W. Matin, 2006) protocol is to generate energy efficient clusters for randomly deployed sensor nodes, where each cluster is managed by a set of associates called a head-set.

DECHP uses a class-based addressing of the form  $\langle \text{Location-ID, Node-Type-ID} \rangle$ . The Location-ID identifies the location of a node that conducts sensing activities in a specified region of the network. It is assumed that each node knows its own location information from GPS or some localization system and remaining energy level. Each node within the cluster is further provided with a Node-Type-ID that describes the functionality of the sensor.

## V. ROUTING PROTOCOL ARCHITECTURE

In Time Dependant-LEACH, competition for cluster-heads (CHs) no longer depends on a random number as in LEACH, and a random time interval instead. Nodes which have the shortest time interval will win the competition and become cluster heads.

In order to obtain a constant number of cluster-heads, set a counter which shows optimum no. of cluster heads (Kop). When the number of the counter has reached specified value, nodes no longer continue competition for cluster-heads.

For example, the nodes need to elect four CHs. Every node in the network produces a random timer at the beginning of a round. When the timer expires, and if the number which node has received of CHs' advertisement messages (CH ADV) is less than four, the node broadcast a CHs advertisement message to announce its CH status by using a non-persistent carrier-sense multiple access (CSMA) MAC protocol. Else, it can't become a Cluster-head.

Once CHs are elected, the following processes are completely similar to LEACH. This algorithm is still a distributed algorithm, that is, nodes make autonomous decisions without any centralized control.

The proposed algorithm also employs cluster member threshold to avoid the very big cluster and the very small cluster existing at the same time. As shown in figure there are 6 clusters and marked them A to F and A to D are the very small cluster and E, F are the very big cluster. Very big clusters (E, F) and the very small clusters (A, B, C and D) exist at the same time; the energy of the nodes in the very small cluster will be used up quickly.

The reason that the energy of node in a small cluster declines sharply is explained below: The cluster head must wait until all members of the cluster finished to collect and send data once before starting the data aggregation, and then sent the aggregated data to the BS. The small cluster has fewer members, so the time for completion of data acquisition and delivery is shorter; the result is the small cluster will send data to the base station more frequently than the big cluster (As shown in below Table

I). From a simulation result [7], found that in a small cluster the average energy consumption of cluster member node were significantly higher than a big cluster. So there is need to balance the clusters. so, algorithm use cluster member threshold to balance the clusters.

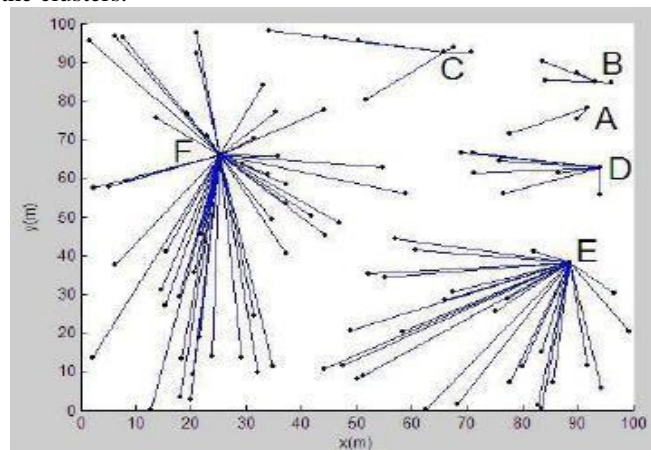


Figure: The very big cluster and the very small cluster exist at the same time

## VI. IMPLEMENTATION AND SIMULATION OF LEACH PROTOCOL

### 6.1 LEACH Matlab Code

- LEACH matlab code is available. I have tested the code.
- LEACH matlab code has following important functions.
  - (1) Cluster head selection phase.
  - (2) Cluster formation phase.
  - (3) Cluster head assign the time schedule to cluster members.
  - (4) According to the TDMA schedule cluster member node send the data to CH.

• I understood the implementation of LEACH in matlab and after executing, it has generated the graph which is shown in the figure 6.1 of nodes alive over the rounds. Applying this technique it will improve the life time of sensor nodes.

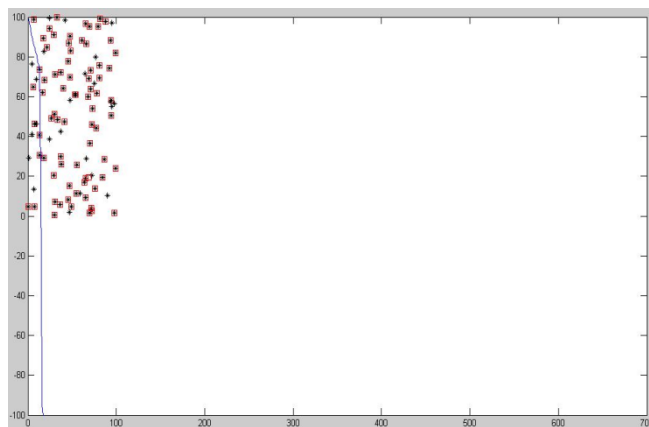


Figure 6.1: No. of nodes alive over the rounds in LEACH

## VII. CONCLUSION

In this paper we have examined the current state of proposed hierarchical routing protocols, specifically with respect to their power and reliability requirements. In wireless sensor networks, the energy limitations of nodes play a crucial role in designing any protocol for implementation. In addition, Quality of Service metrics such as delay, data loss tolerance, and network lifetime expose reliability issues when designing recovery mechanisms for clustering schemes. However there is still much work to be done. Many energy improvements thus far have focused with minimization of energy associated in the cluster head selection process or with generating a desirable distribution of cluster heads.

Optimal clustering in terms of energy efficiency should eliminate all overhead associated not only with the cluster head selection process, but also with node association to their respective cluster heads. Sensor network reliability is currently addressed in various algorithms by utilizing re-clustering that occurs at various time intervals; however the result is often energy inefficient and limits the time available within a network for data transmission and sensing tasks. Further improvements in reliability should examine possible modifications to the reencountering mechanisms following the initial cluster head selection. These modifications should be able to adapt the network clusters to maintain network connectivity while reducing the wasteful resources associated with periodic re-clustering. In addition, other mechanisms such as the ability of nodes to maintain

Membership in auxiliary clusters can reinforce the current state of sensor network reliability.

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