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Retraction

Retracted: Energy-Efficient Clustering and Routing Algorithm Using Hybrid Fuzzy with Grey Wolf Optimization in Wireless Sensor Networks

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This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] J. Singh, J. Deepika, Zaheeruddin et al., "Energy-Efficient Clustering and Routing Algorithm Using Hybrid Fuzzy with Grey Wolf Optimization in Wireless Sensor Networks," *Security and Communication Networks*, vol. 2022, Article ID 9846601, 12 pages, 2022.

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Research Article

Energy-Efficient Clustering and Routing Algorithm Using Hybrid Fuzzy with Grey Wolf Optimization in Wireless Sensor Networks

Jainendra Singh,[1] J. Deepika,[2] Zaheeruddin,[1] J. Sathyendra Bhat,[3] V. Kumararaja,[4] R. Vikram,[5] J. Jegathesh Amalraj,[6] V. Saravanan ,[7] and S. Sakthivel[8]

[1]*Department of Electrical Engineering, Jamia Millia Islamia, New Delhi, India*
[2]*Department of Information Technology, Sona College of Technology, Salem, Tamilnadu, India*
[3]*Department of MCA, St. Joseph Engineering College, Mangaluru, Karnataka, India*
[4]*Department of Computer Science and Engineering, K. Ramakrishnan College of Engineering, Trichy, Tamilnadu, India*
[5]*Department of Computer Science and Engineering, M. Kumarasamy College of Engineering, Karur, Tamilnadu, India*
[6]*Department of Computer Science, Government Arts and Science College, Cuddalore, Tamilnadu, India*
[7]*Department of Computer Science, College of Engineering and Technology, Dambi Dollo University, Dambi Dollo, Oromia Region, Ethiopia*
[8]*Department of Information Technology, Paavai Engineering College, Namakkal, Tamilnadu, India*

Correspondence should be addressed to V. Saravanan; saravanan@dadu.edu.et

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Wireless networking is popular due to the "3 any" concept: anyone, anytime, anywhere. Wireless communication technology advancements have covered the opportunities for sustainable development of low-power, low-cost, multipurpose sensor nodes in wireless sensor networks. In sensor networks, the network layer handles routing problems. Since radio transmission requires a significant amount of energy, it is essential to investigate power efficiency and optimization. As a result, the conservation of energy is a critical concern in wireless sensor networks. Recent research is focused on developing routing algorithms that use less amount of energy during communication, thereby prolonging the network's life. Wireless sensor networks with energy recovery nodes use nodes that can extract energy from their environment. The fuzzy-GWO method and the energy-saving routing algorithm are proposed and analyzed in this research work. For simulation, the MATLAB 2021b working environment is used. The LEACH, HEED, MBC, FRLDG protocols, along with the proposed protocol F-GWO, are compared. From the obtained results, it is found that the network lifetime is increased by 20%, 14.8%, 12.5%, and 3.8%, respectively. In addition, the proposed method has a 37.5%, 33.3%, 16.6%, and 6.25% reduction in average energy consumption when compared with the conventional algorithms. According to the experimental data obtained through simulation, the proposed F-GWO algorithm outperforms the LEACH, HEED, MBC, and FRLDG in network lifetime, packet delivery ratio, throughput, bit error rate (BER), buffer occupancy, time analysis, and end-to-end delay.

1. Introduction

A wireless sensor network (WSN) comprises many small, low-cost, low-power, and flexible sensor nodes that communicate wirelessly over short ranges. These sensor nodes are placed randomly throughout the area of interest and are often used for tracking and surveillance duties [1]. A discovery unit, a processor unit, a communication unit, and a power supply unit are the four subsystems that make up a node. Power units are of particular interest to scientists and researchers. LEACH is a cluster-based protocol in which all nodes are selected periodically to be cluster heads. Sensor nodes communicate with one another to generate critical information about the physical environment. Each node gathers data and transmits it to the base station (BS). No sensor nodes need to send data simultaneously; they might send it separately with surrounding nodes. This wireless sensor network is reliable, precise, and simple to use [2, 3]. Wireless multimedia sensor networks have grown in popularity due to the development of WSN. Sensor nodes in WSN sense and gather data from other nodes, process these data, and then transfer the collected data to the base station by the HEED routing protocol [4]. Environmental monitoring, healthcare, industrial automation units, high-performance building control, traffic management object tracking, military surveillance, and other computing platforms all use sensor networks.

Multihop balanced clustering (MBC) routing protocol is a centralized protocol based on k-means clustering. The whole sensor node is a battery-powered device, and the node's energy usage while transmitting or receiving data packets impacts the network's complete life cycle. Because WSN nodes have limited power and memory, it turns out that nodes need a lot of power or energy to transmit data instead of detecting it. Hence, the critical concern is to save energy to extend the sensor network's lifetime [5]. Clustering is a quick and practical approach to accomplish this. A cluster is a grouping of many nodes in a WSN that communicate with the base station via a cluster head (CH). Choosing a cluster and matching CH are challenging and time-consuming tasks. Over the years, several strategies have been utilized to get the best CH selection.

Cluster-based technology is one of the most cutting-edge technology in WSN, and it has been proven to be scalable and flexible. All sensors in this technology are grouped, and each cluster center's cluster head is responsible for specialized tasks such as retrieving information from sensors within the clusters, data integration, and direct transfer of merged data to the base station. Several nodes can connect short distances with this CH, which minimizes the quantity of data transferred over the networks and saves battery life [6, 7].

Depending on the network layout, WSN routing protocols can be classified into three groups: location-based, data-centric, and hierarchical. Traditional routing algorithms focus on finding the shortest path to convey data from the source node to the destination [8, 9]. The network layer in a WSN is meant to optimize lifetime by locating energy-efficient routing and dependable data relay routes from sensor nodes to receivers. WSNs face a challenge in selecting a routing scheme. Network viability, availability, and service improvement are shared by all routing protocols to make sensor networks last longer. Reducing transmission delays to improve WSN performance is critical. Various considerations, including deployment, energy usage, and security, impact routing protocol designs. As a result, researchers are concentrating their efforts on developing energy-efficient nodes and protocols that can handle various tasks [10].

As a result, an efficient routing method is required to reduce network energy consumption while extending the network's lifespan. Several research projects have been undertaken to lower node energy consumption by employing innovative routing strategies to increase network performance and lifetime. Choosing the optimal cluster head is a critical challenge in the WSN's cluster-building process. In recent years, fuzzy logic has shown to be more advantageous for WSN researchers when it comes to selecting the most acceptable cluster head.

As the network increases, the algorithm complexity increases linearly. Clustering algorithms are combined with many hybrid models to improve the overall performance of the network. During that process, interference of the network is also gradually increased. LEACH is based on the assumption that each sensor node contains an equal amount of energy that is not valid in real scenarios. LEACH, performing clustering in each round, imposes significant overhead on the network. This overhead causes noticeable energy dissipation, which results in decreasing the network lifetime.

There are some limitations with HEED as follows: the use of tentative CHs that do not become final CHs leaves some uncovered nodes. As per HEED implementation, these nodes are forced to become a CH and these forced CHs may be in the range of other CHs or may not have any member associated with them. As a result, more CHs are generated than the expected number and this also accounts for unbalanced energy consumption in the network.

An energy-efficient opportunistic routing (EEOR) protocol is proposed to reduce energy costs in selecting and prioritizing a forwarder list under opportunistic routing and increasing the lifetime of a network. It is multipath routing. EEOR has two power models, nonadjustable and adjustable ones. Simulation results prove that EEOR is more efficient in terms of energy consumption, packet delivery, throughput, loss ratio, and delay than ExOR.

The proposed protocol in this article uses fuzzy-GWO for the selection of CH. The reason for choosing GWO over other metaheuristic techniques is that the GWO has a faster convergence rate. Moreover, GWO leads to the continuous reduction of search space as well as decision variables are less. It also avoids local optima.

This article presents fuzzy-GWO with a new opportunistic routing protocol for wireless sensor networks. Section 2 will review the literature on energy-efficient routing techniques. The proposed approach is presented in Section 3. The outcomes and analyses of the F-GWO algorithm are described in Section 4. Section 5 concludes with a summary of the findings.

2. Literature Review

Xie et al. [11] developed an improved hierarchy protocol for low-energy clustering based on the ensemble method. This work primarily optimizes and enhances the LEACH protocol. The authors examine the energy shortcomings of LEACH and the energy loss for each step in the LEACH cluster. The energy waste at the node was summarized, and a new LEACH algorithm was proposed. According to the comparison results, the revised approach increases the network's life and improves performance to balance the energy in each cluster.

Zhu et al. [12] proposed a tree cluster-based data gathering algorithm for industrial WSNs with mobile sinks.

For shortening, these articles present TCBDGA, a tree cluster-based data collection algorithm with a portable sink. The authors proposed a distributed protocol that creates a cluster structure and selects a rendezvous node (RN) with sufficient energy for a long enough time and close to the mobile sync (MS). This algorithm's cluster scheme creates a cluster structure of various sizes. The distance between the cluster heads from the MS path is inversely proportional to the size of each cluster. The proposed protocol minimized the network's power and it can be used in various situations like industrial settings with large amounts of heterogeneous sensory data.

Daniel et al. [13] presented an energy-efficient tree-based resilient cluster header-based framework for densely distributed WSN IoT devices based on three measurements: neighborhood repetition, bisection indexing, and algebraic connections. This study offers an FRLDG-based model that captures the data collection nodes of all clusters present in a densely distributed WSN. The authors also discussed the mobile sync nodes and all-groups tree by choosing a full cluster head depending on residual power, distance, and latency.

Preeth et al. [14] proposed energy-efficient fuzzy logic-based clustering with quasioppositional firefly-based routing protocol for WSN system. The algorithm developed in this article is an energy-efficient type II fuzzy logic-based clustering and virtually opposite learning firefly algorithm for routing in WSN-assisted IoT networks. Adding quasiopposite learning (QOL) to the firefly (FF) algorithm speeds up convergence and results in the best solution set.

Khan et al. [15] stated energy optimization using a distance-aware PR-LEACH routing scheme in an IoT network. This research aims to use routing protocols to reduce energy consumption. The proposed protocol outperforms the original protocol by a wide margin. The proposed protocol differs from its parent protocol and it converts the global threshold calculation method into a local threshold calculation. This add-on enhances the selected protocol, making it more dynamic and effective. The improved protocol is helpful in IoT networks because it reduces the amount of energy needed to communicate between sensor nodes and the outside world via the cloud.

Pattnaik and Sahu [16] developed the assimilation of the fuzzy clustering approach and EHO-Greedy algorithm for efficient routing in WSN. This study incorporated the EHO-Greedy algorithm, and a fuzzy clustering approach was created for effective routing in WSN. With extended EM, nodes are first formed in multiple clusters. The proposed strategy makes it difficult for densely placed heterogeneous WSN CHs or BSs to process such huge amounts of statistics, especially in natural form. Furthermore, data transfer to the base station for WSN required a lengthy time.

Moharamkhani et al. [17] developed a multiobjective fuzzy knowledge-based bacterial foraging optimization for traffic congestion control. This article offers moFIS-BFO, a combined protocol for energy-efficient clusters in WSNs based on moFIS and BFO algorithms; prioritization is provided to manage gender in cluster headers, control congestion, and avoid severe package waste. As a result, the moFIS-BFO protocol is unsuitable for large-scale WSNs (above 200 m).

Ben Fradj et al. [18] invented the opportunistic routing system for wireless sensor networks. This study proposes the EEOR-FL protocol for wireless sensor network applications as a unique "OR" protocol. This article uses a new opportunistic routing strategy to decrease and balance power consumption across nodes in wireless sensor networks. According to simulation data, the method effectively balances energy consumption and increases the life of the network.

Elavarasan and Chitra [19], based on WSN's multilayer routing architecture, offered an effective fuzzy-based continuous node refinement approach. The main task is to create a secure communication path for wireless sensor networks that spans multiple layers. The objective is to track the sensor node's location and observe its behavior. The fuzzy-based continuous node refinement technique was developed to investigate its conduct. The algorithm identifies and removes nodes that are unsuitable for communication. The transmitting node controls the activity of all intermediary nodes in the routing path.

Al-Baz and El-Sayed [20] developed a new CH selection algorithm for the LEACH protocol for wireless sensor networks. This article focuses on hierarchical routing protocols based on clustering algorithms, notably the low-energy adaptive cluster hierarchical protocol (LEACH), which is the first hierarchical energy adaptive protocol and extends the life of the entire network. Using LEACH, the cluster head rotation mechanism can prevent unexpected node outages.

Rajakumar et al. [21] presented an energy-efficient cluster formation in a wireless sensor network using grey wolf optimization. The grey wolf optimization (GWO) algorithm was used to choose energy-efficient cluster heads for this project. This algorithm appeals to several academics due to its effective leadership capabilities and hunting methods; however, it falls short in exploration and exploitation, resulting in poor clustering in WSN when used. The suggested methodology contains a tuning parameter for efficient exploration and exploitation, which will resolve the WSN issue. The results of the experiments indicate that the proposed method achieves better outcomes.

Rozner et al. [22] developed a simple opportunistic adaptive routing protocol for wireless mesh networks. In this article, a simple opportunistic adaptive routing protocol (SOAR) to explicitly support multiple simultaneous flows in wireless mesh networks is proposed. An A18-node wireless mesh testbed is used for the analysis and the evaluation shows that SOAR significantly outperforms traditional routing and a seminal opportunistic routing protocol, ExOR, under a wide range of scenarios. Ramalingam et al. [23] proposed blynk IoT server-based efficient data transmission for different applications. A smart IoT device is designed for real-time application using blynk and a wireless sensor network. This smart IoT device has been used to collect the data and transmission into the cloud [24].

Karunanithy and Velusamy [25] developed cluster-tree-based energy-efficient data gathering protocol for industrial automation using WSNs and IoT. A cluster tree-based energy-efficient data gathering (CTEEDG) protocol is presented in the article to increase the lifetime and throughput of WSNs. The CTEEDG employs fuzzy logic to choose the cluster head (CH) depending on the local information. The tree topology is established between the clusters towards the base station (BS) during the intercluster communication phase, ensuring the availability of the congestion-free shortest path to the BS. From the simulation results, the proposed CTEEDG outperforms the FAMACROW and DL-LEACH throughput by 28.81% and 38.18%, respectively. Furthermore, compared to FAMACROW and DL-LEACH, the proposed method reduces average energy consumption by 29.26% and 49.29%, respectively.

Fradj et al. [26] described a new opportunistic routing protocol called energy-efficient opportunistic routing-forward list (EEOR-FL). They used the same basic concept as the EEOR protocol but also used a new method of choosing the list of candidates for the goal and minimizing energy consumption. EEOR-FL is an opportunistic routing protocol based on EEOR, which uses a new method of selecting the list of candidates. When a source wishes to transmit data to a destination, a frame sent in broadcast will be received potentially by all nodes of the neighborhood. Those who have received the frame return an acknowledgment to the source, each in turn in the order defined by the list in the header of the frame. By receiving these acknowledgments, the source can calculate the cost and determine the list of candidates that is the best to advance the frame to the destination.

3. Proposed Methodology

In this research work, a fuzzy-based GWO approach and energy-efficient opportunistic routing algorithm are proposed. A new opportunistic routing technique that reduces power usage and balances power consumption between nodes in a wireless sensor network is proposed. A new parameter to elect the CHs is included in fuzzy-GWO. The terminology utilized in the proposed methodology and the fitness function employed in the proposed protocol are described as follows.

3.1. System Model. Whenever the threshold distance (d_0) is larger than the propagation distance (d), node's energy consumption is proportional to d^2. The following equation describes the overall energy usage of each node when transmitting an L-bit packet of data:

$$E_{tx}(L,d) = \begin{cases} L \times E_{\text{ele}} + L \times \varepsilon_{fs} \times d^2, & \text{if } d < d_0, \\ L \times E_{\text{ele}} + L \times \varepsilon_{mp} \times d^4, & \text{if } d \geq d_0, \end{cases} \quad (1)$$

where E_{tx} is the total energy necessary to transmit, E_{ele} is the energy dissipated per bit to operate the circuit, i.e., transmitters or receivers, ε_{fs} is the free space model's amplifying energy and ε_{mp} in the multipath model, and d_0 is the threshold transmission range.

Similarly, the receiver circuit's energy usage for receiving L-bits of data is provided by the following equation:

$$E_{rx}(L) = L \times E_{\text{ele}}, \quad (2)$$

where E_{rx} is the energy consumption required to receive information and E_{ele} is the energy dissipation per bit required to operate the circuit, i.e., transmitters or receivers, and is affected by a variety of factors including modulation, digital coding, signal spreading, and filtering.

In general, the propagation of the radio wave is highly variable and is very complex to model and the total energy loss is calculated using the following equation:

$$E_{\text{total}} = E_{tx} + E_{rx}. \quad (3)$$

3.2. Selection of Cluster Heads Using Fuzzy Approach. After investigation of the works in literature, it has been seen that a large portion of the intended works assumed multiple different factors for the clustering process. In the WSNs, the residual energy of SNs had been considered while placing the CHs. But in the proposed approach, residual energy, node centrality (NC), and neighborhood overlap (NOVER) are considered for choosing an exact node as a CH. Moreover, the proposed method considers the link quality assessment for routing in WSN.

Choosing the optimal cluster head is a critical challenge in the WSN's cluster-building process. The CH node is responsible for aggregating and transmitting data from all sensor nodes (SNs) to the base station. In recent years, fuzzy logic has been shown to be more advantageous for WSN researchers when it comes to selecting the most acceptable CH. Three parameters were examined when fuzzy logic was used to select CH. Combine the NC, NOVER, and residual energy of sensor networks to conserve energy and increase the lifespan of sensor networks. The following is a list of the input parameters:

Residual energy: the CH will be picked from the nodes with the highest energy. Consider E_i to be the initial energy of the node. After the time "t," the energy spent by the node $E(t)$ is expressed as follows:

$$\begin{aligned} E(t) &= \left(n_{\text{tpkts}} \times a\right) + \left(n_{\text{rpkts}} \times b\right), \\ E_{\text{RES}} &= E_i - E_t, \end{aligned} \quad (4)$$

where n_{tpkts} and n_{rpkts} denote the number of data packets transmitted and received, respectively. "a" and "b" are constants with values between and (0, 1).

NC: it indicates the degree to which the selected CH is central to the entire network of its neighbors:

$$NC = \frac{\sqrt{\sum d^2\left(c_i, c_j\right)/T}}{M}, \quad (5)$$

where $d\,(c_{i,j})$ is the length between the cluster head node and any of its child nodes.

NOVER: the NOVER method is used to measure the degree of the mutual neighborhood across a link's termination nodes. A link with a low NOVER connects two distinct networks, while a connection with a high

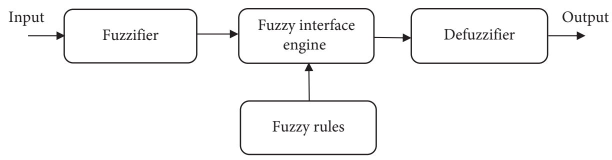

Figure 1: Cluster head selection using a fuzzy method.

NOVER must be between nodes in the same network. $N(u)$ and $N(v)$ separately determine the neighbors of nodes u and v.

$$\text{NOVER}(u-v) = \frac{2 * |N(u) \cap N(v)|}{|N(u)| + |N(v)| - 2}. \quad (6)$$

In this case, each u and v will have the same set of neighbors, and NOVER will equal "1." The fuzzy method is depicted in Figure 1.

Figure 2 shows the flowchart of the fuzzy reinforcement learning method. The system inputs of residual energy, NOVER, and NC system input transform fuzzy groups. Low, medium, and high residual energy fundamental features are available. Near, appropriate, and distant are the three criteria of NC membership. NOVER's characteristics are grouped into good, medium, and poor, as shown in Table 1.

3.2.1. Nascent of the Fitness Functions. The parameters responsible for the fitness function's derivation are as follows.

A fitness function is calculated to select the CHs. This fitness function ensures that the node having the highest energy and the node located near the BS have a higher chance of selection as CH.

(1) Average Intracluster Distance (f1). The intracluster space is measured as the sum of the spaces between the sensor nodes and their respective CH. This intracluster distance must be decreased to reduce network energy usage. It is supplied because sensor nodes waste some energy when communicating with their separate CH, given as follows:

$$f1 = \sum_{j=1}^{m} \left(\frac{1}{lj} \sum_{k=1}^{lj} \text{dis}\left(s_{k,\text{CHj}}\right) \right). \quad (7)$$

(2) Average Sink Distance (f2). The distance between the base station and the cluster head to the total number of sensor nodes existing in the corresponding CH is used to compute the average sink distance. Space has a significant impact on energy consumption; hence, this aspect is considered. As a result, there is a need to reduce this distance to save energy.

$$f2 = \sum_{j=1}^{m} \left(\frac{1}{lj} \text{dis}(\text{CHj}, BS) \right). \quad (8)$$

(3) Residual Energy (f3). Because a network's life cycle is dependent on the use of energy, there is a great need to reduce energy consumption. As a result, this parameter is taken into consideration. It is calculated as the sum of all specified channels' current energy. Because total energy must be maximized, each objective function is balanced by the opposite.

$$f3 = \frac{1}{\sum_{j=1}^{m} \left(E_{CHj} \right)}. \quad (9)$$

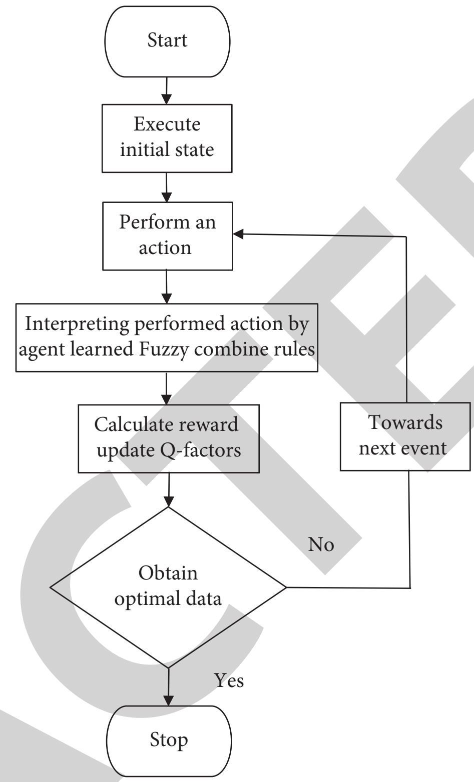

Figure 2: Flowchart of a fuzzy reinforcement learning method.

Table 1: Fuzzy rule set used for the research.

Rule	Residual energy	NC	NOVER	Rank
1	High	Close	Medium	High
2	Medium	Adequate	Poor	Medium
3	Low	Adequate	Poor	Low
4	High	Close	Good	Very high
5	Medium	Close	Medium	Very low
6	Low	Far	High	Medium

(4) CH Balancing Factor (f4). The cluster must be balanced; there is a chance that some large and small groups will form as a result of the random grouping of sensor nodes. As a result, this characteristic is taken into account when balancing energy usage.

$$f4 = \sum_{j=1}^{m} \frac{n}{m} - l_j. \quad (10)$$

The fitness functions listed above are in perfect sync with one another. The fitness function is as follows:

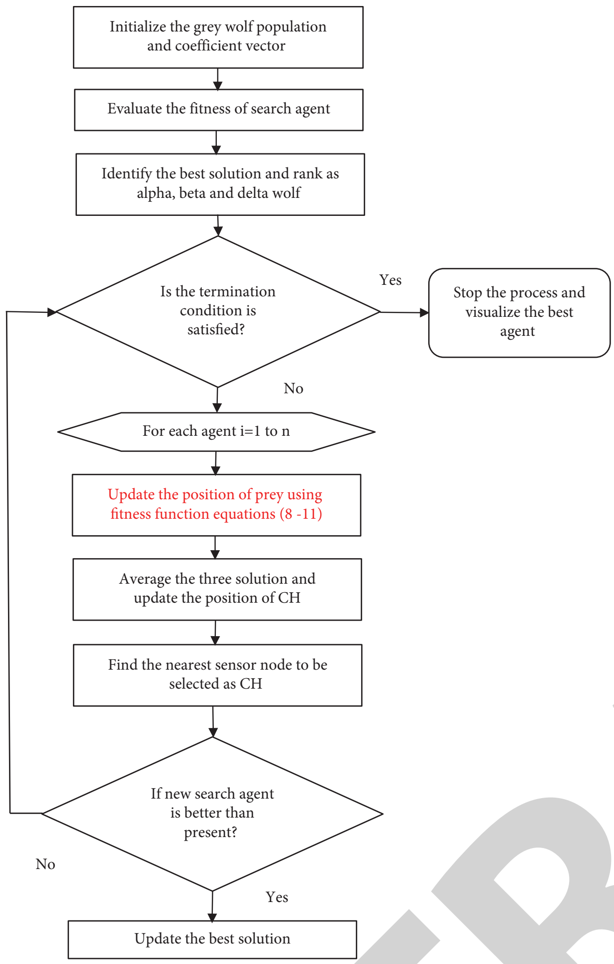

Figure 3: Proposed hybrid grey wolf optimization algorithm.

$$\text{Fitness function} = (p \times f1) + (q \times f2) + (f3 \times r) + (f4 \times (1 - p + q + r)), \tag{11}$$

where p, q, and r represent constant value and $p + q + r = 1$.

Figure 3 shows the flow diagram of the proposed hybrid grey wolf optimization algorithm.

3.3. Grey Wolf Optimizer. In the GWO technique, a pack signifies the number of CHs. The flowchart of the proposed algorithm is given as follows: the hybrid fuzzy-GWO algorithm is used to make the multiple clusters and efficient cluster head selection is made by GWO. A fitness function is calculated to select the CHs. This fitness function ensures that the node having the highest energy and the node located near the BS have a higher chance of selection as CH. For the selection of CHs, the first 10% of the alive sensor nodes whose residual energy is greater than the average residual energy are selected as a CH for each pack. Then, the fitness function value is calculated for each CH present in a pack. The node whose fitness function value is less in a pack than that node is selected as a new and final CH. After the application of GWO, nodes in a pack are the final CHs, as explained in the flowchart of the proposed algorithm depicted in Figure 3. After this phase, a cluster is formed, as explained in the next section. Once the election of CHs is done, non-CH nodes join the nearest CHs. Non-CH nodes transmit a message to request the CHs to join the cluster. Then, CHs send accept messages to the non-CH nodes. Nodes having minimum distance will join the CH. In this way, cluster formation is done.

GWO is a new metaheuristic algorithm that can solve various optimization problems. The grey wolf hunting naturally has a leadership system from which GWO takes inspiration. It is a relatively new optimization approach and algorithm. The method is comparable to the genetic algorithm in implementation and application. The algorithm's mathematical equations are generated from observed patterns in the swarm hunting mechanism. Then, to discover a long-term optimization solution, modify the equations to the current problem. The hierarchy of social dominance of grey wolves can also be used to classify candidate solutions. For replicating the leadership structure, four sorts of grey wolves are used: alpha, beta, delta, and omega. Furthermore, the three basic hunting processes are implemented: seeking prey, encircling prey, and attacking prey. The approach is then compared to low-energy adaptive clustering hierarchy (LEACH), hybrid energy-efficient distributed clustering (HEED), and minimum bandwidth (MBC). The results reveal that when compared against these well-known algorithms, the GWO algorithm delivers very competitive outcomes. As a result, alpha (α) is used to represent the best and most ideal solutions, while beta (β) and delta (δ) are used to describe the second- and third-best solutions, respectively.

3.4. Energy-Efficient Opportunistic Routing (EEOR) Protocol. Routing protocols must be analyzed to assess the strategy's performance and reliability. The steps for routing are as follows:

Step 1: each node transmits information about the quality of the links regularly

Step 2: a node decides the default path and a list of transferring nodes is transmitted based on this information

Step 3: it then sends out a data packet containing this information

Step 4: the transfer list's nodes save the packet and display a transfer timer

Step 5: the packet is transmitted first by the node nearest to the destination and has a small timer

Step 6: to avoid repeated transmissions, the other nodes will delete the relevant packet from their queues

Network energy efficiency is a significant concern in WSN and it includes SN and the number of sink nodes (base stations). Fixed and detachable sinks are available in sink nodes. Within the cluster, each node transmits messages to CH. CH is now the sender and the receiver nodes are sink nodes. As a result, the path between the transmitter and the receiver must be of low power, low latency, and low traffic.

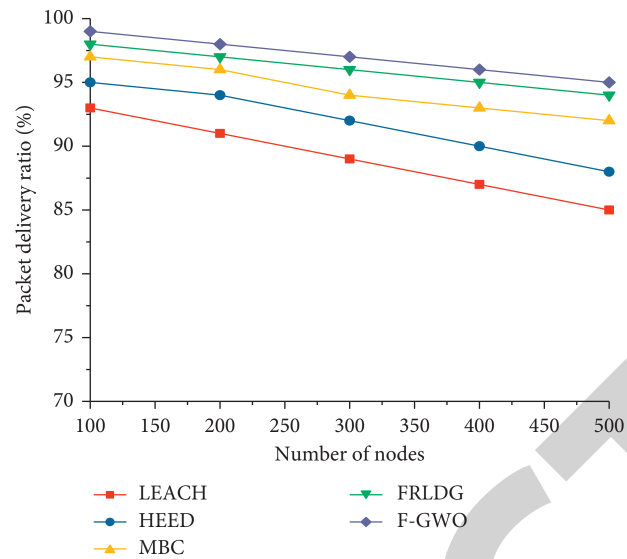

FIGURE 4: Number of nodes vs. packet delivery ratio.

TABLE 2: Comparison of packet delivery ratio (%).

Number of clusters	LEACH [2]	HEED [4]	MBC [5]	FRLDG [13]	Proposed F-GWO
100	93	95	97	98	99
200	91	94	96	97	98
300	89	92	94	96	97
400	87	90	93	95	96
500	85	88	92	94	95

The importance of choosing the shortest path for message transmission cannot be overstated. It also has other possible connections, and as a result, the routing schedule forces the fastest route to be chosen. Some essential tasks in routing programs are link quality and shortest path detection. An energy-efficient opportunistic routing (EEOR) protocol algorithm for data transmission is proposed to address these two issues. In routing areas, EEOR is used to solve link problems, and the time complexity will be drastically reduced.

As networks grow in size, the amount of data collected consumes a lot of energy and causes nodes to shut down prematurely. Several energy-saving protocols have been created to limit the amount of power consumed to sample and gather data to extend the network's life. The EEOR protocol seeks to reduce energy consumption over the network, but it ignores the residual energy balance and packet delay. Candidate selection and prioritizing algorithms are optimized in this protocol to reduce energy consumption. Furthermore, using EEOR, the transmission power can be adjusted. The transmit power steadily increases until it reaches the maximum threshold; this will boost the number of candidates nearby.

As a result, the transmitter will increase the number of nodes in the sequence for different transmit power levels. The sender chooses the reachable node with the lowest energy consumption from a list of nodes ranked by energy cost. When compared to the existing protocol, EEOR requires less time to send and receive data, and the routing list size is less. EEOR outperforms the existing method in terms

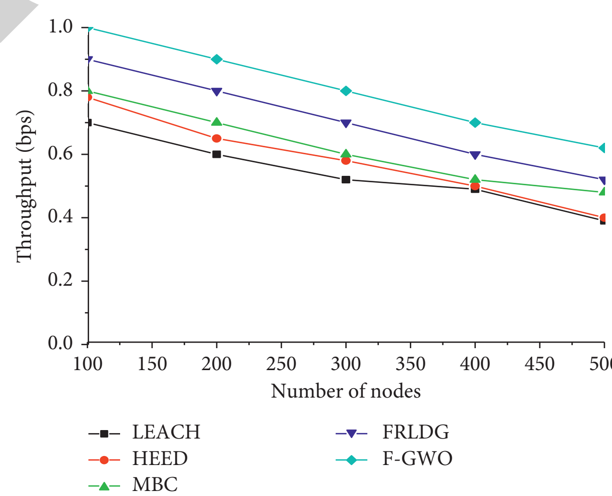

FIGURE 5: Number of nodes vs. throughput.

of total energy use. When comparing packet loss rates and end-to-end latency protocols, EEOR outperforms other existing protocols.

4. Results and Discussion

The proposed method is implemented using MATLAB 2021b tool. The nodes are initially placed arbitrarily in the network region. Using the enhanced EM algorithm, all SNs

Table 3: Comparison of throughput (bps).

Number of clusters	LEACH [2]	HEED [4]	MBC [5]	FRLDG [13]	Proposed F-GWO
100	0.7	0.78	0.8	0.9	1
200	0.6	0.65	0.7	0.8	0.9
300	0.52	0.58	0.6	0.7	0.8
400	0.49	0.5	0.52	0.6	0.7
500	0.39	0.4	0.48	0.52	0.62

are divided into several groups. The residual energy, NOVER, and NC determine the cluster heads chosen in each group. Sensing nodes with the highest power, the best NOVER, and the closest NC are prioritized for the selection of CHs. When a sink is repaired, the CH node collects all information from SNs and sends it directly to the BS. Otherwise, the portable sink moves across the network to collect data from all CHs using the F-GWO algorithm's efficient routing scheme.

The performance of the proposed technique is compared to the existing clustering and routing protocols of LEACH [2], HEED [4], MBC [5], and FRLDG [13]. The performance parameters of system lifetime, throughput, energy consumption, bit error rate, buffer occupancy, end-to-end delay (E2ED), and packet delivery ratio (PDR) are calculated using 500 nodes compared to other existing methods. These simulations put one hundred homogeneous sensor nodes and nine cluster head nodes with infinite battery energy in a $1000 \times 1000\,m^2$ space.

Based on the proposed data gathering scheme, the network performance was simulated in terms of the packet delivery ratio (PDR), throughput, delay, total energy, and speed. Figures 4–9 illustrate the relationship between the performance of the network (PDR, throughput, total energy consumption, and delay) and the number of deployed nodes.

4.1. Packet Delivery Ratio. PDR is the ratio of packets received at the receiver to packets sent by the transmitter. Figure 4 depicts the PDR assessment of existing and proposed schemes. The figure demonstrates that the proposed system is more advanced than other schemes.

When compared to other systems, the proposed method achieves a high (95%) PDR. The number of SN growths will boost the PDR. The PDRs of existing techniques of LEACH, HEED, MBC, and FRLDG are 85%, 88%, 92%, and 94% individually. The comparison of the packet delivery ratio is shown in Table 2.

4.2. Throughput. Throughput is the ratio of the number of packets received at the receiver to the time it takes for a packet to be sent. Figure 5 depicts the proposed methods and existing methods' throughput performance. The figure clearly shows that the proposed technique has been improved in terms of expressiveness. The proposed system outperformed existing solutions in terms of throughput, as shown in Table 3.

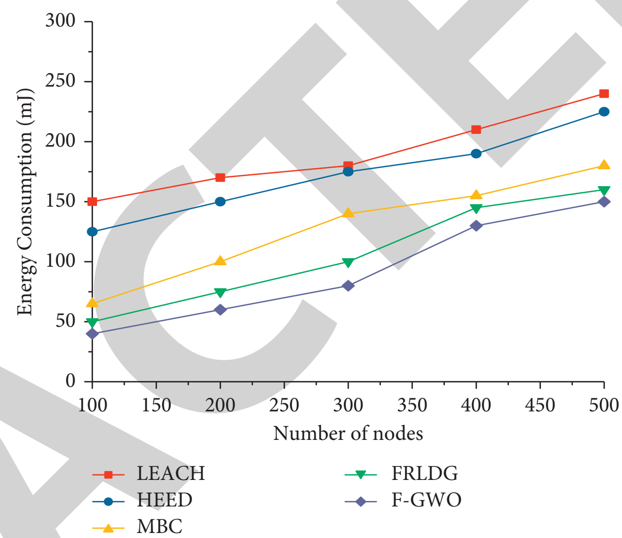

Figure 6: Number of nodes vs. energy consumption.

4.3. Energy Consumption. Energy consumption is defined as the sum of received energy, transmitted energy, and the number of nodes. Figure 6 depicts the proposed scheme's overall energy usage in comparison to other existing schemes. In comparison to other existing approaches, the created technology used less energy (150 mJ) in 500 nodes. The graph above shows how the planned methodology is expressively boosted when compared to others. The quantity of SN upsurges will raise the amount of energy used. Existing LEACH, HEED, MBC, and FRLDG protocols consume 240, 225, 180, and 160 mJ of energy, respectively, as given in Table 4.

4.4. End-To-End Delay. It is the ratio of the entire time taken to deliver a packet to a receiver to the number of packets received. Figure 7 expresses the E2ED analysis for proposed and existing methodologies. The proposed method attained less (8 ms) E2ED than other current schemes. If the number of nodes rises, then the E2ED will be increased. The E2ED of existing approaches LEACH, HEED, MBC, and FRLDG are 10, 9.5, 9, and 8.8 ms, respectively, are given in Table 5.

Model of signal transmission over two wires. The information envelope is 512 bytes in size, with an intracluster transmission range of 40 meters and an intercluster transmission range of 80–120 meters. The transmission is completed; the detection range is 20 meters. Each sensing node's energy parameter can be set to 300 mJ.

Table 4: Comparison of energy consumption (mJ).

Number of clusters	LEACH [2]	HEED [4]	MBC [5]	FRLDG [13]	Proposed F-GWO
100	150	125	65	50	40
200	170	150	100	75	60
300	180	175	140	100	80
400	210	190	155	145	130
500	240	225	180	160	150

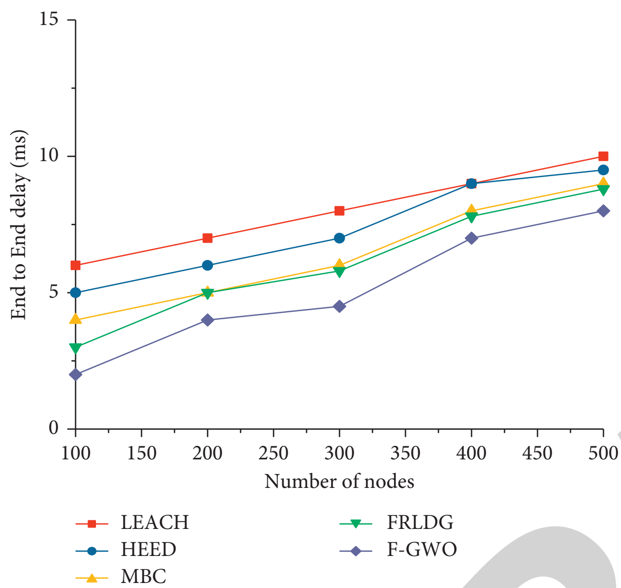

Figure 7: Number of nodes vs. end-to-end delay.

Table 5: Comparison of end-to-end delay (ms).

Number of clusters	LEACH [2]	HEED [4]	MBC [5]	FRLDG [13]	Proposed F-GWO
100	6	5	4	3	2
200	7	6	5	5	4
300	8	7	6	5.8	4.5
400	9	9	8	7.8	7
500	10	9.5	9	8.8	8

4.5. Bit Error Rate. The bit error rate (BER) is the percentage of bits that have errors relative to the total number of bits received in a transmission. Figure 8 expresses the bit error rate analysis for proposed and existing methodologies. Table 6 shows the comparison of bit error rate for various approaches with the proposed F-GWO.

The proposed method attained a less bit error rate than other current schemes. If the number of nodes rises, then the bit error rate will be increased. The bit error rate of existing approaches, LEACH, HEED, MBC, and FRLDG, are 28, 24, 20, and 15, respectively.

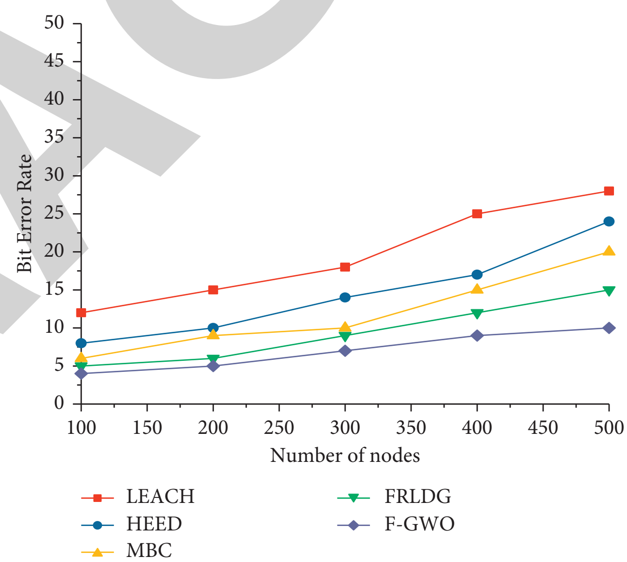

Figure 8: Number of nodes vs. bit error rate measurement.

4.6. Buffer Occupancy. Figure 9 depicts the proposed scheme's overall buffer occupancy in comparison to other existing schemes. In comparison to other existing approaches, the created technology used less buffer occupancy (12.5) in 500 nodes.

The graph above shows how the planned methodology is expressively boosted when compared to others. If the number of nodes rises, then the buffer occupancy will be increased. Existing LEACH, HEED, MBC, and FRLDG protocols consume 26, 20, 17.5, and 15, respectively, as shown in Table 7.

4.7. Network Lifetime. The system lifespan is the amount of time it can operate during which it can do the devoted task(s). Figure 10 compares the performance of the created methodology and the existing technique during the lifetime of a network. The graph above shows that the proposed strategy has a longer system lifetime (5400 rounds) than existing methods. The comparison of network lifetime for different techniques with the proposed F-GWO is given in Table 8.

As the number of nodes in the system grows, the system's lifetime decreases. For the present techniques LEACH, HEED, MBC, and FRLDG, the lifetime of a system is 5200, 4800, 4700, and 4500 rounds, respectively.

4.8. Time Analysis. It represents the overall amount of time spent on cluster creation and CH selection. Figure 11 shows the cluster-building method's performance over time. In this article, the proposed method for cluster creation took less time to execute than existing methods. The time will rise as

Table 6: Comparison of bit error rate (BER).

Number of clusters	LEACH [2]	HEED [4]	MBC [5]	FRLDG [13]	Proposed F-GWO
100	12	8	6	5	4
200	15	10	9	6	5
300	18	14	10	9	7
400	25	17	15	12	9
500	28	24	20	15	10

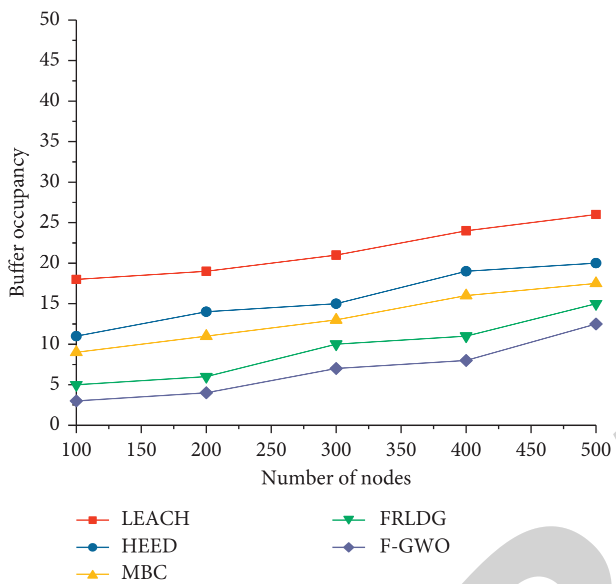

Figure 9: Number of nodes vs. buffer occupancy.

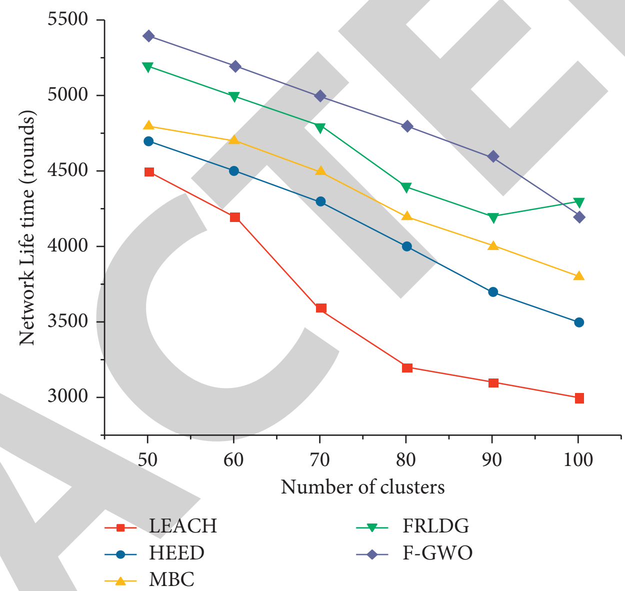

Figure 10: Number of clusters vs. evaluation of network lifetime.

Table 7: Comparison of buffer occupancy.

Number of clusters	LEACH [2]	Heed [4]	MBC [5]	FRLDG [13]	Proposed F-GWO
100	18	11	9	5	3
200	19	14	11	6	4
300	21	15	13	10	7
400	24	19	16	11	8
500	26	20	17.5	15	12.5

Table 8: Comparison of network lifetime (rounds).

Number of clusters	LEACH [2]	Heed [4]	MBC [5]	FRLDG [13]	Proposed F-GWO
50	4500	4700	4800	5200	5400
60	4200	4500	4700	5000	5200
70	3600	4300	4500	4800	5000
80	3200	4000	4200	4400	4800
90	3100	3700	4000	4200	4600
100	3000	3500	3800	4300	4200

the number of clusters increases. The proposed strategy achieved a lower execution time (82 s) than other existing approaches in five clusters, as shown in Table 9.

Figure 12 shows the CH selection method's performance over time. In comparison to existing strategies for CH selection, the proposed method took less time to execute in this article. The time will be extended if the number of CHs is increased. In comparison to other current techniques, the proposed scheme achieved a short execution time (65 s) in five CHs, as given in Table 10.

Using the suggested technique, the relation between network performance, quality of services, and the number of installed nodes is depicted in Figures 4–7. As the number of nodes grows, LEACH, HEED, and MBC cannot increase PDR, total energy usage, latency, or throughput. The mobile sensor environment is compared to LEACH [2], HEED [4], MBC [5], and FRLDG [13]. As seen in Figures 8 and 9, this system performs exceptionally well. According to simulation results, the suggested approach provides a stable link with modified adaption, suitable for areas with a high level of motion.

The proposed solution shows improved PDR and reduces end-to-end latency in a highly mobile environment. However, irrespective of the number of sensor hubs in the system, the proposed technique can be directly deployed to reduce execution time. Temporary connections in WSNs based on mass portability can result in packet loss and retransmissions. In this instance, the sensor hub's energy usage may increase. It can also lower PDR and increase throughput. The proposed technique can ensure a reliable connection while protecting the tuned system's energy. As a result, the proposed scenario appears to be well-suited to

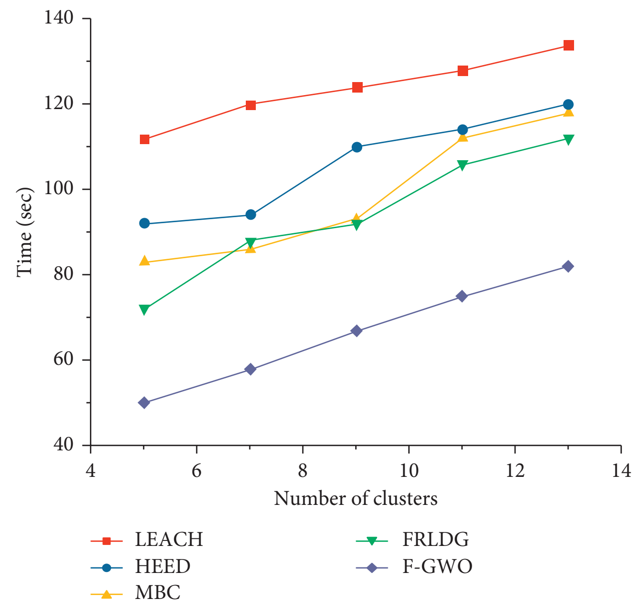

Figure 11: Number of clusters vs. time for cluster formation.

Table 9: Comparison of time for cluster formation.

Number of clusters	LEACH [2]	Heed [4]	MBC [5]	FRLDG [13]	Proposed F-GWO
5	112	92	83	72	50
7	120	94	86	88	58
9	124	110	93	92	67
11	128	114	112	106	75
13	134	120	118	112	82

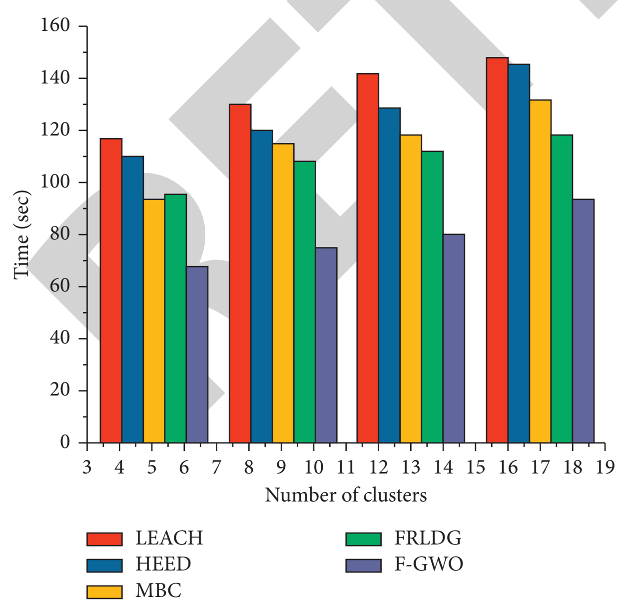

Figure 12: Time for cluster head selection.

meeting high mobility requirements. Finally, it is reasonable to believe that the proposed data collection is cost-efficient, increasing the system's life and improving its reliability. It is prepared for exceptional, adaptable conditions that match the quality. The proposed hybrid algorithm is used for real-time data collection applications.

Table 10: Comparison of time for cluster head selection.

Number of clusters	LEACH [2]	Heed [4]	MBC [5]	FRLDG [13]	Proposed F-GWO
5	117	110	94	96	68
9	130	120	115	108	75
13	142	129	118	112	80
17	148	145	132	118	94

5. Conclusion

In WSN, many sensor nodes acquire large areas, rapidly influencing security and commercial applications in real time. A cluster tree is used to design network management architecture, and this research work introduced a fuzzy-GWO approach and energy-efficient opportunistic routing algorithm. The GWO is a comparatively modern technology that can be enhanced in various ways, and it is used to choose the CH. A new opportunistic routing technique that reduces power usage and balances power consumption between nodes in a wireless sensor network. This approach is effectively implemented and verified using the MATLAB 2021b tool in a simulation. On mobile sensor nodes, the ultimate goal is to leverage throughput, PDR. To reduce network traffic caused by buffer occupancy, the proposed system enables reliable link data collecting nodes and improves service metrics such as throughput, PDR, bit error rate, and end-to-end latency. Compared to the LEACH, HEED, MBC, and FRLDG protocols, the proposed protocol, F-GWO, has increased the network lifetime by 20%, 14.8%, 12.5%, and 3.8%, respectively. Compared to existing approaches, the created technology used less energy by 37.5%, 33.3%, 16.6%, and 6.25%, respectively. When the suggested protocol, F- GWO, is compared against LEACH, HEED, MBC, and FRLDG, the result shows that the proposed protocol excels in a network lifetime, packet delivery ratio, throughput, bit error rate, buffer occupancy, and end-to-end delay.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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