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Energy Oriented Multi-Objective Route Optimization Using Donkey Smuggler Optimization in Cluster Based Wireless Sensor Networks

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ABSTRACT

This research introduces an Energy oriented Multi-objective Donkey Smuggler Optimization Algorithm (EM-DSOA) for cluster-based routing in Wireless Sensor Networks (WSNs). The proposed method aims to enhance energy efficiency and network lifespan by optimizing cluster head selection and routing. EM-DSOA utilizes a two-phase approach: a non-adaptive Smuggler algorithm to find potential solutions and an adaptive Donkey algorithm for optimal path selection. The method employs multi-objective fitness functions considering energy, communication cost, cluster head balancing factor, and node degree. K-Means clustering is used for initial node grouping. The performance of EM-DSOA is evaluated using metrics such as energy efficiency, end-to-end delay, packet loss, and network throughput. Simulation results demonstrate that EM-DSOA outperforms existing techniques like Multi Weight Chicken Swarm Based Genetic Algorithm (MWCSGA) and Adaptive Hybrid Cuckoo Search and Grey Wolf Optimization (AHCS-GWO). The proposed method achieves higher energy efficiency (99.13%), lower end-to-end delay (17.04 ms for 20 nodes), reduced packet loss, and improved network throughput (1370.34 Kbps) compared to existing approaches. EM-DSOA's effectiveness in optimizing cluster-based routing contributes to prolonging the overall lifespan of WSNs.

1. INTRODUCTION

WSNs are referred as combination of millions of sensor nodes which are dispersed in the environment for the purpose of sensing, assessing and receiving data. The nodes of WSN are cost efficient and have high capability to process and receive data [1]. The nodes present in WSN are positioned in a randomized distribution with a small autonomous device to detect the structure of the phenomenon in the physical conditions [2, 3]. WSN is widely employed in various applications, including manufacturing, national defense, traffic management, disaster avoidance, environmental monitoring, and health care applications. Even though the WSN has countless applications, it still has some limitations. These include limited transmission range, limited battery power, and limited storage. The non-rechargeable battery-powered sensor nodes will not last very long. Energy efficiency is therefore seen as WSN's primary goal. Implementing energy efficiency in the sensor nodes of WSN is a challenging task due to the presence of energy constrained sources which is operated independently for long time duration. Though, the non-rechargeable nodes can be activated by replacing the batteries which is a cost consuming process and has limited energy autonomy [4]. So, the base stations act as a significant component to send the data and process it.

Various energy efficient protocols are developed that offer an appropriate utilization of energy while transmitting the data packets. But the intruders present in the network leads to higher energy consumption when the data is transmitted for longer distance [5]. Considering the structure of the network, routing protocols are categorized into two classes such as flat routing protocols and cluster-based routing [6, 7]. The development of energy-efficient routing protocols aims to provide a suitable use of energy during packet broadcasting. Because they eliminate the energy waste that happens during collisions, overhearing, and idle listening, cluster-based routing protocols perform better than non-clustering protocols

The clustering-based routing is highly responsible to transmit data without energy loss and achieve the state of energy efficiency. In hierarchical design, the nodes with high energy capabilities are utilized to transmit information and the low energy nodes operates near the region of target [8]. The clusters are generated from splitting the sensors and one of the nodes present in the cluster is chosen as Cluster Heads (CHs). The CHs are responsible to gather data from the members of clusters and helps in transmitting data to the Base Station (BS) [9]. It is hard to select the CH from the applicable nodes of clusters due to its high energy consuming activity. So, replacement must be done at proper interval to maintain effective performance. But it is a time-consuming process and leads to lack of energy efficiency [10, 11]. Optimal clustering technique switches the one-hop communication among CH and sink node to alleviate the rate of energy consumption and enhance the network's life time [12]. Additionally, routing plays a critical role to ensure a secured end-to-end transmission of data packets in WSNs. Energy awareness and minimized route maintenance is considered as the major requirement in the process of data transmission [13, 14]. So, this research focused in providing an energy-efficient cluster-based routing in the nodes of WSNs using optimization technique.

The paper highlights the importance of energy optimization in WSNs, as sensor nodes operate on battery power and are often located in remote areas. The energy-efficient cluster-based routing technique using an EM-DSOA. This algorithm is inspired by real-world transportation behavior, including route searching and selection performed by donkeys. The technique aims to improve energy efficiency and enhance network lifespan in WSNs. The main contributions of the research:

1. Enhancing energy efficiency through K-Means clustering and optimal CH selection using EM-DSOA.
2. Making precise predictions of optimal paths to achieve energy efficiency with minimal data packet loss during transmission.
3. Performing energy-efficient routing using EM-DSOA by considering fitness parameters such as energy, communication cost, CH balancing factor, and node degree. The work in the context of existing research on energy-efficient protocols in WSNs, highlighting the need for more advanced optimal route selection with minimal data packet loss.

2. LITERATURE SURVEY

The primary operational sustainability issue with WSN pertains to its limited energy resources. Due to their high degree of data transfer flexibility, wireless communications have seen substantial exploitation in recent years. Using air as a medium, wireless communications offer mobility and connectivity. Wireless sensor networks are the most widely used of the numerous wireless technologies currently in use. From an energy and computational perspective, they need an effective communication setup, which can be ensured by creating the best possible algorithms for communication protocols. Recent years have seen a large variety of energy-efficient clustering methods for WSNs proposed depending on the routing operations and network architecture.

Sharma et al. [14] have introduced a flower pollination-based algorithm (FPSTERP) for stable energy efficient clustering. The algorithm main focuses on energy conservation in each sensor node by using FPA-based CH selection energy optimization clustering. One drawback of FPSTERP is that, when compared to competing algorithms, it takes a little longer to generate the data transmission process from a node to BS.

Based on the Yellow Saddle Goatfish Algorithm (YSGA), Rodriguez et al. [15] introduced a unique energy-efficient clustered routing protocol. The major goal of the designed protocol was to extend the network lifespan by reducing the system's energy usage. The data transmission and reception process, which is dependent on packet size and distance, causes the energy loss in the network. With the introduction of the routing protocol, this YSGA is used to select the best cluster head and the quantity of cluster heads. The YSGA technology was employed to decrease the energy consumption. As a result, the network's longevity increased. Nevertheless, the protocol that was built could only function in offline mode.

Senthil et al. [16] have introduced an optimized Orphan – LEACH (O-LEACH) method to facilitate the formation of clusters which consumes minimal amount of energy with enhanced network lifespan. The orphan node produced by the introduced method retain adequate energy to provide better network coverage. The Orphan –LEACH method is optimized using hybrid of Simulated Annealing with Lightning Search Algorithm (LSA) (SA-LSA), and Particle Swarm Optimization with LSA (PSO-LSA) algorithm. This hybrid optimization technique helps to choose an optimistic path and reduce the consumption of energy by enhancing the lifetime of WSN. However, Orphan – LEACH method is not opted for multi-objective problems.

Malisetti and Pamula [17] have introduced an improved cluster-based routing method using Moth Levy adopted Artificial Electric Field Algorithm (ML-AEFA) and Customized Grey Wolf Optimization (CGWO) algorithm. Here, the optimal clusters are selected using ML-AEFA algorithm and the data is transmitted using CGWO algorithm. Degree of the nodes, distance among sensor nodes, energy was considered as a major parameter to evaluate the performance while selecting optimal cluster heads. The introduced cluster-based routing method transmit a greater number of packets to the base stations and attained high convergence rate. However, the proposed technique does not consider death rate of the nodes.

Ajmi et al. [18] have developed a MWCSGA to perform energy efficient clustering in the nodes of WSN. In MWCSGA, crossover technique is used to choose the best individuals and the best fitness function diversity is evaluated by using mutation process. There are three phases employed in MWCSGA such as selection of CHs, formation of clusters and collection of data. The MWCSGA employed data aggregation process to remove the recurrent nodes and helps to enhance the performance of optimization algorithm. However, delay occurs in the proposed MWCSGA when it is implemented with large scale operations.

Selvi et al. [19] have introduced a cluster-based routing algorithm on the basis of gravitational approach to deliver an optimal route for effective clustering and routing. Additionally, fuzzy based interpretation system was utilized to select the appropriate cluster heads. The routes selected using the fuzzy based method offers better lifespan of the nodes of WSN and helps to improvise the overall efficacy of the introduced algorithm. However, there was lack of communication among the nodes due to presence of unoptimistic clusters heads.

Arunachalam et al. [20] have introduced a Spider Monkey Optimization based energy efficient routing protocol to select the CHs. The transmission of data occurred from the node at source to the node at destination by utilizing the relays and CHs, that helps in reducing the energy consumption in WSN. Additionally, Classy-Bellman Ford algorithm is utilized in detecting the optimal path with short distances and the security is maintained by the mechanism of data aggregation. The introduced technique attains better convergence rate with minimal consumption of energy. However, the Spider Monkey Optimization based routing technique is not efficient for multi-objective problems in WSN.

Rangappa and Dyamanna [21] have introduced AHCS and GWO algorithm to perform energy efficient cluster-based routing in hybrid wireless sensor networks. Here, AHCS was used to enhance the levy flight technique and population development approach of cuckoo search algorithm. Moreover, inertia weight and the parameter adjustments are performed using GWO algorithm. The AHCS with GWO transferred packets with less consumption of energy and balance the energy level clusters by maintaining optimal CHs. However, the minimization of running time in AHCS with GWO technique may enhance the overall performance in detecting the optimal route.

Saoud et al. [22] proposed in order to find the best selection of cluster head (CH) by taking in consideration the energy at each sensor node, based on Firefly Algorithm. They compared the proposed scheme with LEACH, EAMMH, SEP, E-SEP, BRE, NEAHC and WEB protocol. Experimental results show that the proposed scheme yields better performance than the compared routing protocols in terms of better energy consumption and packet delivery between sensor nodes and base station. Results obviously prove that the proposed scheme could improve the WSN lifetime.

Wang et al. [23] created a clustering algorithm that combines an enhanced artificial bee colony (ABC) algorithm to increase the network's longevity and energy efficiency. WSNs utilize a lot of energy since their clusters have to do a lot of work. As a result, choosing the best cluster heads for WSN becomes crucial. Here, the fuzzy C-means clustering was optimized using the ABC algorithm, which implemented the best clustering technique. The polling control technique based on busy/idle nodes was introduced into intra cluster communication to decrease the energy consumption and improve the throughput of the network. Nevertheless, the technique that was devised could only be applied in stationary networks.

It is observed that the existing techniques face challenges such as optimal selection of fitness function parameters and rely of single hop data transmission. While these advancements present promising solutions, challenges remain in balancing energy efficiency with other performance metrics, such as latency and reliability, which may require further exploration of hybrid optimization techniques. In order to overcome these constraints, a more advanced optimal route selection with minimal loss of data packets is necessary. Energy-oriented multi-objective route optimization in cluster-based wireless sensor networks (WSNs) can significantly enhance energy efficiency and network longevity. The integration of Donkey Smuggler Optimization (DSO) with existing clustering techniques can yield substantial improvements in energy consumption and routing efficiency.

The proposed work facilitates the selection of Optimal CH selection and identify the optimal path from source node to destination node using the proposed EM-DSOA.

3. EM-DSOA METHOD

The proposed work utilizes EM-DSOA to develop the cluster-based routing to reduce the energy consumption and increase the lifespan of network. The position of the sensors, selecting the energy efficient CHs and generation of cluster-based routing is the important process while considering the implementation of EM-DSOA in selecting an optimal path. This method has three important phases named Clustering, CH Selection and Route Path Generation. The block diagram for the proposed EM-DSOA method is represented in Figure 1.

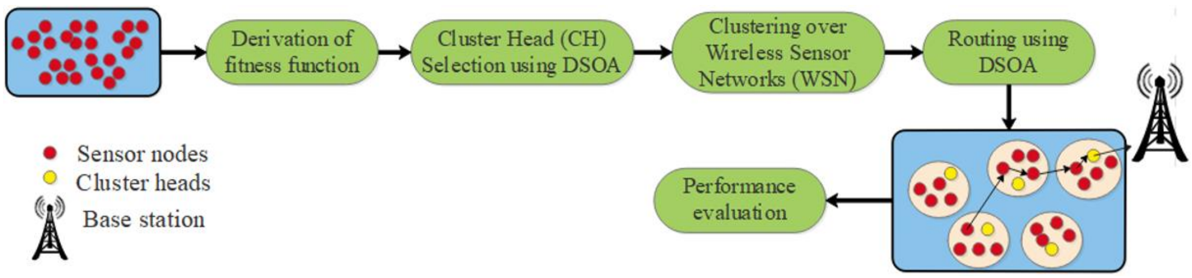

Figure 1. Block diagram for EM-DSOA method

The selection of Optimal CH and route is done using the proposed EM-DSOA to enhance the energy efficiency and improve the lifetime of WSN. The improvisation in the delivery rate is performed by optimizing EM-DSOA with the multi-objective fitness parameters such as energy, Communication cost, CH balancing factor and degree of the nodes.

3.1 K-Means clustering technique

The initialization of sensors is the foremost phase where the sensor nodes are deployed in a random manner over the large-scale networks like WSN. The nodes clustered using K-Means clustering technique, which divides the sensors into k number of clusters The K-Means clustering is mainly depend on calculating the Euclidian distance between the nodes. After clustering the network, then from each cluster optimal CH is selected using EM-DSOA

3.2 EM-DSOA method

In this phase, EM-DSOA is utilized to select the optimal nodes known as CHs. The optimal selection of CH helps to minimize the energy consumption rate and helps to enhance the lifespan of network. The major objective of EM-DSOA method is to achieve a proper fitness by evaluating energy, Communication cost, CH balancing factor and degree of the nodes.

3.2.1 Multi objective fitness function for DSOA

EM-DSOA uses Multi Objective fitness function to select optimal CH with high residual energy. The fitness function considers parameters like residual energy, communication cost, balancing factor, and degree of nodes.

(1) Energy

Energy is one of the most significant fitness parameters to be considered in cluster-based method. According to the proposed technique, the allotment of CHs plays an important role in aiding overall efficiency. Whenever the data is transmitted in nodes with poor efficiency, it consumes more energy than the normal nodes. In the process of suggesting an effective CHs, the proposed technique considers the ratio of initial energy. Moreover, the proposed method makes the nodes energy dependent and helps the nodes to acts as an effective CH. The formula to detect the energy ratio in the fitness function is represented in Eq. (1).

$$f_1 = \sum_{i=1}^{n} \frac{E_o}{E_o - S(i).E} \tag{1}$$

where n is known as the total number of nodes and E_o is the initial energy of the node. $S(i).E$ denoted the node's energy at the present state. The ultimate aim is to lower the energy consumption of nodes to maintain a minimal energy consumption. Whenever the range of energy is reduced, the energy present in the node remains high. Selecting the higher residual energy nodes helps to enhance the performance and lifespan of the network. The direct impact is created whenever the node with minimal energy is selected as CHs.

(2) Communication cost

During the process of data transmission, the minimal power is utilized which is directly proportionated to the squared value of distance between the candidate nodes and the source nodes. The communication cost is evaluated using Eq. (2).

$$f_2 = \frac{D_{Avg}^2}{D_0^2} \tag{2}$$

where the average distance present among the optimal nodes and the neighboring nodes is represented as D_{Avg} and the radius of the transmission path is represented as D_0.

(3) CH balancing factor

The randomized sensor node organization in the network leads to formation of both bigger and smaller clusters which leads to imbalance in the network. So, CH balancing must be considered as a significant parameter to balance the energy consumption among the nodes. Eq. (3) denotes the formula to evaluate the balancing factor of CHs.

$$f_3 = \sum_{j=1}^{i} \frac{n}{i} - l_j \tag{3}$$

where the total number of alive nodes are denoted as n and the total number of cluster heads are represented as i. The total number of sensor nodes present in the cluster is represented as l_j.

(4) Degree of the nodes

The node degree is the count of non-cluster head candidates who fits to the corresponding mobile nodes. Whenever there is minimal number of mobile nodes, the persistency occurs in a longer time duration. So, the node with minimum node degree should be considered and the node degree can be minimized using Eq. (4).

$$f_4 = \sum_{i=1}^{m} I_i \tag{4}$$

Performing individual minimization leads to incompatibility so, it is better to combine the overall objectives utilizing weighted sum method. Additionally, every fitness parameter has different objective value so, normalization must be performed for every individual objective by assigning the weights as $\beta_1, \beta_2, \beta_3, \beta_4$ for each fitness function. Eq. (5) represented below helps to normalize the individual objectives.

$$N = \frac{f_i - f_{min}}{f_{max} - f_{min}} \tag{5}$$

where the normalized value which lies in the range [0,1] is represented as N and the function value is denoted as f_i. The minimal and the maximal value is represented as f_{min} and f_{max} respectively.

$$F = \beta_1 \times f_1 + \beta_2 \times f_2 + \beta_3 \times f_3 + \beta_4 \times f_4 \tag{6}$$

The formula to evaluate the overall fitness function is represented in Eq. (6).

3.2.2 Working of EM-DSOA based CH selection

EM-DSOA is initialized with a set of candidate nodes which are need to be chosen as CHs. The ultimate aim of the research is to detect an optimal path to transmit the data packets with minimum energy consumption. EM-DSOA is utilized in this research to detect the optimal path by considering the fitness function parameters such as energy, Communication cost, CH balancing factor and degree of the nodes.

EM-DSOA algorithm selects the CHs in two stages. A non – adaptive Smuggler algorithm finds the probable solution (i.e., location of CH). The smuggler algorithm verifies all the probable routes from the source to destination to effectively transmit the data without any intruders. In the part of smuggler algorithm, the fitness function is evaluated to detect the best path which helps the donkey to transmit the data effectively. The fitness of the smuggler algorithm is evaluated based on parameter such as energy, communication cost, balancing fact of cluster head and node degree. The smuggler algorithm determines the parameter for each solution by computing the fitness value using Eq. (1) as follows,

$$f(X_i) = \frac{\sum_{j=0}^{J} X_{ij} + \prod_{j=0}^{J} X_{ij}}{\sum_{z=0}^{Z} X_{iz} + \prod_{z=0}^{Z} X_{iz}} \tag{7}$$

where the probable solutions are denoted as X_{ij}, the number of possible solutions is represented as i. The number of parameters for each probable solution is denoted as j and the inversely proportional possible solutions as denoted as z. The parameters hold by the numerator and denominator is proportional directly and indirectly in a corresponding manner. The fitness solution (i.e., best cluster head) obtained from Eq. (7) will be organized in a group on the basis of their fitness value. Thus, the best function will be set up and transmitted to the donkey.

The donkey algorithm to is an adaptive routing algorithm that is used to provide better results in consistent traffics. To avoid Congestion and delay due to traffic, a choke packet is used to update the routing table, when the update is made in the routing table, the best solution will be updated in it. Whenever the choke packet lacks its fitness, the following steps are need to be followed:

Run: Select the path to find better solution and re-compute the best probable fitness value to upgrade the best solution. When the best solution is distinguished in non-adaptive phase is considered as worst, the drop is made in the non-adaptive phase to choose a best solution based on new changes.

Face and suicide: The best solution adopted in the first stage of the algorithm is no longer available due to the changes which affects the fitness. The solution of the first stage is dropped till it retains the ideal state and the solution in the second stage is utilized as a best solution. The best solution in the second stage is determined using the formula represented as follows:

$$best_{suicidesolution} = f(X_i) - f(best_{solution}) \tag{8}$$

where the number of probable solutions is denoted as i.

There is minimal fitness obtained in the solution populations so, the fitness of best solution is neglected from the solution of all probable solutions and the variation among them is considered as the newly obtained best solution.

Face and support: Whenever the overloading occurs in the best solution which was initiated by smuggler, the dropping is avoided in the solution by assigning the best solution of the second phase till the overloading is removed. In other words, two channels are utilized to transmit and receive the data to avoid re-evaluation of probable fitness solutions in the population. The next best solution used to avoid the overloading until the prior solution retains its normal form and it can be computed using Eq. (9) and the best support solution is evaluated using Eq. (10).

$$secondbest_{solution} = f(best_{solution}) - f(X_i) \tag{9}$$

$$best_{supportsolution} = best_{solution} + secondbest_{solution} \tag{10}$$

The second-best solution will be determined by Eq. (9) which is obtained by neglecting the fitness of the all-probable solutions. After this, Eq. (10) will be utilized to combine the best solution that uses two path ways to perform a single task.

The iterative process involved in EM-DSOA method which helps to find an optimal route to transfer the data with minimal energy consumption is described in the following steps,

-The process of reading takes place in the input data within the decision variable range of n1 and n2. Where, n denotes the dimensional solution of the matrix.

-The smuggler phase is initiated to create solutions in a random population for row =1 as n1 and column = 1 as n2.

The parameters of the random solution are created by using Eq. (11).

$$Parameters(row, col) = rand([decision\ variable\ range\ ], n1, n2) \tag{11}$$

-Consideration is made as $e = 1$ for n1 and the fitness value is evaluated for each solution based on Eq. (1), then the population is updated for all the probable solutions to set the best solution. The obtained best solution is passed to the phase of donkey algorithm.

-Compute the variation occurred while computing the fitness value. If any variation occurs, the fitness of the best solution will be probably low.

-Then according to the behavior of the donkey, the best solution is updated using the Eq. (8).

-After this, the solution with second best fitness value is considered as the best solution which is used to detect the optimal route for transmission of data packets.

-The solution with second best fitness supports the best solution in the population without updating it for population fitness which is represented in Eqs. (9) and (10).

3.3 EM-DSOA based routing

In the process of routing, the dimensions of every population is similar to cluster head quantity. This research aims to select an optimal route from every CHs to their corresponding Base stations. In DSOA, the route is created among the CH at the source and BS at the destination point. Moreover, the similar fitness functions used in cluster head selection is considered for optimal routing.

3.3.1 Initialization

In the process of routing, EM-DSOA presents the path to forward the data packet from Cluster head to the BS. The dimensional value of each solution of EM-DSOA is equal as the number of CH present in the network. Additionally, an extra position is included in the side of base station. Every best solution obtained from EM-DSOA algorithm is altered by a capable transmitted route among the node at source and destination. The evaluation of each probable solution is similar to the CHs present in their respective route of transmission.

3.3.2 Selection of optimal route

The proposed EM-DSOA considers the similar fitness parameters like energy, Communication cost, CH balancing factor and degree of the nodes which is utilized in cluster head selection to detect an optimal route for transmitting the data. The node at the source perform communication through Route Requests (RREQ) that gets transmitted to the nodes which is present in the neighboring position. Moreover, reverse routing is performed to transmit data to the source at the subsequent node. When the optimal path for routing is initialized, the CH at the source gathers data from the neighboring nodes. After this process, the transmission of data is initiated through the wireless sensor networks.

The overall flow and structure of the proposed EM-DSOA methodology

1. Initialization phase:

-Deploy sensor nodes randomly in the WSN.

-Use **K-Means Clustering** to divide the network into clusters.

2. CH selection using EM-DSOA:

-**Smuggler algorithm** (non-adaptive phase):

•Explore possible solutions (potential CH locations).

•Evaluate fitness based on energy, communication cost, CH balancing factor, and node degree.

-Donkey algorithm (adaptive phase)

•Use the best solution (CHs) for data transmission.

•Update routes dynamically based on fitness.

3. Route path generation:

-Optimal route from CH to BS is determined.

-Transmission of data packets from source nodes to BS through selected CHs.

4. Fitness parameters:

-Energy, communication cost, CH balancing, and node degree are used in both clustering and routing phases.

5. Data transmission and network optimization:

-Minimize energy consumption and improve network lifespan by selecting optimal routes.

The Donkey Algorithm receives the best solution found by the Smuggler Algorithm, but unlike the Smuggler, it can adapt to changing conditions during the transmission phase. If the selected path becomes inefficient (e.g., due to traffic or energy depletion), the Donkey Algorithm can adjust the route or switch to a backup path found by the Smuggler.

-Smuggler Algorithm explores all possible routes finds optimal path based on fitness.

-Donkey Algorithm uses the optimal path for adaptive data transmission adjusts dynamically to optimize performance in real-time. The Smuggler Algorithm focuses on the search and exploration of solutions, while the Donkey Algorithm handles the execution and adaptive optimization of data transmission over the selected routes.

4. RESULTS AND DISCUSSION

The simulation of EM-DSOA method is performed using Network Simulator version 2.34. Generally, 2.34 has two different languages like TCL at frontend and C++ at back end. The Network animator is used as a tool to provide the output node of WSN. The specifications related to simulation and their parameters of the proposed EM-DSOA method is represented in Table 1.

Table 1. Simulation specifications

Parameter	Value
Simulator	NS-2.34
Area	1000m × 1000m
Number of nodes	20, 40, 60, 80, 100
Initial energy	0.5J
Mac protocol	IEEE 802.11
Traffic source	Constant Bit Rate (CBR)
Antenna model	Omni-Directional Antenna
Network interface type	Wireless Phy
Simulation time	100 ms
Optimization algorithm	EM-DSOA
Clustering algorithm	K-Means Clustering
Fitness parameters	Energy, Communication Cost, CH Balancing Factor, Node Degree
Performance metrics	Energy Efficiency, End-to-End Delay (EED), Packet Loss Ratio (PLR), Network Throughput
Comparison methods	MWCSGA, AHCS-GWO

4.1 Performance analysis

The performance of the proposed EM-DSOA is calculated using energy efficiency, EED, packet delivery ratio and network throughput. In this research, the overall efficiency of EM-DSOA is related with existing MWCSGA [18].

4.1.1 Energy efficiency

Energy efficiency is defined as the ratio among the consumed amount of energy and the total amount of energy utilized in the input. The energy efficiency can be evaluated using the formula represented in Eq. (12).

$$\text{Energy efficiency} = \frac{\text{Total amount of consumed energy}}{\text{Total amount of input energy}} \times 100\% \quad (12)$$

The results from the Figure 2 show that the proposed EM-DSOA achieved better energy efficiency when compared with the existing MWCSGA. For instance, the energy efficiency of the proposed EM-DSOA ranges from 91.73% to 99.13% but the energy efficiency of the existing MWCSGA ranges from 20% to 80%. The node degree and the CH balancing factor is utilized to detect the shortest path for data transmission. Thus, the usage of shortest path requires minimum energy and helps to attain the state of energy efficiency. Moreover, the consideration of optimal fitness function helps to enhance the efficiency of overall network. The comparison graph to calculate the energy efficiency of EM- DSOA is represented in Figure 2.

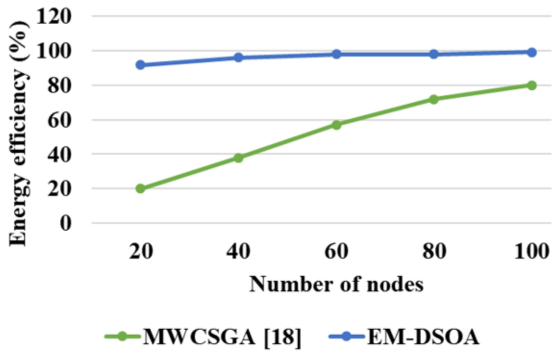

Figure 2. Graphical representation for energy efficiency

4.1.2 EED

The EED is defined as the average time required to transmit the data over the wireless sensor networks and the value of EED can be computed using Eq. (13).

$$\text{EED} = \frac{\text{Total time required to transmit data packet in BS}}{\text{Total count of data packets received by BS}} \quad (13)$$

The results from Figure 3 show that the proposed EM-DSOA achieved minimum delay when compared with MWCSGA. The EED of the proposed EM-DSOA ranges from 11.22 ms to 17.04 ms whereas the delay of the MWCSGA lies among the range of 19ms to 100ms. The proposed EM-DSOA achieved minimum EED due to the transmission of less amount of control messages in the phase of route discovery by using the optimistic fitness parameters. Moreover, the detection of shortest route helps to minimize the delay by transmitting the data in less time.

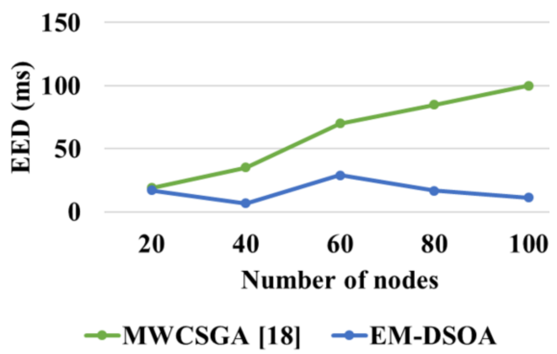

Figure 3. Graphical representation for EED

4.1.3 Packet loss

The packet loss or packet drop is defined as the total number of lost packet detected during the time of data transmission. The packet loss can be evaluated using the formula represented in Eq. (14).

$$\mathrm{PLR} = \frac{N^t - N^r}{N^t} \quad (14)$$

where the total number of received and transmitted data packets are represented as N^r and N^t respectively. The results from the Figure 4 show that the proposed EM-DSOA have lost minimum number of packets when compared with the existing MWCSGA. For an example, consider the packet loss of EM-DSOA which ranges from 3 to 15 packets. But, the existing MWCSGA have lost the data packets from the range of 25 to 150. The proposed EM-DSOA achieved minimum packet loss due to its capability in reducing the node failures and enhancing the scalability of WSN. This reason acts as an effective reason for minimum packet loss and helps to improve the overall performance of the network.

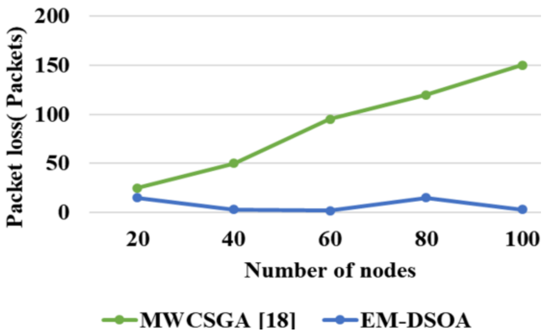

Figure 4. Graphical representation for packet loss

4.1.4 Network throughput

The network throughput is defined as the ratio of data transmitted from one node to another node in a minimal delay time. Eq. (15) represents the formula to evaluate the network throughput.

$$\text{Network throughput} = \frac{\text{Total number of transmitted data packets}}{\text{minimal delay time}} \quad (15)$$

The results from Figure 5 show that the proposed EM-DSOA achieved better network throughput when compared with the existing MWCSGA. The network throughput of the proposed EM-DSOA ranges from 1333.84 Kbps to 1370.34 Kbps whereas the existing MWCSGA achieved network throughput which ranges from 35 Kbps to 190 Kbps. The failure in the node link is diminished which results in effective transmission of data and helps to achieve better network throughput.

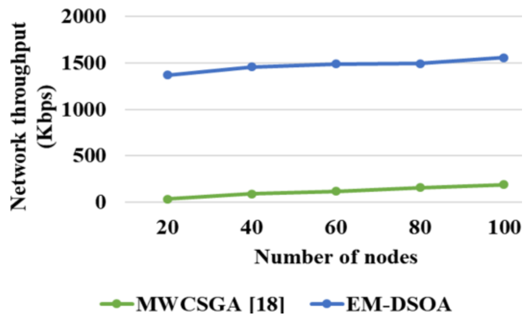

Figure 5. Graphical representation for network throughput

4.1.5 Comparative analysis

The effectiveness of the proposed EM-DSOA is proven by comparing it with the existing methodologies such as MWCSGA [18] and AHCS-GWO [21]. The Table 2 denotes comparison of the proposed EM-DSOA with the existing techniques such as MWCSGA and AHCS-GWO based on energy efficiency, EED, Packet drop and network throughput.

Table 2. Comparative analysis

Performances	Methods	Number of Nodes				
		20	40	60	80	100
Energy efficiency (%)	MWCSGA [18]	20	38	57	72	80
	EM-DSOA	91.7394	96.1026	97.839	97.8549	99.1312
EED (ms)	MWCSGA [18]	19	35	70	85	100
	AHCS-GWO [21]	20	18	30	45	70
	EM-DSOA	17.0472	6.81927	28.9478	16.6811	11.2275
Packet drop (packets)	MWCSGA [18]	25	50	95	120	150
	AHCS-GWO [21]	20	40	65	70	75
	EM-DSOA	15	3	2	15	3
Network throughput (Kbps)	MWCSGA [18]	35	90	120	160	190
	EM-DSOA	1333.84	1367.54	1370.34	1333.84	1367.54

The results from the Table 2 show that the proposed EM-DSOA achieved better performance in overall metrics such as energy efficiency, EED, packet drop and network throughput. Due to improper consideration of optimistic fitness parameters, the existing MWCSGA and AHCS-GWO methodologies attained poor performance. But, the proposed EM-DSOA takes account of multi-objective fitness parameters such as energy, Communication cost, CH balancing factor and degree of the nodes.

5. CONCLUSION

This research introduced an energy efficient clustering-based routing method to enhance the conservation of energy and the network's lifespan. The improved clustering and routing are developed to detect an optimal path to transmit the data packets to the base stations. This research introduced EM-DSOA method which effectively selects the CHs and optimistic path to deliver the data packets to the base station from the source nodes. The selection of optimal path provides energy efficiency due to transmission of data in the shortest distance and the delay time will be minimized. Moreover, the key benefits of this research lie in network throughput and minimum loss of data packets during the transmission. The transmission of data in WSN is enhanced by the fitness parameters like energy, Communication cost, CH balancing factor and degree of the nodes. The energy efficiency of the proposed EM-DSOA is 99.13% which is comparatively higher than the existing MWCSGA and AHCS-GWO. The future work will be based on using novel optimization techniques to perform effective clustering and routing which retains better energy efficiency.

REFERENCES

[1] Maheshwari, P., Sharma, A.K., Verma, K. (2021). Energy efficient cluster based routing protocol for WSN using butterfly optimization algorithm and ant colony optimization. Ad Hoc Networks, 110: 102317. https://doi.org/10.1016/j.adhoc.2020.102317

[2] Moussa, N., El Belrhiti El Alaoui, A. (2021). An energy-efficient cluster-based routing protocol using unequal clustering and improved ACO techniques for WSNs. Peer-to-Peer Networking and Applications, 14(3): 1334-1347. https://doi.org/10.1007/s12083-020-01056-4

[3] Wang, Z., Ding, H., Li, B., Bao, L., Yang, Z., Liu, Q. (2022). Energy efficient cluster based routing protocol for WSN using firefly algorithm and ant colony optimization. Wireless Personal Communications, 125(3): 2167-2200. https://doi.org/10.1007/s11277-022-09651-9

[4] Amutha, J., Sharma, S., Sharma, S.K. (2022). An energy efficient cluster based hybrid optimization algorithm with static sink and mobile sink node for Wireless Sensor Networks. Expert Systems with Applications, 203: 117334. https://doi.org/10.1016/j.eswa.2022.117334

[5] Lakshmanna, K., Subramani, N., Alotaibi, Y., Alghamdi, S., Khalafand, O.I., Nanda, A.K. (2022). Improved metaheuristic-driven energy-aware cluster-based routing scheme for IoT-assisted wireless sensor networks. Sustainability, 14(13): 7712. https://doi.org/10.3390/su14137712

[6] Al-Sadoon, M.E., Jedidi, A., Al-Raweshidy, H. (2023). Dual-tier cluster-based routing in mobile wireless sensor network for IoT application. IEEE Access, 11: 4079-4094. https://doi.org/10.1109/ACCESS.2023.3235200

[7] Nandhini, P., Suresh, A. (2021). Energy efficient cluster based routing protocol using charged system harmony search algorithm in WSN. Wireless Personal Communications, 121(3): 1457-1470. https://doi.org/10.1007/s11277-021-08679-7

[8] Sathya, P., Kavitha, V., Immaculate, P.S., Thiruvenkadam, T. (2022). Performance analysis of multiple routing algorithms based on optimization techniques for machine learning application. Journal of Pharmaceutical Negative Results, 13(9): 4675-4684. https://doi.org/10.47750/pnr.2022.13.S09.581

[9] Aydin, M.A., Karabekir, B., Zaim, A.H. (2021). Energy efficient clustering-based mobile routing algorithm on WSNs. IEEE Access, 9: 89593-89601. https://doi.org/10.1109/ACCESS.2021.3090979

[10] Behura, A., Kabat, M.R. (2020). Energy-efficient optimization-based routing technique for wireless sensor network using machine learning. In Progress in Computing, Analytics and Networking: Proceedings of ICCAN 2019, pp. 555-565. https://doi.org/10.1007/978-981-15-2414-1_56

[11] Kumar, N., Rani, P., Kumar, V., Verma, P.K., Koundal, D. (2023). TEEECH: Three-tier extended energy efficient clustering hierarchy protocol for heterogeneous wireless sensor network. Expert Systems with Applications, 216: 119448. https://doi.org/10.1016/j.eswa.2022.119448

[12] Rami Reddy, M., Ravi Chandra, M L., Venkatramana, P., Dilli, R. (2023). Energy-efficient cluster head selection in wireless sensor networks using an improved grey wolf optimization algorithm. Computers, 12(2): 35. https://doi.org/10.3390/computers12020035

[13] Zheng, M., Wang, C., Song, M., Liang, W., Yu, H. (2021). SACR: A stability-aware cluster-based routing protocol for cognitive radio sensor networks. IEEE Sensors Journal, 21(15): 17350-17359. https://doi.org/10.1109/JSEN.2021.3076995

[14] Sharma, R., Mittal, N., Sohi, B.S. (2020). Flower pollination algorithm-based energy-efficient stable clustering approach for WSNs. International Journal of Communication Systems, 33(7): e4337. https://doi.org/10.1002/dac.4337

[15] Rodríguez, A., Del-Valle-Soto, C., Velázquez, R. (2020). Energy-efficient clustering routing protocol for wireless sensor networks based on yellow saddle goatfish algorithm. Mathematics, 8(9): 1515. https://doi.org/10.3390/math8091515

[16] Senthil, G.A., Raaza, A., Kumar, N. (2022). Internet of things energy efficient cluster-based routing using hybrid particle swarm optimization for wireless sensor network. Wireless Personal Communications, 122(3): 2603-2619. https://doi.org/10.1007/s11277-021-09015-9

[17] Malisetti, N., Pamula, V.K. (2022). Energy efficient cluster based routing for wireless sensor networks using moth levy adopted artificial electric field algorithm and customized grey wolf optimization algorithm. Microprocessors and Microsystems, 93: 104593. https://doi.org/10.1016/j.micpro.2022.104593

[18] Ajmi, N., Helali, A., Lorenz, P., Mghaieth, R. (2021). MWCSGA- multi weight chicken swarm based genetic algorithm for energy efficient clustered wireless sensor network. Sensors, 21(3): 791. https://doi.org/10.3390/s21030791

[19] Selvi, M., Santhosh Kumar, S.V.N., Ganapathy, S., Ayyanar, A., Khanna Nehemiah, H., Kannan, A. (2021). An energy efficient clustered gravitational and fuzzy based routing algorithm in WSNs. Wireless Personal Communications, 116: 61-90. https://doi.org/10.1007/s11277-020-07705-4

[20] Arunachalam, G.S., Ramalingam, G., Nanjappan, R. (2023). A classy energy efficient spider monkey optimization based clustering and data aggregation models for wireless sensor network. Concurrency and Computation: Practice and Experience, 35(2): e7492. https://doi.org/10.1002/cpe.7492

[21] Rangappa, M.H., Dyamanna, G.C. (2021). Energy-efficient cluster based routing for hybrid wireless sensor networks using adaptive hybrid cuckoo search and grey wolf optimization algorithm. International Journal of Intelligent Engineering & Systems, 14(5): 226-237. https://doi.org/10.22266/ijies2021.1031.21

[22] Saoud, B., Shayea, I., Azmi, M.H., El-Saleh, A.A. (2023). New scheme of WSN routing to ensure data communication between sensor nodes based on energy warning. Alexandria Engineering Journal, 80: 397-407. https://doi.org/10.1016/j.aej.2023.08.058

[23] Wang, Z., Ding, H., Li, B., Bao, L., Yang, Z. (2020). An energy efficient routing protocol based on improved artificial bee colony algorithm for wireless sensor networks. IEEE Access, 8: 133577-133596. https://doi.org/10.1109/ACCESS.2020.3010313