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Energy-Efficient Clustering in WSN using Bacterial Foraging and Krill Herd Optimization

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Abstract: Wireless Sensor Networks (WSNs), a ground-breaking technology, potentially altered the use of a wide range of applications through the advent and usage of IoT. Even though there have been various proposals on energy-efficient clustering in WSN, an optimized approach concerning the restrictions and sustainability of IoT components is still demanded. The proposed research work combines the behavior of bacterial foraging and Krill herd optimization for the benefit of optimized cluster head selection. An optimized path through cluster heads is achieved using the Geiger Muller Counter Auto Extraction. This approach brings up the network lifetime, as proved by the simulation results.

Keywords: *Bacterial Foraging, Clustering, WSN, Routing, Krill Herd Optimization.*

1. Introduction

Wireless Sensor Network (WSN) is a promising platform for pervasive computing and emergency sectors. Data sensing and communication combine to make up the WSNs. WSNs have been used effectively for a diverse application range, including threat detection, environmental tracking, and object monitoring. Data transmission in WSN is performed as single-hop [1,2] or multi-hops [3,4,5]. Consequently, clustering applications also find their way into clustering of single-hop transmission nodes [6] and clustering of multi-hop transmission nodes [7]. Applications of single-hop data transmissions are commonly found in intra-vehicular like intra-transmissions required systems, that collect the data from sensors and transmit it to the electronic control unit [8,9].

The WSN lifetime may be prolonged in accordance with the optimized protocols to increase the longevity of sensor nodes, which are suitable for a number of applications [10]. In the event of a fire or other emergency, the source node will send the data right away to the sink node. The quantity of energy needed to detect fires is closely related to the activity going on in that particular area. Additionally, it has been determined that the produced data includes spatial and temporal relationships. Utilizing these relationships, clusters are created based on various criteria. Clusters are made up of connected sensor nodes. Since it has a better power supply, more communication modules, and interfaces, the Cluster Head (CH), which is a power node, is selected for each cluster [11]. For even more power savings, the CH node can compress the packets that must be sent to the sink node [12]. Data processing will result in energy consumption. Instead of sending data as periodic packets, data can be transmitted to the sink node based on demand to save energy.

1.1. Clustering in WSN

The geographic protocols deliver data packets to the base station based on the sensor node's location. Finding the nodes' geographic location in this case is a major challenge consuming energy at each hop [13]. Clustering algorithms classify each group as a cluster and organize nodes into groups based on their geographic proximity. CH can perform a variety of duties as the cluster's organizer, including data transportation, data compilation, cluster upkeep, and intra-cluster communication arrangements. Since effective CH selection can reduce energy usage, CH selection methods and processes differ depending on the application. Apparently, most of the algorithms proposed so far work as a two-step process. In the first step, CHs are selected based on a critical variable known as leftover energy, and in the second stage, a cluster member cycle is performed to equalize the utilization of energy.

Due to the significant inter-cluster communication delay, CHs located near sinks are over crucial linkages may die sooner and hence hierarchical designs are used in hierarchical protocols for data transportation to minimize this effect. The hierarchical protocols incorporate clusters into the network's infrastructure, each with its own CH, in order to provide multi-hop routing [14,15,16,17]. Single-hoping minimizes energy use for short distances, and for longer transmissions, the utilization of energy at the sender and receiver nodes is more and the performance degrades

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for a scalable network.

Routing in WSNs has effectively used swarm intelligence-based methods and made it possible to simultaneously optimize the QoS parameters [18, 19]. A very necessary QoS indicator is the effective utilization of the bandwidth that can be achieved by energy-efficient routing [20]. To balance the trade-offs between energy efficiency, coverage, and network lifetime, the energy efficiency and service quality for WSNs are considered as a multi-objective optimization issue and are carefully studied in the Harmony search algorithm [21], Tabu particle swarm optimization [22], Whale optimization algorithm [23] and Evolutionary algorithms.

1.2. Motivation of the Proposed Work

- Energy efficiency in WSN is crucial, and numerous energy-efficient algorithms have been developed but the algorithms are deficient in one or other way. The drawback of the existing methods is that they involve complex computations and transmission fading, reducing system performance and shortening sensor node operational lifetimes.
- Data collision, network congestion, and meaningless power consumption are issues that arise when every node in an ad hoc network communicates directly with the sink node. Single-hop networks are not suitable for big networks, and multi-hop ad hoc network implementation challenges in topology maintenance and overheads.
- The issue of a large number of networks being able to be expanded is inappropriate in this case and does not produce better outcomes. One problem is that it only works in homogeneous networks and not in heterogeneous ones. However, the biggest disadvantage of a homogenous sensor network is that all network nodes might be able to serve as cluster heads, which implies they must have the necessary hardware capabilities, if a low residual energy node is selected as CH, it will ultimately restrict the network lifetime to a brief period.

1.3. Objective of the Proposed Work

- The proposed work aims to provide energy-efficient clustering that improves the lifetime of the network.
- The work focuses on achieving scalability and heterogeneity of WSN for the deployed application.
- The work aims to reduce the delay that occurs during the routing process so that the approach can be used in critical applications.

1.4. Key Contributions

The main contributions of the proposed work are as follows:

- The process of data transmission in the entire network is segmented at the node level by the formation of optimal clusters.
- A new, hybrid approach of Bacterial and Krill foraging behaviors has been proposed for the cluster-based energy-efficient routing approach.
- A new, cluster head selection strategy is developed using a bacterial foraging optimization algorithm.
- A new, cluster heads-based transmission path formation strategy has been proposed using the Krill herd optimization algorithm.
- A new, cluster head maintenance strategy is proposed using the Geiger-Miller auto extraction technique.
- Each sensor node maintains its own fitness value and examines each path's fitness in terms of energy use, residual energy, link quality, the number of nearby nodes, transmission power, etc.
- The clustering approach with nodes has been analyzed and the data is monitored in the WSN simulator, Cooja. Preprocessing and filtration of the collected data is done using the Wireshark tool. Finally, the planned algorithm is related to the existing algorithms in the Python platform with the support of machine learning libraries to prove the performance achieved using the proposed work.

This research article is organized as follows. A review of current WSN energy-aware routing techniques is given in Section 2. The proposed system methodology with the architecture is explained elaborately in Section 3. The simulation findings are presented in Section 4, and Section 5 presents the summary of this work.

2. Literature Survey

Researchers' interest has grown in recent years due to the examination of neural learning approaches in various WSN protocols and applications. The term "routing protocol" refers to the collection of guidelines used to develop a routing approach, and in this sense, several protocols have been taken into account in various contexts.

LEACH (Low-energy adaptive clustering hierarchy) is one of the first routing protocols among the numerous easily accessible well-known cutting-edge clustering-based routing techniques. In order to support multi-hop routing in an energy-efficient manner, the researchers have devised various modified LEACH techniques. Sama et al [24] proposed the ELEC-LEACH protocol, to develop the energy-effective lowest cutting-edge computational multi-hop clustering LEACH. According to the simulation, the ELEC-LEACH routing protocol outperforms the basic LEACH approaches, in terms of longevity, consumption of energy, node failure, and message dropout.

Dhand et al [25] proposed SMEER and SCR, two secure protocols for multi-tier energy-efficient routing, using chaotic key cryptography based on elliptic curves. SMEER Protocol uses sphere-shaped grid-based multi-curve Elliptical shape encrypted routing to deliver the data and clusters the data using K-means and has used an Ant Lion optimization algorithm.

Mehta et al [26] present a Fuzzy Multi-Criteria Clustering and Bio-Inspired Energy-Effective Routing in the Hierarchical Routing Protocol (FMCB-ER) that can boost the performance of WSN-based applications and increase network lifetime. To create robust clusters, this method employs a grid-based clustering algorithm. The best CH is then found using an adaptive Fuzz Multi-Criteria Making Decisions (AF-MCDM) method that combines Fuzzy-AHP and TOPSIS.

Narayan et al [27] suggested a unique swarm optimization method to construct the cluster in the WSN and a fuzzy-based energy-effective routing protocol (E-FEERP) to effectively transfer data from the CH to the base station (BS) using battery power, the average distance of the sensor node from the BS, node density, and communication quality.

Maharajan et al [28] offered a cutting-edge Swarm intelligence-based, Clustering, and Routing-based approach with a QoS awareness (QoSCRSI) method to meet the WSN's QoS requirements. Two-level clustering procedures are used in the QoSCRSI approach, and an expert routing mechanism follows. Glow-worm Swarming Optimization (GSO) based clustering (HFGSOC) approach and the Quant Salp Swarming Optimization Algorithm (QSSA)-based routing strategy (QSSAR) were then used to select the best routes for the destination node. However, there is a lot of duplicated data transmission.

Jeske et al [29] proposed an approach to optimize energy usage and provide reliability. This is considered as a multi-objective numerical problem for the WSN routing issue. Sennan et al [30] introduced a lion optimization approach (LOA) for CH selection in lossy, low-power networks. There are three processes in LOA-RPL: cluster development, CH decision-making, and path establishment. LOA is utilized to choose CH using the Euclidean distance.

Veerapaulraj et al [31] use Elephant Herd Optimization (EHO) as a trust-based security technique. Depending on the trust values, the recommended routing approach selects the optimal secure channels for data transmission. The efficacy of the suggested EHO-based routing has been shown by experimental data. Cherrapa et al [32] developed a cluster head selection algorithm for WSNs, employing K-medoids with Adaptive Sailfish Optimization (ASFO), clustering, and multi-hop routing protocol (CMRP) algorithms. This technique can be used to choose the best CH from potential nodes. Speed, remaining power, and initial decaying node were three common measures used to compare the results.

Visu et al [33] proposed a Krill Herd Optimization-based dual-cluster heads approach (DC-KHO). The end-to-end delay of the current wireless routing methods, which use a random path for data transmission, is significantly larger and inversely connected with energy usage. The current study calculates the path trust value using the created KHO method, which is then utilized to choose the best way. The suggested DC-KHO algorithm amplifies the network's lifetime while being energy-efficient.

3. Proposed Methodology

WSNs operate in real-time environments that are typically dynamic, location-dependent, and subject to other hardware limitations. It evolves with time and establishes communication solely by sensing all of the data from the sensors which is a challenging task. A novel hybrid swarm optimization method for clustering algorithms has therefore been developed in order to have a better and more energy-efficient WSN. Each node in the cluster must maintain a fitness value for each activity and state, and the fitness of each node in the network is affected by a number of variables, including transmission power, residual energy, ETX (link quality), and the number of neighbor nodes. Bacteria explore local areas in the cluster and move to choose the best CH based on which node has the most fitness. When multiple nodes have the same maximum fitness, the CH is chosen from the node with the highest priority. According to the requirement, the priority of residual energy, link quality, transmission power, and other elements, may change.

Bacteria can proliferate and produce new CH for every cluster after deciding on the optimum path, and each CH communicates with other CH through the chemotaxis reproduction mechanism that is directly proportional to CH and inversely proportional to distance from one another. Additionally, CH communicates with other cluster nodes, which involves data forwarding, data aggregation, and cluster management. Following these evaluations, krill (member of the cluster) travels and transmits information to CH. As a result, when data is transmitted along the optimum path, power consumption is reduced and network lifetime is increased. After that, CH will specify a threshold energy level, and if the need is fulfilled, it will automatically choose the next CH based on the criteria.

Fig. 1 shows a block diagram for swarm optimization-based energy-efficient routing in a WSN, demonstrating how each sensor node considers state and contains variables including residual energy, transmission power, connection quality, stability, and neighbor nodes. Based on these considerations, the fitness value is calculated and the one with the maximum fitness is chosen as CH and the lowest fitness as cluster member (CM), and transmit this message to all neighbor nodes. Then, each CM node transmits data packets to the CH, which then communicates with all nodes to administer the cluster, forward data, and other tasks. After that, CH will specify a threshold energy level, and if the demand is met, it

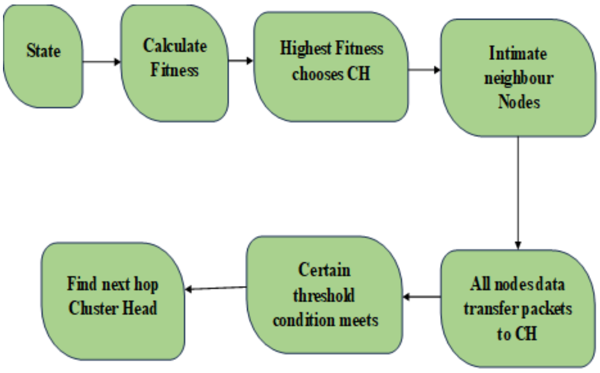

Fig. 1. Overview of the proposed energy-efficient WSN. Every node considered to be in a state initiates the process of finding fitness and proceeds to select the CH will automatically select the following CH based on these criteria.

An energy-aware routing protocol for WSNs is proposed that can identify the best paths to the sink node using a hybrid swarm optimization method. Each sensor node represents a state, and the data flow in the WSN is the action performed by an agent's consent. However, the direct communication between each node and the sink node in an ad hoc network causes issues including data collision, network congestion, and excessive power consumption. By utilizing resources effectively, cluster formation within the network aids in resolving these critical problems. Each cluster selects a cluster head that reduces the transmission distance between the sensing nodes and the sink. CH performs data aggregation, data forwarding, intra-cluster transmission arrangements, inter-cluster data transmission, and cluster maintenance.

Every node must maintain fitness for each activity and state and the fitness for each node in the network is determined by the following factors: residual energy, ETX (link quality), number of neighbor nodes, transmission power, etc. The node with the higher fitness is designated as a prospective cluster head. As a potential cluster head, the node with the highest fitness is chosen. The node with the greatest priority is chosen to serve as the cluster head when multiple nodes have the same highest fitness value. Location, remaining energy, link quality, transmission power, and other variables can all influence priority. Every node has an equal opportunity to be the cluster head throughout each iteration; and also the node that hasn't held that position recently gets a chance to become cluster head again.

3.1. Architecture of the Proposed Work

Fig. 2 depicts the stages of the Particle Swarm Optimization-based unique hybrid BFO and KHO method that is proposed to increase network efficiency in WSNs. There are three stages assumed: creating an energy-conscious cluster, managing the cluster, and maintaining the cluster.

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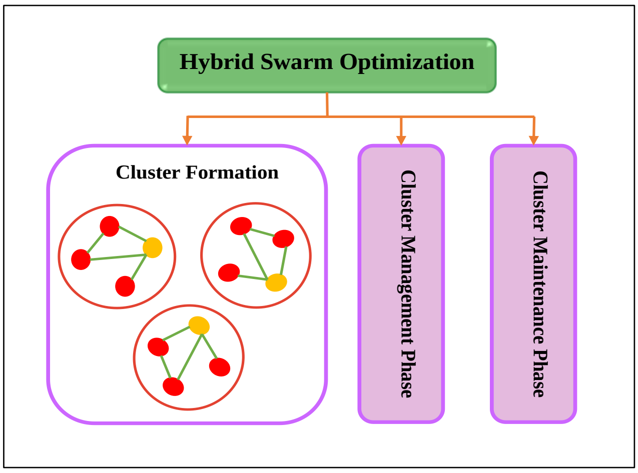

Fig. 2. Phases of the Hybrid Swarm Optimization-based Cluster Routing Approach

forwarding, intra-cluster transmission arrangements, inter-cluster data transmission, and cluster maintenance.

Every node must maintain fitness for each activity and state and the fitness for each node in the network is determined by the following factors: residual energy, ETX (link quality), number of neighbor nodes, transmission power, etc. The node with the higher fitness is designated as a prospective cluster head. As a potential cluster head, the node with the highest fitness is chosen. The node with the greatest priority is chosen to serve as the cluster head when multiple nodes have the same highest fitness value. Location, remaining energy, link quality, transmission power, and other variables can all influence priority. Every node has an equal opportunity to be the cluster head throughout each iteration; and also, the node that hasn't held that position recently gets a chance to become cluster head again.

3.2. System Modelling

This approach combines Bacterial Foraging Optimization

(BFO) and Krill Herd Optimization (KHO) to create a unified hybrid optimization technique known as BKHO. The networking environment of this system is built with a collection of sensor nodes that have different speeds, energy, bandwidth, and other attributes. Every sensor node is assumed to behave having the character of a bacteria and a krill. Initially in the cluster formation phase, apply BFO (local exploration) to allow bacteria to explore local network areas while assessing their energy use and travel time to the destination. In BFO, bacteria choose CH (with more resources) based on which node has a higher fitness by shifting their positions in accordance with the gradient of the objective function.

Priority in choosing a cluster head, even with the highest fitness value, may vary, depending on the location, remaining energy, link quality, transmission power, and other factors. Bacteria have the ability to multiply and develop new solutions. Bacteria with better fitness are more likely to reproduce during reproduction, passing on their genetic material to the following CH. Each bacterium (CH) interacts with the other CH through chemotaxis that is directly proportional to CH and inversely proportional to distance from one another. And CH interacts with other nodes in the cluster which has an impact on data forwarding, data aggregation, and cluster management. The global investigation of the solution space may be aided by this communication. Based on these evaluations, they adjust their paths, favoring those that use less energy. Then, KHO (global exploration) demonstrates aggregation behavior by forming a ring around the promising routes that bacteria have

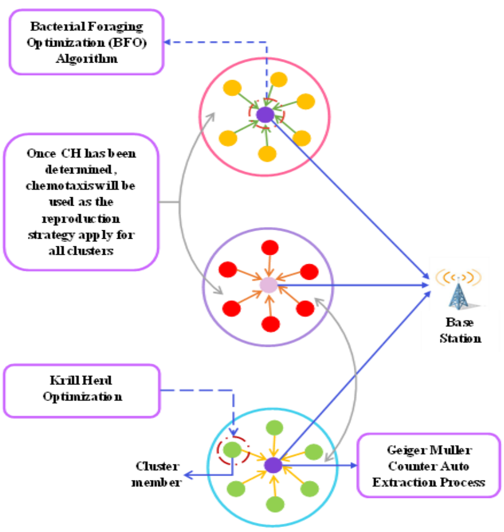

Fig. 3. Architecture of the proposed methodology. Bacterial foraging is performed to find the cluster head with each cluster. Chemotaxis aids Krill herd optimization to explore neighbor cluster heads to reach the root node. Geiger Muller Counter mechanism is used for cluster head replacement

found. The krill population can therefore concentrate on the most advantageous paths as a whole. In the cluster management phase, each krill (member of the cluster) moves using the KH algorithm, which depends on CH motion.

For effective cluster administration, cluster members must match CH's speed. Every time a krill updates its fitness function, it does so based on its own mobility and knowledge of the present and past positions of CH. This means that while bacteria optimize paths locally, krill help in exploring diverse routes globally. Evaluating each path's bacterial and krill fitness in terms of energy use and distance from CH.

Reproduction and selection mechanisms to favor routes and less beneficial paths may be replaced with variations of better-performing paths. The algorithm repeats the chemotaxis, reproduction, and swarm movement phases until the convergence criterion is satisfied or after a predetermined number of generations. As a result, power consumption is decreased when data is transmitted along the best route, and network lifetime is improved. Next, the cluster maintenance phase is carried out based on the threshold energy level of CHs, using the Geiger Muller Counter Auto extraction procedure (GMCAE) method.

Fig. 3 shows the architecture diagram for the suggested method, which indicates how the BFO chooses the CH depending on factors such as link quality (ETX), number of neighbors, residual energy, etc. For each node, fitness values are computed, and the CH with the highest fitness value is chosen. Chemotaxis will be used as the reproductive strategy after CH has been established and will be applicable to all clusters. Following the execution of KHO to transmit data packets to CH neighbor to neighbor, which is done with the aid of bacterial movements. Next, CH will set a threshold energy level, and then automatically extract the subsequent CH based on the parameters utilizing the Geiger Muller Counter Auto extraction technique (GMCAE) method to record threshold events when the condition is satisfied.

3.3. Cluster Head Selection based on the Fitness

According to (1) the maximum fitness value is designated as CH at best and the other nodes with fitness value lesser are CMs. The fitness function of all nodes is calculated as in (2). The residual energy at the sensor nodes is calculated using (3), where $E_{initial}$ is the initial energy of the node, $E_txt$is the energy consumed during data transmission, E_rxt is the energy consumed during data reception, and E_sleep is the energy consumed when the node is in an idle or listening state.

$$\frac{Best}{Worst} = \frac{Max(fit(i))}{Min(fit(i))} = \frac{CH}{CM}$$
(1)

$$fitness\ function = Max(Residual\ energy, ETX, number\ of\ neighbor\ nodes)$$
(2)

$$Residual = E_{initial} - (E\_txt + E\_rxt + E\_sleep)$$
(3)

The predicted transmission count is derived using a link's forward and reverse delivery ratios. The following (4) is a description of Exp_txc:

$$Exp_{txc} = \frac{1}{d_f * d_r}$$
(4)

Where d_f, also known as the forward delivery rate, is the delivery ratio from node A to node B, and d_r, also known as the reverse delivery rate, is the delivery ratio on the same link going from node B towards node A. In order to determine Exp_txc, each node transmits a packet to its partners once every predefined interval for the time known as CK_{Time}. All nodes are kept aware of the packet interval and the CK_Time values. The packets that the receiving nodes, or nearby nodes, received during the CK_Time are counted. The delivery ratio is then calculated by contrasting the quantity of packets actually received with the quantity anticipated during the CK_Time. The computed delivery ratio is subsequently piggybacked by the receiving node to the sender. The forward delivery rate for the transmitting node and the reverse delivery rate for the receiving node are represented by this delivery ratio. When a node possesses both the forward and reverse delivery rates of a link, it can calculate the Exp_txc value. In this way, each node defines the ETX values of the links connecting it to its neighbors. By using the positions of nearby nodes as a guide, bacteria and krill positions are modified, as follows in (5).

$$P_i(t) = P_i(t-1) + \frac{P_x(t) - P_i(t)}{Distance}$$
(5)

Based on a node's distance from the BS, the fitness value of that node is determined as in (6). Using the formula, the separation between two nodes or the node from the base station is determined by (7).

$$fv = dis(i,j) + dis(j,bs)$$
(6)

$$dis(i,j) = \sqrt{(x_1 - x)^2 + (y_1 - y)^2}$$
(7)

Fig. 4 shows the proposed architecture's flow diagram, which demonstrates the fundamental WSN configuration and initial cluster formation phase using bacterial foraging optimization technique. Higher fitness to choose the CH is based on residual energy, link quality (ETX), transmission power, and other factors. Once the preferred best node as CH has been selected, the

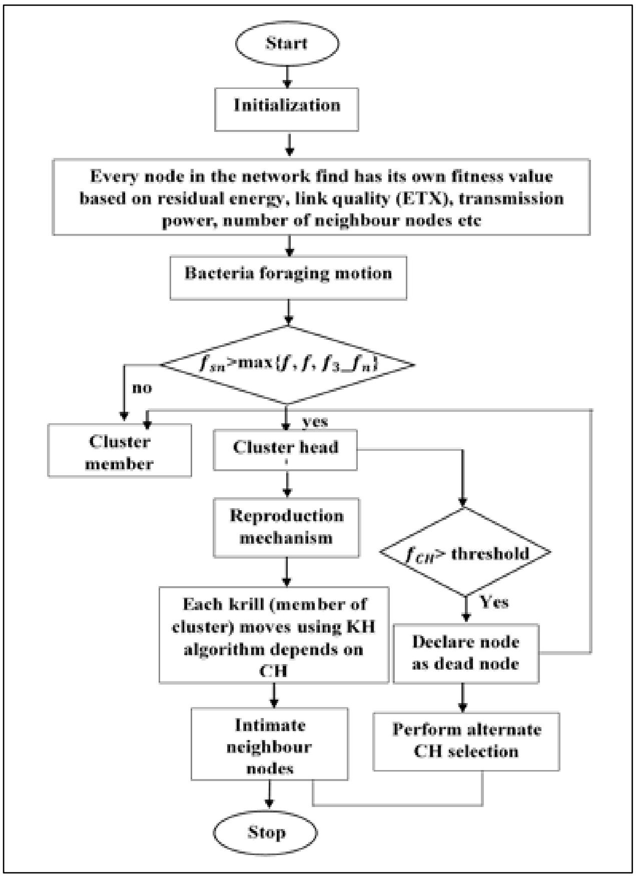

Fig. 4. Flow diagram of the proposed architecture

reproduction mechanism is applied, and each CH interacts with the other CHs through chemotaxis.

4. Results and Discussion

4.1. Simulation and Implementation

The real-time scenario of WSN with a different number of nodes is simulated in the Contiki OS Cooja platform. A scenario generated with 50 sky mote sensors is shown in Fig. 5. The collected data has been pre-processed in the Wireshark tool. The generated data set is used for implementing the algorithm in Python platform. The proposed BKHO method has been implemented in Python 3.12, with system configuration being Intel(R) Core (TM) i7-3770 CPU @ 3.40GHz, 8.00 GB RAM, and 64-bit operating system with x64-based processor.

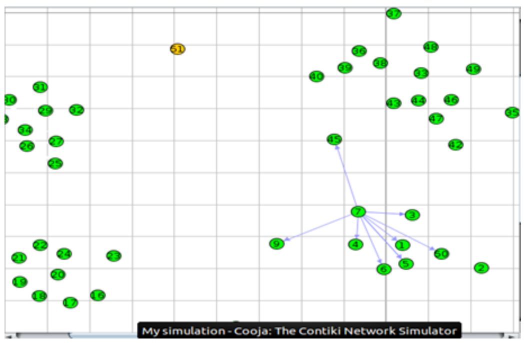

Fig. 5. A WSN scenario generated with 50 sensor nodes in the Cooja simulator

4.2. Performance Metrics

The proposed BKHO is evaluated against three existing algorithms: Low Energy Adaptive Clustering Hierarchy (LEACH), Modified Gravitational Search Algorithm-Optimal Relay Selection (MGSA-ORS), and Fuzzy-based Energy Aware Routing Mechanism (FEARM).

The performance is analyzed using the following different metrics: Propagation Delay, throughput, Energy Consumption.

4.2.1. Delay

Latency at the nodes and the transmission latency should be minimal. The following characteristics are used to determine delay: Expected transmission rate; propagation lag; and communication lag across the network Here, the WSN's two nodes' time delay is calculated using (8) below, where ETC_n indicates the predicted transmission count for the n^{th} node and TD signifies the transmit delay at the node, and PD_n indicates the nth node propagation delay.

$$D(n) = \sum_{i=1}^{n} ETC_n(TD + PD_n) \quad (8)$$

4.2.2. Throughput

The ratio of all received packets to time is referred to as throughput as referred in (9). This parameter guides us to monitor the performance of the network to successfully transmit data packets.

$$Throughput = No.of.Packets\ received/time \quad (9)$$

4.2.3. Energy Consumption

The total quantity of energy utilized by the CHs and member nodes which is given in (10), where CH_E stands for the amount of energy used by the CH in the network and S_E stands for the energy used by the member node.

$$E_T = [\sum_{n=1}^{l} CH_E(N) + \sum_{m=1}^{kn} S_E(MN)] \quad (10)$$

The amount of energy that is still present in the active set of nodes after data transmissions, which is represented as in (11), where $E_{initial}$ refers to the initial energy level of a sensor node and $E_{Consumed}$ refers to energy utilized is given below.

$$RE = E_{initial} - E_{Consumed} \quad (11)$$

4.3. Performance Analysis

End-to-end delay is a metric for evaluating network performance based on time duration required for data transmission. The higher latency reduces the network's overall performance. As seen in Table. 1, the suggested model outperforms the benchmark models. The simulation's findings demonstrate that the latency is substantially less than that of earlier methods.

Table 1. Propagation Delay of the Proposed Model vs. other Models in ms

No. of Nodes	LEACH	FEARM	MGSA	Proposed Model
100	0.36	0.48	0.22	0.04
200	0.37	0.51	0.24	0.05
300	0.36	0.5	0.24	0.08
400	0.39	0.52	0.26	0.08
500	0.41	0.52	0.29	0.09

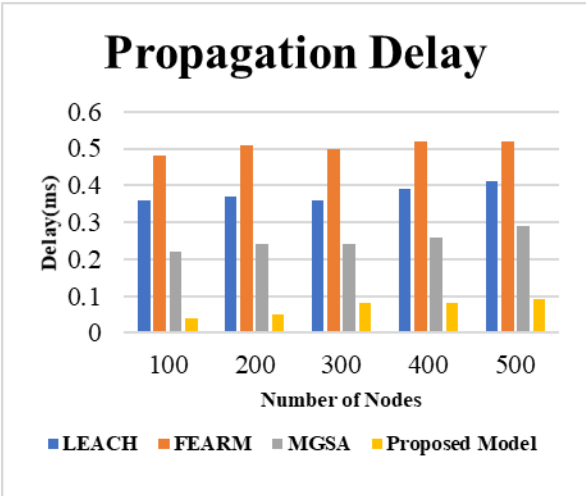

Fig. 6. Comparison graph of the proposed model with other models for performance delay

During the local exploration by bacteria, each bacterium makes use of all local regions' information in the cluster, finding the node with more resources as CH, the highest fitness depending on factors such as transmission power, link quality, and residual energy. Then, by forming a ring around the promising paths that the bacteria have discovered, KHO (global exploration) exhibits aggregation behavior. The krill population can consequently concentrate on the overall best routes. Every krill in the cluster moves around and communicates with CH. Next, CH will set a threshold energy level, and then automatically extract the subsequent CH based on the parameters utilizing the Geiger Muller Counter Auto extraction technique (GMCAE) to record threshold events when the condition is satisfied. For the respective number of nodes 100, 200, 300, 400, and 500, the suggested model gave extraordinarily low values of delay as 0.04ms, 0.05ms, 0.08ms, 0.08ms, and 0.09ms for various simulation times. Fig. 6 shows a graph comparing the proposed model and alternative models for performance delay, demonstrating that BKHO, where each bacterium uses all of the cluster's local areas to seek the CH with the highest fitness based on transmission power, connection quality, and residual energy, outperforms existing models and that the recommended model is superior to them.

As a result, the cluster's krill members focus on the overall best routes, which generally avoid the promising routes that the bacteria have found. In the cluster, every krill moves and interacts with CH. The next step is for CH to define a threshold energy level, and when the condition is reached, it will automatically extract the succeeding CH based on the parameters and record threshold events using the Geiger Muller Counter Auto Extraction Approach.

Table 2. Throughput in kb/s of the Proposed Model vs. Other Models

No. of Nodes	LEACH	FEARM	MGSA	Proposed Model
100	87	90	81	150
200	91	96	82	157
300	90	94	82	149
400	89	95	82	159
500	89	95	81	250

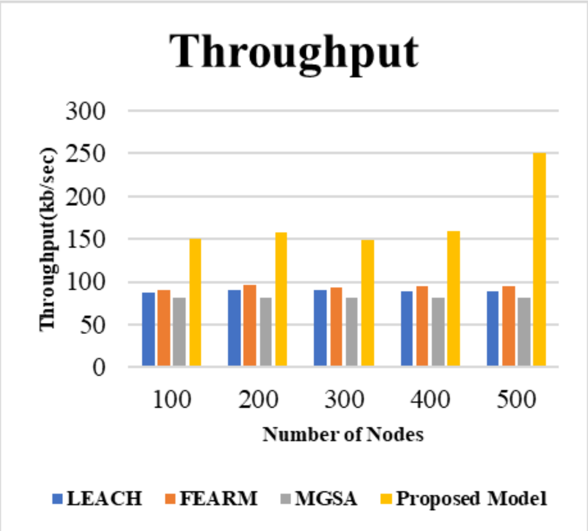

Fig. 7. Comparison graph of the proposed model with other models for Throughput

In this context, throughput refers to the rate of data delivery. Data transmission is usually impacted by a variety of circumstances, which can be reduced by adopting an efficient CH selection. Table. 2 demonstrates through the throughput values that the suggested model outperforms the existing models. The findings show that the throughput is substantially higher than it was for earlier techniques. The BKHO approach employs swarm optimization to determine the best optimal path and select CH.

The member's cluster then sends those packets to CH, which gathers and sends the compiled data packets to the BS. The proposed approach led to high throughput values of 150, 157, 149, 159, and 250 with the corresponding no. of nodes as 100, 200, 300, 400, and 500 respectively.

Fig. 7 shows a comparison graph for throughput analysis between the suggested model and other models, demonstrating that the suggested model outperforms existing models Because of BKHO, each bacterium searches its local areas of the cluster for the CH that has the highest fitness based on transmission power, connection quality, and residual energy, while the other members of the cluster (krill) focus on the overall best routes, which typically avoid the promising routes that the bacteria have discovered.

The member's cluster then sends these packets to the CH, which gathers and sends the data packets that have been aggregated to the Base Station (BS). Better-fit bacteria are more likely to reproduce during the reproduction phase, transferring their genetic material to the next CH through chemotaxis. If CH maintains a threshold level and it is met, GMCAE will automatically switch to another CH.

Table 3. Residual Energy in J of the Proposed Model vs. other Models

No. of Nodes	LEACH	FEARM	MGSA	Proposed Model
100	41.3	58.9	26	19.14
200	45.6	59.6	31.2	28.71
300	52.6	61.1	33.6	37.7
400	58.0	61.5	41	47.34
500	60	61.9	42.5	57.17

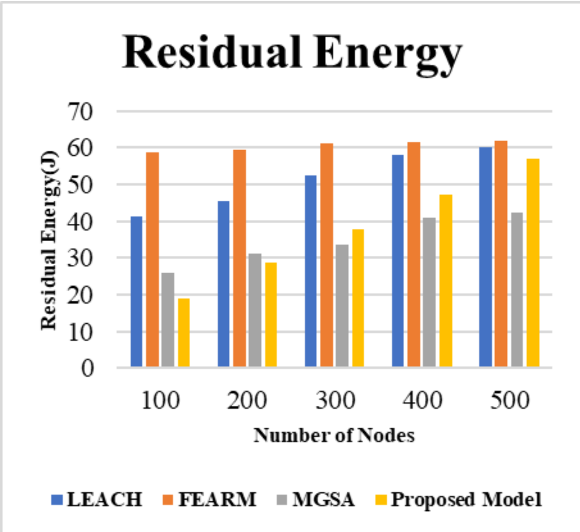

Fig. 8. Comparison graph of the proposed model with other models for Residual Energy

To engage in network operations, sensor nodes need energy and if energy usage is kept to a minimum, network longevity will be increased. It takes a lot of energy to transmit data. Table. 3 shows that the suggested model outperforms the existing models. The energy consumption is substantially lower than it was for prior approaches, per simulation duration. To find the best optimal path and choose CH, the BKHO technique uses swarm optimization, while each bacterium searches throughout the cluster's local areas for the CH that has the highest fitness based on transmission power, connection quality, and residual energy.

The krill focuses on the overall best routes, which typically avoid the promising routes that the bacteria have found. In the event that CH maintains a threshold level and it is reached, GMCAE will immediately switch to another CH. With the corresponding number of nodes as 100, 200, 300, 400, and 500, the suggested model resulted in lower energy consumption values of 19.14J, 28.71J, 37.7J, 47.34J, and 57.17J. Fig. 8 shows a comparison graph for energy consumed between the suggested model and other models, demonstrating that the suggested model outperforms existing models due to BKHO selecting the CH with the highest fitness value.

5. Conclusion

Energy efficient WSN routing technique is proposed in this research paper. To increase the network lifespan for WSNs, the proposed BKHO-GMCAE algorithm relies on the optimization of clustering and routing processes using the critical dependent parameters. In BPO, where each bacterium utilizes all local locations in the cluster to find the most resources as CH, the highest fitness is determined by criteria including transmission power, link quality, and residual energy. Better-fit bacteria are more likely to reproduce during reproduction, passing on their genetic material to the following CH via chemotaxis. Then, KHO (global exploration) aggregation behavior is used to explore the potential pathways that the bacteria have found. As a result, the krill population can concentrate on the overall optimal paths. Due to this, power consumption is decreased and data is transmitted along the best route, and the network lifetime is also improved. The experimental results show that the proposed BKHO-GMCAE framework performs better than LEACH, MGSA-ORS, and FEARM. On average, the proposed work is better than other algorithms by 7.44 times lower propagation delay, 1.59 times more throughput, and 1.84 times more residual energy.

Author contributions

Aruna Reddy H: Conceptualization, Methodology, Writing-Original draft preparation, Software. **Shivamurthy G:** Data curation, Software, Validation. **Rajanna M:** Investigation, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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