Maximizing Performance and Longevity of Wireless Sensor Networks and IoT Systems through Energy Optimization

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Abstract— **Heterogeneous sensor networks have become increasingly important in various fields, but the limited energy resources of sensors pose a significant challenge to their longevity and energy efficiency. In this study, we propose a novel approach to improve the efficiency and effectiveness of heterogeneous sensor networks by implementing more efficient clustering and selecting better cluster heads (CH). We employ the Fuzzy C-Means (FCM) clustering mechanism, known for its effectiveness in clustering heterogeneous data, and the Grey Wolf Optimization (GWO) algorithm to optimize CH selection. To optimize CH selection, we employ the Grey Wolf Optimization (GWO) algorithm, which balances exploration and exploitation in the search space, inspired by the social behavior of grey wolves. This algorithm has fewer parameters, making it easier to implement, and reducing the chance of overfitting. Our approach uses a variety of features, such as residual energy, communication distance, connection requests to nodes, and maximum communication region as fitness functions in the GWO algorithm. Our study demonstrates the effectiveness of our proposed approach, which can significantly enhance the efficiency and longevity of heterogeneous sensor networks. Our findings have significant implications for various industries and fields, such as environmental monitoring, industrial automation, and healthcare..**

Keywords— **energy efficient protocol, lifetime enhancement, optimization approach, internet of things, etc.**

I. INTRODUCTION

The Internet of Things concept assures that computers may access information without communicating with humans. It was designed to complement information supplied by individuals, which was viewed as an impediment in terms of frequency, precision, and cost purchase. Although the Internet of Things (IoT) may be utilized in a variety of industries, security for the IoT has grown increasingly important. A considerable number of sophisticated gadgets and other sorts of equipment are networked and interact through the IP protocol, resulting in a globally accessible and widespread system. In the IOT methodology, two different kinds of technology are explored that serve as important enablers, namely Radio-Frequency Identification (RFID) as well as Wireless Sensor Networks (WSN)[1]. In the IoTs concept, the wireless sensor network represents a fictitious layer. WSNs offer ubiquity in geographical availability, the state of numerous environmental elements, as well as information collecting for future Internet of Things (IoT) surveillance. Due to current enhancements, several electricity-efficient methods have been planned because power was the most significant limitation in the creation procedure of wireless networks with sensors [2]. Wireless sensor networks can be depicted as an assortment of huge, little sensor hubs distributed across an enormous region to recognize and collect different information from the earth and designs for various applications including ecological observing, creature following, debacle reaction, board meetings, bio-clinical applications as well as within the field of IoT [3]. Wireless sensor nodes constitute an array of sensors and a source of water in a WSN, which can be made up of many of these nodes. The WSNs are made up of an enormous amount of low-cost, low-power units that can interact securely and conduct minimal processing. Collaboration between these units may be used to achieve certain purposes including detecting, monitoring, and warning. With the help of such features, mobile detectors may be used to follow supportive soldiers on battlegrounds, observe army applications, keep updated on modifications to the environment, and observe events that happen naturally. Sensor systems must be highly reliable to complete those responsibilities. These nodes might be divided across a variety of smaller groupings termed clustered to assist in gathering information by successful networking organizations. Every group consists of several participating units including a supervisor known as the group leader [4]. Utilizing the right grouping approach provides an additional

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method to reduce the resource of electricity since these techniques are considerably more resource-efficient than traditional transportation methods. In this, nodes that collect data are brought collectively to create compact groups, and the cluster head (CH) for every group was chosen. In this system, every sensor hub imparts information to its own CH, which then gathers the data and advances it to the base station, which receives it. The effort of electricity used by sensors in clustered was minimal since the information was only transmitted across tiny distances between each cluster, while in the instance of CHs, greater power was used to transport signals over large distances, such as from CHs to the main Stations [5]. Any impromptu framework can be different or homogenous. The organization where sensor hubs are provided with an equivalent measure of energy named homogeneous is shown in Fig. 1(a). Heterogeneous networks as shown in Fig. 1(b). [6].

Environmental surveillance constitutes one of the complex IoT fields of application. IoT technology has applications for tracking variables related to the environment such as weather, precipitation, river height, and others. Using the IoT each of those networks was linked to a global or centralized system for making decisions. As wireless sensor organizations and the IOT advance, we will be able to track places that are inaccessible to humans, such as regions affected by eruptions from volcanoes, mountain abysses, and certain distant regions [7].

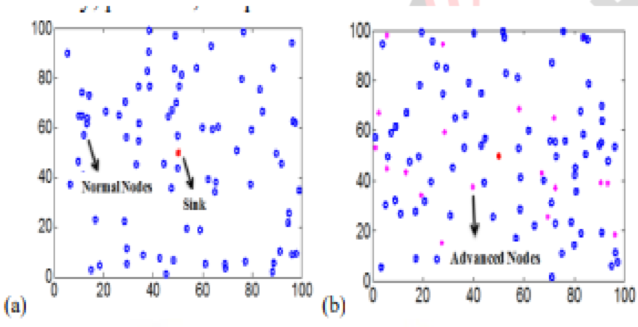

Fig. 1. (a) Homogeneous (b) Heterogeneous

WSN has various problems. It contains seven different layers, for instance. Every single layer has various difficulties, such as simulated instruments with highly outdated configurations and outdated simulated applications. There are gadget problems, such as the need for computers to maintain certain gadgets. Energy usage, sensor batteries, and other essential factors are also crucial. Node implementation, relayed node selection, cluster head selection, usage of energy, heterogeneity, pathloss, delay, failures in the system, and safety concerns are a few of the major difficulties. Although there are several challenges in this sector, scholars are still working to find solutions through their study in it. Advance Simulation with suitable hardware and gadgets that have been updated by software developers will be useful for investigation tasks and allows researchers to conduct numerous updates on WSN.[8]

Many investigators have put forth multiple approaches to address issues like managing energy, analysis of data, safety, and organizing themselves that WSNs face in IoT-based surveillance of the environment. To make sure the suggested strategy is fresh and efficient; a comprehensive analysis of the current literature must be done before suggesting any new method or solution. A survey of the available literature can assist in locating current approaches, knowledge gaps, and prospective improvements. To build novel techniques or enhance current ones to solve the problems of WSNs in IoT-based environmental monitoring, an extensive literature review was necessary. The remaining part of this paper includes an examination of the literature for the IoT-WSN area to grasp the existing difficulties, problems, and remedies, then addresses the deficiencies discovered. The main contribution of this study has been identified after this current work. In conclusion, there exists a subsection on outcomes and debate, as well as an assessment and future objectives of the study.

II. Related Work

This section provides the literature study of existing protocols scheme for the sensor network in domain of IoT. M.K. Roberts [9] have pointed out that wireless sensor nodes facing network fragmentation problems may eventually lose connectivity with the base station, leading to their failure. To demonstrate the effectiveness of their proposed solution, they have used various metrics, including the rate of identifying ransomware attacks, the ergodic remaining power across rounds, the initial identification of clone attacks, throughput amplification, latency, limit amplification, and network lifetime expectancy. Jia Yanfei, et al [10], proposed a better routing technique with greater energy efficiency for heterogeneous wireless sensor networks. Initially, it assumes that the various component categories are dispersed among the various zones. Furthermore, by raising the limit, units with high lingering energy have a superior possibility of forming into bunch heads. Eventually, an integrated data transfer mechanism develops. By doing this, the communication between the cluster leader and the ground station can use less energy. Kofi Sarpong Adu-Manu, et al [11], stated that for heterogeneous wireless sensor networks, a better routing technique with greater energy efficiency has been suggested. Initially, it assumes that the various component categories are dispersed among the various regions. Furthermore, by raising the limit, units with high residual energy have a better chance of developing into cluster heads. In the end, an integrated data transfer mechanism develops. By doing this, communications between the cluster leader and the ground station can use less energy. Mishra, Anamika, et al [12], stated that this study examines a period of heterogeneous WSN reliability. Using this approach, researchers evaluate the outcomes based on several factors, such as stabilization time for two- and three-level variation, compared to those obtained using current protocols, such as Leach, SEP, and other SEP variants. The stability phase was the main emphasis of this work; efficiency has barely improved. Verma, Sandeep, et al [13], proposed that

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eliminating the communication gap between nodes and the intermediary node and addressing the network's hotspot issue are intended to increase network endurance and reliability. This design consists of an external surveillance area network with numerous nodes known as gateways distributed evenly among them. The recommended MGN-based networking design enhances clustering head decision by taking into account the number of node factors in addition to resource and duration. Jibreel, F, et al [14], suggested that the transportation method was founded on the inclusion of heterogeneous nodes in the current scheme, choosing the head based on remaining power, implementing the multi-hop method of communication across all the areas of the system, and executing the energy gap reduction approach. All of these tactics are designed to lower energy use and increase network longevity. Results reveal that the suggested transportation strategy makes better than the two other options when speaking of capacitor leftover energy, and network reliability. Mohammed, Ibrahim Yahia, et al [15], In this study, a new clustering method for heterogeneous wireless sensor networks based on LEACH was proposed and was known as master, advanced, and normal nodes. LEACH (MAN-LEACH) addresses heterogeneity and makes an effort to address certain LEACH's initial shortcomings. The ratio between each node's remaining energy after a specific round and the network's average energy was taken into account while choosing the cluster leaders in MAN-LEACH. According to Mohamed et al. [16], the authors of this study have classified Wireless Sensor Network (WSN) applications based on multiple criteria to identify the major challenges in developing protocols for them. Specifically, the study has investigated the thermal efficiency of contemporary preemptive transportation methods from various perspectives. The research findings have revealed that two crucial factors affecting the longevity and productivity of the network are power consumption and route selection. These factors are among the most effective elements that need to be considered for enhancing the performance of WSNs. Al-Obady, Ahmed Sh, et al [17], in this study proposes the Future Search Algorithm-Temperature Routing protocol, which focuses on temperature and novel techniques to determine the ideal set of groups. The suggested protocol's structure incorporates SDN and Cloud techniques. To find the optimal solution, a Multi-objective FSA that takes into account the sensor's constraints on resources, such as energy and transmission capabilities, was given. Dogra, Roopali, et al [18], suggested a cluster-based routing mechanism in this research that might be applied at the sensing layer of smart city IoT. Cluster Head (CH) was selected depending on energy, distance, network energy, and node density. Researchers ran simulations in MATLAB to highlight the importance of WSN scalability in smart city applications. Researchers discovered that this protocol falls short when it comes to scalability. T. Morassini, et al [19], stated that the research paper mainly deals with optimizing simulation network settings to increase the lifespan of the network. Several studies have been carried out to test the likelihood of node distribution in the present EDEEC protocol. This article analyses the efficiency of the DEEC method variants and the suggested Extended EDEEC technique. Zhao, X.; Ren, S, et al [20], proposed a network of routes for HWSNs that utilizes an improved grey wolf optimizer. The procedure initially identifies the suitable starting groups by establishing distinct fitness coefficients for diverse power nodes; the fitness ratings of the nodes are then computed and used as the first weights in the GWO. Chiti, F, et al [21], in this study researchers present a new Objective Function (OF) for RPL based on a composite metric that takes into account both the residual energy of a node (parent) and the energy that a neighbor node (child) can transmit to the parent using the Wireless Power transmit (WPT) concept. The optimum path in RPL has been selected based on the recommended energy-efficient criteria. In comparison to the OFs often studied in the literature, performance evaluation on a practical scenario revealed significant energy savings to prolong network lifespan by picking the optimum path towards the sink node. According to Zou et al. [22], the efficiency of Wireless Sensor Networks (WSNs) relies on the presence of an efficient routing mechanism for transmitting data, taking into account their limited energy supply and processing capabilities. To address this, researchers have employed ant colony optimization techniques to discover the shortest paths, resulting in reduced energy consumption. As a result, an improved ant colony method has been proposed, which incorporates the creation of the sensor node transfer function and pheromone update rule. This method can also automatically determine the optimal information route by exploiting the dynamic state of the network.

Thangarasu et al. [23] have highlighted that the presence of unbalanced resources and diverse connectivity in the Internet of Things (IoT) imposes constraints on energy consumption. To address this challenge, the authors have proposed a solution that utilizes a Chaotic Whale Optimization framework to optimize energy usage in a combined Wireless Sensor Network (WSN)-IoT environment. The research outcomes have shown that the proposed approach leads to significant energy savings in a WSN-IoT scenario.

The increasing popularity of the Internet of Things (IoT) has resulted in the widespread deployment of sensor networks that facilitate the transfer of data from the physical to the digital world. However, the effective operation of these networks is plagued by several challenges, including the scarcity of energy resources available to these networks, which operate on batteries. To ensure optimal network performance, the energy consumption of network equipment must be minimized to increase their longevity. Another challenge that sensor networks face is the inclusion of heterogeneous devices, which have a range of capabilities, including varying levels of computing power and energy consumption. This presents a significant obstacle to effective communication, making it challenging to develop efficient routing algorithms for diverse networks. While researchers have developed strategies for homogeneous sensor networks, the issue is much more difficult in the case of heterogeneous networks. Creating

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efficient routing algorithms requires more resources, such as powerful computers and sophisticated algorithms, which are not readily available. As a result, current research has focused on clustering and CH selection algorithms inspired by homogenous systems. However, further research is needed to optimize these algorithms for heterogeneous networks.

III. Present Work

The focus of this research is to improve the longevity and energy efficiency of heterogeneous sensor networks by implementing more efficient clustering and selecting better cluster heads. To achieve this, the proposed study will utilize a Fuzzy C-Means (FCM) clustering mechanism, which is a highly effective means for clustering heterogeneous data due to its ability to accommodate overlapping and fuzzy clusters. Additionally, the Grey Wolf Optimization (GWO) algorithm will be used to optimize the selection of cluster heads. The GWO algorithm has consistently shown success in locating the best solution to various optimization problems and is based on the social behavior of grey wolves in the wild, where alpha, beta, delta, and omega are the four main types of wolves that exist in a pack. The proposed study aims to discover the CH with the lowest energy usage that can efficiently cover the greatest communication zone while taking connection requests to the node into account. To achieve this, a variety of features, such as residual energy, communication distance, connection requests to nodes, and maximum communication region, will be used as fitness functions in the GWO algorithm. The energy model used for simulation assumes an LEACH-like protocol, where the transmission energy is composed of a fixed amount of energy consumed by the electronics and a propagation energy that varies proportionally with the square or fourth power of the distance between the transmitter and receiver, depending on whether the distance is above or below the crossover distance. It is anticipated that the proposed research will result in the development of a clustering and CH selection technique that is both efficient and effective. This, in turn, will lead to heterogeneous sensor networks with longer lifespans and improved energy efficiency, providing more effective and efficient solutions for a variety of IoT applications.

A. Methodology

The proposed methodology for our project involves several critical steps that are interconnected and build upon each other to achieve a successful outcome. Each step is important, and the success of the final outcome depends on the successful completion of each step.

Step 1: Initialization of network parameters and related factors: The first step is to initialize the network parameters, such as the number of nodes, their energy levels, and capabilities. In a heterogeneous network, we assign energy levels to each node based on their capabilities. We use a randomized approach to determine the number of clusters that will be formed in the network.

Step 2: Clustering of nodes using FCM: After randomly choosing the number of clusters, we use the Fuzzy C-Means (FCM) clustering algorithm to group the nodes into different clusters. The FCM algorithm starts by randomly assigning membership values to each data point for each cluster. These membership values represent the degree to which a data point belongs to each cluster.

Step 3: Compilation of nodes to clusters: After determining the number of clusters, the next step is to compile the nodes into clusters. This step is essential as it enables efficient data aggregation and communication. By clustering similar nodes together, we can reduce the amount of data that needs to be transmitted and processed, leading to lower energy consumption and improved network performance.

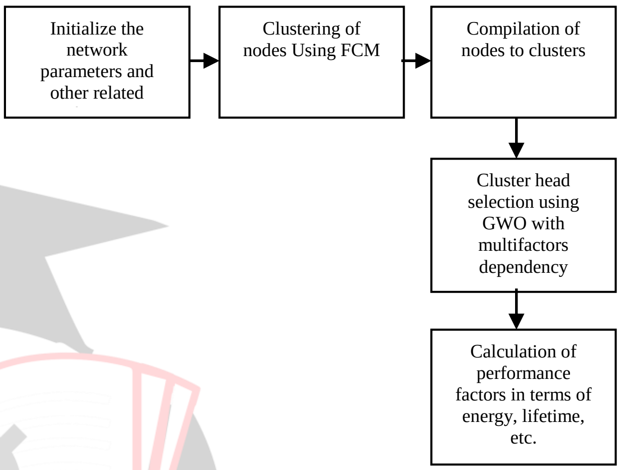

Fig. 2. Proposed methodology of IoT-WSN scheme

Step 4: Cluster head selection using GWO with multifactors dependency: Once the nodes are grouped into clusters, the next step is to select the cluster heads. In this step, we utilize the Grey Wolf Optimizer (GWO) optimization algorithm to select the cluster heads based on a fitness function. The fitness function considers various factors, including residual energy, distance for communication, and connection requests to the node, and maximum communication region, to select the optimal cluster head for each cluster.

Step 5: Communication: In this step, the nodes communicate with their respective cluster heads. The cluster heads then aggregate the data received from the nodes and communicate it to the sink. The communication takes place in two stages - the first stage is between the nodes and their respective cluster heads, and the second stage is between the cluster heads and the sink.

Step 6: Performance Evaluation: The final step involves evaluating the network's performance based on various parameters, such as network lifetime, number of dead nodes, throughput, first node to die, and the last node in the network. By analyzing these metrics, we can determine whether the network is functioning as expected and identify areas for improvement. The performance evaluation helps in identifying the efficiency of the proposed IoT-WSN scheme.

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IV. Results and Discussion

In the results section, we show and analyze what we found in the study. We use simple descriptions and pictures like graphs and tables to help explain complex information. To understand how the system works and find ways to improve it, we used a special software tool called MATLAB to run simulations.

A. Simulation Parameters

This section provides a detailed description of the simulation parameters used in the current study. The simulation parameters play a critical role in determining the behavior and performance of the system under investigation. Thus, we carefully selected and controlled these parameters to simulate a wide range of conditions. The proposed model is based on these parameters, and by incorporating them, we were able to achieve significant improvements in the performance of the system. Therefore, it is essential to understand the role of these parameters in the proposed model and how they contribute to the overall results

TABLE I. SIMULATION PARAMETERS OF THE NETWORK

Sr. No	***Simulation Parameters***	***Values***
1	A	0.1
2	B	0.3
3	α	2
4	Total Network Eo	50j
5	Nodes	100
6	Area	100*100
7	Packet	4000
8	Population	5
9	Iteration	10
10	GWO (a)	[2 0]

The above table 1 depicts the simulation parameters of the network that are used in this proposed work.

The line graph in Figure 3 shows that the number of dead nodes in a wireless sensor network increases as the number of communication cycles (rounds) increases. Initially, when the rounds are zero, there are no dead nodes, which are expected.

However, as the rounds increase, the energy consumption during communication causes the nodes to exhaust their energy faster, resulting in more dead nodes. The graph also suggests that the number of rounds required for a particular number of nodes to die is not constant. For example, when 100 nodes have died, it took 12,000 rounds for that to happen

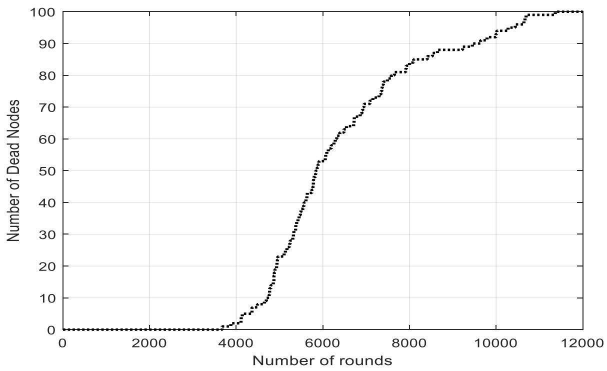

Fig. 3. Graph shows the number of dead nodes with respect to communication rounds

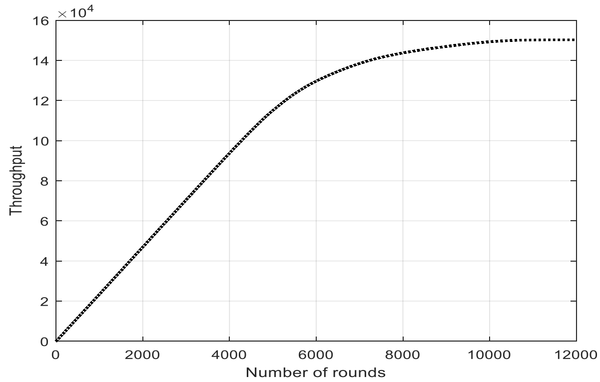

Fig. 4. Graph depicts the throughput utilized in communication rounds

Figure 4 presents a line graph illustrating the relationship between the number of rounds and the throughput of a network. The graph shows that as the number of rounds increases, the network's throughput also increases. At the initial stage, there was no data transmission, and the throughput was zero. However, as data transmission increased, the network's throughput also increased. The graph indicates that the network's throughput continued to increase until it reached a peak value of 15 when the number of rounds was 12000. This suggests that the network's ability to handle more data was improving, which is a positive indicator of its performance. Figure 5 presents a comparison of three different techniques: DEEC, I-SEP, and FCM-GWO, with respect to the lifetime of a network. The graph shows that both DEEC and I-SEP resulted in a rapid decrease in the number of alive nodes, with all nodes dead by 7000 rounds. In contrast, the proposed technique FCM-GWO was able to sustain the network for a longer period, with a constant number of alive nodes even after 7000 rounds, and 20 alive nodes after 8000 rounds. This indicates that FCM-GWO outperformed the other two techniques in terms of network lifetime. The graph demonstrates that the proposed technique is more effective in prolonging the lifetime of the network compared to the other two techniques. The line graph in Figure 6 compares the network throughput of three algorithms - DEEC, I-SEP, and FCM-GWO. The x-axis represents the number of rounds, while the y-axis represents the number of packets transmitted.

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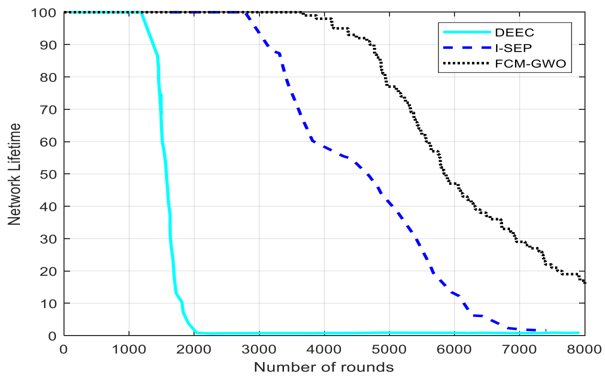

Fig. 5. Graph show the network lifetime over proposed algorithm in communication rounds

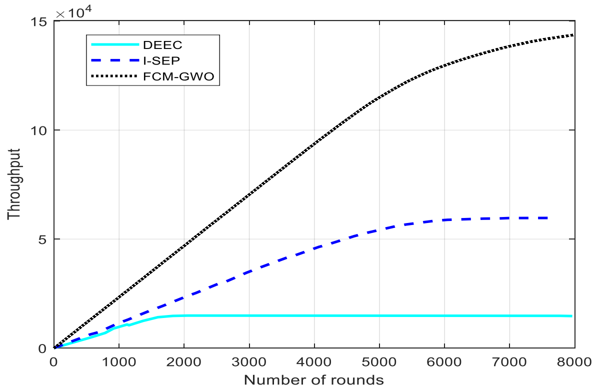

Fig. 6. Graph shows the throughput utilized in the different algorithm with respect to no. of rounds

The figure 6 shows that all three algorithms were able to increase the network throughput as the number of rounds increased. The DEEC algorithm had a steady throughput of 15 for a large number of rounds after an initial throughput of 2. The I-SEP algorithm had an initial throughput of 3, which gradually improved over time until 7500 rounds. The proposed FCM-GWO algorithm had a continuous improvement in the network throughput till 8000 rounds, where the throughput peaked at 14. This indicates that the FCM-GWO algorithm has a good performance and can handle a large number of rounds while maintaining a high throughput.

V. Conclusion

The goal of this research was to improve the longevity and energy efficiency of heterogeneous sensor networks by implementing more effective clustering techniques and selecting better cluster heads. The proposed approach utilized the fuzzy c-means clustering mechanism and the Grey Wolf Optimization algorithm to select the most efficient cluster heads. By using various fitness functions, the algorithm was able to identify the cluster heads that used the least amount of energy while effectively covering a large communication zone and taking connection requests into account. In addition, the proposed FCM-GWO algorithm achieved better results than other techniques in terms of network lifetime and throughput. Specifically, the DEEC and I-SEP techniques resulted in a rapid decrease in the number of alive nodes, with all nodes dead by 7000 rounds. In contrast, the FCM-GWO algorithm was able to sustain the network for a longer period, with 20 alive nodes even after 8000 rounds. In terms of throughput, the DEEC algorithm maintained a steady throughput of 15 over a large number of rounds, while the proposed FCM-GWO algorithm showed continuous improvement in network throughput, reaching a throughput of 14 at 8000 rounds. Moreover, these results indicate that the FCM-GWO algorithm performs well and can handle a large number of rounds while maintaining a high throughput. Overall, the proposed approach achieved better results compared to other techniques.

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