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Energy Efficient Routing Protocol tuned with whale optimization algorithm in Heterogeneous WSN

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Abstract: - Heterogeneous wireless sensor network (WSN) has the potential to improve the network node life time and optimal energy to do quality communication. The sensor nodes (SN) have the restricted power and inefficient transmission is the major problem in WSN. In this paper, the whale optimization algorithm (WOA) is adopted to utilize to create the cluster head and the routing is based on Fuzzy based energy efficient routing protocol for the data transmission in quality manner. The multi-objective parameters considered here for optimization are node density, average distance and the quality of received power in order to enable the computing operation. The whale optimization inspired with the behavior of humpback whales to get an optimal solution. The combination WOA and Fuzzy based routing increases the node coverage and to reduce the computational complexity. The network is assessed through comparison with the benchmark algorithms proposed in previous research. The outcome of this research is better throughput, energy consumption, Network life time and load balancing ratio.

Keywords: Wireless Sensor Network (WSN), Whale optimization algorithm; Fuzzy-based routing; energy consumption

I. INTRODUCTION

The applications of wireless Sensor Networks (WSNs) are numerous such as IoT, aircraft security, disaster management and defense security aspects. WSN consists of several nodes to monitor the environmental factors and collect the data which is transmitted via wireless links. The performance of homogeneous WSN is not good enough to support real life applications due to limited energy sources and rechargeable battery support. Recent research concentrated on increasing the lifetime of network through various optimization techniques such as swarm-based optimization (PSO, WOA, Wolf) in heterogeneous WSN [1]. The network lifetime is prolonged in heterogeneous WSN by means of various types of sensors [2]. The main concern to design the energy efficient network lies in the design of routing protocols and clustering heads. With this the scalability is improved and hence the lifetime is prolonged in base station (BS) scenario [3]. The SNs are battery oriented and unattended, due to this practical reason, It is difficult to minimize the energy consumption. The sensor's battery power is taken into consideration for prolonging network lifetime [4]. A group of sensors which are responsible for recording physical conditions like weather information and sensory data. These data is being transmitted via wireless links in network [5] Energy management is very hard to handle in WSN, since the energy source cannot be recharged [6]. The information from the sensor is routed through various approach such single and multiple hops, chain-built tree-based, cluster-oriented communication [7]. Low Energy Adaptive Clustering Hierarchy (LEACH) is a cluster based hierarchical routing protocol. The groups of cluster Nodes are created to form the cluster heads [8]. Clustering approach resulted in longer life span. The source node (SN) consists of many clusters, Each SN transmits the sensed data to its CH [9]. The CH generates data from cluster SN and routing the data to the BS for transmission. During cluster formation, not every node becomes the member but there are some left over nodes to monitor for uncertainties in the vigilant area. These left over nodes are commonly called individual nodes [10]. The individual nodes consume more power than the other nodes since they become connected with sink node to give routing and data information. [11-14] There is a direct connection between individual nodes and sink node. Though, these nodes are used to send control messages for the optimal routing direction. Network optimization is required for enhancing the lifetime of a node. In clustering formation, the left-over nodes do not belong to any SN [15-17]. When the nodes are active, WOA combined with fuzzy-based clustering produces a good performance. Complete information about the clustering problem is not needed to reach the appropriate results. Information regarding the future position of nodes and the tracking data is considered so as to improve communication reliability. In [18] LEACH-ERE protocols method is developed to improve the energy consumption based on

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fuzzy logic. Residual energy is used to detect CH hence the energy criterion is met. Fuzzy-based Hyper Round Policy (FHRP) is suggested in [19] to reduce energy overhead. This fuzzy based method is dynamically managing to control the cluster using fuzzy logic. Residual energy and Euclidean distance are considered to calculate for flexible scheduling. An Aquila Optimizer (AO) is proposed in [20] to solve real world applications. AO is derived from the behavior of Aquila's prey hunting to optimize for global and local search. The creation of clustering is considered for the optimization of the network.

The proposed work implies that the cluster formation with the help of whale optimization algorithm and efficient routing takes place after utilizing the Fuzzy based energy efficient routing protocol. This WOA meta-heuristic algorithm works in four ways: selecting the search space, exploring the divergent search space, using the convergent search space, and moving by walking and catching prey.

In this work WOA is inspired by the humpback's social behavior of whales. The contributions are as follows,

- To develop meta-heuristic WOA algorithm for WSN clustering and by adopting a Energy efficient Fuzzy based routing (EEFBR) protocol enhanced with WOA for enhancing network clustering for efficient routing
- To optimize the clustering process with the whale optimization algorithm to improve the accuracy and to avoid left out nodes. Then EEFBR is proposed to maintain energy balance, CH selection and routing.
- To compare the experimental results with prevailing methodologies refereed in previous research to enable the prominence of the proposed EEFBR

The contributions of the paper is organized as follows: Section 2 gives the methodologies present in this paper Section 3 discusses the overview of WOA algorithm and EEFBR algorithm Section 4 focuses on the performance and comparative analysis of heterogeneous sensor network. Section 5 presents design issues of routing in heterogeneous wireless sensor network Section 6 conclude this paper.

II. SYSTEM METHODOLOGY

The role of CH node is a lead workload and cautious about energy consumption when compared to other nodes. In this work EEFBR (Energy efficient Fuzzy-based routing) is offered equal distribution and the Heterogeneous network is divided into regions based upon essential parameters such as residual energy, Distance between node and CH and Angle between node and BS. Clustering formation is the main role of proposed WOA which is considered as a multi-objective optimization approach. The fitness function is optimized through the clustering convergence protocol. The clustering optimization tries to improve the network lifetime by reducing the energy consumption. After clustering approach, Fuzzy logic tries to maintain the energy balance among the nodes. Fuzzy based routing strategy is modeling based upon human-decision strategy and previous experiences. As a result, its accuracy is outperformed when compared with probabilistic model. The proposed fuzzy logic comprises of three steps, 1. Fuzzifier includes the inputs and converting those inputs into linguistic variables. 2. Inference Engine, In which analysis and inference are performed as per the set of rules. 3. De-Fuzzifier, The conversion of fuzzy output into appropriate output.

2.1 WOA based clustering

WOA starts with a random selecting space and exploring search space for the prey, using the convergent search space, and moving by walking and catching prey. It is inspired by the actions of humpback whales hunting process. It swims in the region of prey at a circle which will be reduced slowly with a spiral shaped nature. Here the algorithm is used to explore or exploit basis depends on searching or foraging for prey. Hence the clustering process is based upon the sensing region assumed as (X,Y) and the radius of coverage is assumed as r. The representation of cluster formation is shown in fig.1. The cluster co-ordinates of a sensing zone is considered as (x,y), The number of clusters generated is determined using the following equation

$$NC = {}^{XY}\!/_{xy} \quad (1)$$

Let the cluster co-ordinates x and y is equal to t means,

$$NC = {}^{XY}\!/_{t^2} \quad (2)$$

The radius of coverage is computed as

$$r = {}^{t}/_{\sqrt{2}} \tag{3}$$

The total number of clusters formed in WSN is determined as

$$NC = {}^{XY}/_{2r^2} \tag{4}$$

The count for the upper bound NC is calculated as

$$NC = [(XY/xy) + (X/x) + (Y/y)] \tag{5}$$

The above equation (5) is re-written as if X=Y, $t=r^2$

and x=y=t

$$NC = [(X^2 + 2\sqrt{2x^*}\, r)/2r^2] \tag{6}$$

The average NC can be computed as

$$NC_{Avg} = [(X^2 + 2\sqrt{2x^*}\, r^*)/2r^2] \tag{7}$$

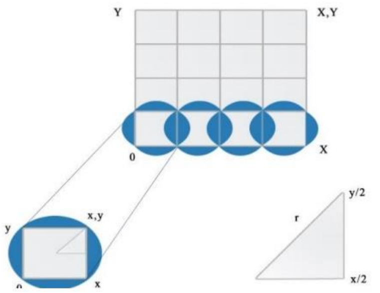

Fig.1 Cluster formation using WOA

The general articulation diagram for the proposed EEFBR is elaborated in Figure 2.

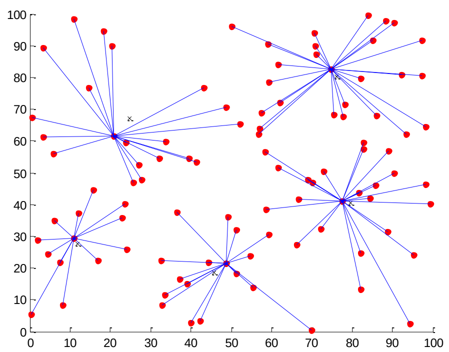

Fig. 2 Articulation of EEFBR Approach

The clustering process is started after the deployment of SN to monitor the region. The BS collected the information from all the nodes and transmits it based on the following multi-objective parameters.

1.The node energy level E,

2. The velocity of the node v1 and v2 where v1 is the average velocity and v2 is the current velocity of the node.

3. Location or position of the node (x,y)

The sample space is occupied with sensor nodes (prey) which is denoted as $= \{1,2,3, \ldots. m\}$. The generated swarm particles are based on the position (x,y) and the velocity (v1,v2).

The fitness function is based upon the node energy (E_N), specific particle energy (p) and the distance between particles (d).

Cluster formation is discussed for the prior knowledge about WOA optimization

2.1 Energy Efficient Fuzzy based Routing

In EEFBR, the total network is divided into small regions based on the network lifetime and the clustering formation. The proposed system utilizes the knowledge of data for training and test evaluation. The MATLAB simulation environment is created using poisson point process and there is no need of pre-processing. As already discussed, the EEFBR algorithm has 3 functional steps. The BS calculates the Euclidean distance between each node and the center of the region. It is computed as

$$d(i, C_{Nj}) = \sqrt{(X_i - X_{Cj})^2 + (Y_i - Y_{Cj})^2} \quad (8)$$

C_{Nj} is the co-ordinate of each region center and i is the coordinate of each node whereas j is the region number.

The number of CH is calculated as

$$K = floor(\sqrt{N} \times randn) \quad (9)$$

K is the optimized number of CH then N is the live nodes in each region.

The CH node routing is based on fuzzy logic as per the following steps.

2.1.1 Fuzzification

The fuzzy system comprises of three variable inputs such as low, medium and high. The key parameters for fuzzification are the distance between nodes, node angle and residual energy of the node.

2.1.2 Set of rules and inference engine

The inference engine is based on Mamdani method. The set of rules observed in this work are minimum residual energy, shortest distance and lowest angle between the node and the BS.

2.1.3 Defuzzification

The inference results are converted into appropriate output values. The output membership function is low, medium and high. Each node selects CH using the shortest distance and the maximum power received from the BS.

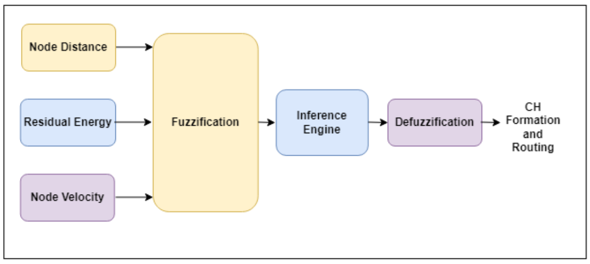

Fig.3 Attributes of Fuzzification

The BS requires the residual energy to select CH in consecutive trials. The received information from the SN is transmitted to the BS. The energy consumption is compared to other SN tasks.

2.3 EEFBR enabled with Whale optimization algorithm

The whale optimization algorithm is a meta-heuristic algorithm offered to make the universal optimum for fuzzy centroid function until the segmentation quality is met. WOA is inspired by the actions of humpback whales hunting process. It swims in the region of prey at a circle which will be reduced slowly with a spiral shaped nature. Here the algorithm is used to explore or exploit basis depends on searching or foraging for prey.

Step 1: Initialization

The population is initialized with $S_i(i = 1,2,3 \dots m)$ N set cluster centroid, coefficients U and V, Maximum Iteration count x and optimum vector $\overrightarrow{S_*}(x)$

Step 2: Fitness Function

The task is to optimize the centroid value based upon the accuracy of segmentation function.

$$FV = \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 \dots \dots \dots \dots \alpha_m x_m \tag{10}$$

We know that $\alpha_1 and\ \alpha_2$ are the random coefficient between 0 and 1.

$$\alpha_3 = 1 - \alpha_1 - \alpha_2 \dots \dots \dots \dots \dots \dots \dots \dots \dots \tag{11}$$

$$x_1 = \sum(d_N - d_p)/C_n) \tag{12}$$

Where d_N represents N^{th} node $d_N - d_p$ is the distance between sensor and N^{th} node and C_n is the number of clusters

$$x_2 = E_A V_p / E(p) \tag{13}$$

$$x_3 = \frac{1}{C_n} \tag{14}$$

$$V_{update} = \omega . v_{t-1} + \omega_1(p_{t-1} - p_t) + \omega_2(p_{t-1} \times p_t) \tag{15}$$

ω weights associated with the velocity

ω_1 & ω_2 are the weights of the location

p_{t-1} , p_t Preceding and present Position of node

v_{t-1} Preceding velocity

Step 3: Surrounding Prey

As already explained Humpback whales find the finest location and increase the quantity of iteration.

$$\vec{A} = \left| V . \overrightarrow{S_*}(x) - S(x) \right| \tag{16}$$

$$\vec{S}(x+1) = \overrightarrow{S_*}(x) - \vec{U} . \vec{A} \ \ if\ d < 0.5 \tag{17}$$

Step 4 Updating Spiral position

The position are updated in spiral form to attack the prey and the mathematically represented as

$$\vec{S}(x+1) = \vec{A}\, e^{hx} \cos(2\pi l) + \overrightarrow{S_*}(x) \ \ if\ d \geq 0.5 \tag{18}$$

Step 5 Searching for prey

$$\vec{A} = \left| V . \overrightarrow{S_{rand}}(x) - S(x) \right| \tag{19}$$

$|\vec{U}| > 1$ – Exploiting EEFBR algorithm

$|\vec{U}| < 1$ – Explore and update the finest centroid.

Step 6: Termination

The optimal set of cluster formation is the result of WOA enabled EEFBR, and the cluster centroid is fixed when the maximum number of iterations has been completed. We compute the new city clusters after allocating each pixel, based on the minimum distance, to the nearest cluster centre. Until the cycle is complete and the criteria are met, it is repeated. The node with the highest fitness value is considered as a reference, and nodes within its communication range denoted to as CMs are added to form clusters. The global best value is broadcast to each CH. In relation to the node id, the information is supplied.

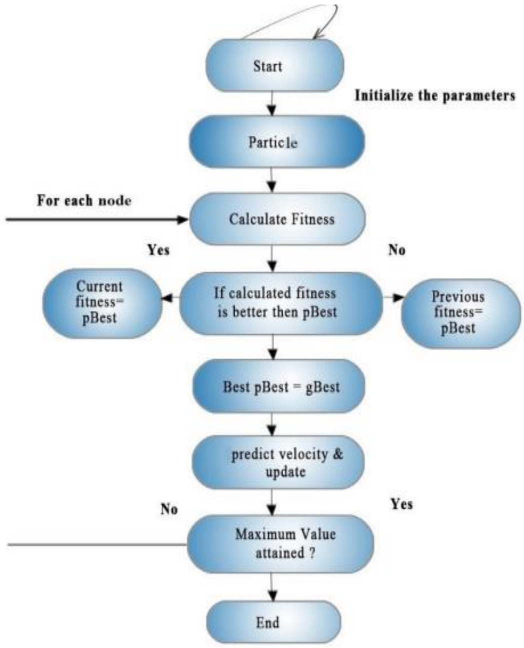

Fig.4 Flowchart of WOA clustering Algorithm

EEFBR + WOA clustering Algorithm		
Initialize	:	Values for N_a, N_d , E, $S^0 = [0]$ ε-Termination criterion {0, 1}
Ensure	:	a) all center vectors w_k b) all membership degrees O_m c) loop counter b = 1
Repeat	:	d) update clustering centroid using WOA e) update membership degrees update objective functions
Until	:	$\|O_m^b - O_m^{b-1}\| < \varepsilon, b > 1$
Return	:	f) O_m^b – Average distance and energy are good
Apply		g) Each data item into the cluster whose $\lambda_{jk} > max$ **End if**

III. RESULTS AND DISCUSSION

A. Simulation Environment

In this section, the proposed method (EEFBR), is compared with MSCR and LEACH. The evaluated parameters are simulated through MATLAB software in terms of their strengths and weaknesses. The SN are randomly distributed, and the GPS is not provided for communication. The fuzzy rules of the environment are detailed in Table 1. Here 3 input parameters (variables) are used, and each variable can be assigned one of 3 MF values (adjectives), then the total possible rules computed as 3×3×3=27.

Table 1. Fuzzy rule base for optimal routing and data transmission

Rule no.	Average Distance	Residual Energy	Node velocity	Output
1	High	High	High	High
2	Low	Medium	Good	Good
3	Medium	High	Low	High
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
27	Low	Low	Low	Low

All nodes in the cluster start sensing and sending data to their respective CHs as soon as the cluster is formed, and the CH is chosen using the WOA technique. Thus, to lessen data redundancy, the CHs start the process of aggregating incoming signals. Therefore, each CH must determine the quickest and most dependable path for transmitting the aggregated data before forwarding the detected data to the BS. Each cluster head starts by choosing the best hop to take as a result.

B. Discussion

The evaluation parameters of the proposed algorithm are CH formation, Average Energy of the node, CH formation delay and number of dead nodes. These parameters are compared with the existing algorithms such as LEACH and MSCR popular methods in this field, The sensor's features, parameters, and implementation method (simulation) were all completed under identical circumstances and using the simulation parameters table (Table 2).

Table 2 Simulation Parameters

Parameter	Value
Hetnet WSN Environment	$100 \times 100\ m^2$
Number of Sensor nodes	100
Base Station radius	200 m
Initial Energy	0.55 J
Maximum Fitness value	10
Data packet length	6400 bits
Control packet length	250 bits
Round time (T)	25 s
Packet Inetrval	0.1 sec

The randomness is obtained through repeated executions after 2000 iterations. Network average energy and network lifetime are obtained. Due to the randomness of the location of the sensors and their velocity are considered. The Hetnet WSN is simulated with 100 numbers of sensor nodes and BS in deployment region of $100 \times 100\ m^2$. The simulated WSN environment is shown in Figure 5.

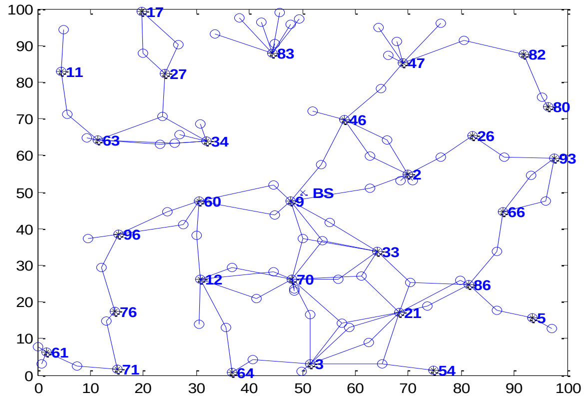

Fig.5 WSN cluster formation Phase

Network lifetime is defined as a number of rounds, and the higher number, the longer lifetime. The simulation and comparative results of the mentioned methods in terms of network lifetime are shown in Fig. 5.

Their FV determines the formation of clusters. Every node is given a priority index in each iteration, and every node is taken to be the CH. Every iteration experiences the same issue, which implies that the number of nodes in the deployed WSN will decrease or remain unchanged. This is referred to as a global iteration, and it is the point at which the cluster creation process comes to an end. At this point, there are either zero or very few remaining nodes.

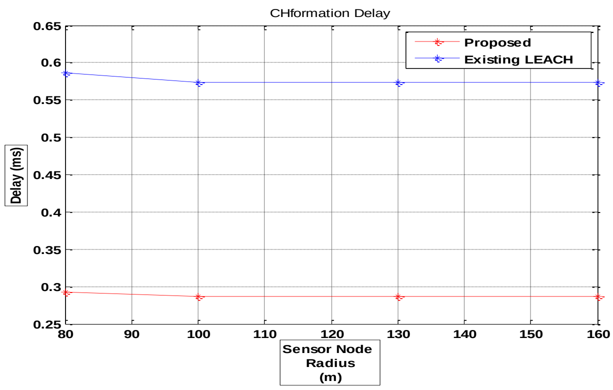

Fig. 6 Comparative results of CH formation Delay

Figure 6 indicates that the nodes run out of energy very quickly in the LEACH protocol due to inattention to the issue of energy and the lack of a specified system in CH selection. Farahzadi method, which considers the parameters of residual energy and Euclidean distance to the center of each region has increased by 100% compared to the LEACH protocol.

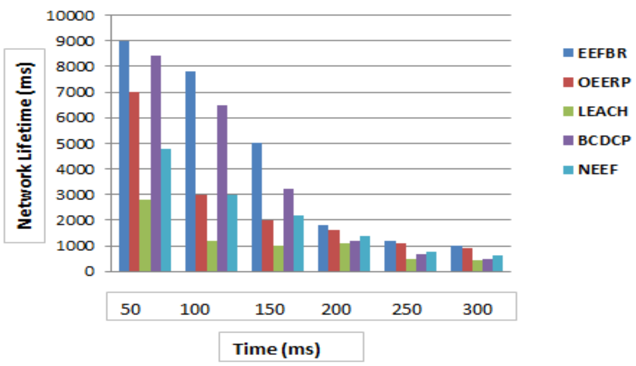

Fig.7 Comparative Network Lifetime

The proposed EEFBR method has prolonged node lifetime than the conventional methods as the combination of WOA with fuzzy logic for the optimal route selection. CH formation in EEFBR method is properly done through WOA, the total iterations have improved by 116%, 15%, and 10% linked to LEACH, Farahzadi, and MSCR methods, respectively.

The network stability is yet other important parameters. The comparative performance analysis is shown in figure 7. The set of network lifetime results are compared against the prevailing methods such as OEERP [13], LEACH [9], BCDCP [4], and NEEC [8] proposed in previous works. The probability of the nodes alive in the simulation is 0.4 and the percentage of the SN become CH is 2%.

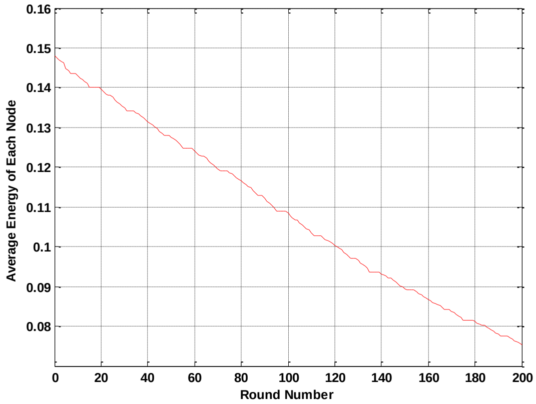

Fig. 8 Average Energy of Each Node

The average network energy of each node is depicted in figure 8 still has some remnant nodes at the end of the iteration.

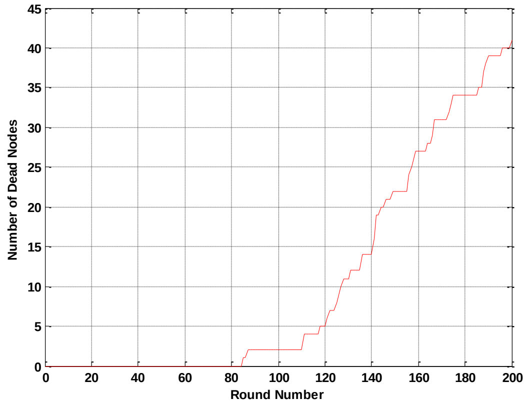

Fig. 9 Number of dead nodes in the network

The leftover number of dead nodes is depicted in the figure 9 for the assessment of a network. The total count of left over nodes is 35, 42, 17 and 19 for the prevailing methods OEERP [13], LEACH [9], BCDCP [4], and NEEC [8] respectively.

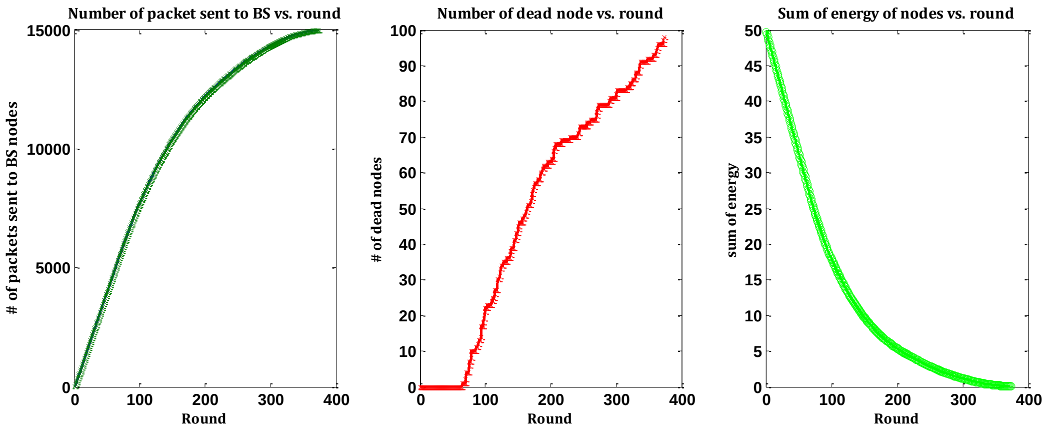

Fig. 10 Performance of EEFBR method

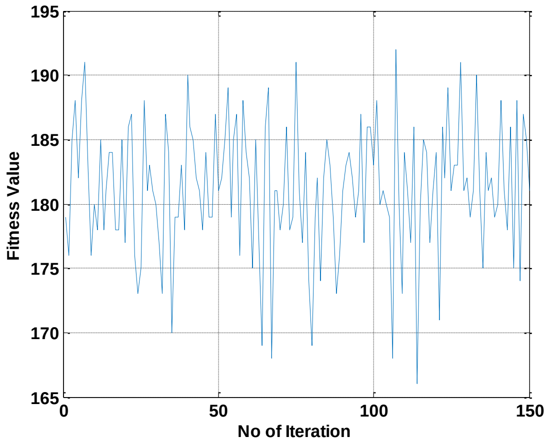

Fig. 11 Fitness value of EEFBR method

When compared to prevailing protocols, the proposed EEFBR protocol significantly improves the lifetime of WSN by making optimal use of energy usage inside the network. Figures 10 illustrates the overall performance of the proposed EEFBR method and Figure 11 shows the fitness value of the proposed EEFBR method.

IV. CONCLUSION

The inefficient transmission issue of Heterogeneous WSN is eradicated through the residual node energy and the battery power available to sensor nodes (SN). The cluster head is created using the whale optimization algorithm (WOA), and the fuzzy based energy-efficient routing protocol is developed to ensure high-quality data transfer. Network lifetime, Node density, average distance, and the quality of received power are the multi-objective characteristics that are taken into consideration for optimization. The fitness value is derived to facilitate computation and to find the best CH formation using the humpback whale behavior. We have proposed clustering to get around this energy efficiency challenge. A thorough explanation of how protocols OEERP, LEACH, BCDCP and NEEC are operated. We have also provided the specifics of the simulation and its outcomes. After a brief analysis of the simulation, we have concluded that EEFBR is better than all the prevailing methods in smaller networks with fewer than fifty nodes overall, and when the heuristic probability of Cluster Head selection is higher. Advantages: 1) It increases the network life time. 2) It is used to outrage the battery replacement problem in nodes. 3) Average complexity.

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