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Energy Aware Routing Mechanism for Wireless Sensor Network using Enhanced Chemokine Operation for Optimal CH Selection

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Abstract: Geographic routing has been viewed as an interesting technique in the resource-constrained wireless sensor network (WSN), where it uses the node's location information rather than the global topology to send the data. When a heterogeneous device uses the WSN routing protocol and high energy is employed for data transmission, routing problems might arise. The battery's capacity and energy efficiency determine how long the sensor network will last. Thus, for WSN to function properly, battery capacity enrichment and energy utilisation are essential. A significant adjustment is made to the network structure and data transmission environment in order to meet this demand. A cluster-based routing system is started, and it makes use of an optimization-based cluster mechanism to enhance throughput while minimising energy usage. Artificial Fish Swarm Optimization is used to pick the cluster heads, and the bacterial foraging method is used for routing. The suggested approach's goal function offers a reliable routing method. The simulation results' presentation demonstrates how to balance the size of the cluster with the available data transmission bandwidth. The results show that the energy usage is lowest for a variety of nodes when the suggested strategy is compared to the current methodology.

Keywords: *Optimization, WSN, energy efficiency, routing, cluster, swarm intelligence, energy consumption, and lifetime.*

1. Introduction

Wireless Sensor Network (WSN) is a collection of low power devices which are used in geographically remote areas. WSNs are frequently differentiated into a number of disjointed clusters and every cluster was provided with a representative cluster head for data gathering and routing process with maximum efficiency [1]. Every CH collects the data from its sensor nodes and broadcasts it to a Base Station (BS). The sensors are localized with non-replacement batteries. The accessibility of minimum cost and tiny sensor devices assists in enhancing diverse application such as ecological and effluence observation [2, 3].

Clustering procedures are categorized as reactive, arbitrary, and deterministic, according to the parameter selection utilised for CH. In certain deterministic methodologies, distinct inherent SN attributes namely the count of neighbours they hold and identification (ID) related information are considered. In the Adaptive technique, the CHs are elected from the SN by considering node with high weights that comprises communication expenses, retained energy, etc. The CHs are chosen randomly and utilised in secure grouping techniques, without considering the account of remaining energy etc. In the process of routing, the path utilised for routing is classified into query-based, protocol-based, QoS-based and negotiation-based techniques.

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As sensor networks are positioned in non-accessible areas, energy preservation is considered as a significant task in WSNs. Sensor nodes employ non-changeable batteries for energy supply and lifetime of sensor node are based on batteries [4, 5]. The replacement of these batteries remains complex in various applications. In order to conserve energy in WSN, permanent power supply to sensor nodes is to be provided. Many energy efficient data aggregation methods and routing techniques were introduced to advance the performance of sensor network in data transmission, but it still experiences certain drawbacks. Therefore, a number of research papers are investigated and analyzed for enhancing the process of routing in WSN [6].

An effective strategy to group the data pieces is to employ the data mining technique of clustering. It is an unsupervised learning strategy in which the data collection does not necessarily need to include class labels [7, 8]. To create cluster-based routing schemes, several scholars conducted their study on cluster formation. The k-means clustering technique is a crucial clustering technique. When the user provides the k value, it creates k-clusters from the dataset. All nodes involved in clustering are denoted to as comparable nodes since they are close to one another and share a number of common characteristics [9].

The clustering of nodes can divide them into smaller groups so that they can more readily exchange information and interact among themselves [10]. To make more effective judgments regarding routing and the available resources, the data gathered by the sensor nodes must be sent to the base station in many real-world applications. In order to provide the safe transfer of data packets from the source node to the sink node, cluster-based routing technique design is a crucial design challenge [11]. The ability to choose cluster heads and route packets through the cluster heads is provided by clustering. Through more efficient load sharing, this will lengthen the network's lifespan [12, 13].

An effective technique to increase network performance, including network longevity, is through the selection of a suitable Cluster Head (CH). Additionally, the CH is in charge of selecting the next trustworthy node for data forwarding and collecting data from cluster members in order to make judgments on routing with regard to data acquired by member nodes. CHs are often chosen from nodes with minimal mobility, a close proximity to neighbouring nodes, high energy, and high trust ratings [14]. This will fluctuate on a regular basis as a result of changes in mobility and energy levels across different nodes. Both static nodes and low mobility nodes can be chosen as CH, however static nodes are preferred. However, because of the CH rotation procedure, the majority of nodes will get a chance to become CH. Optimization techniques provide more appropriate facilities for selection of CH and cluster-based routing through the appropriate CH [15].

With the use of various optimization approaches, energy conservation is often the major emphasis of WSN. Numerous optimization techniques have been created in the past using inspiration from nature [16]. As the power required for communication frequently determines a node's power budget, these methods should concentrate on communication and operation management. In this research work, the process of data transmission is attained using clustering and the cluster head selection is achieved using optimization technique. The CH selection is attained using Enhanced Chemokine Operation based Algorithm (ECOA).

The article is systemized as follows: previous research about clustering and optimization in WSN is detailed in Section 2, the proposed energy aware routing mechanism is elucidated in Section 3, simulation outcomes are illustrated with discussion in Section 4, and the article is concluded in Section 5.

2. Related Works

Sheriba, S. T., & Rajesh, D. H. (2021) developed an approach using black widow optimization and fuzzy logic for WSN. The WSN protocols encountered a number issues in previous years, including increased computational complexity, subpar cluster head selection performance, higher energy consumption, costly cluster head selection, scalability management, unequal load distribution, etc. This paper develops a BM-BWO with fuzzy logic-based HEED protocol (BMBWFL-HEED). The boosted mutation-based black widow optimization (BM-BWO) algorithm and the HEED procedure are combined in BMBWFL-HEED to choose the greater residual energy. With the aid of the direction average method, the Black Widow Optimization (BWO) algorithm's mutation phase is particularly enhanced (BM-BWO). The optimal cluster heads are chosen using a fuzzy logic algorithm [17].

Khediri, S. E., et al., (2021) proposed a Distance Energy Evaluated (DEE) Approach. The complexity of the message size is smaller in the DEE technique. The main goal is to reduce the amount of energy used for data transmission to the base station and cluster building levels. The algorithms provided are not unique to any one sort of sensor network or application [18].

Liu et al (2018) developed High-Speed Backbone Path construction method (HSBP). Various High-speed Backbone Paths (HBPs) were executed at diverse network positions and duty cycles of nodes were enhanced. Then, data was broadcast by HBPs with reduced sleeping delay and transmission latency. HBPs were constructed in regions with acceptable residual energy and controlled the nodes for balancing the energy utilization. Minimum transmission delay was achieved but data communication was not improved efficiently [19].

Karimzadeh-Farshbafan&Ashtiani, F (2018) designed a semimyopic method for allocating the transmissions with better performance and minimum complexity. The structure of cost function was applied which assisted to create scheduling decision at each superframe with respect to its impact on upcoming superframes. The semi-myopic method was considered in two incoming packet circumstances such as deterministic and random arrivals. A negligible difference was identified between designed method and Partially Observable Markov Decision Process (POMDP) in terms of energy utilization and consistency. But, execution time of semi-myopic method was higher [20].

Jabbar et al (2018) analyzed on WSN routing. This analysis provided a detailed description about WSN technology, energy preserved routing and factors impacting energy aware routing process. Then, authenticity was determined with the aid of algebraic and graphical modelling. Subsequently, routing approaches were employed in supporting to handle transfer of data through energy aware nodes. Besides, security problems remain addressed in WSN routing [21].

Waghmare et al (2017) described Fuzzy Rule Based Inference method for cluster head selection and data aggregation. Euclidean distance approach assisted in identifying a shortest path with higher network lifetime. The sensor node was provided with high association separated into identical groups to achieve exact data aggregation. The computational overhead was reduced with and high communication accuracy. Then, data aggregation method also enabled the cluster head to eliminate the unnecessary data. In addition, system development was also discussed and optimization of results was performed. But, control overhead issues were not addressed [22].

Sirdeshpande&Udupi (2017) created FLION clustering method, or fractional lion. In order to create an energy-efficient routing path, FLION was used. By choosing a quick cluster head, the clustering strategy was used to increase the energy and network lifetime nodes. For creating a new fitness function, a multi-objective FLION clustering technique was used. To find a suitable routing path, the resilient cluster centroid was identified with the use of this fitness function. While FLION extends network lifetime, network dependability was not effectively increased [23].

Reddy&Balaji (2017) designed Compound-Low Energy Adaptive Clustering Hierarchy (COM-LEACH) protocol to perform data aggregation with higher energy efficiency. But, information loss was increased [24].

Sharma et al (2017) presented rendezvous-based routing protocol. A rendezvous region was produced in the centre of network and a tree was implemented within that region. It has two distinguished forms of data transmission. A tree was intended towards the sink and the data was broadcast by the source node to the sink. Then, the sink broadcasts its location to the tree and the sink"s location was acquired by source node from the tree for transmitting the data to the sink. The data packet delivery ratio was increased with reduced energy utilization and end-to-end latency. However, reliability of network was not maintained by using routing protocol based on rendezvous [25].

Singh&Verma (2017) presented a hybrid routing method for heterogeneous networks depending on adaptive threshold sensitive disseminated energy efficient cross layer routing. Weighed probability was employed in allocating Cluster Head of network cluster. Then, an integration of proactive and reactive network was considered to achieve optimal data transmission and enhanced the network lifetime. But, Energy optimization was not performed efficiently [26].

3. Energy Aware Routing - Artificial Fish Swarm with Bacterial Foraging Algorithm

One of the best swarm intelligence algorithms is the Artificial Fish Swarm Algorithm (AFSA), which has benefits including robustness, global search capability, parameter setting tolerance, and beginning value insensitivity. ASFA has been seen to converge very quickly and resemble the behaviour of fish swarms feeding. Each fish in the search is given a random solution at the beginning. Fish follow another fish that has found a better option once their fitness has been assessed. The swarming process is started if the answer is less than ideal. Preying is started if the desired outcome is not achieved. Until the required threshold or termination requirements are satisfied, this procedure is resumed.

Four AFSA functions were modelled after fish swarm behaviour. As in nature, fish roam freely in the swarm when they are not hunting prey. This is the first function. The second purpose is predatory behaviour, where it makes use of all accessible senses on their body, including their sense of smell and eyesight. In AFSA, the neighbourhood with a visual-sized radius represents the region where an artificial fish may detect a prey. The third purpose is the fish's tendency to lead other swarm members to food when it finds it. The final feature is swarm behaviour, which is similar to how fish in nature always strive to stay in the swarm and never leave it in order to avoid being hunted. The solution space is the environment in which an AF resides. The AFSA's goal function in the water domain is the degree of food consistency. Assume that the artificial fish swarm's state vector is X = (x1, x2,... xn), where x1, x2,... xn represents the status of the fish. Visual distance refers to the length of the field of vision, with fake fish only appearing in the circle's inner radii. The formula for the food concentration at this position of the fish is y = f (x), where y is the value of the objective function. The fake fish are separated by a distance di,j = ||Xi - Xj||, where I and j are random fish. Step refers to the largest possible step size for fake fish. a represents the level of congestion.

Pretend that X_v represents the visual position at some point. The new role is X_{next}. After then, Eq. (1) is used to illustrate the movement process:

$$X_v = X_i + visual * rand(\,), \quad i \in [0, n]$$

$$X_{next} = X + \frac{X_v - X}{\|X_v - X\|} * step * rand()$$

The behaviour of fish in the predatory phase is indicated by Eq. (2):

$$prey(X_i) = \begin{cases} x_i + step \dfrac{x_j - x_i}{\|x_j - x_i\|} & if\ y_j - y_i \\ x_i + (2rand - 1).step & else \end{cases}$$

Here rand is a random function with a [0, 1] range here. The behaviour of the swarm during the swarming phase is described by Equation (3):

$$swarm(X_i) = \begin{cases} x_i + step\dfrac{x_j - x_i}{\|x_j - x_i\|} & if\ \dfrac{y_c}{n_f} > \delta y_i \\ prey(X_i) & else \end{cases}$$

Eq. (4) provides the behaviour for the subsequent phase.

$$follow(X_i) = \begin{cases} X_i + step\dfrac{x_{max} - x_i}{\|x_{max} - x_i\|} & if\ \dfrac{y_{max}}{n_f} > \delta y_i \\ prey(X_i) & else \end{cases}$$

The aforementioned three procedures guarantee the achievement of both global and local search as well as the search direction following the greatest food source.

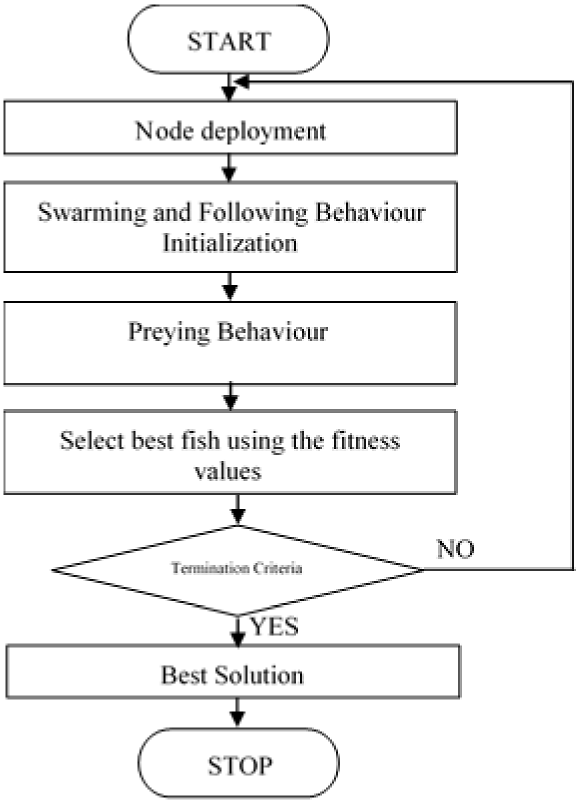

Fig 1. Overall Flow of ECOA

The extent of the calculated route from AFS is E, and the bacterium is significant to a single pathway c_x^*. The E.Coli bacteria searches for nodes in a identical direction and in a random manner, respectively, while swimming and trembling to carry out its function [25]. The bacteria goes around the whole network in search of the proper node after removing any nodes that have insufficient ability for data transmission. To determine the direction of advancement in which the fitness value is increased, the chemokine operation is started. The predicted chemokine action is

$$Fitness^{c_x^*}(y + r + l) = Fitness^{c_x^*}(y, r, l) + A(c_x^*)\emptyset(c_x^*) \text{ ---------- } (5)$$

$$\emptyset(c_x^*) = \frac{\Delta(c_x^*)}{\sqrt{\Delta^T(c_x^*)}} \text{ ---------- } (6)$$

where $Fitness^{c_x^*}$ depict the flora fitness, $A(c_x^*)$ depict the swing direction, $\Delta(c_x^*)$ depict the direction of modification, and $\emptyset(c_x^*)$ depict the unit step, which is after the alteration of direction.

The fitness value is advanced in this manner, and the advancement is computed as follows:

$$B_{cc}(Fitness^{C_x^*}, Fitness^{c_x^*}, (y, r, l) = \sum_x^E B_{cc}^x\,(Fitness^{C_x^*}, Fitness^{c_x^*}, (y, r, l) = \sum_x^E \left[-d_{att}exp\left(-w_{att}\sum_{o=1}^D (Fitness_o^{C_x^*} - Fitness_o^{C_x^*})^2\right)\right] + \sum_x^E \left[-h_{rep}exp\left(-w_{rep}\sum_{o=1}^D (Fitness_o^{C_x^*} - Fitness_o^{C_x^*})^2\right)\right] \text{---------- } (7)$$

where the depth of gravitation is indicated as d_{att}, the width gravitation is indicated as w_{att}, repulsive height is indicated as h_{rep}, the repulsive width is indicated as w_{rep}. Among the entire flora, o^{th} bacteria component is determined as $Fitness_o^{C_x^*}$ and others are indicated as $Fitness_o^{C_x^*}$.

The new fitness value is estimated after the chemokine operation is estimated as follows,

$$Fitness^{c_x^*},(y+1,r,l) = Fitness^{c_x^*},(y,r,l) - A(c_x^*)\emptyset(c_x^*) + B_{cc}(Fitness^{C_x^*},(y+1,r,l), Fitness^{c_x^*},(y+1,r,l)) \text{ ---------- } (8)$$

The fitness function of bacteria is used to measure the health of the bacteria, and the bacteria with the lowest health are eliminated while the bacteria with the highest health are reproduced. By ignoring the local optimal solution, the global optimum solution is found. The condition of the bacteria is as follows:

$$B_{health}^{c_x^*} = \sum_{y=1}^{P_a} Fitness^{C_x^*}(y,q,l) \text{---------- } (9)$$

where the health value of a bacterium is denoted as $B_{health}^{c_x^*}$, which represents the bacterium's energy function C_x^*. The health of the bacterium determines the energy of the bacteria (node). The reproduction is complete when the value reaches b=Nre. The migration is started with a certain probability and then redistributed at random in the new search area. The migration continues until optimization is reached. To make the WSN routing protocol selection procedure as efficient as possible, the AFS-BFA approach is used. It efficiently manages overhead, lowers energy consumption, and shortens transmission latency.

4. Result and Discussion

This section discusses about the performance of the proposed approach and comparison is accomplished using existing techniques.

4.1. Cluster Change

Clustering is one of the most used techniques for controlling WSN topology. A clustering technique places nodes into a set of groups known as clusters based on a number of pre-established criteria, such as supporting Quality of Service (QoS), optimising resource utilisation, network load balancing, etc.

Table 1. Comparison of Cluster Change

Nodes	BMBWFL-HEED	DEE	ECOA
200	6	8	5
400	9	12	7
600	13	16	9
800	18	22	15
1000	21	25	17

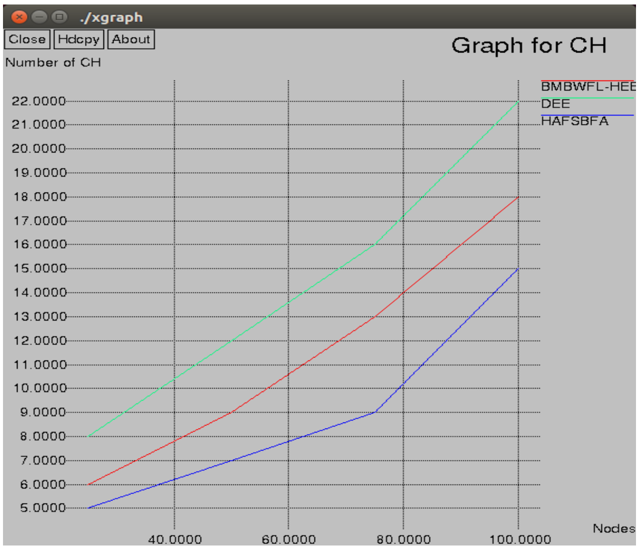

Fig 2. Comparison of Cluster Change

In Figure 2, the cluster change is illustrated for BMBWFL-HEED, DEE, and ECOA algorithm. From the observation it is identified that the cluster change is effective in proposed technique. The proposed approach with cluster is highly stable compared to other approaches.

4.2. Comparison of Delay

The delay is the additional time required to send the data from the source to the destination node. The shortest transmission latency is regarded as the most efficient protocol. Using the ECOA protocol, the cluster-based scheduling method achieves effective data transfer with the least amount of latency. Table 2 and Figure 2 show the resulting delay values for the BMBWFL-HEED, DEE, and ECOA algorithms. The clustering-based strategy successfully reduces the end-to-end delay time of the proposed protocol ECOA.

Table 2. Comparison of Delay

Nodes	BMBWFL-HEED	DEE	ECOA
200	0.69	1.12	0.54
400	2.15	4.65	1.97
600	6.68	9.51	5.04
800	8.92	11.54	7.02
1000	9.34	12.56	8.09

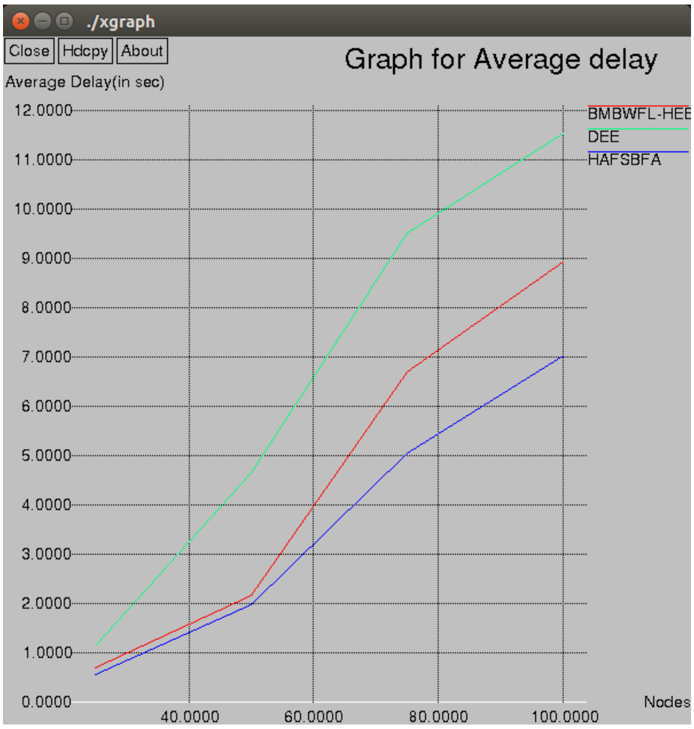

Fig 3. Comparison of Delay

In Figure 3, the transmission delay is illustrated for BMBWFL-HEED, DEE, and ECOA algorithm. From the observation it is identified that the transmission delay is minimal in proposed technique.

4.3. Comparison of Energy Consumption

Every sensor node in the WSN is equipped with rechargeable batteries for use in the data transmission environment. However, because these batteries require a minimal amount of energy, charging them is challenging. The cluster and duty cycle scheduling system starts the data transfer. Without any hiccups, data transfer is completed over the shortest route possible while utilising the least amount of energy. This circumstance lessens the energy exhaust in the transmission nodes. The ECOA protocol has reduced energy consumption over a range of transmission distances and network density. Tables 3 and Figure 3 provide the energy consumption values for the current and suggested techniques.

Table 3. Comparison of Energy Consumption

Nodes	BMBWFL-HEED	DEE	ECOA
200	1.44	2.48	0.98
400	2.31	3.21	1.30
600	3.30	5.98	2.45
800	4.98	7.69	3.12
1000	5.11	8.21	4.65

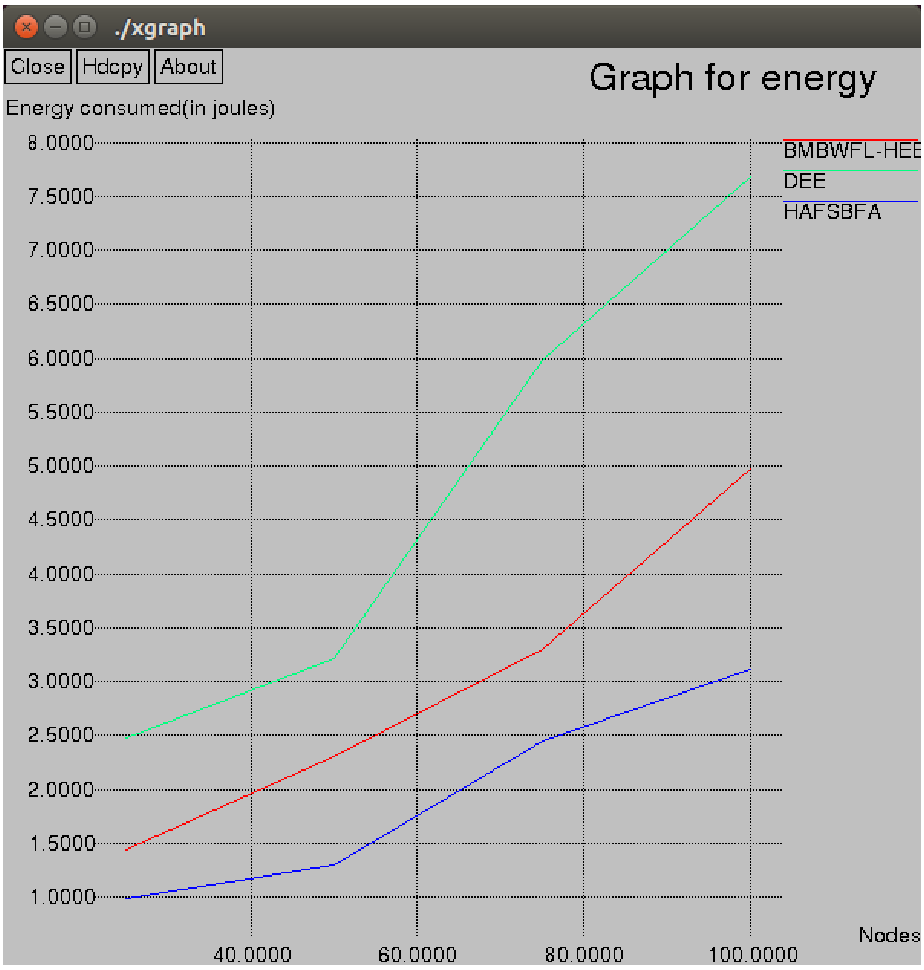

Fig 4. Comparison of Energy Consumption

In Figure 4, the energy consumption is illustrated for BMBWFL-HEED, DEE, and ECOA algorithm. From the observation it is identified that the energy consumption is minimal in proposed technique.

4.4. Comparison of Packet Delivery Ratio

The Packet Delivery Ratio (PDR) is determined using the total number of data packets transmitted from the source to the destination node and the number of delivered data packets [19]. The optimal data transmission method is one that delivers the largest percentage of packets. When compared to other geographic and scheduling techniques, the rate of PDR is high, thus the cluster building is started in order to achieve data delivery with the right scheduling mechanism. The data transmission schedule in the ECOA is started based on precedents that help to achieve the limitations of the data transmission delay. Table 4 and Figure 4 show how the BMBWFL-HEED, DEE, and ECOA algorithm performed.

Table 4. Comparison of Packet Delivery Ratio

Nodes	BMBWFL-HEED	DEE	ECOA
200	98.56	92.02	99.02
400	95.38	87.76	96.70
600	89.09	84.57	90.45
800	86.39	80.23	87.12
100	84.31	79.34	85.34

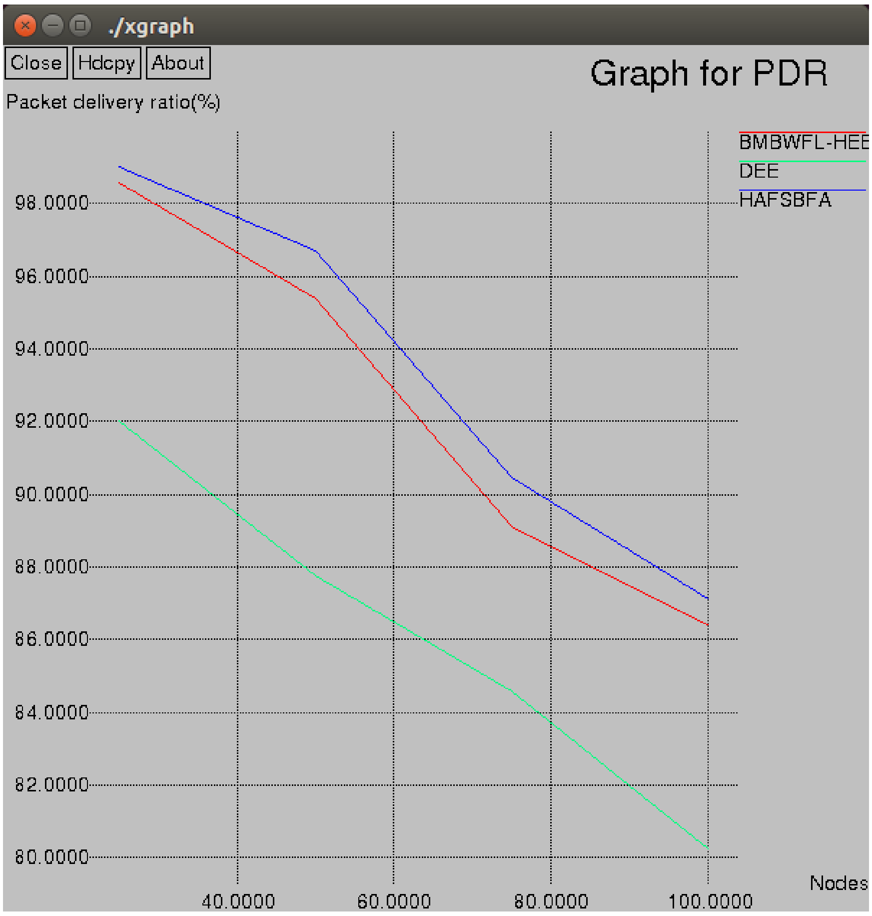

Fig 5. Comparison of PDR

In Figure 5, the PDR is illustrated for BMBWFL-HEED, DEE, and ECOA algorithm. From the observation it is identified that the PDR is high in proposed technique.

4.5. Comparison of Network Lifetime

At some point, the network's sensor nodes will run out of power or energy, which causes a loss of functionality and prevents packet transmission.

Table 4.5. Comparison of Network Lifetime

Nodes	BMBWFL-HEED	DEE	ECOA
200	71.69	57.48	73.67
400	62.15	53.21	64.58
600	56.68	25.98	58.87
800	28.92	17.69	30.53
100	26.87	16.56	25.78

Fig 6. Comparison of Network Lifetime

In Figure 6, the life time is illustrated for BMBWFL-HEED, DEE, and ECOA algorithm. From the observation it is identified that the lifetime is high in proposed technique.

5. Conclusion

The WSN routing has been viewed as an alluring technique in the resource-constrained scenario, where it uses the node's location information rather than the global topology to send the data. When a heterogeneous device uses the WSN routing protocol and high energy is employed for data transmission, routing problems might arise. The battery's capacity and energy efficiency determine how long the sensor network will last. Therefore, for WSN to function properly, battery capacity enrichment and energy utilisation are essential. A significant adjustment is made to the network structure and data transmission environment in order to meet this demand. A cluster-based routing system is started, and it makes use of an optimization-based cluster mechanism to enhance throughput while minimising energy usage. The suggested approach's goal function offers a reliable routing method. The simulation results' presentation demonstrates how to balance the size of the cluster with the available data transmission bandwidth. The results show that the energy usage is lowest for a variety of nodes when the suggested strategy is compared to the current methodology.

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