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Performance Analysis of New Hybrid Distributed Energy Efficient Clustering Approach for WSNs

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Abstract:

One of the biggest obstacles to the development of wireless sensor network (WSN) is achieving energy efficiency. Since transmission accounts for the majority of energy consumption, clustering of the network is adopted by the research community to address this issue. In clustering protocols, the prime focus is given on cluster head selection method to achieve better network lifetime. In this paper, the cluster head selection is optimized by using Firefly method where the attractiveness of the nodes is computed using Firefly which optimizes the head selection process. The protocol was simulated in MATLAB and the performance of the network was analyzed based on energy consumed in the network and number of nodes alive. The proposed protocol showed better performance than the other two indicating the achievement of better network lifetime.

Keywords: ***Wireless sensor network (WSN), Firefly Optimization, Clustering, Energy efficiency***

1.INTRODUCTION

Emerging low-cost and adaptable technologies called wireless sensor networks (WSNs) allow for controlled environmental monitoring. They typically comprise of a large number of little sensors that can analyze data and communicate wirelessly. These SN can be placed in a variety of settings to execute activities including smart grids, home and business automation, military surveillance, habitat monitoring [1], [2]. Electronic circuit architecture innovations in recent years have made it possible to create sensors that are lighter, cheaper, and much more energy-efficient. Nevertheless, further study is needed in many aspects, particularly energy efficiency. SN frequently have non-rechargeable batteries, which reduces the lifetime of the network. Lifetime can be defined in a variety of ways, including the amount of time until the first node, the last node, or a certain percentage of nodes die. The network's performance will significantly deteriorate upon the death of the first node [3]. According to [4] node lifespan, coverage, and connection are used to define network lifetime. Though Energy Harvesting Wireless Sensing Networks (EHWSN) are looking at the usage of renewable energy sources for sensor nodes, long-lasting WSN still need to make judicious use of the energy available. The majority of WSNs measure physical factors such object position, humidity, or temp. These metrics' samples could be averaged for neighbor sensors because they are locally related. Many hundred times more energy is needed for information processing than it is for data transfer. Hence it makes sense to compress data before sending it. The lifetime of the network is extended & communications energy consumption is significantly reduced as a result of the data compression via signal aggregate. By dividing nodes into numerous spatial clusters in which only one sensor (CH) is in charge of gathering the signals & relaying data to the base station, hierarchical clustering algorithms take advantage of this characteristic to increase network lifetime. The only form of communication used by the other cells is brief, intra-cluster connectivity, which uses a considerable amount of energy. A CH has two options for delivering data to the BS: either immediately (single-hop) or via another node acting as a relay (multi-hop). In order to ensure balance energy usage, the clustering algorithms also split the network lifetime into a number of rounds & attempt to rotate the CH duty across all nodes in each cycle. An example of a hierarchical clustering over a WSN is shown in Fig. 1.

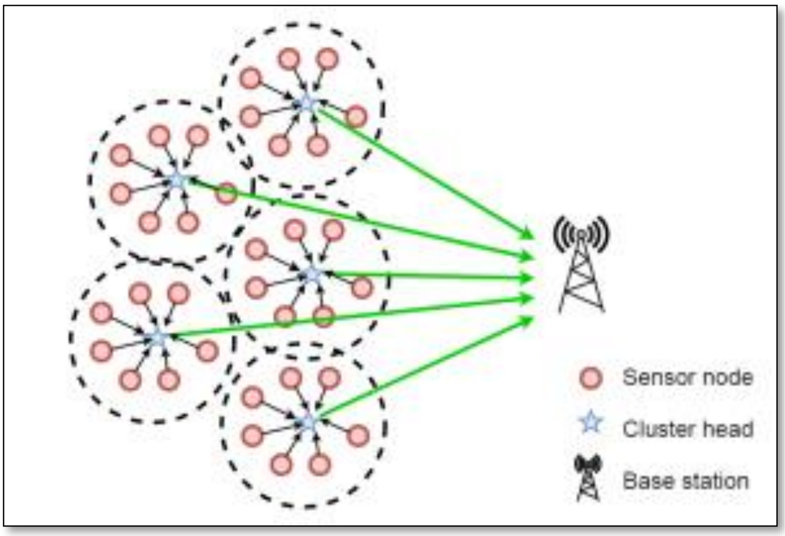

Fig. 1.Structure of a typical WSN [5]

Clustering is a basic approach used in WSN to improve their life by reducing energy usage[6] & ensuring productivity, flexibility, and safety. Clustering is the division of a WSN into short devices of low SN. These low devices can be classified as clusters, or each cluster is managed by a unique sensor node known as a CH. CH must be chosen via the SN or pre-defined through the system administrator in each cluster. The Cluster has two types of nodes, one of which is a CH & the other is a SN. SNs are low-energy nodes relative to CHs; greater-energy nodes (CH) handle all types of information processing; routing [7], but low- energy SNs could only execute sensing tasks. By employing efficient management procedures, the CH could extend the battery life of individual sensors as well as the life of the system. Clustering has various advantages: (1) It lowers long range connectivity and total energy consumption, (2) It lowers channel contention & packet collision as well as (3) It results in greater throughput under high load. A protocol's effectiveness is significantly influenced by the CHs that are selected. The selection of m ideal CHs from n nodes presents (m) alternatives, making CH election an NP-hard issue. As a result, traditional optimization strategies are impractical. Because according to this, a lot of cluster analysis to achieve various outcomes relies on heuristic and metaheuristic techniques to identify reasonably ideal CHs. One of the most current metaheuristic swarm intelligence techniques is called firefly.

1.2 Firefly Optimization Algorithm

Firefly Algorithm (FA) was developed in 2007 by Yang and is a population-based optimization algorithm. The behavior and actions of fireflies is based upon. This is a multimodal algorithm, of course. It can therefore be appropriate for problems of structural engineering, particularly in the case of multimodal problems, when planning such engineering alternatives. FA [8] uses three idealized laws in essence:

- Fireflies are unisexual in order to cater to other fireflies regardless of sex.
- Attractiveness is proportional to the brightness, and both of them decrease as their distance increases. Therefore, the brighter one shifts towards the brighter one for any two fireflies. If there is nothing brighter than a firefly, it's flying spontaneously.
- The luminosity of a firefly is determined by the objective function & landscape.

1.3 Clustering using Firefly Algorithm

Every other node time is determined based on its brightness. Every other cluster adds nodes based on their distance from CH to form a new cluster and avoid residual nodes. The difference among nodes is computed as follows: Distance = (X1 -X2)2 (Y1 -Y2)2 (Y1 -Y2)2 0.5 (5), Clustering energy of sensor nodes is regarded as firefly light intensity in the Firefly approach. The sensor that is brighter is regarded to have the most energy. Fireflies with a low intensity move toward fireflies with a higher intensity. Likewise, in clustering, lower energy nodes gravitate against higher energy nodes. Fireflies migrate from one place to another due to their attraction to brighter fireflies. The Firefly approach increases network lifetime as well as throughput by selecting CH based on residual energy & nodes in cluster coverage based on distance.

2.RELATED WORK

Prof. N.V.S.N Sarma, Mahesh Gopi.,(Apr 2014) discussed Energy Efficient Clustering using Jumper Firefly Algorithm in Wireless Sensor Networks. Energy efficient clustering for wireless sensor networks using Firefly and Jumper Firefly algorithms are simulated. A new cost function has been defined to minimize the intra-cluster distance to optimize the energy consumption of the network. The performance is compared with the existing protocol LEACH (Low Energy Adaptive Clustering Hierarchy)[1].

Zhao Hongwei1 ,Tian Liwei and Wang Dongzheng(2015) discussed Improved Firefly Optimization Algorithm Based on Cooperative for Clustering. An optimization model and proposed an improved firefly optimization algorithm called CFA, which is based on firefly Cooperative. The main idea of CFA is to extend the single population FA to the interacting multi-swarms by cooperative Models. In this work, firstly, CFA algorithm is used for optimizing six widely-used benchmark functions and the comparative results produced by, firefly optimization algorithm(FA) are studied. Secondly, CFA algorithm used in data mining, clustering analysis on several typical data sets. The performance of typical data clustering results showed that the biological heuristic algorithm based on clustering analysis algorithm with the existing success of FA compared to faster convergence, and the clustering of higher quality[2].

Saini et al., (2018) discussed EDEEC for heterogeneous Wireless Sensor Networks. DEEC used regular nodes and advanced nodes whereas EDEEC added one more type of nodes, called super nodes thereby increasing the level of heterogeneity up to three levels. Super nodes have more power than the advanced nodes. The CH selection is based on random rotation, as in the case of LEACH, but due to heterogeneity, the probability of becoming a CH is different for different types of nodes. Average energy of the network is also calculated like in DEEC. Then, the total energy dissipation in the total rounds of the network is calculated along with the optimal number of clusters. Number of live nodes, total Set of data packets received at BS and the network lifetime are calculated as performance metrics. Results of EDEEC, calculated with SEP, show better but complex performance and increased time consumption due to the presence of many types of nodes for cluster head selection[3].

Gupta et al., (2018) discussed a meta-heuristic algorithm named ICSCA (Improved Cuckoo Search-based Clustering Protocol for Wireless Sensor Networks). In this protocol, a fitness function is devised which is based on cluster size i.e. set of nodes in a cluster, residual energy of nodes and distance between the CH and member node. Nodes which have the highest fitness values are considered as candidates for CH and cost of each eligible node is calculated. The node selected as a CH has the least cost based on average Euclidian distance (between nodes and CH) and ratio of total energy of all nodes to the total energy of all CHs. This algorithm when compared with LEACH, PSO-ECHS and E-OEERP shows significant improvement in the network lifetime[4].

Hiremani et al.,(2019) For apps such as HWSNs, an energy efficient cluster-based routing algorithm significantly improved cluster formation (EERRCUF) procedure is presented. At first, authors use PSO to achieve proper clustering for gathering nodes based on geolocation characteristics. Using PSO, all nodes will cluster without residual nodes, as well as the CH and super CH will be based primarily on the trusted integration of various by the Differential Evolution based Trust Inference (DETI) design for every node. The GSA performs via inter-cluster routing . The numerical simulations demonstrated the efficacy of suggested EERRCUF protocol in terms of QoS constraints like throughput, delay, as well as energy consumption, as well as Quality of Experience (QoE) restrictions like PSNR, SSIM , as well as Video Quality Measurement (VQM)[5].

Behera et al.,(2020) discusses how clustering algorithms help with power management in energy- constrained networks, as well as how choosing a cluster head will properly distribute system weight, lowering capacity and increasing life span. The researchers aimed to select the CH based on important characteristics such as beginning power, residual capacity, and cluster head amount. The authors focused on an effective selection system that rotates cluster head placement across members while retaining a positive electrical charge, which is different from other schemes. The authors confirm that simulation research shows that the alternative version beats the LEACH algorithm by increasing production by 60%, life span by 66 percent and remaining energy by 64 percent [6].

Fattoum et al.,(2020) To enhance network lifetime, a new two-level energy-efficient clustering strategy depend on a FL model is proposed. A two-level clustering case is known, in which fuzzy logic is used in both Steps 1 and 2 for CH selection & cluster formation processes, in both. To quantify the spatial relationship of network information, the suggested design uses similarity variables: similarity difference rate and similarity coverage rate, as well as distance variables: closeness to CH, closeness to the sink, and residual energy as fuzzy logic inputs. Through simulation, the new suggested FL -based clustering outperforms other strategies as well as variations of clustering approaches in terms of energy consumption as well as lifetime of the network extension [7].

FAZLI WAHID August 21, 2020-An Enhanced Firefly Algorithm Using Pattern Search for Solving Optimization Problems**.**Firefly Algorithm (FA) is one of the most recently introduced stochastic, nature-inspired, meta-heuristic approaches used for solving optimization problems. The conventional FA use randomization factor during generation of solution search space and fireflies position changing, which results in imbalanced relationship between exploration and exploitation. This imbalanced relationship causes in incapability of FA to find the most optimum values at termination stage. In the proposed model, this issue has been resolved by incorporating PS at the termination stage of standard FA[8].

Sakin et al.,(2021) presented a modified version of PSO to pick sensor nodes as cluster heads in the most effective way. The effectiveness of the proposed algorithm is tested and contrasted with that of well-known optimization methods. The suggested method yielded improved outcomes in terms of remaining energy, living node count, dead node total, or converging rate [9].

Hardik et al.,(2022) presents a method for choosing the CH based on Grey Wolf optimization (GWO), and then applies fuzzy logic (FL) to effectively create clusters. Remainder energy, standard intra-cluster stretching, spacing from sink, balancing factor, & node degree are the fitness metrics utilized in cluster head selection. On the other side, the two factors that serve as crisp inputs into the fuzzy inference framework (FIS) to determine the cluster formation method are fitness of the CH and spacing between a node and a CH. Our approach shows improvements in network performance metrics including FND (First node death), residual energy, or throughput after simulating the proposed methodology & contrasting it with similar protocols [10].

3.PROPOSED SOLUTION

The selection of the cluster head is one of the imperative thing while designing the clustering protocol for WSN. In the proposed protocol, we will make use of firefly optimization to evaluate the probability of the node to become

CH. Initially, the fitness value of the nodes will be evaluated which will be dependent on residual energy of the node, its proximity from the base station and the size of the cluster it desires to form in the neighborhood. The residual energy of the node must be high else if the node having lower energy is elected as cluster head, it is likely to die out soon. Furthermore, the cluster head also aggregates the data from the entire cluster and if it dies out, the entire data gets lost.

The second parameter to be considered for the head election is the distance of the node from the base station. The energy consumption in WSN is directly proportional to the distance between two communicating nodes. Therefore, the cluster head chosen must be near to the base station.

Third factor is related to the size of cluster that node will form if it gets elected as cluster head. If the size of cluster is huge, the data aggregation cost and cluster formation cost increases. This is not beneficial for cluster head or cluster members either. Also, if the size of cluster is very small, it defeats the entire concept of clustering the entire network to save the energy. Therefore, it has to be near the average value.

Considering this, the fitness function is defined as:

$$f_i = \alpha * \frac{Remaining\ energy}{initial\ energy} + \beta * \frac{d0}{d_{base\ station}} + \gamma * (CS_i - \frac{\sum_{i=1}^{N} CS_i}{N})$$

Where: α, β, γ are the weights assigned to three parameters and has sum equaling to unity; $d0$, $d_{base\ station}$ is the threshold distance and distance of the node from the base station; CS_i, N is the cluster size of the node and number of nodes in the network respectively.

Once, the fitness values have been computed for the nodes in the network, the attractiveness value of the nodes will be computed and the nodes with best attractiveness value will be selected as cluster heads. These heads will form clusters with nearby nodes.

Once the clusters have been created, the next step is data transmission where the cluster members will aggregate data at the respective cluster head. Each cluster head will send data to the base station via other cluster heads. The main question is to choose the relaying cluster head. This will be done by computing the fitness value for each of the neighboring CHs. The fitness value will depend on the distance from the base station as well as remaining energy of the neighboring cluster head. The CH with highest fitness value will be used to transfer the data to the BS.

4.SIMUALTION & RESULTS

This section presents the findings of the suggested method. To verify the suggested technique, the energy conversion efficiency as well as clusters transferred to BS are chosen as output parameters. All sensor nodes in the aforementioned sensor area are evenly distributed, and BS is expected to be within the sensor zone. The suggested approach is designed in the MATLAB environment. The energy conservation variable is defined by the collection of alive and dead nodes. For simulation, 100 randomly dispersed nodes in the network were used to create four situations. The amount of average remaining energy utilized, the number of alive nodes, the number of dead nodes, and the systems throughput were all used to measure the network & efficiency.

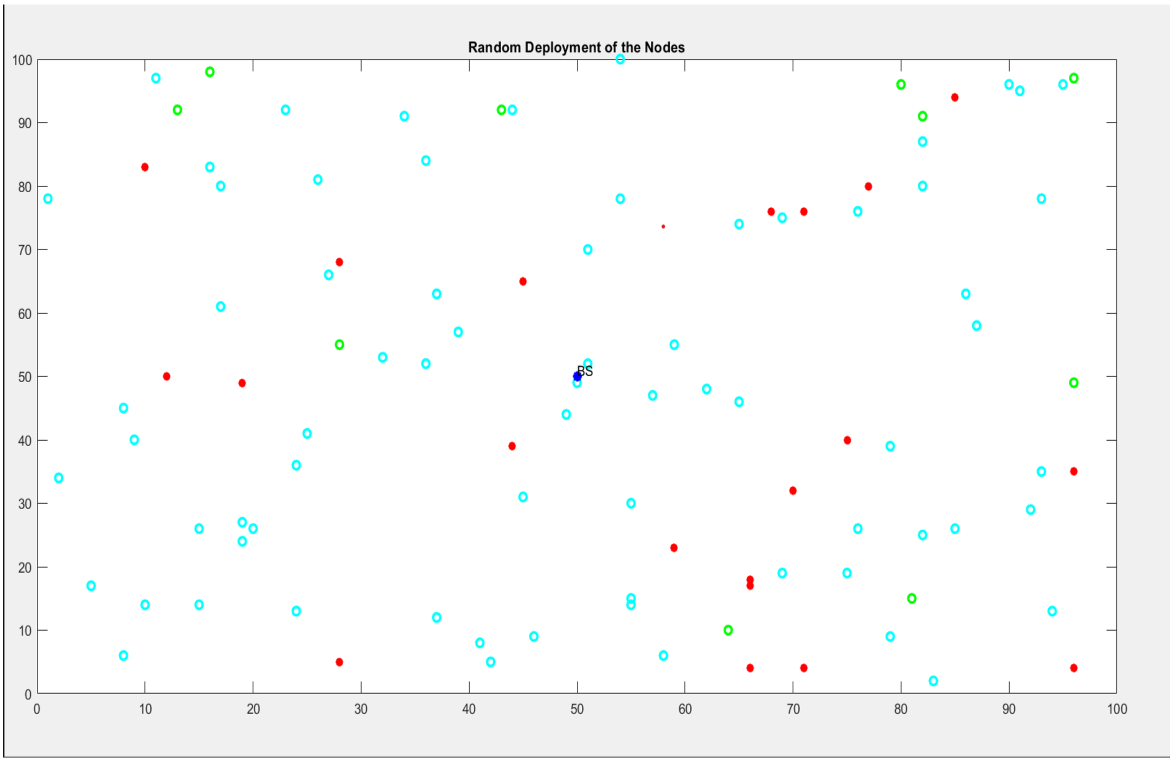

Figure 2: Random Deployment of Nodes

- Number of Alive Nodes: The set of alive nodes was determined for every round to determine the devices energy usage. For the suggested work the set of rounds contains is [500,1000,1500,2000,2500,3000,3500,4000].

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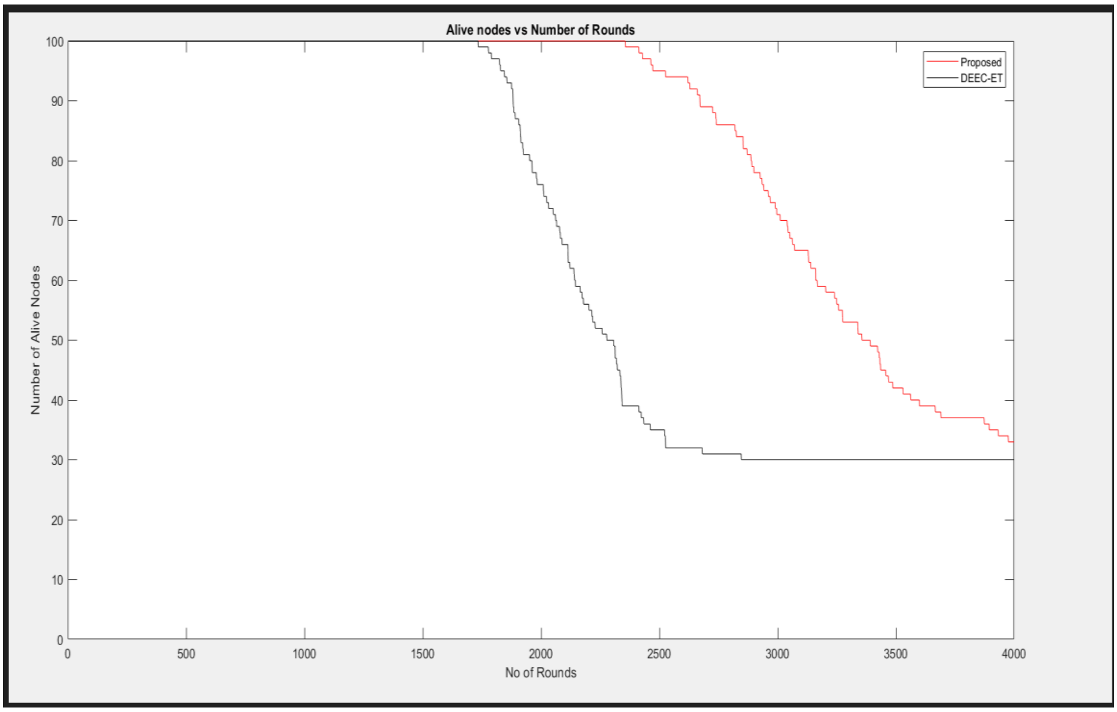

Figure 3: Alive Nodes vs Number of Rounds

Table 1: Alive Nodes

Technique	**Set of Rounds**
DEEC-ET	2800
Proposed	4000

Figure 3 shows that for current work, the first node alive on the 2800th round, while for suggested technique, the first node alive on the 4000th round. As a consequence, it is clear that the provided method improves system stability because CH are chosen correctly using the suggested approach.

- **Number of Dead Nodes:** Each cycle, the number of dead nodes was calculated to find the system's energy consumption. The number of dead rounds for the suggested task is [500,1000,1500,2000,2500,3000,3500,4000].

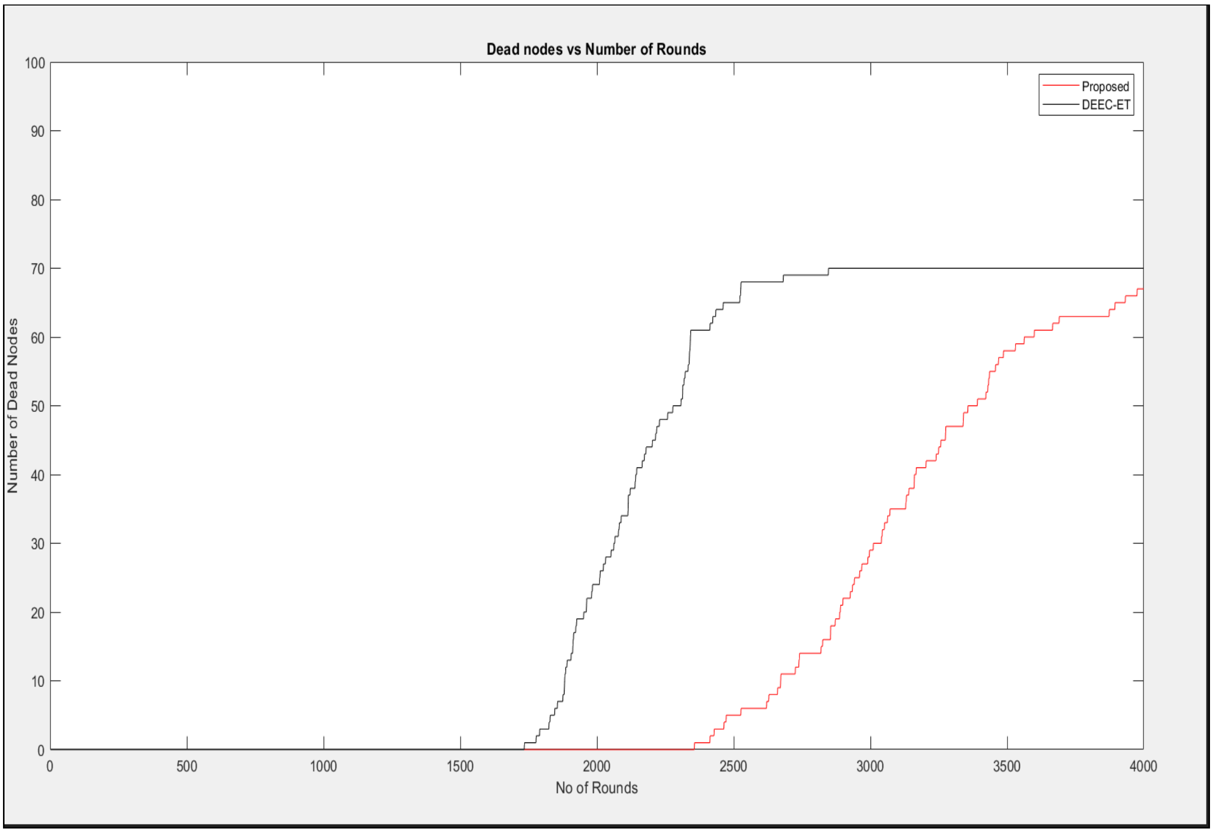

Figure 4:Dead Nodes vs Number of rounds

Table 2: Comparison of Dead Nodes

Technique	**Number of Rounds**
DEEC-ET	2700
Proposed	4000

According to Fig 4, the first node dies on the 2700th round, while for suggested technique, the first node dies on the 4000th round. As a consequence, it is clear that the provided method improves system stability because CH are chosen correctly using the suggested approach.

- Throughput : is a term used to describe the amount of successful data transmission in a network. In this case, the previously indicated formula is designed to estimate throughput:

$$\textbf{Throughput}=\frac{\text{Total Number of packets successfully transferred}}{Total\ Number\ of\ \ packets\ \ transferred}$$

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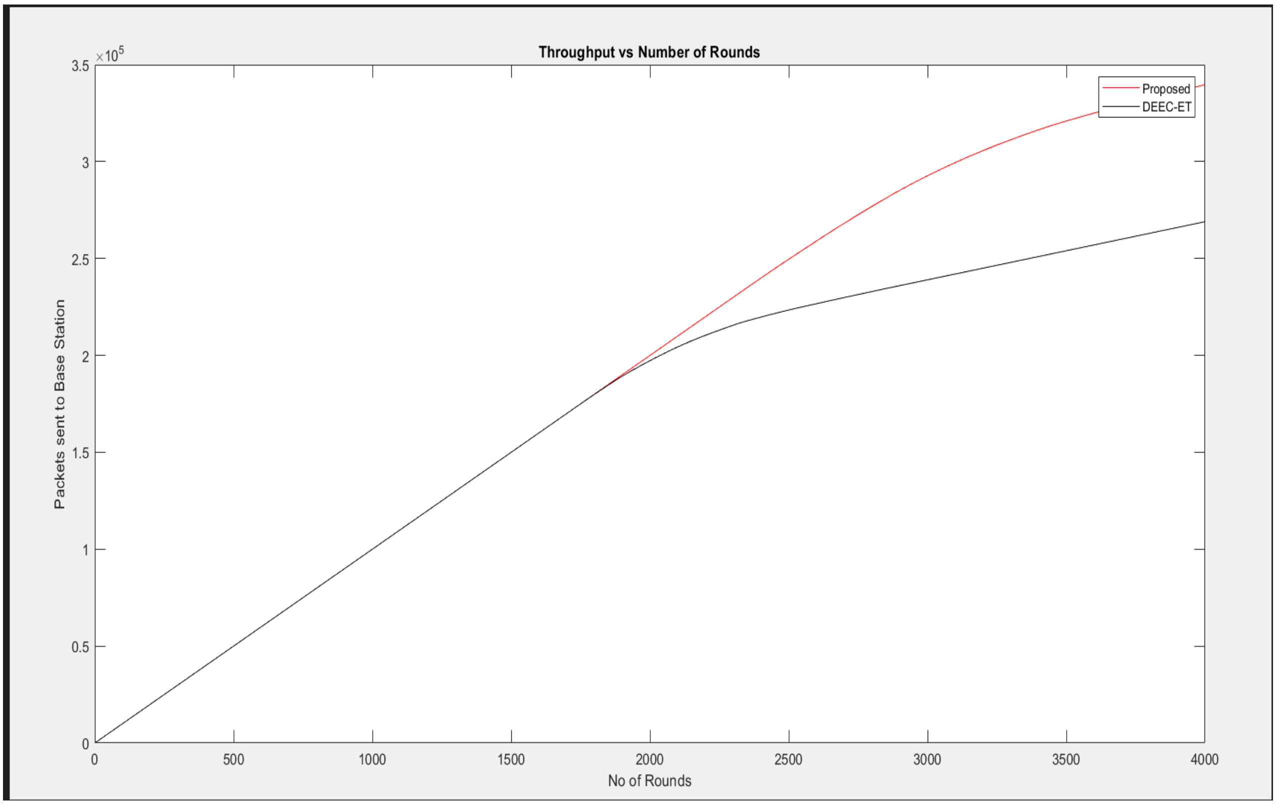

Figure 5:Throughput vs Number of rounds

According to Fig 5, the throughput of a suggested method improved to 4000 packets successfully sent, which is higher than the existing method 2000 packets transferred directly, since alive nodes in the system for a longer length of time present a better bandwidth.

- **Average Residual Energy:** The major resource of WSN nodes is energy, which defines the network's longevity.

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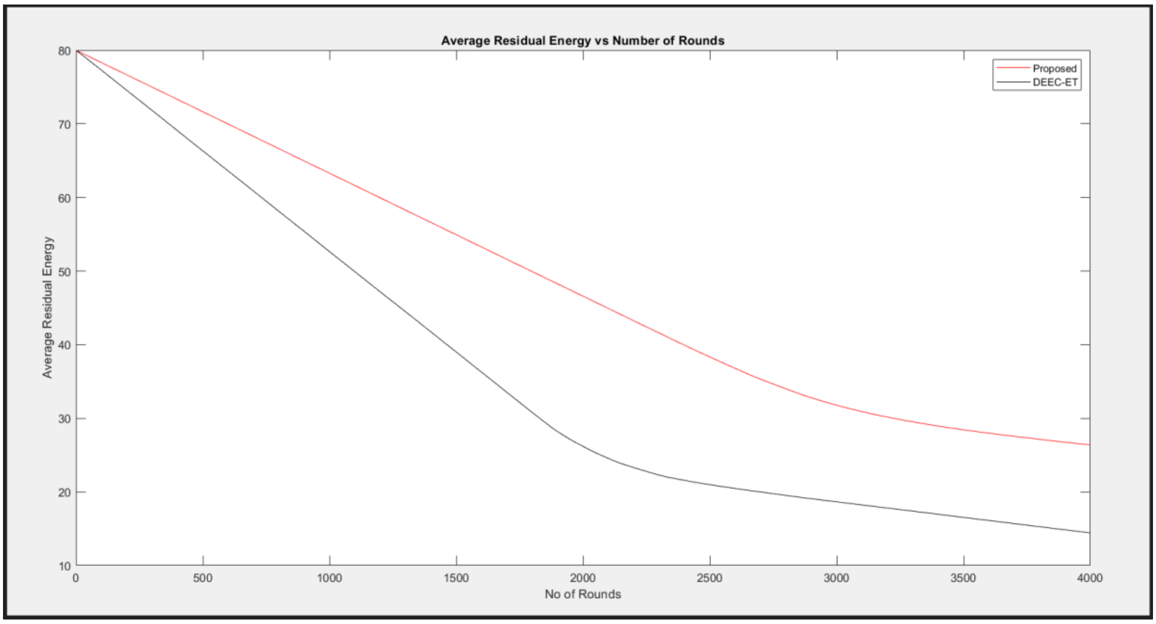

Figure 6:Average Residual Energy vs Number of rounds

Figure 6 demonstrates that the existing has steeper reductions in average RE than the proposed method, indicating that the steeper declines indicate faster energy depletion. The suggested technique enhances the numbers for all four metrics, including RE, throughput, and the number of alive and dead nodes. Additionally, because a singlroute is not employed, the strain on the CH building the route is raised. In comparison to previous ways, the CH would send data to the BS via an adjacent CH or directly to the BS (if the BS could be extended immediately).

5.CONCLUSION

In this study, we proposed a clustering protocol in which the selection of cluster heads is done based on firefly optimization. The output of the Firefly optimization was to optimize the selection of cluster heads. The primary objective of the research was to improve the network lifetime by reducing the energy consumption of the nodes. The simulation was analyzed in three scenarios by placing Base station at different locations. The results showed that the network had achieved better performance for the proposed protocol.

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