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Energy Efficient Optimized LEACH-C Protocol using PBO Algorithm For Wireless Sensor Network

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Abstract: Wireless sensor networks have gained popularity because they have the potential to completely transform a variety of facets automation in the transportation and healthcare industries, as well as environmental monitoring and conservation, manufacturing, and commercial asset management. The number of nodes in a wireless sensor network is large ranging in number from a few to thousands, each of which is connected to a single sensor. Lifetime and energy usage is this network's most difficult assignment. The most widely recognised routing methods for wireless sensor networks are cluster-based ones since they increase network longevity and use less energy. Numerous protocols, including LEACH, Multi-hop-LEACH, LEACH-V, LEACH-C, and OLEACH-C, have been created.. To enhance the functionality of the LEACH-C protocol, we will concentrate on an optimization technique based on pollination, commonly known as OLEACH-C. The PBO technique is used for clustering in WSN. The cluster head will be determined by which node has the most energy remaining. The cluster head will be chosen by the distance between two nodes if their energies are equal. Based on which node is closest to the base station, the CH will be decided. The optimal CHs that ensure routing optimization with the least amount of energy consumption and the least expensive communication lines between nodes inside of each other are chosen using the OLEACH-C protocol.

Key Words*: LEACH, Multihop-LEACH, LEACH-V, LEACH-C, OLEACH-C*

I.INTRODUCTION

The creation of intelligent environments for data collection and transmission that rely on sensory data from the actual world is made possible by the widespread use of wireless sensor networks (WSNs). Figure 1 depicts the fundamental construction of a smart sensor. The batteries are referred to as the power source. The sensor nodes often have a restricted battery capacity. At the moment, sensors can replenish their energy through vibration, temperature differential, or solar sources. The microcontroller analyses the information and operates the various parts of the sensor node's capabilities. On-chip memory and flash memory are the only types of external memory. In WSN, the base station (BS), which may serve as an internet gateway, or other sensors, are connected via the transceiver.

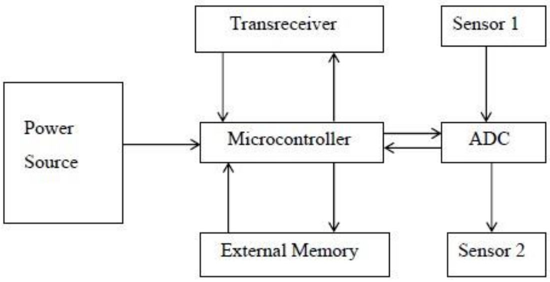

Figure1.1-Sensor Architecture

Cluster-based routing is one of the various protocols, and it uses a mechanism for data aggregation to save energy. Data aggregation is the process of collecting data from all sensor nodes and sending it to the aggregator. Data aggregation algorithms' major goal is to collect and aggregate data in an energy-efficient way to extend network lifetime. None of the nodes in a wireless sensor network can directly communicate with the base station. A sensor node, also called a "cluster head" (CH), gathers information from nearby nodes, combines it, and then transmits the resulting information to the base station.

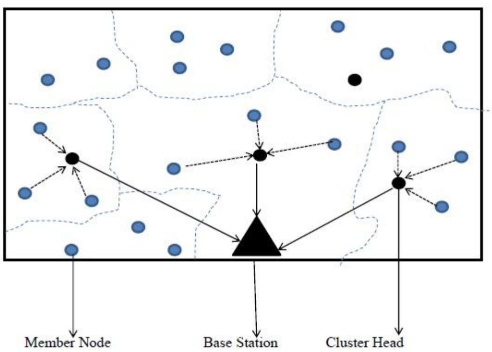

Figure 1.2Communication in Wireless Sensor Networks with Clustering

Up until now, altering the MAC layer and network layer has been the main method of reducing energy loss. There are two additional pressing issues: how to arrange the cluster heads over the grid and how many clusters would be present in a network. The network's lifespan will be extended and energy loss will be decreased if the cluster heads are placed correctly over the grid and enough clusters for*m.*

II. HIERARCHICAL ROUTING PROTOCOLS

Routing is one of the greatest issues WSNs face. The key factors contributing to the complexity of routing protocols in WSNs include the dynamic nature of nodes, computational overhead, lack of a standardised addressing scheme, self-organization, and the limited transmission range of sensor nodes. The battery life of the sensor nodes is limited. The initial battery capacity of the sensor nodes dictates how long the network will last because of the environment in which they are located, where batteries are typically non-replaceable and non-rechargeable. Several routing methods are now available for WSNs. The hierarchical architecture of the flat, hierarchical, and location-based routing protocols enables the use of higher energy nodes for data processing and transmission and lower energy nodes for environment sensing. As a result, a hierarchy of nodes with high and low energy. Low Energy Adoptive Clustering Hierarchy is a basic energy-efficient hierarchical routing technique (LEACH). Numerous protocols have developed from LEACH with the help of various upgrades and the application of cutting-edge routing algorithms. Energy-efficient, well-defined routing protocols include LEACH, LEACH-Centralized (LEACH-C), LEACH-V, Multi-Hop LEACH, and Optimized LEACH-C. (OLEACH-C). Hierarchical routing systems separate several clusters into distinct network nodes. Each cluster has a node that follows the leading rule. In clustering routing systems, Cluster-Heads (CHs) are the only nodes that can speak directly to the BS [2]. Normal nodes must communicate to closer CHs as a result, which dramatically lowers their long distance transmission overhead.

1. LEACH Protocol

One of the first hierarchical routing systems for WSNs, LEACH compresses data before sending it to the base station to save energy and increase the network lifetime.

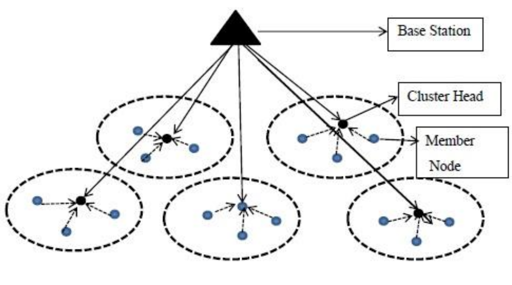

Figure 2.1-LEACH Protocol

Sensor nodes cluster together in LEACH, as depicted in figure 2.1. For each round, LEACH undertakes self-organizing and re-clustering tasks. One sensor node serves as the cluster head (CH) for each cluster, and the other sensor nodes serve as the cluster's member nodes. Data is gathered from all nodes by CHs, who then combine the data they have received and send all useful compress information to BS. Due of these new tasks, CH uses up more energy and will quickly perish if it continues to be CH, as is the case with static clustering. To solve this issue, LEACH uses randomised CH rotation, which preserves individual node batteries. LEACH prolongs network lifetime while also minimising energy consumption by compressing data before sending it to BS. Every iteration of the LEACH process normally consists of two stage. These are the setup phase and the steady state phase.

Setup Phase-

During setup, clusters and CHs are constructed. To manage all the nodes, several clusters are employed. Some nodes independently select themselves as CHs without seeking input from other nodes. The recommended percentage P and the CHs' historical performance as CHs are used to select the CHs. Every node that wasn't a CH in the prior 1/p rounds generates a number between 0 and 1, and if that number is lower than the T (n) threshold, that node becomes a CH. The value of the Threshold established by this formula

If n belongs to G , then $T(n)=P/1-p^*(rmod^1)_p$ 0,Otherwise

Here, G stands for the group of nodes that weren't picked as cluster heads in the first 1/p rounds, where p represents the projected percentage of cluster heads. or the round that is now underway. After the subsequent 1/p rounds, nodes that become CHs in the current round will remain CHs[1]. This means that the energy will disperse uniformly throughout the network and that each node will behave similarly to a CH.

Steady State Phase-

In the steady state phase, data transfer happens. Once a candidate has been chosen, each CH will broadcast an advertisement message to the other nodes via the CSMA MAC protocol. By comparing received signal strength indication, non-CHs choose their cluster heads. The non-CH nodes begin gathering data and sending it to the CH once for each TDMA frame that is provided to them. The node is thought to always have data to send in this scenario. The node enters a sleep state in order to conserve energy until the next time slot is approved. Data from cluster nodes must be continuously received by the CH, which requires that its receiver be turned on. CH combines all of the data before transmitting it to the base station.

2. Multi-hop LEACH Protocol

Another improved LEACH extension to improve WSN energy efficiency is multi-hop LEACH. Another distributed clustering routing protocol is multi-hop LEACH. The section 3.1 description of Multi-Hop LEACH communication architecture. Like LEACH, CH rotates in an arbitrary manner. The optimal route with the lowest energy consumption is selected using Multi-Hop LEACH. Keep overall distance from BS to intermediate CH as one of the selection criteria since distance substantially correlates with energy dissipation. Consequently, the route with the fewest hops between source CH and destination BS is picked.

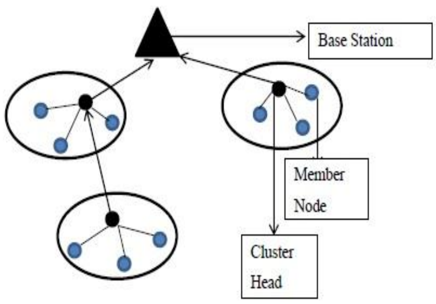

Figure 3.1-Multi-hop LEACH Protocol

The Multi-hop LEACH protocol primarily takes into account inter-cluster and intra-cluster multi-hop communication. This protocol has the advantage of allowing sensor nodes to expand inside the monitored area of the network. Thus, it exhibits its capacity for scalability and flexibility. Without a doubt, throughput is higher than that of the LEACH protocol.

3. LEACH-V Protocol

In the V-LEACH protocol, the cluster also has a vice-CH Since the data from the cluster nodes always reaches the BS, there is no longer a need to elect a new CH each time the existing CH dies. The entire network lifespan will be extended.

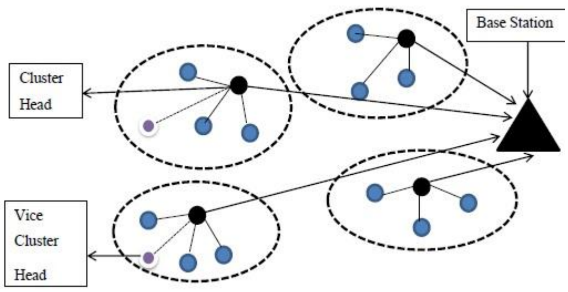

Figure 3.2-LEACH-V Protocol

Figure 3.2 demonstrates how Vice Cluster Head, an alternate Cluster Head, is used by V Leach. The Vice Cluster Head succeeds the deceased Cluster Head [3]. The network rapidly starts utilising less energy until it completely shuts down if the Vice Cluster Head fails to provide a repair.

4. LEACH-Centralized (LEACH-C) Protocol.

Each node communicates the base station information about its location, node ID, and energy condition during the LEACH-Centralized setup phase. The Central Control method is used by BS to specify CHs and non-CH nodes. The central control algorithm is used by BS to compare each node's energy to a predetermined average energy level. If a node's energy is below the norm, BS classifies it as a member node. The node IDs of these nodes are broadcast to all network nodes by BS, who selects them as the nodes with the highest potential number of CHs. Minimizing the distance between member nodes and CHs is the aim of BS. LEACH-C lessens member node energy dissipation in this manner because of the close transmission distance between them and CH [4]. Compared to the distributed control method, this central control methodology yields significantly superior clustering. The underlying idea of LEACH-Centralized means that each node can compute its energy, is aware of its location, and may broadcast this information to CH even while the BS is remote from the node. As a result of nodes' ability to alter their communication range for intra-cluster and inter-cluster communication to accommodate varying transmission power levels.

5. Optimized LEACH-C Protocol

To lower energy usage and increase the lifetime of the WSN network, a new version of LEACH-C has been suggested. Below is a schematic that illustrates the Optimized LEACH-C (OLEACH-C) procedure. A list of nodes in decreasing order of energy is compiled by the base station when using LEACH-C, using a sorting algorithm. The cluster head for the current round will be chosen as the node with the greatest amount of energy remaining. The protocol is functioning effectively overall. The LEACH-C technique does have certain drawbacks, though. The cluster head will be determined by the node's id rather than by distance if two or more network nodes have the same energy level. Therefore, the effectiveness of the current LEACH methodology won't be considerably improved by this strategy. It costs more and consumes more energy.

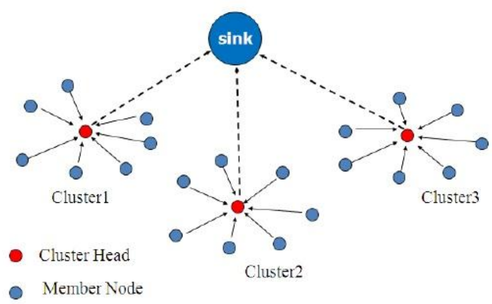

Figure 3.3- Optimized LEACH-C Protocol

In the proposed study, a methodology for selecting the cluster head will be developed using the PBO (pollination-based optimization) optimization technique, in which the cluster head nodes are selected based on their energy and distance . If there is a tie in energy between the two nodes that can be chosen as the cluster head, the cluster head will be picked based on distance rather than ID. Based on which node is closest to the base station, the CH will be decided. With the suggested system paradigm, the current LEACH protocol's cost, network, and energy efficiency can all be significantly increased.

III. PBO ALGORITHM

By utilising the optimization technique known as pollination-based optimization, the suggested work improves the LEACH-C protocol. The pollination-based optimization (PBO) method increases network lifetime and reduces node energy usage. Pollination base optimization, the most recent population-based optimization technique, imitates flower pollination procedures. With regards to optimization, integer programming, wireless sensor networks, etc., the PBO algorithm is applied. The PBO tries to encourage plant reproduction and the "survival of the fittest" principle. The process of pollination essentially entails the transfer of pollen from a flower's male stigma to its female stigma, resulting in plant reproduction. There are two methods for pollinating an object:

1..Self pollination

2.Cross pollination

BS stands for base station, AE for network average energy, C H for cluster head, CM for cluster member, and disti and distj for nodes' distances from base station, according to the follo wing suppositions.

N is the total number of nodes when the set of energy from al l nodes, E, is taken into account.

(a) Each node updates the BS with its position and energy lev el.

(b) BS estimates the AE of the network and only labels the nodes with higher energy (AE, CM, N, CH, E).

1. I 1

2. While I <= N

3. If (Ei >AE) then

4. CH (i) = True

5. Else

6. CM (i) = True

7. End if

8.For(j = 1; j < N; j++)

9. If (Ei = Ej)

10. i++ then

11. Apply the PBO algorithm

12. If (disti < distj) from BS, then

13. CH (i) = True

14. Else

15. CH (j) = True

16. End if

17. End if

18. End while

IV. ANALYTICAL COMPARISON OF HIERARCHICAL ROUTING PROTOCOLS

To do analytical comparisons, it is essential to understand the radio model assumption that the energy-efficient routing algorithms employ. Each routing protocol makes a number of assumptions about radio uniqueness.. The energy efficiency of routing protocols significantly varies due to these various factors.

1. First Order Radio Energy Model

We employ an easy-to-understand first order radio model, as shown in Fig. 4.1, in which the transmitter dissipates energy to drive the radio electronics, as well as the power amplifier and receiver.

$$(l, d) = E_{Tx-elec}(l) + E_{Tx-amp}(l, d)$$

$$lE_{elec} + lE_{fs}d^2, d < d_0$$

$$= \{ lE_{elec} + lE_{fs}d^4, d \geq d_0$$

and to receive this message, the radio expends

$$E_{Rx}(l) = E_{Rx-elec}(l) = lE_{elec}$$

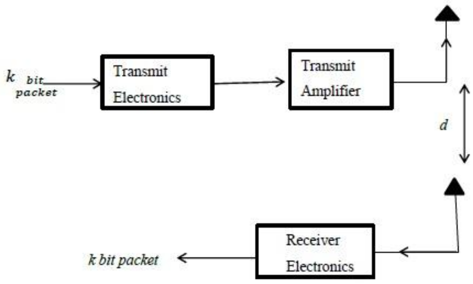

Figure 4.1-First Order Radio Energy Model

Tables 4.1 and 4.2 compare the LEACH, Multi-hop LEACH, LEACH-V, LEACH-C, and Optimized LEACH-C procedures. According to performance analyses, both routing methods exhibit many of the same behaviours. All routing protocols aggregate data, are homogeneous, and operate at predetermined bit rates (BS). For CH selection, the distributed algorithms LEACH, Multi-hop LEACH, and LEACH-V are used. For CH selection, LEACH-C employs a central control mechanism. We employ a mechanism based on pollination for Optimized LEACH-C The distance between BS and CHs is one hop in the routing protocols LEACH, LEACH-V, LEACH-C, and Optimized LEACH-C; it may be several hops in Multi-Hop LEACH .The LEACH protocol allows for some scaling. Multi-Hop LEACH scales the best thanks to the multi-hop communication option for CHs, while LEACH-C, LEACH-V, and Optimized LEACH-C also support good scaling. Compared to Multi-hop LEACH and LEACH-V, the LEACH protocol uses more energy inefficiently. LEACH-C and Optimized LEACH-C, on the other hand, offer exceptionally high energy efficiency.

Table 4.1 –Comparing based on routing protocol type, CH choice, scalability, and energy efficiency

PROTOCOLS	CLASSIFICATION	HOMOGENEOUS	MOBILITY	HOP COUNT
LEACH	Hierarchical	Random	Limited	Poor
MULTI-HOP LEACH	Hierarchical	Random	Good	High
LEACH-V	Hierarchical	Random	Good	High
LEACH-C	Hierarchical	Based on residual energy	Very Good	Very High
OPTIMIZED LEACH-C	Hierarchical	Based on residual energy	Very Good	Very High

Table 4.2 -Comparison based on data aggregation, homogeneity, mobility and hop-count

PROTOCOLS	DATA AGGREGATION	HOMOGENEOUS	MOBILITY	HOP COUNT
LEACH	Yes	Yes	Fixed BS	Single
MULTI-HOP LEACH	Yes	Yes	Fixed BS	Multi
LEACH-V	Yes	Yes	Fixed BS	Single
LEACH-C	Yes	Yes	Fixed BS	Single
OPTIMIZED LEACH-C	Yes	Yes	Fixed BS	Single

V. RESULTS AND ANALYSIS FROM SIMULATIONS

We construct a wireless sensor network to validate OLEACH-functionality. C's The simulation of the outcomes was done using the MATLAB software. Nodes are initially introduced into the network. Nodes are fixed in number. selecting the simulation's parameters.

The list of requirements for simulating various LEACH protocols with encryption techniques is provided below.

Parameter	Value
Network Size	100m*100m
Total no. of nodes	100
Number of rounds at most	10,000
Initial energy	0.75J
P(CH percentage)	0.1J
Energy required to convey each bit (ETX)	50 nJ/bit
energy required to receive each bit (ERX)	50 nJ/bit
Model of the energy of empty space (Efs)	10pJ/bit
Multipath model's energy (Emp)	0.0013 pJ/bit
Aggregation of Data and Energy (EDA)	5 nJ/bit

Node Deployment

According to Figure 5.1, the network consists of 100 nodes. The nodes are evenly dispersed throughout a 100m by 100m area. The nature of each node taken into consideration is homogeneous. Every operation in the network uses a sizeable percentage of the nodes' energy.

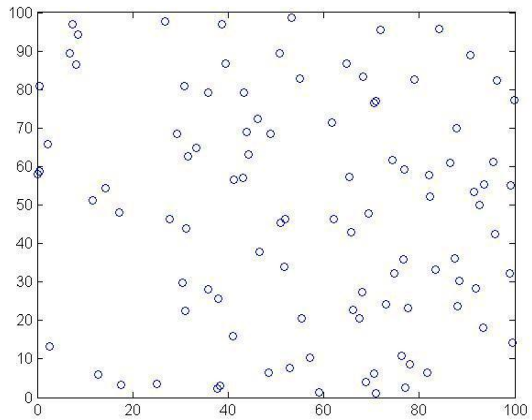

Figure 5.1(100 nodes Network)

Wireless Sensor Network in Figure 5.1 with 100 nodes

In this case, 100 nodes are formed over a 100m*100m region.

The base station is located at BS (50,50). 2. Results of the LEACH protocol analysis.

Figure 5.2 The LEACH protocol's alive node v/s round plot is displayed in Figure 5.2. About 90% of nodes survive the protocol's 2200 rounds, or almost all nodes. One of the current practises is this.

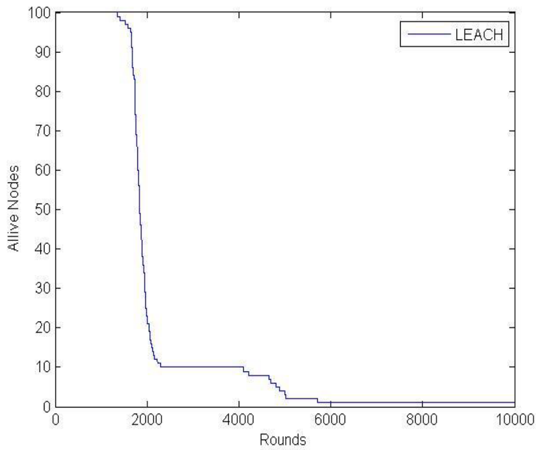

Figure 5.2- LEACH protocol live nodes vs. rounds plot

Figure 5.3 depicts the LEACH protocol's dead nodes v/s round plot. The node runs out of rounds after 1500. Between 1900 and 2200 rounds, the 50th and last nodes perish.

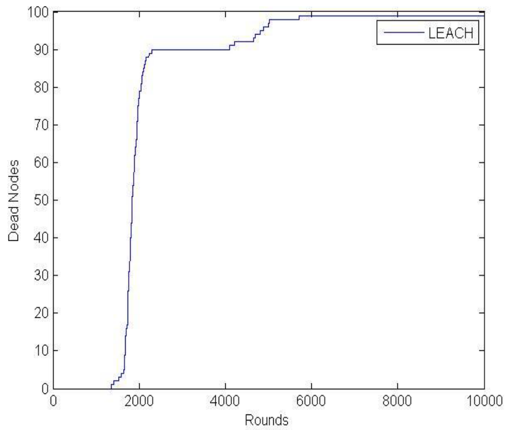

Figure 5.3- LEACH protocol Dead nodes v/s rounds plot

Fig. 5.4 displays the alive node v/s round plot for the LEACH-C protocol. Nearly all nodes are still in functioning after 2700 rounds. It yields better results in comparison to the LEACH protocol, which calls for nodes to communicate for 2200 cycles.

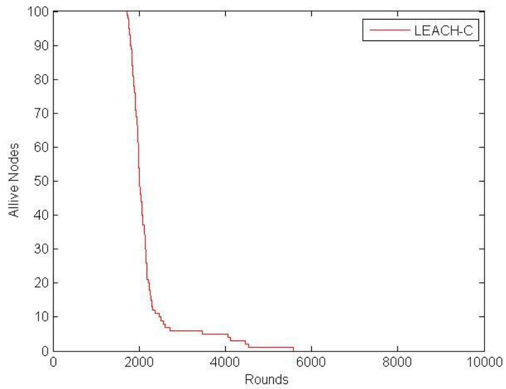

Figure 5.4- LEACH-C protocol live nodes vs. rounds plot

Figure 5.5 depicts the dead no v/s round plot for the LEACH-C protocol. The first and last nodes die between 1700 and 2700 rounds. After around 2200 cycles, the LEACH protocol's last node expired. Therefore, LEACH-C performs better than the LEACH protocol.

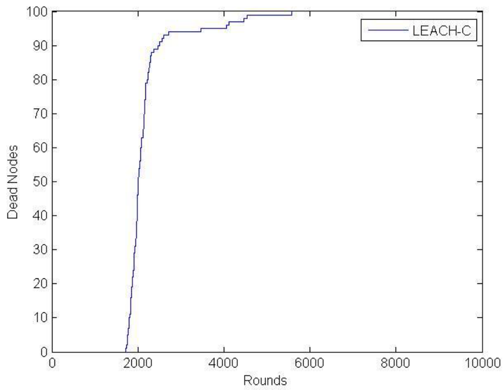

Figure 5.5- LEACH-C protocol Dead nodes v/s rounds plot

The OLEACH-C protocol, which is the best of the three shown in Fig. 5.6, allows all nodes to communicate for 3200 cycles. When choosing the cluster head, this technique takes the remaining energy and the distance into account.

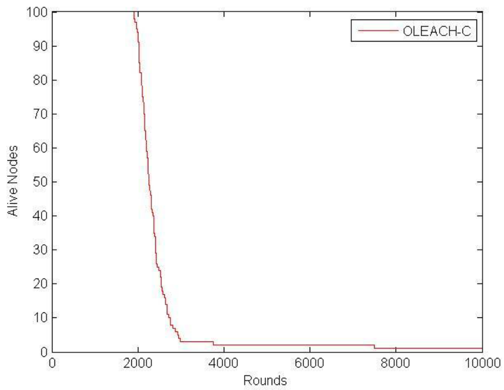

Figure 5.6- OLEACH-C protocol Alive nodes v/s rounds plot

Figure 5.7 displays a study of the dead nodes vs. rounds plot for the OLEACH-C protocol. Around 1950 rounds later, the first node expires. Between 2000 and 3200 rounds pass before the tenth and last nodes pass away. The fact that this protocol can communicate for up to 3200 rounds makes it the best one we've discussed so far.

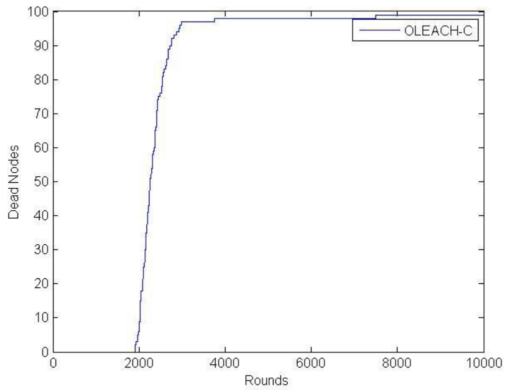

Figure 5.7- OLEACH-C protocol Dead nodes v/s Rounds plot

The comparison of the LEACH, LEACH-C, and OLEACH-C protocols is shown in Fig. 5.8. Cluster creation causes the LEACH protocol to lose energy since more energy is required because clusters form after each round. However, the base station forms the LEACH-C clusters, whereas the OLEACH-C clusters are formed based on residual energy and distance utilising an optimization method known as Pollination Based Optimization (PBO).

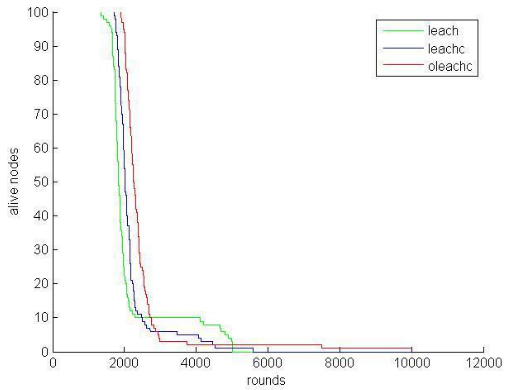

Figure 5.8- Comparison of the proposed OLEACH-C with various existing protocols using an alive nodes vs. rounds plot

In Fig. 5.9, dead nodes for the LEACH, LEACH-C, and OLEACH-C protocols are contrasted. When compared to other methods, OLEACH-C produces better outcomes. Here, the first node runs out of rounds after roughly 1950. In LEACH and LEACH-C, the initial node expires after 1500 and 1700 cycles, respectively.

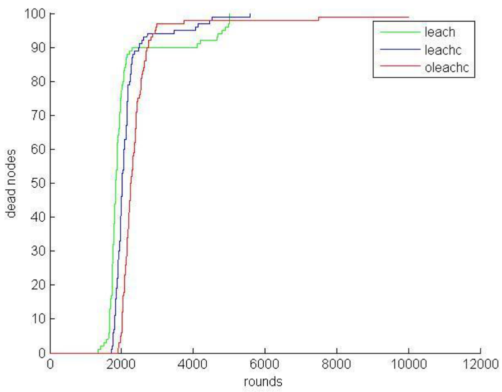

Figure 5.9- Comparison of the proposed OLEACH-C with various existing protocols using a dead nodes vs. rounds plot

The packet transmitted to the base stations in response to the specified round is shown in Fig. 5.10. The OLEACH-C protocol sends more data to base stations and cluster heads than the LEACH and LEACH-C protocols, which extends network lifetime and lowers energy usage.

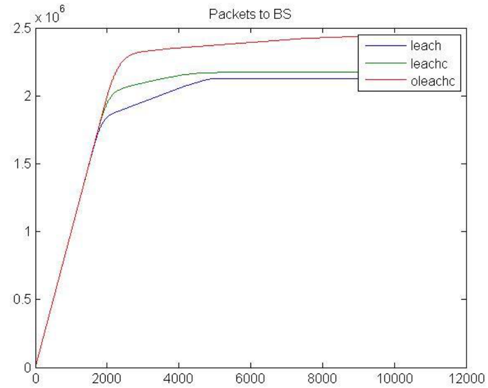

Figure 5.10- Rounds plotting the proposed OLEACH-C against various existing protocols are broadcast to BS packets.

Figure 5.11 compares the network lifetime of the OLEACH-C protocol to that of other active protocols. The first dead node for the LEACH(1), LEACH-C(2), and OLEACH-C(3) protocols has been used as the basis for this comparison. Figure shows that compared to older protocols, the proposed Optimized LEACH-C protocol provides a longer network lifetime.

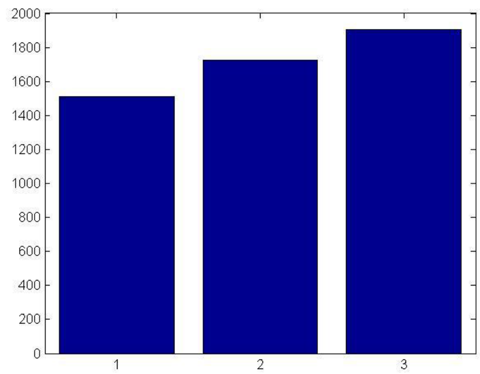

Figure 5.11- OLEACH-planned C's network lifetime in contrast to other existing protocols

The OLEACH-C protocol therefore extends the life of the wireless sensor network by selecting the cluster head based on their remaining energy as well as distance and attaching the cluster nodes according to the distance to the ideal cluster head. With the least amount of energy consumption and the most affordable communication connections between nodes, the OLEACH-C protocol and other energy-efficient communication protocols for wireless sensor networks select the ideal CHs to ensure route optimization.

VI. CONCLUSIONS

Due to the limited energy resources available, one of the major issues while developing routing protocols for WSNs is how to use energy effectively. The routing protocol's main goal is to maintain the sensors' usefulness for as long as is practical while simultaneously prolonging the network's lifespan. The majority of the energy used by the sensors is used for sending and receiving data. As a result, to increase the lifespan of individual sensors and, by extension, the network as a whole, routing algorithms created for WSNs must be as energy-efficient as is practicable. We have discussed numerous LEACH-based techniques in this work. This study's primary goal was to evaluate the effectiveness of various energy management and throughput-improving strategies. With the use of analytical comparison and the outcomes of We examined the durability and data transfer characteristics in our simulation .Because it chooses the cluster head by taking into account the node's remaining energy and distance, the proposed OLEACH-C protocol outperforms the existing LEACH, Multi-hop LEACH, LEACH-V, and LEACH-C protocols, according to the simulation results. These processes still need to be refined. The establishment phases of all routing systems should be improved by the development of distributed and centralised algorithms. Application standards also need to be improved for the electronics of sensor nodes, deployment management, and the choice of effective and efficient routing protocols for WSNs, among many other areas.

FUTURE SCOPE

Future work on energy efficiency at the MAC layer and the viability of these protocols in heterogeneous environments are both priorities for us. Only two dimensions for node position are taken into consideration in the proposed protocol because nodes are deployed on the same surface in this case. Future study will concentrate on simulating the outcomes while taking into account the third dimension.

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