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ENERGY EFFICIENT CLUSTERING MODEL: MODIFIED LEACH-R PROTOCOL

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Abstract

Routing in Wireless Sensor Network (WSN) is usually an important area of research. Rapidly increasing applications of sensor nodes in monitoring of physical environment has led to an increased significance of WSN. Modified LEACH-R introduces the energy efficient clustering scheme for Wireless Sensor Network which is dependent on Low Energy Adaptive Clustering Hierarchy structure and removed many of the limitations of the Enhanced LEACH-R protocol. Modified LEACH-R uses the remaining energy of the current cluster head which makes the process of routing better and efficient. In heterogeneous network, a cluster head node aggregate and collects data from their member nodes and send that aggregated data towards the base station. The proposed protocol uses super advance nodes. The role of super advance nodes is to act as cluster head and to

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perform the task of data aggregation while consuming low power during operation. Modified LEACH-R protocol is tested and simulated in MATLAB software package. Modified LEACH-R protocol increases the frequency of packets that can be transmitted between base stations to cluster heads and between cluster head and nodes. The findings of the simulation revealed that MODIFIED LEACH-R provides better results as compared to Enhanced LEACH-R and LEACH-R protocol. Modified LEACH-R protocol enhances the time of first dead node and as well as increases the duration of operation of the last node and hence enhances the overall network lifetime.

I. Introduction

Wireless Sensor Network (WSN) consists of self-sufficient sensors which can be devised to monitor the physical and also ecological conditions like temperature, weight and so forth. Wireless Sensor Networks are comprised of hundreds or even a large number of nodes to perform the dedicated task [1]. Sensor node is tiny little gadget which usually incorporates three necessary segments for sensing the physical conditions: processing subsystem, sensing subsystem and remote correspondence subsystem. Environmental conditions tend to be sensed by sensor nodes where data is collected, processed and sent to the base station (Central Support System) [2]. Sensor networks are widely deployed in industries, medical, farming, military and ecological areas. The communication between Central Support System and the other nodes are carried out wirelessly. The network involves sensor nodes which usually communicate with other nodes through wireless links. The sensor nodes are deployed in large numbers and operate in the area of interest [3, 4]. In Wireless Sensor Networks (WSN), the sensor node transmits collected information and also cooperates with some other sensor nodes to perform special functions of routing data in the network [5]. Though a lot of work has been carried out in Clustering and Data Aggregation models but still there are limitations in their energy efficient algorithms. Proposed protocol is specially designed for energy constrained networks as it takes into consideration the heterogeneity of various nodes. Nodes in the cluster are classified based on the attributes they carry like memory, processor etc. This heterogeneity based decision making approach is followed in this paper.

II. Clustering Structure

LEACH stands for Low Energy Adaptive Clustering Hierarchy: a protocol designed to collect information from various nodes, aggregating it and then passing it to the base station whilst consuming the low power during operation. LEACH distributes the sensor nodes into clusters and each cluster has its own cluster head [6, 7]. To avoid collision, TDMA schedule is followed. TDMA calendar is created by the cluster head and other nodes of the cluster, i.e., member nodes. To all the member nodes, TDMA opportunities are doled out that is utilized to trade the information between member nodes and cluster head. With the exception of their time opportunities, member nodes spend their energy within the slumber state [8]. The cluster head spend huge amount of energy for transmission if the sink node is far away from the cluster head. The cluster heads are energy dependent. This creates a necessity to replace the cluster head with the passage of time. Every node decides autonomously whether alternate nodes change into a cluster head or not. In LEACH protocol, nodes settle over a choice whether they change into a cluster head or not for now. The selection process of whole area into clusters is time variable. Every cluster head node haphazardly selects a CDMA code for communication [9, 10]. The process of clustering is segmented in two parts: Set-up phase and Steady state phase. In set-up phase cluster head is elected and advertised whereas in steady state phase monitoring and relaying of messages via cluster head begins.

1. Set-up phase: Set-up phase begins with self-elected nodes. In set-up phase, cluster head node advises the neighborhood nodes with advertisement packet. Non-cluster head node gives recommendations to the advertisement packet through separate channel. Cluster head is elected based on the threshold value [10].

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

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

where p represents fraction of nodes, cluster head is selected based on the value of threshold value $T_{\circ}(n)$. The quantity is dependent upon the percentage with the cluster to turn out to be cluster head (p), r is the number of rounds and G is the number of clusters that did not become a cluster head in the last $(1/p)$ rounds [11].

2. Steady state phase: In this phase, the non-cluster head nodes start sensing information and send it to the cluster head nodes as per the TDMA strategy. After collecting information from the member nodes, the cluster head aggregates the knowledge and send it to the sink node. The system goes into this set-up stage soon after certain time and chooses the new cluster head. To reduce the interference from the nodes, each cluster head communicates with other clusters through different CDMA codes [11, 12].

III. Proposed Scheme: Modified LEACH-R

Modified LEACH-R protocol tends to improve the procedure of selecting the new cluster head. The prime idea of this protocol is to take decisions depending upon available residual energy in the node. Judging by residual energy, the algorithm decides that which node will be the cluster head among the rest for the next round [12]. Cluster heads are generally randomly selected by the nodes for the first round and in the next round, residual energy of each node is taken into consideration to select the node as a cluster head. In each round, n nodes participate to become cluster head until the last dead node. This protocol furthermore partitions into many rounds as compare for the LEACH protocol. Every round contains established phase and constant state phase [13].

In cluster set-up phase, nodes that have more residual energy become the cluster head. The responsibility of the newly elected cluster head is to inform about its election as a new cluster head. The normal nodes that has less residual energy sends request for joining the cluster to cluster head [13]. In cluster steady state development, nodes send information to the other nodes as well as to cluster head if the destination exists outside the cluster. All this communication is carried out according to the TDMA plan. Cluster head then transmits information to the sink node. As time passes, the network again starts the re-election process of the cluster head [14].

IV. Algorithm and Parameters

Proposed protocol is virtually tested in software assuming a heterogeneous sensor network with randomly deployed 100 sensor nodes over a region of $100^{*}100m^2$ area. The base station is located at (50*m*, 50*m*). The packet size assumed in the testing procedure is 40000 bits. Initial energy of the each node will be 0. 5J. Modified LEACH-R algorithm is implemented in MATLAB package and performance is evaluated by measuring the parameter values that resulted after simulation. For introspection of protocol, we measured the duration of the network in rounds to see when the 1st node dies. The actual threshold value will be figured out as:

$$Tr(n) = \begin{pmatrix} \dfrac{P}{1 - P * \left(r \bmod \dfrac{1}{P}\right)} \left[\delta P + (1 - \delta P) \dfrac{E_{residual}}{E_0}\right] & \text{if } n \in G \\ 0 & \text{otherwise} \end{pmatrix}, \quad (2)$$

where $E_{residual}$ is residual node energy, E_0 is initial energy, δ is the continuous number involving number of rounds. After the cluster formation, an arbitrary node is selected from cluster based upon the residual energy and distance from base station.

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

where d_{toBS} is the gap between base station and cluster head. Lambda is calculated among all nodes in the cluster. The node having the greatest value of lambda is considered as the arbitrary node which is further made as a cluster head.

Table 1. Assumed parameters and their dimensions

Parameters	**Dimensions**
Sensor field (m^2)	100*100
Sink position (m^2)	50*50
No. of nodes	100
M (% of advance nodes)	0.3
Packet size (bits)	40000
E_{fs} (free space energy)	$10\text{pJ}/\text{bit}/m^4$
E_{mp} (energy consumption due to multipath propagation)	$0.0013\text{pJ}/\text{bit}/m^2$
E_{DA} (energy consumption due to data aggregation)	50nJ/bit
E_0 (initial energy)	0.5
P (% to become cluster head)	0.1
A (% of nodes superior than normal nodes)	4
B (% of nodes superior than advance nodes)	6

1. Formation of clusters: The suggested work is based upon the hierarchical clustering routing protocol. In this clustering process, where in just about every round clusters are usually re-secured. In this specific clustering network, new cluster heads are chosen in each and every round and burden grows to be all around disseminated and adjusted among all the nodes of the system. Optimal numbers of nodes are selected to be the cluster head in each and every round. To decide the cluster head among the selected nodes, threshold value can be calculated as [1]:

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

where r is the number of current rounds, G is the number of nodes that are not chosen as cluster head before. Cluster heads in the proposed protocol is selected based upon the threshold value which varies between random numbers 0 and 1.

2. Optimum number of cluster heads: With this investigation, first order LEACH model is employed, with receiving expense $E_{Rx(l)}$ and transmission expense $E_{Tx}(l, d)$ of t bits per message. The expense can be calculated using the mathematical formula [15]:

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

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

where E_{elec} is the energy every bit dissipates for collecting data and sign data. Two ray design and free space model are used using the distance between receiver and transmitter. d_o is the particular threshold distance and it could be calculated as [15]:

$$d_o = \sqrt{\frac{E_{fs}}{E_{amp}}}. \tag{7}$$

In the event that $d < d_o$ free space model is utilized; otherwise two ray model is utilized.

To locate the ideal number of groups following formula is utilized:

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

The optimal probability of a node to show into a cluster head might be calculated as [10]:

$$P_{opt} = \frac{k_{opt}}{n}. \tag{9}$$

First, calculate the energy available in the standard or normal nodes, advance nodes and super advance nodes as:

$$E_1 = E_0(1 + a), \tag{10}$$

$$E_2 = E_1(1 + b), \tag{11}$$

$$E_t = n \cdot E_0 \cdot (1 + a), \tag{12}$$

$$E_s = n \cdot E_1 \cdot (1 + b), \tag{13}$$

where E_0 is the energy of normal nodes, E_1 is the energy of the advance nodes and E_2 is the energy of the super advance nodes. The proposed protocol allocates a weight to each node based upon energy. Weight describes the probability of a node to turn into a cluster head. This weight is added up in the initial energy of the node. Every node will turn into a cluster head once either the nodes are heterogeneous or homogenous. To define the weighted likelihood probability of super advance nodes in addition to normal nodes and advance nodes are as follows:

$$P_{nrm} = \frac{P_{opt}}{1 + P \cdot a}, \tag{14}$$

$$P_{adv} = \frac{P_{opt}}{1 + P \cdot a + (1 + a)}, \tag{15}$$

$$P_{sup} = \frac{P_{opt}}{1 + P \cdot b + (1 + b)}. \tag{16}$$

V. Simulation Results

Reliability depends upon the working and efficiency of the protocol. In order to verify it, the protocol is virtually tested and simulated in MATLAB. The parameters and their values used during the simulation are already stated in the previous section. Figure 1 shows the initial phase of debugging process which displays the random deployment of sensor nodes in the presumed area. All nodes tend to be randomly deployed in presumed area of $100m * 100m$, where base station is positioned in the middle $50m * 50m$.

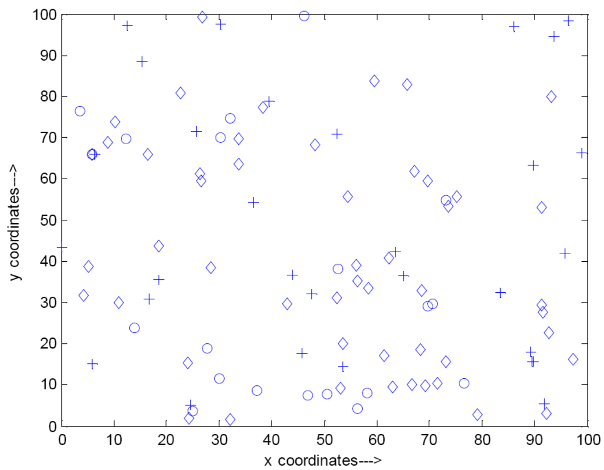

Figure 1. Random deployment of sensor nodes.

Figure 2 shows the initial configuration in energy LEACH. All the nodes are in active state. Nodes deployed are differentiated with the thought of different energy levels, tasks allocated and operation. Here normal nodes are represented by circles, advance nodes are represented by (+), super advance nodes are represented by D and cluster head are represented by (*).

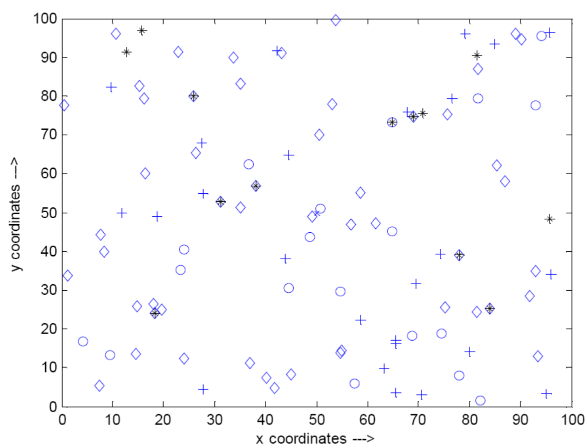

Figure 2. Diverse nodes in existence.

Figure 3 exhibits the network with half dead nodes. Nodes are brought up to perform some tasks. While in operation, they consume energy. Due to limited resource of battery in nodes, the sensor nodes die early. Figure represents the same scenario where after a certain period of initialization of network, many nodes have due to consumption of whole energy source available. Hence, the scenario is shown where the dead and active nodes are represented by different colors: red – dead nodes.

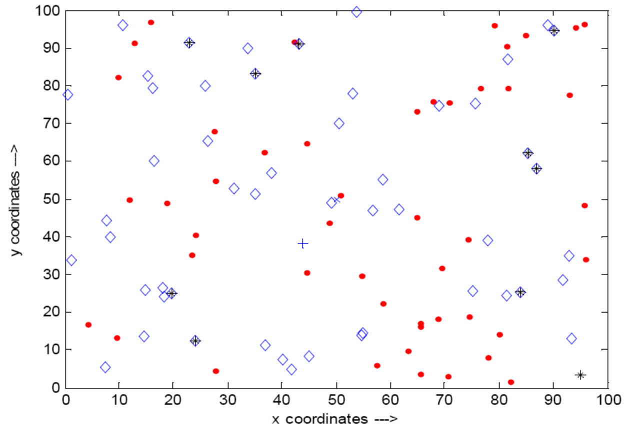

Figure 3. Network with half dead nodes.

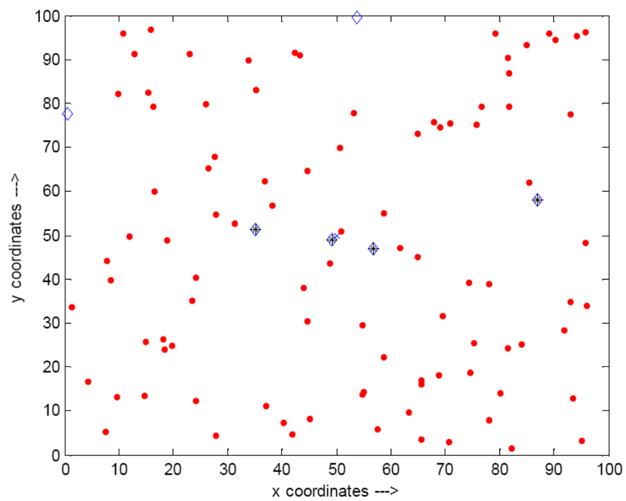

Figure 4. Network with all dead nodes.

Figure 4 exhibits the network when all the nodes have died, i.e., no longer operational. Results reveal that the last node of the network operated under modified LEACH-R protocol dies after 9999 rounds. It is far better in comparison with the techniques: Enhanced LEACH-R and LEACH-R.

Table 2. Calculations for modified LEACH-R protocol

Parameters	**Values**
$r_{\max}$ (maximum no. of rounds)	9999
K (optimal number of cluster heads)	2.5536
d_1 (distance between CH & BS)	38.2500
E_r (initial energy of random nodes)	0.0445
d_2 (distance between nodes & CH)	24.9649
d_0 (threshold distance)	87.7058
P_{nrm} (Probability of normal nodes)	0.0455
P_{adv} (Probability of advance nodes)	0.2273
P_{sup} (Probability of super nodes)	0.1346
dead_a (advance dead nodes)	30
dead_sup (super dead nodes)	19
Dead (no. of dead nodes)	100
first dead	1752
flag_first dead	1
Temp	64.1099
Min_dis	64.1099
RcountCHs	104197

Figure 5 demonstrates the correlation of the conventional techniques (LEACH-R, Enhanced LEACH-R) and modified LEACH-R. In modified

LEACH-R, the nodes of the cluster inform about its very own status to the cluster heads. This protocol is quite effective in terms of energy conservation. Thus, protocol improves the regions of cluster based hierarchical course of action using heterogeneity guidelines like determination regarding super advanced nodes and extra vitality factor between advance nodes and super advance nodes. Hence, modified LEACH-R protocol has increased stability time pertaining to first dead node and correspondingly increasing the time of last dead node.

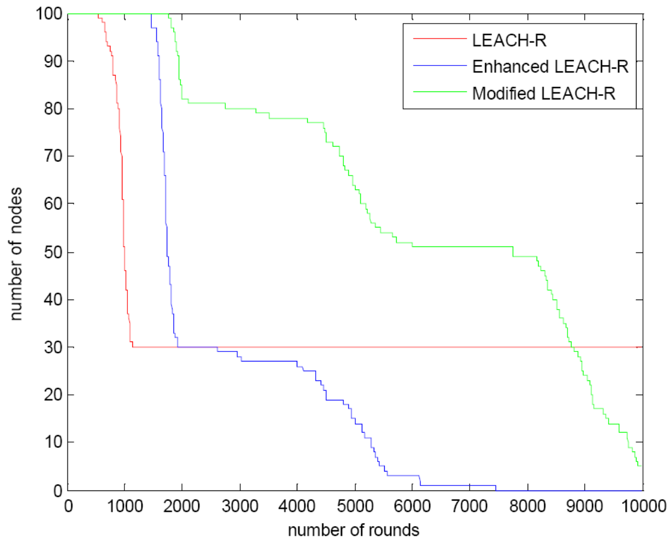

Figure 5. Comparison of LEACH-R, Enhanced LEACH-R and modified LEACH-R.

VI. Conclusions

Wireless Sensor Networks are designed to extract crucial information where the human intervention is not possible or where the precision is required. Manual inspection does not lead to precision. So WSN plays a vital role in reliable and precision data gathering applications. Unnecessary energy consumption could lead to reduction of network lifespan. But there are many techniques that are designed like LEACH-F, LEACH-C, LEACH-R to overcome that problem but they are limited in functionality. Therefore, this proposed work is accomplished as a possible improvement to the particular LEACH-R protocol, Enhanced LEACH-R protocol and thus giving another name for this protocol, i.e., modified enhanced LEACH-R protocol. In this protocol, nodes from the cluster inform about unique status to their cluster heads. This protocol is extremely effective in terms of energy conservation. This protocol has improved the clustering method using heterogeneity parameters like offering of super advanced nodes and inclusion of additional energy factor to assist the selection mechanism of clustering.

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