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Energy-Efficient Routing Protocol for Hybrid Wireless Sensor Networks Using Falcon Optimization Algorithm

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Abstract: Hybrid Wireless Sensor Networks (WSNs) comprise both portable and static sensors to help different applications. The static type sensors are used to discover the atmosphere and state the actions (sensor deployment) that happen in the sensor area and the Mobile sensors (MSs) are transferred to Event Locations (ELs) to ensure advanced research. A major test is to plan these MSs voyaging ways in an energy-adjusted way so their general lifetime is amplified. The lifetime of sensor nodes completely depends on energy deployment and energy utilization during the transmission process. Heuristics algorithms permit discretionary quantities of portable sensors and ELs in each stage to produce an energy-adjusted idea. The major aim of this paper is to dispatch the sensor to EL in an energy efficient manner. This research proposes a basic and productive way of dispatching the portable sensor to the EL utilizing a new calculation called Falcon Optimization Algorithm (FOA). This calculation is used to limit the mobile sensor moving energy utilization and boost the framework lifetime. The simulations of the proposed FOA displayed up to 50 secs which provided the results in terms of minimizing the energy consumption as 0.130 J, end-to-end delay as 10.19 ms, packet delivery ratio of 0.99% and increases the network lifetime up to 562.40s.

Keywords: Event location, Energy consumption, Falcon optimization algorithm, Hybrid wireless sensor networks, Mobile sensors.

1. Introduction

Wireless sensor networks (WSNs) enrich our life by providing context-aware monitoring of the physical environment. Hybrid WSNs comprising static and portable sensors have more adaptability than traditional WSNs containing just static sensors [1, 2]. On one hand, static sensors are utilized to lead ecological detecting and keep up with network communication [3]. Then again, sensors have more assets like detecting ability, registering force, and energy [4]. They can move to assigned areas to complete missions like dissecting occasions or supplanting broken nodes. For the past few years, hybrid WSNs have been applied in several applications which are clearly explained in [5, 6]. Here, concentrate on the issue of dispatching portable sensors to the areas of occasions showing up in the detecting field. The static sensors will recognize where dubious occasions show up and report them to portable sensors to complete inside and out examinations [7]. Since MCM sensors are normally battery-fueled and the moving expense overcomes their energy utilization to improve the proficiency of deployed sensors. While taking into account, sensor deployment seems to be inefficient for dispatch one mobile sensor which follows the subsequent sensor [8].

Hence, a strategy is required for separating time into multiple rounds to schedule the traveling paths of mobile sensors properly [9]. Then, a sensor dispatch process decides how to dispatch multiple sensors into the ELs given in each round that extends the network's lifetime [10, 11]. Here, framework lifetime has been characterized as the number of rounds until certain ELs can't be reached by any reasonable sensor because of an absence of energy [12]. The detecting field might contain difficulties, so, a major test is required to dispatch the sensor into the EL without crashing into any obstructions and the portable sensor should arrive at the EL most briefly. Consequently, the target of the paper is to dispatch the sensor to the EL in the briefest impact freeway [13]. This paper gives an adjusted calculation to dispatch portable sensors from their situation to the EL. Some of the researchers propose a basic way of dispatching the portable sensor to the EL within the sight of a deterrent with altered calculation [14]. This paper contributes to characterizing a broader and most effortless dispatch arrangement within the sight of hindrances. The significant commitment of this examination is referenced as follows,

- This paper introduced the FOA technique to dispatch the sensor to EL for the case when mobile sensors are less than the ELs.
- The proposed FOA limits the additional development of a mobile sensor to visit the EL and it reduces the energy utilization.
- This will boost the lifetime of the sensors which are answerable for the effective working of the WSN and thus it will expand the network lifetime.
- This technique is the most effortless, straightforward, and effective way for a sensor to visit every one of the ELs in the detecting field.

The organization of this research paper is given as follows: The survey of the recent techniques related to dispatch mobile sensors in HWSN is described in Section 2. The problem statement of this research is given in Section 3. The preliminaries and their system model are explained in Section 4. The description of the proposed FOA with a block diagram is specified in Section 5. The simulation results and its comparative analysis of FOA are declared in Section 6. The conclusion portion is specified in Section 7.

2. Literature review

Sachithanantham and Jaiganesh [15] exhibited an Enhanced Energy Effective Routing Protocol (EEE-RP), a new routing mechanism that extends network life by minimising end-to-end delays by sending data packets to their destinations in the most efficient and optimal way feasible using the best path, was shown. EEE-RP is better at detecting network problems, choosing the best route for forwarding data packets, reducing energy usage, reducing delay time, and extending network lifetime. Those nodes, however, have been shifted in the same manner as their previous objective places where it was in process.

Ezhilarasi and Krishnaveni, [16] developed an Evolutionary Multipath Energy-Efficient Routing convention (EMEER) to work on the life expectancy of the system. The progression of utilizing the Cuckoo Search Algorithm (CSA) completely depended on four parameters, such as packet size, battery power, node area, and distance. As per the four boundaries, the CSA chose the ideal way for information transmission. The energy utilization was limited by taking on the routing plan. But the computational speed gets decreased when the node counts reach nearer to 180.

Rodríguez [17] introduced a clever energy-effective grouping steering convention dependent on the Yellow Saddle Goatfish Algorithm (YSGA). The proposed method was primarily acquainted to strengthen the network life expectancy by limiting the energy utilization. For selecting the cluster leader and group leader, this YSGA has been presented with the routing protocol. The energy utilization has been decreased and network lifespan has been improved by utilizing the YSGA method. At different node counts, this proposed protocol has been disconnected automatically.

Wang, [18] proposed a clustering calculation with a further developed Artificial Bee Colony (ABC) calculation to further develop the energy proficiency and the life expectancy of the network. Since the groups utilized in WSNs perform more assignments through a huge measure of energy. The ABC algorithm was used to implement the optimal clustering method by optimizing the fuzzy C-means clustering. This control component was dependent on inactive nodes which were in correspondence with the energy utilization and throughput of the system. But in this research, the produced design does not have the option to apply in a static network.

Manjunath and GuruPrakash [19] exhibited an Energy-Aware Mobile Dispatches and Scheduling Method (EMDSM) for energy mindful planning for WSNs. In the proposed research work half and hybrid Genetic Particle Swarm Optimization calculations were used to pick the ideal energy route. After that, comparable information gathering is done to diminish the calculation overhead. To diminish the memory utilization, sensor accumulated information will be packed, along these lines the memory utilization and energy utilization can be accomplished. The refinement cycle plans to diminish the number of sensor nodes; nonetheless, it won't decrease the network inclusion.

Feng [20] introduced Confident Information Coverage Hole Prediction (CICHP) in Large-Scale HWSN. The CICHP calculation can anticipate the earlier data of CICHs by utilizing the period-by-period energy utilization data of sensor nodes. In any case, the proposed calculation was more possible for genuine applications since the HWSN has a few attributes, i.e., network elements, computational ability and restricted battery limit. Although, the persistent energy requirements are less when compared to existing calculations.

Jothikumar [21] showed an Efficient Routing Approach name called Optimal Cluster-Based Routing (Optimal CBR) to Maximize the Lifetime of Wireless Sensor Networks in 5G. The Optimal-CBR convention utilizes the k-implies calculation for clustering the nodes and the multi-bounce approach for chain steering. The nodes are clustered utilizing the essential k-implies calculation during the group stage of the centroid which is chosen as the Cluster Head (CH). This enhances energy productivity and life expectancy. The network utilizes the adjusting of energy among the clusters however, it has a delay in data transmission.

3. Problem statement

- Sensors utilize some confinement plans to get their areas and structure an associated network that completely covers the detecting field.
- It is difficult to distinguish occasions of the very trait that could show up anyplace in the detecting field.
- Thus, every occasion detailed by the static sensor(s) is related to just one property. Likewise, there is no suspicion of the appropriation of (EL).

3.1 Solution:

The paper tends to the sensor dispatch issue in a half-breed WSN, whose objective is to plan the ways of MSs to stay ELs in every cycle, with the end goal that their lifespan is boosted. Recreation results check that the FOA calculation enormously expands the lifetime of MSs, as contrasting and different strategies.

4. Preliminaries

Hybrid WSNs comprise mobile sensors and static sensors which have received an intensive research interest in modern trends. Static sensors are used to detect environmental data. Mobile sensors have all the more remarkable detecting and processing capacities, and they can move to target areas to carry on operations. By joining sensors to WSNs, the networkability can be additionally worked on in numerous perspectives. Static sensors might be conveyed unevenly in the network area. In this paper, FOA-based sensor dispatch is proposed with the presence of obstacles to extending the lifetime of the hybrid WSN.

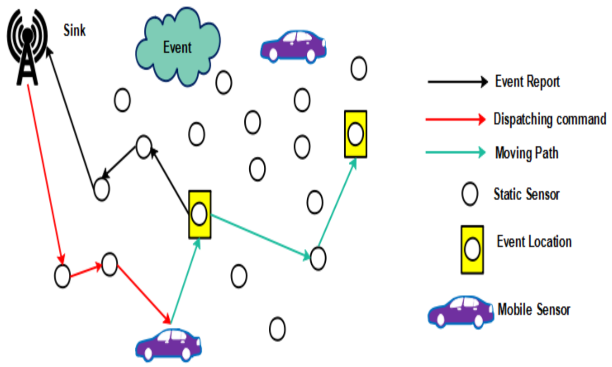

Figure. 1 Sensor dispatch in hybrid WSN

4.1 Network model

Fig. 1 illustrates a sensor dispatch in Hybrid WSN. Static sensors can recognize a similar occasion by utilizing the strategy to communicate the sink node. Subsequently, every occasion can be demonstrated by an in the detecting field. (MS) are randomly dissipated over the detecting field.

4.2 Energy model

At the certain interval, mobile sensor visit the event location which is specified as T_j^D . In cooperation with, the summation time is mentioned as T_j^C which stays for $service^2$. In the energy model, s_j can be re-energized for a quantity of power which is determined by Eq. (1).

$$s_j = min\{r \times (\max\{T_{max} - T_j^D - T_j^C, 0\}, e_{max} - e_j\} \quad (1)$$

where e_j is referred to as residual energy of s_j. From Eq. 1, s_j has a chance to restore the series merely once $T_j^D - T_j^C < T_{max}$. So that, the duration $\max\{T_{max} - T_j^D - T_j^C, 0\}$ is used. Also, because of battery measurements, it can be re-energized through a quantity $(e_{max} - e_j)$ of energy.

4.3 Collision free path

To identify the shortest collision-free route from MS location to EL's location that is preserved as the endpoint or objective. In particular, the development should not crash into any deterrent. A few examinations have resolved this issue. The creators utilized novel calculation to track down the briefest way from the sensor to the EL, which is treated as a target. In certain cases, this strategy is having a collision problem. The objective of the paper is to overcome this collision during sensor dispatch, so,

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novel calculation method name called FOA is proposed in this research to avoid a collision.

5. Proposed method

In this paper, the FOA strategy introduced a technique to discover the most limited and impact-free way for a sensor to reach EL which will be treated as a target. This strategy is the least demanding, basic and productive way of discovering the way for a portable sensor. The proposed FOA method is applied to dispatch the portable sensor to the EL, which overcomes the disadvantage of the existing procedures. When the static sensor recognizes the EL, a portable sensor will be dispatched to the EL. While moving the mobile sensor towards the EL, it should not collide with any other sensors present within the network. Sensor nodes are battery arranged, energy minimization is vital in WSN and portable sensors have less moving energy it should arrive at the EL at a base distance. The schematic diagram of the proposed system is displayed in Fig. 2.

Step 1: At first, the sensor node is deployed with sink and EL.

Step 2: Once the sensor nodes are deployed, FOA method is chosen as a proposed method to compute the fitness calculation.

Step 3: After that, the process of the fitness function is calculated based on the proposed FOA.

Step 4: Then the process of CH selection occurs and progress the routing over Hybrid WSN based on FOA.

Step 5: After the clustering/routing process, analyse the transmitted data (whether it is collision-free or not).

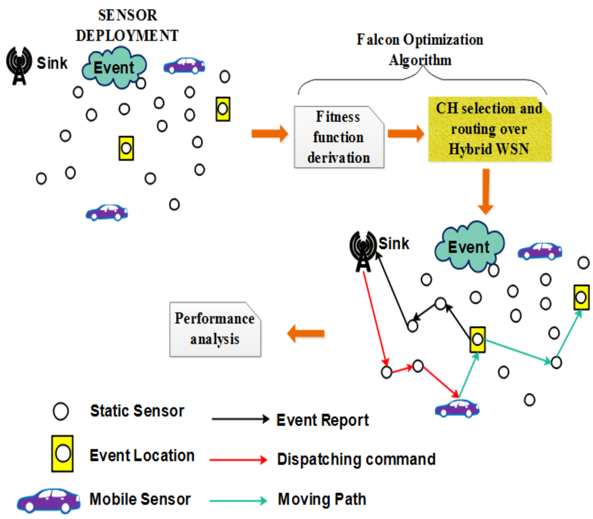

Figure. 2 Overview representation of FOA method

5.1 Falcon optimization algorithm

The main inspiration for the proposed algorithm and details about its implementation are presented in this section.

5.1.1. Hunt behaviour of falcons

As indicated by a few works of flying predators (falcons), the falcon is incorporated and consists of various habits such as unmistakable habits and twisted habits to attack their prey.

Stage 1: Initialize the FOA parameters and their control boundaries. The variable constraints of FOA coefficients are also addressed.

Stage 2: Reset the speed and position of falcons. The birds of prey are haphazardly situated (utilizing age of irregular qualities with uniform dispersion) in a D-dimensional cosmos regarding the limit situations, creating the lattice:

$$x = \begin{bmatrix} x_{1,1} \dots \dots x_{1,D} \\ . \\ . \\ . \\ x_{NP,1} \dots \dots x_{NP,D} \end{bmatrix} \quad (2)$$

where the position of falcon is specified as x, concerning the amount of NP applicants in every dimension D. The velocities are arbitrarily produced amongst v_{max} and v_{min} boundaries, which are described in Eqs. (3) and (4).

$$v_{max} = 0.1ub \quad (3)$$

$$v_{min} = -v_{max} \quad (4)$$

where v_{max} and v_{min} are the most extreme and least speeds permitted, individually, and ub is the upper bound breaking point scope of the issue for each measurement.

Stage 3: Assess and discover worldwide and individual best situations for every falcon the wellness worth for the issue is gotten, creating the vector:

$$OF = \begin{bmatrix} of_1 \\ . \\ . \\ . \\ of_2 \end{bmatrix} \quad (5)$$

where, OF represents the objective fitness. At that time, the individual best is fixed as g_{best} and best individual location of every falcon is represented as x_{best}.

Stage 4: Generate two arbitrary numbers (P_{AP} , P_{DP}) which are created with uniform dissemination for each bird of prey for the correlation with mindfulness and jump probabilities. Then, at that point, the principal likelihood thought about is the mindfulness likelihood, wherein case P_{AP} is less than the falcon, which can be expressed as Eq. (6):

$$x_{iter} = x_{iter-1} + v_{iter-1} + C_c r\big(x_{best,iter-1} - x_{iter-1}\big) + S_c r\big(g_{best,iter-1} - x_{iter-1}\big) \quad (6)$$

where x_{iter-1} and v_{iter-1} are the current position and speed of the falcon, separately. $C_c r$ is stated as cognitive rate; $S_c r$ is represented as social. Assuming P_{AP} is higher than AP (Adaptive Probability), the jump likelihood is contrasted and P_{DP}. Assuming P_{DP} is higher than DP (Dive Probability), the falcon targets one picked prey (x_{chosen}) and plays out its underlying development for hunting, the logarithmic twisting given by:

$$x_{iter} = x_{iter-1} + |x_{chosen} - x_{iter-1}| \exp(bt)\cos(2\pi t) \quad (7)$$

where x_{iter} is the newly obtained position; b is a consistent characterizing the state of the logarithmic twisting, equivalents to 1, and t is an irregular number in the reach [−1, 1] that characterizes how much the following situation of the falcon would be near its genuine objective. Assuming P_{AP} is lower than P_{DP} , the wellness of the picked prey is contrasted with the wellness of the falcon where if the prey is fittest it will be trailed by the bird of prey, like a jump development:

$$x_{iter} = x_{iter-1} + v_{iter-1} + f_c r(x_{chosen} - x_{iter-1}) \quad (8)$$

where, $f_c r$ is stated as following constant; Uncertainty, the falcon achieves a measure conferring to its specific discrete finest location,

$$x_{iter} = x_{iter-1} + v_{iter-1} + C_c r(x_{best,iter-1} - x_{iter-1}) \quad (9)$$

Once, the new fitness functions are registered which are described as g_{best} and x_{best}. This process is already described in Step 4.

Stage 5: Finally, after every one of the assessments the cycle proceeds until the most extreme number of ($iter_{max}$) in this manner rehashing Step 4.

5.2 Fitness function

Many conventional research has concentrated on decreasing the routing paths for mobile sensors to reduce the collision problem.

5.2.1. Average delay

Let average delay D is used to transfer the data at node i.

$$Minimize\ f_1 = avg\ D = \frac{\sum_{i=1}^{n} \beta_i de_i}{\sum_{i=1}^{n} \beta_i} \quad (10)$$

Here, the delay factor is determined as β_i at node ni and fixed to Ri, where $i = 1,2, \dots .n$. Average delay is signified as de_i.

5.2.2. Residual energy

The second objective of the residual energy is f_2 that is reduced and represented in Eq. (11).

$$Minimize\ f_2 = \sum_{i=1}^{m} \frac{1}{E_{CHi}} \quad (11)$$

5.2.3. Cost

The cost essential for transmitting with the neighbour node is described in Eq. (12).

$$C_{com} = \frac{d_{avg}^2}{d_0^2} \quad (12)$$

Where, d_{avg}^2 is specified as the distance between the neighbour and node; node radius is defined as d_0^2.

5.2.4. Distance

It is defined as the distance between the ML to EL. Thus, the fourth objective related to distances is f_3 that can be represented as follows:

$$Maximize\ f_3 = \frac{1}{\sum_{i=1}^{m} dis(CH_i, NH) + dis\ (NH, EL)} \quad (13)$$

Subsequently, all the multiple objective fitness is conflicting with each other, so it is transformed into a single objective fitness value as shown in Eq. (14).

$$Maximize\ Fitness = \emptyset_1(f_1) + \emptyset_2(f_2) + \emptyset_3(f_3) \quad (14)$$

Where $\sum_{i=1}^{3} \emptyset_i = 1, \emptyset_i \in (0,1)$. Here $\emptyset_1$, $\emptyset_2$ *and* $\emptyset_3$ are weights related through every above-mentioned objective.

At the point when some portable sensors are not exactly number of ELs, ELs are assembled into groups utilizing clustering plans. Then, at that point, the portable sensor will be dispatched to the cluster of EL. The previously mentioned coordinating with calculation is utilized to dispatch portable sensors to the cluster of ELs and afterward the calculation will be utilized to visit the ELs inside the groups. The main goal is to limit the energy consumption while deploying the sensor into Event Location because the sensors lifetime depends on energy utilization.

6. Results and discussion

In this section, the resultant model assesses the exhibitions of the proposed FOA method using the simulation setup. Here, the detecting field is set up as 450m×300m square shape. The exhibition assessment of the proposed technique EMDSM was contrasted and LEACH convention. The examination was done dependent on boundaries are called Routing overheads, PDR, throughputs, Energy Consumption, and deferral. In this model of WSN, every single node is addressed by a product specialist. This multi-specialist framework when recreated on the NS2 test system showed ideal results when contrasted with different techniques.

- Energy Consumption: It is outlined as in general energy consumed by the network for the time of data packet transmission.
- End-to-End delay: It is outlined as the period while the source node sends the data packets and the end point received the packet.
- Packet Delivery Ratio (PDR): It is outlined as the extent of packet count received to packet count transmission by a base station.
- Life Time: It is determined at every node while going through route requests. Then again, every node guesses the route life expectancy among actual and previously mentioned nodes.

The main test assesses the network lifetime of various calculations while dispatching 50 to 200 portable sensors at various rounds.

Table 1. Constraints measurement

Constraint	Assessment
Radio propagation range	250 m
Physical layer	IEEE 802.11b DCF
Simulation time	180 s
Number of sensor nodes	100–200
Network size	1000 × 1000 m
Data packet size	1000 bytes
Channel capacity	2 M bits/s

The constraints measurement is tabulated in Table 1. The proposed energy-efficient plan has been effectively carried out and tried with EMEER [16] and YSGA [17], IABC [18] & Optimal CBR [21] in terms of PDR, energy utilization, network lifetime, delay and throughput.

6.1 Performance of energy consumption

The examination of proposed FOA and related frameworks, for instance, Optimal CBR [21] in the circumstance for utilization of energy, is outlined in Fig. 2. Fig. 3 shows that the proposed FOA consumes less energy when compared with existing techniques. In the FOA strategy, a less amount of nodes has deviated during packet data transfer. Moreover, it requires an additional node while dispatching the identical data packet. Table 2 shows the Performances of Energy Consumption.

6.2 Performance of end-to-end delay:

The performance of delay parameters is analyzed under various rounds. The result of delay for proposed and existing techniques are given in Fig. 4. When the node count is started to increase, at that point, the element of the sensor also rises which leads to an increase in delay. Table 3 shows the

Table 2. Performances of energy consumption

Number of Rounds	Energy Consumption (J)	
	Optimal CBR [21]	Proposed FOA
0	0.121	0.115
15	0.111	0.102
30	0.131	0.115
45	0.131	0.120
60	0.113	0.109
75	0.128	0.120
90	0.134	0.126
105	0.140	0.131
120	0.140	0.131
135	0.136	0.130
150	0.131	0.123
165	0.130	0.122
180	0.129	0.127
195	0.137	0.130

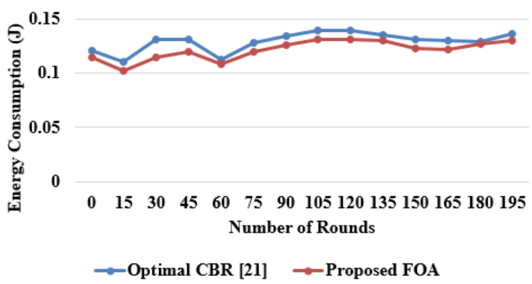

Figure. 3 Performance analysis of energy consumption

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Table 3. Performances of end-to-end delay

Number of Rounds	End-to-End Delay (ms)	
	Optimal CBR [21]	Proposed FOA
0	8.79	7.28
100	8.99	7.59
200	9.37	7.96
300	9.73	8.32
400	9.96	8.71
500	10.06	9.04
600	10.37	9.40
700	10.61	9.77
800	10.80	9.93
900	11.1	10.01
1000	11.2	10.13
1100	11.2	10.19
1200	11.2	10.19

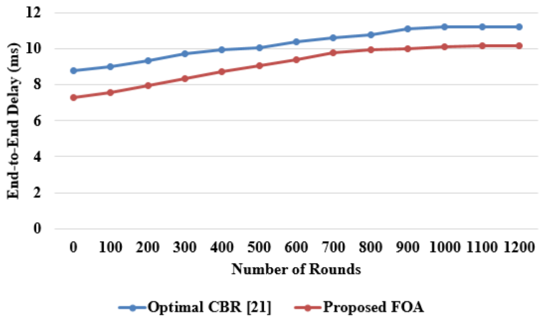

Figure. 4 Performance analysis of end-to-end delay

performance of end-to-end delay and it also shows that the delay of proposed FOA increases from 7.28 ms to 10.19 ms where Optimal CBR [21] varies from 8.79 ms to 11.2 ms. Table 3 shows the performances of End-to-End delay.

6.3 Performance of packet delivery ratio (PDR):

The result of PDR for proposed and existing strategies are outlined displayed in Fig. 5. Table 4 shows the exhibition examination for the Packet

Table 4. Performances of PDR

Number of Rounds	PDR	
	Optimal CBR [21]	Proposed FOA
0	**0.71**	**0.79**
100	**0.73**	**0.81**
200	**0.75**	**0.84**
300	**0.77**	**0.87**
400	**0.78**	**0.89**
500	**0.80**	**0.89**
600	**0.81**	**0.90**
700	**0.83**	**0.91**
800	**0.83**	**0.93**
900	**0.86**	**0.95**
1000	**0.88**	**0.97**
1100	**0.89**	**0.99**
1200	**0.90**	**0.99**

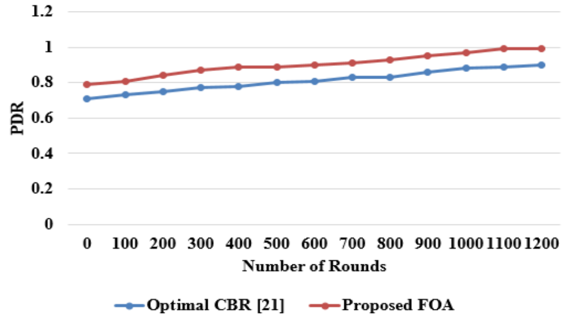

Figure. 5 Performance analysis of PDR

Delivery Ratio (PDR). Table 4, unmistakably shows that the PDR of FOA varies from 0.79 to 0.99 whereas Optimal CBR [21] varies from 0.71 to 0.90. Table 4 organizes the presentation investigation of PDR.

6.4 Performance of alive nodes:

The proposed FOA model has a higher count of alive nodes per cycle when contrasted and the Optimal CBR [21]. They include the living nodes in every cycle as shown in Fig. 6. After fulfillment of 1200 thousand rounds, proposed FOA and Optimal-CBR have 325 and 280 alive nodes, individually. However, in the proposed FOA process through less

Table 5. Performances of alive nodes

Number of Rounds	Performance of Alive nodes	
	Optimal CBR [21]	Proposed FOA
0	500	510
100	500	501
200	452	491
300	410	458
400	398	429
500	374	402
600	359	387
700	341	371
800	326	360
900	311	343
1000	301	330
1100	293	327
1200	280	325

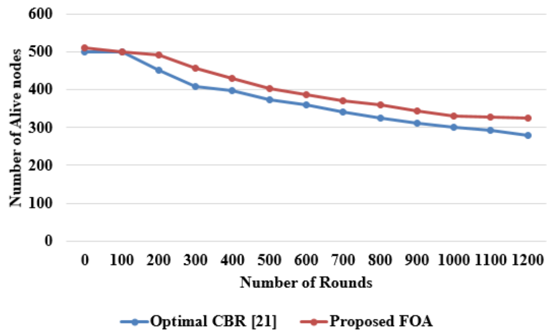

Figure. 6 Performance analysis of alive nodes

Table 6. Performance analysis of dead time

Energy (J)	Node location	EMEER [16]	YSGA [17]	Proposed FOA Method
0.01	25,75	28	30	40
0.02	25,75	26	32	44
0.03	25,75	40	43	51
0.04	25,75	49	50	60
0.05	25,75	88	92	100
0.01	75,75	35	39	46
0.02	75,75	48	52	59
0.03	75,75	62	66	71
0.04	75,75	110	111	123
0.05	75,75	140	143	152

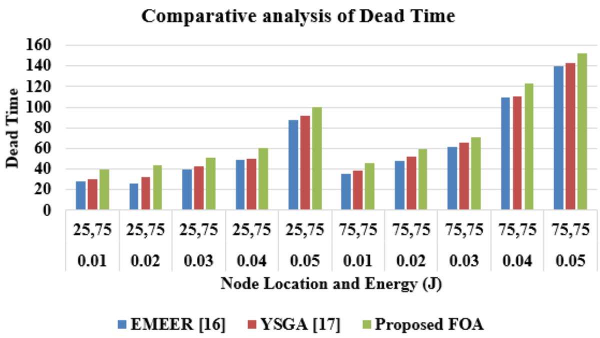

Figure. 7 Performance analysis of dead time

energy and expands the alive nodes in the network nearly. Table 5 shows the exhibition examination for Alive Nodes.

6.5 Comparative analysis

6.5.1. Analysis of dead time

Deadtime examination is introduced in Table 6 and its first node is looked at against the EMEER [16] and YSGA [17]. Fig. 7 illustrates the dead time investigation of existing and proposed FOA calculation. Fig. 8, clearly shows that the proposed FOA extends the alive time of every node when compared with existing techniques whose nodes fail more quickly.

From the performance investigation of Dead Time, it is presumed that the FOA gives preferable execution over the EMEER [16] and YSGA [17]. FOA gives better execution because of its ideal CH selection and routing path generation. Accordingly, the dead time of the FOA method is increased in the HWSN. Moreover, the node and link failure are avoided in the routing due to an appropriate fitness function. Consequently, the energy consumption of the FOA method is minimized while minimizing the packet drop.

6.5.2. Analysis of network lifetime

The performance of network lifetime is analysed through proposed FOA and existing technique IABC [18] which is outlined in Fig. 7. Fig. 7, clearly shows that FOA accomplishes better outcomes when compared with existing strategies. In addition, the node can lapse at a specific time span. In the FOA technique, the ideal node is assigned to move the bundles that cause an ascent in battery life and network lifetime. Table 7 shows the relative examination of Network Lifetime execution. From Table 7, it shows that the proposed FOA expands the lifetime at a predefined node when contrasted and existing strategies.

Table 8 shows the comparative analysis of PDR. From the Fig. 9, it clearly shows that the proposed FOA achieves less Packet Drop Ratio when compared with existing EEE-RP [15].

Table 7. Comparative analysis of network lifetime

Number of Sensors	Network Lifetime	
	Existing IABC [18]	Proposed FOA
300	512.38	562.40

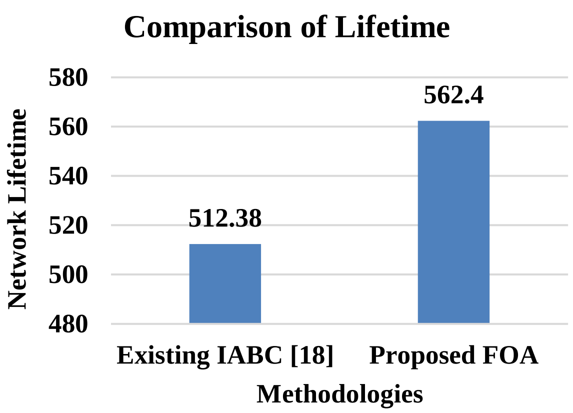

Figure. 8 Comparative analysis of lifetime

Table 8. Comparative analysis of packet drop ratio

Number of Nodes	Performance of Packet Drop Ratio (%)	
	EEE-RP [15]	Proposed FOA
500	10	8.2
750	11.5	9.8
1000	14.8	11.2
1250	17.6	15.3
1500	19.2	17.9
1750	21.8	19.1
2000	23.9	21.2
2250	25.7	22.5
2500	27.3	24.7

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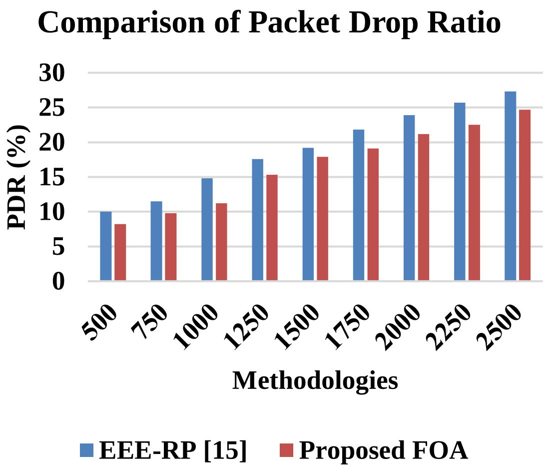

Figure. 9 Comparative analysis of PDR

7. Conclusion

This paper focuses on deploying the sensor nodes in a hybrid WSN through the FOA method to deploy MSs to visit ELs for extending the network lifespan. The FOA calculation to take care of this NP-difficult issue. MSs are then planned on their ways of visiting ELs to increment re-energizing proficiency. The simulations show that FOA outspreads an additional 8.89 % of lifespan over the existing IABC approach. Additionally, the gathering system incredibly affects execution, where the proposed FOA procedure can cluster ELs into more modest gatherings, which lessens and stability dynamism expenses of MS. In addition, the proposed FOA expands the network lifetime by extending the functioning period of mobile sensors. In the future, this proposed work is prolonged to discover the effect of mobile sensor nodes under various shapes.

Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

The paper conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing—original draft preparation, writing—review and editing, visualization, have been done by 1st author. The supervision and project administration, have been done by 2nd author.

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