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# Energy Efficient and Reliable WSN based on Improved Leach-R Clustering Techniques

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## Abstract

**Background/Objectives:** Routing in Wireless Sensor Network (WSN) is an important area of research due to its rapidly increasing application in monitoring various kinds of environment by sensing physical phenomenon. The aim of this study is to increase the lifetime of the network. **Methods/Statistical Analysis:** Enhanced LEACH-R introduces the energy efficiency clustering algorithm for wireless sensor network which is based on Low Energy Adaptive Clustering Hierarchy and removed some of the limitations of the LEACH-R protocol. In this protocol we considered the advance nodes and normal nodes both but the advance nodes have more energy than the normal nodes. **Results:** The proposed protocol is tested virtually in MATLAB tool. All the nodes are randomly deployed in the region 100*100 $m^2$ and base station is located at the center position i.e. (50, 50). Enhanced LEACH-R protocol gives us the better result as compared to the LEACH-R protocol in terms of energy conservation. **Conclusion:** This protocol improves the regions of cluster based hierarchical process using heterogeneity parameters like selection of advanced nodes (m) and additional energy factor between normal and advance nodes (a). This protocol has increased the stability time for first dead node and correspondingly the lifetime of last dead node is also increased.

**Keywords:** Advance Nodes, Dead Nodes, Energy Consumption, Normal Nodes, Wireless Sensor Network

## 1. Introduction

Wireless Sensor Network (WSN) is a self-sufficient sensor which is utilized to screen the physical and ecological conditions like temperature, weight and so forth. Sensor nodes communicate together with many wireless strategies and these communication strategies are administrated with the routing protocols[1]. Wireless sensor system is developed of hundreds or even a large number of nodes. Sensor node is a little gadget which incorporates three essential segments for sensing the physical natural conditions: processing subsystem, sensing subsystem and remote correspondence subsystem. Environmental conditions are sensed by sensor nodes and send that data to the base station[2]. This network uses wireless media and consists of sensor nodes which communicates with other sensor nodes through the wireless links. Random deployment can be realized by following normal distribution from its center to the boundaries. We analyze the energy consumption in transmission and sensing by all the sensors[3]. In Wireless Sensor Network (WSN) the sensor node transmit collected information and cooperates with other sensor nodes to accomplish special functions of wireless communicating manner. Sensor networks are widely deployed in the industries, medical, agriculture, military and environmental areas. Sensor nodes have the limited resources. Major energy is needed for data transfer between nodes. To reduce energy consumption, efficient routing protocol is considered as a new direction for the energy constrained sensor networks[4,5].

## 2. Clustering Techniques

### 2.1 Leach

LEACH protocol stands for Low Energy Adaptive Clustering Hierarchy and accept that a thick homogeneous

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sensor system and vitality obliged nodes report their information to the base station. Macintosh convention taking into account TDMA is incorporated in LEACH with grouping and a basic steering convention. LEACH separates the sensor nodes into clusters and each cluster has a particular node i.e. cluster head. TDMA calendar is made by the cluster head and rest of the nodes of the cluster, is member nodes[6,7]. To all the member nodes TDMA openings are doled out which is utilized to trade the information between member nodes and cluster head. Except for their time openings member nodes invest their energy in the slumber state. The cluster head spend critical measure of energy for their transmission if the sink node is far from the cluster head. The member of cluster head are energy dependent and is in charge of long transmission extent and it is constantly exchanged on. Every node chooses autonomously whether alternate nodes turn into a cluster head or not[8]. In LEACH protocol, nodes settle on a choice whether they turn into a cluster head or not in the meantime. On the premise of got sign quality, cluster head is chosen. The dividing of system into groups is time variable. Every cluster head node haphazardly picks a CDMA code for its cluster heads. A discriminating parameter of system is deciding the rate for cluster head. On the off chance that if there is couple of number of group heads are introduced then the separation between cluster head and member node becomes more extensive. If the distance between the cluster head and the base station is more, then the cluster head requires more energy for the transmission of information[9,10].

#### 2.1.1 Set-Up Phase

Set-up phase begins with the self-elected nodes. In set-up phase, cluster head node advises the neighborhood node with advertisement packet. Non-cluster head node picks the advertisement or promotion packet with the solid got signal. Utilizing a CSMA protocol, member nodes inform the cluster head nodes again. After the cluster set-up stage, the quantity of member nodes and identifiers are known by the cluster head.

$$T(n) = [p/\{1-p*(r \bmod 1/p)\}] : n \in G$$

$$T(n) = 0 : \qquad \text{otherwise} \qquad (1)$$

Where p stands for fraction of nodes and chooses themselves as a cluster head nodes and that can be possible according to the threshold value T (n). The quantity depends on the percentage of the cluster to become cluster head (p), r is the number of rounds and the clusters that didn't become a cluster head in the last round (1/p) & is denoted by G[10].

#### 2.1.2 Steady State Phase

In this phase, the non-cluster head nodes start sensing the environment and then send the collected information to the cluster head node as per the TDMA plan. After collecting information from the member or part nodes the cluster head aggregates the information and send it to the sink node. The system goes into the set-up stage after certain time and chose the new cluster head. To reduce the interference amongst the nodes, each cluster communicates using different CDMA codes[10,11].

### 2.2 Enhanced LEACH-R

This protocol improves the selection of cluster head. The main part of this protocol is the residual energy. On the basis of residual energy, the protocol decides cluster head among all nodes for the next round. Each node has the same probability for being selected as a cluster head for the first round. Cluster heads are randomly selected by the nodes for the first round and after that residual energy of each node is taken into consideration to select the node as a cluster head. Total *n* nodes to be selected as a cluster head with their residual energy for the next rounds and so on until the last dead node[12]. This protocol also partitions into many rounds as compared to the LEACH protocol. Every round contains set up phase and steady state phase.

In cluster set up phase formation, every node decides which node to be selected as a cluster head based on residual energy. Nodes which have more residual energy become a cluster head and this information of elected cluster head node is sent to other nodes. The normal nodes which have less residual energy send frame for joining the cluster to cluster head. In cluster steady state formation, nodes send information to the other nodes according to the TDMA plan and cluster head collect information and transmit information to the sink node[13]. After a certain period of time, the network again forms the selection of cluster head procedure.

## 3. Experimental Set Up

In this work, the author assumed a heterogeneous sensor network with randomly deployed 100 sensor nodes over a region 100*100 $m^2$ area. The base station is located at a point (50, 50). Nodes transmit the data to cluster head with the packet size of 40,000 bits. Initial energy of the each node is 0.5 J. This algorithm is tested in MATLAB tool and performance is evaluated.

The work carried out measures the lifetime of the network in rounds. The threshold value is figured as:

$$Tr(n) = \frac{P}{1 - P * \left(r \bmod \frac{1}{P}\right)} \left[\delta P + (1 - \delta P)\frac{E_{residual}}{E_0}\right] \quad if\ n \in C$$

$$0 \quad \text{Otherwise} \quad (2)$$

Where $E_{residual}$ is residual node energy, $E_0$ is initial energy, δ is the continuous number of rounds. After the cluster formation, we select arbitrary node from cluster head on the premises of residual energy and separation from the base station. Depending on the value of lambda this decision is made.

$$lambda = \frac{E_{residual}}{d_{toBS}} \quad (3)$$

Where $d_{to\ BS}$ is the distance between base station and cluster head. Lambda is calculated among all the cluster heads. The cluster head who has the greatest estimation of lambda will become an arbitrary node.

In Table 1, parameters and dimensions are defined in which 100 nodes are deployed in the region 100*100 square meter area and base station is located at the position (50,50). Initial energy ($E_0$) of all the nodes is 0.5 J and the probability of selecting the next node as a cluster head is 0.1 and the number of transmitting bits is 40,000. $E_{fs}$ and $E_{mp}$ are the energy of the free space and the multipath.

**Table 1.** Various parameters and their dimensions

| Parameters | Dimensions |
|---|---|
| Sensor field | 100*100 |
| Sink position | (50,50) |
| N | 100 |
| M | 0.3 |
| Packet size (bits) | 40,000 |
| $E_{fs}$ | 10pJ/bit/ $m^4$ |
| $E_{mp}$ | 0.0013pJ/bit/$m^2$ |
| $E_{DA}$ | 50nJ/bit |
| $E_0$ | 0.5 J |
| P | 0.1 |
| A | 4 |

## 3.1 Formation of Clusters

Proposed work utilizes hierarchical clustering routing. In this clustering protocol, where in each round, clusters are re-secured. That means, new cluster heads are chosen in every round and burden gets to be all around disseminated and adjusted among all the nodes of the network. Optimal numbers of nodes are considered that has to be selected as a cluster head in every round. Threshold value is used for deciding the new cluster head among selected ones. Threshold value can be calculated as:

$$T\left(S_{(nrm)}\right) = \begin{cases} \dfrac{P}{1 - P_{nrm}\left(r \bmod \dfrac{1}{P_{nrm}}\right)} & if\ S \in G \\ 0 & otherwise \end{cases} \quad (4)$$

Where r is the quantity of current rounds, G is the number of nodes that has not been chosen as a cluster head for the keep going $\frac{1}{P_{opt}}$ rounds.

## 3.2 Optimum Number of Cluster Heads

For this investigation we utilize first order leach radio model presumptions, the receiving expense $E_{Rx}(l)$ and the transmission expense $E_{Tx}(l,d)$ of l bits message b/w two nodes where d is the separation between two nodes are given by after taking mathematical equations into consideration:

$$E_{Tx}(l,d) = \begin{cases} l * E_{elec} + E_{fs} * d^2 * l & if\ d \le d_o \\ E_{elec} * l + E_{amp} * d^4 * l & if\ d \ge d_o \end{cases} \quad (5)$$

$$E_{Rx}(l) = l * E_{elec} \quad (6)$$

Where $E_{elec}$ is the energy every bit dissipates for gathering data and transmission data. Two ray model and free space model are used according to the distance between receiver and transmitter. is the threshold distance and it can be calculated as:

$$d_o = \sqrt{\frac{E_{fs}}{E_{amp}}} \quad (7)$$

If d < $d_0$, free space model is utilized; otherwise two ray model is utilized.

To locate the ideal number of clusters following formula is used:

$$k_{opt} = \sqrt{\frac{n}{2\pi}} . \sqrt{\frac{E_{fs}}{E_{amp}}} . \frac{M}{d^2} \quad (8)$$

The ideal probability of a node to turn into a cluster head can be calculated as:

$$P_{opt} = \frac{k_{opt}}{n} \quad (9)$$

Initially we calculate the energy of the normal nodes and advance nodes as:

$$E_1 = E_0\left(1+a\right) \quad (10)$$

Where $E_0$ is normal energy of the nodes. $E_1$ is energy of advance nodes.

$$E_t = n.E_0\left(1-P-k\right)+n.P.E_0\left(1+a\right) \quad (11)$$

$$E_t = n.E_0.(1+a) \quad (12)$$

Proposed protocol allocates a weight which defines the likelihood of node to turn into a cluster head in a relevant round. This weight is equal to the initial energy of every node to the initial energy of the normal node. Every node will turn into a cluster head once if the nodes are heterogeneous. The weighted probabilities of advance and normal node are as follows:

$$P_{nrm} = \frac{P_{opt}}{1+P.a} \quad (13)$$

$$P_{adv} = \frac{P_{opt}}{1+P.a+(1+a)} \quad (14)$$

## 4. Simulation Results

Figure 1 shows the random deployment of sensor nodes. All nodes are randomly deployed in square meter area of 100*100 and base station is located at the position of (50,50).

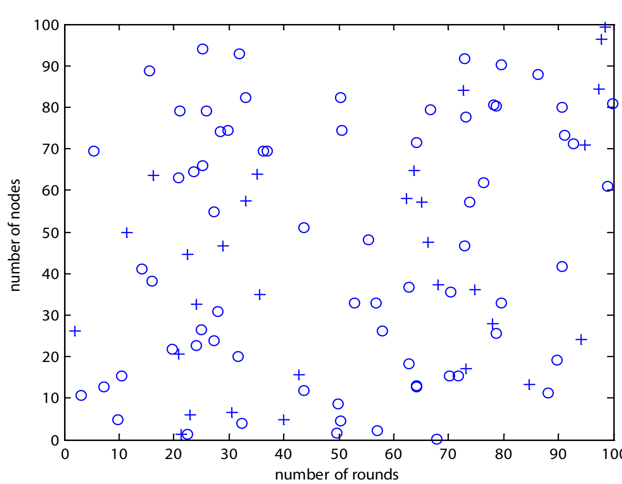


**Figure 1.** Random deployment of sensor nodes.

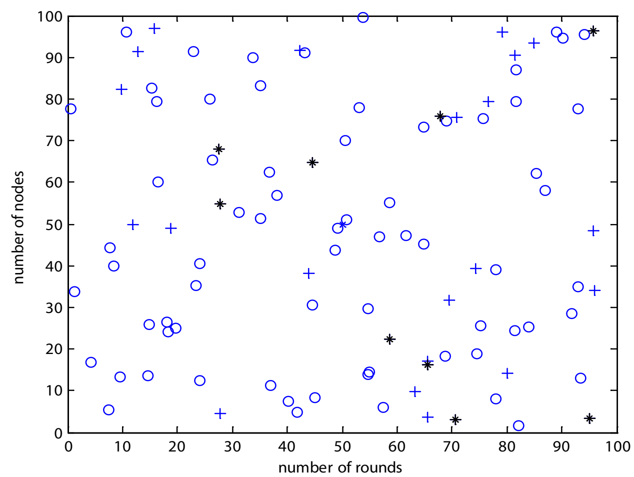


**Figure 2.** Initial configuration in energy leach.

Figure 2 shows the initial configuration in energy leach. All the nodes are in active state. Here normal nodes are represented by circles, advance nodes are represented by (+) and cluster head are represented by (*).

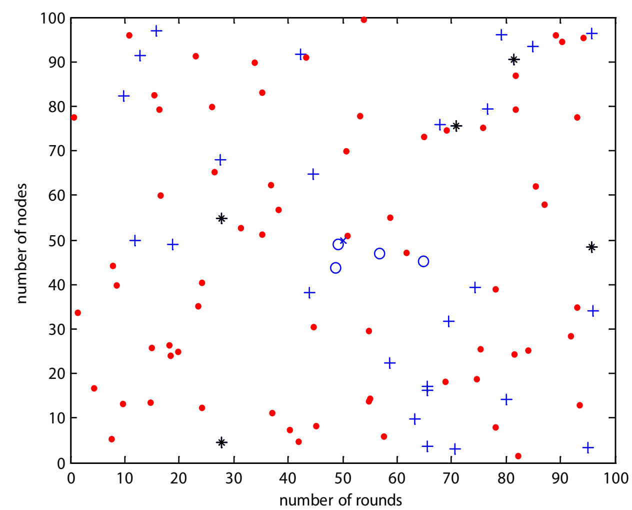


**Figure 3.** Network with half dead nodes.

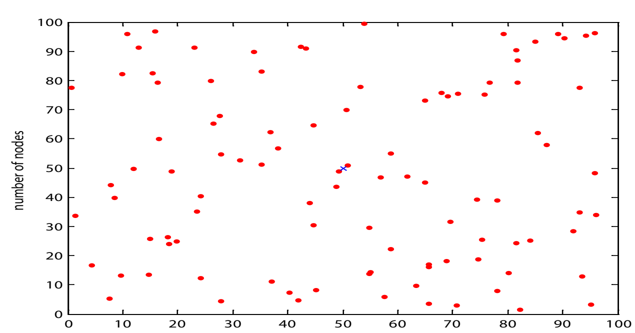


**Figure 4.** Network with all dead nodes.

Figure 3 shows the network with half dead nodes. This figure reflects that some nodes are active and some are dead and dead nodes are represented by the red color.

Figure 4 shows the network with all dead nodes. Here all nodes are dead after the certain amount of rounds but in between 9999 rounds. As compared to our existing technique, the first node takes much longer time to die and correspondingly the last dead node also dies later.

In Table 2 parameters and values are defined which resulted after simulation. Total number of rounds ($r_{max}$) is 9999. K calculates the optimal number of cluster heads. $d_1$ calculates the distance between the cluster head and the base station. $d_2$ calculates the distance between the cluster member and cluster head. $P_{nrm}$ and $P_{adv}$ stands for the probability of the normal node and advance node.

Figure 5 demonstrates the correlation of both the conventions i.e. LEACH-R and Enhanced LEACH-R. In enhanced LEACH-R protocol the members of the cluster inform about its own status to their cluster heads. This protocol is very effective. This protocol improves the regions of cluster based hierarchical process using heterogeneity parameters like determination of advanced nodes (m) and extra vitality factor between normal and advance nodes (a). This protocol has increased the stability time for first dead node and correspondingly the lifetime of last dead node also increases.

**Table 2.** Calculations for Enhanced Leach-R protocol

| Parameters | Values |
|---|---|
| $r_{max}$ | 9999 |
| K | 2.5536 |
| $d_1$ | 38.2500 |
| $E_r$ | 0.0445 |
| $d_2$ | 24.9649 |
| $d_0$ | 87.7058 |
| $P_{nrm}$ | 0.0796 |
| $P_{adv}$ | 0.1538 |
| dead_n | 70 |
| dead_a | 30 |
| Dead | 100 |
| first dead | 1186 |
| flag_first dead | 1 |
| Temp | 7.5762 |
| min_dis | 7.5762 |
| RcountCHs | 18180 |

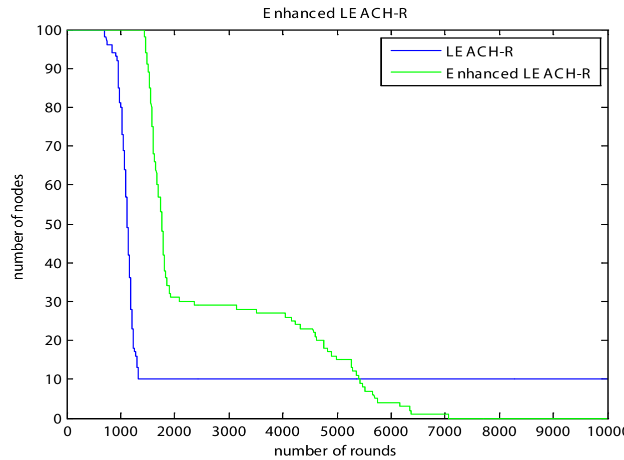


**Figure 5.** Comparison of enhanced LEACH-R and LEACH-R.

## 5. Conclusion

There is lot of energy wastage in sensor nodes of wireless sensor network. But there are many techniques and protocols that conserve energy. There are many leach protocols like leach-f, leach-c, leach-r etc. But the proposed work is accomplished as an improvement to the leach-r protocol thereby giving another name to this protocol i.e. enhanced leach-r protocol. In this protocol the members of the cluster inform about its own status to their cluster heads. This protocol is very effective. This protocol improves the regions of cluster based hierarchical process using heterogeneity parameters like selection of advanced nodes (m) and additional energy factor between normal and advance nodes (a).

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