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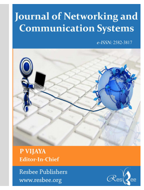

Optimized Cluster Head selection in WSN using GA-WOA

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Abstract: WSN plays an excellent role in offering a dynamic selection of CH. Nevertheless, the CH chosen is the most important confronts because of the flawed CHselection which may cause unbalanced energy utilization. In this work, this challenge is addressed by developing a hybrid optimization method for the chosen CH. The developed CH chosen consists of 3 phases that comprise the setup, transmission, and measurement phase. Initially, energy, and node's mobility, are initialized in the network. The setup phase is processed by selecting Cluster Head exploiting Optimized Sleep-awake Energy-Efficient Distributed clustering that is modeled by deciding optimal threshold and Cluster Head exploiting developed GA based WOA (GA-WOA). The developed GA-WOA is modeled by combining the Genetic Algorithm into Whale Optimization Algorithm. Moreover, the selection of the threshold and CH is performed by exploiting multi-objective constraints that include energy, distance, and delay. Subsequent to the CHs determination, data transmission starts from CHs to BS. Finally, in the measurement phase, the remaining energies generated from nodes are being updated. The developed GA-WOA model exhibits better performance by provided that maximum throughput, energy, and number of alive nodes correspondingly.

Keywords: WSN, Cluster head, energy, alive nodes, base station

Nomenclature

Abbreviation	Description
WSN	Wireless Sensor Networks
GAOC	GA-based Optimized Clustering
CH	Cluster Head
GA	Genetic Algorithm
SN	Sensor Nodes
WOA	Whale Optimization Algorithm
HRFCHS	Hyper-Exponential Reliability Factor-based CHS
O-SEED	O-Sleep-Awake Energy-Efficient Distributed
ABC	Artificial Bee Colony
CHS	CH Selection
PSO	Particle Swarm Optimization
MBOA	Monarchy Butterfly Optimization Algorithm
MS-GAOC	Multiple Data Sinks based GAOC

1. Introduction

Nowadays, the WSN has considered as the expectant modality. WSN examines the environment, by recognizing changes that occurred in scrutinize areas. A number of changes happened such as pressure, vibration, humidity, sound, intensity, temperature, and motion. The WSN applications are generally used in several monitoring systems in areas such as military solicitations, habitat monitoring systems, bio-medical applications.

Sensors gather data and transfer them to central nodes, named base stations in a WSN. As transmitting data directly to base stations utilizes lots of energy, it is not appropriate for an energy-constraint network like WSN whereas nodes converse by means of each other in multi-hop transmissions. The most important disadvantage of multi-hop transmissions is the huge count of packets that must be swapped among linked nodes. It minimizes the lifespan of the network due to its dependency on the node's energy. Therefore, minimizing energy utilization is the most important confront for WSNs. The network coding and topology control are the majority capable approaches that have received widespread concentration for reducing energy utilization and enhancing the performance of the network.

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The central part purpose of co-operative data processing based upon energy consumption of sensors which required to be balanced to attain an utmost lifespan in WSNs. Moreover, SN by means of inadequate energy cannot give for data processing as they cannot supportive in the data collection process self-governing of type of data collected, monitored, and collected. Hence, the energy utilization of sensors on the basis of the remaining energy obsessed using individual SNs is verified by common researchers. Numerous conventional cluster head selection approaches are focused on energy utilization or trust of SN in forwarding packets.

The major objective of this work is to present a method for the selection of CH chosen in WSN and data transmission. At first, the WSN network is implemented by means of SN and CH has chosen is carried out by exploiting the three phases. Here, the developed GA-WOA method is modeled by combining GA into WOA. Moreover, the threshold, and CH, are selected based on multi-objective constraints that include energy, distance, and delay.

2. Literature Review

In 2020, Saeed Doostali and Seyed Morteza Babamir [1], worked on a distributed method to classify the SNs into dynamic clusters to balance energy utilization and minimize superfluous data. The near-optimal probability of CHS was derived on the basis of the Poisson randomization method to reduce intra- and inter-cluster energy utilization. Finally, it was shown that considering the developed method can considerably enhance the lifespan of networks evaluated with conventional techniques. In 2019, Bandi Rambabu et al [2], worked on a "Hybrid ABC-MBOA"-based CHS Scheme for the predominant chosen of cluster heads in the clustering procedure. This developed Hybrid ABC-MBOA restores the employee bee stage of ABC with mutated butterfly altering the operator of MBOA to prevent preceding trapping of solutions into a local optimal point and delayed convergence by altering tradeoff among exploration and exploitation. In 2018, A. Amuthan and A. Arulmurugan [3], presented energy and trust evaluation combined prediction method called "HRFCHE" via Semi-Markov model for enhancing network lifespan. The outcomes of HRFCHE infer its better performance by enhancing the lifespan of the network and minimizes energy utilizations main to the cluster head selection methods exploited for evaluation. In 2018, Kale Navnath Dattatraya andK. Raghava Rao [4], developed a novel CHS method to obtain the utmost lifespan of the network, least energy utilization, delay, etc Moreover, a novel Glowworm swarm "Fruit fly algorithm (FGF)" to select optimal CH in WSN. The adopted FGF performance was evaluated with the existing approaches regarding the energy analysis, alive node analysis, and cost function. In 2016, Snehal P. Dongarea and Prof. R. S. Mangrulkar [5], presented an energy-efficient method to alleviate the collision of both types of attacks at the same time, on enhancing the CHS approach. Moreover, an energy effectual method, on recognizing and prevent the cooperating. During the packets transmission phase, honest nodes were decided to entrust as CH. In 2019 Sandeep Verma et al [6] modeled a "GAOC" protocol for optimized CH chosen by combining parameters of the remaining distance, energy, to the base station, and node density in its formulated fitness function. Moreover, to deal by means of Hot-Spot issue, in addition, to curtail communicating distance from nodes to base station, MS-GAOC was developed. The simulation results of MS-GAOC were performed by means of protocols proposed to operate by means of multiple database stations to have a superior comparative analysis.

3. Data Transmission Using Developed GA-WOA Algorithm in WSN

In this section, CH chose and communication algorithm exploiting O-SEED clustering, with a sensor node that is positioned in the environment is demonstrated. The algorithm is modeled in 3 phases that involve setup, transmission, and measurement phases. The CH is selected to transfer data to Base Station from SN by exploiting the O-SEED clustering in the setup phase that is decided by choosing the optimal threshold and Cluster Head by exploiting the developed GA-WOA method. The developed GA-WOA method is the integration of the GA into WOA. Moreover, the cluster head and threshold are selected by using the multi-objective constraints, namely, delay energy and distance. Subsequent to chosen of CH, CH data transmission is initiated to the Base Station. Finally, the measurement phase is experienced for updating residual energies. Fig. 1 demonstrates the architecture model of adopted GA-WOA for optimal CHS

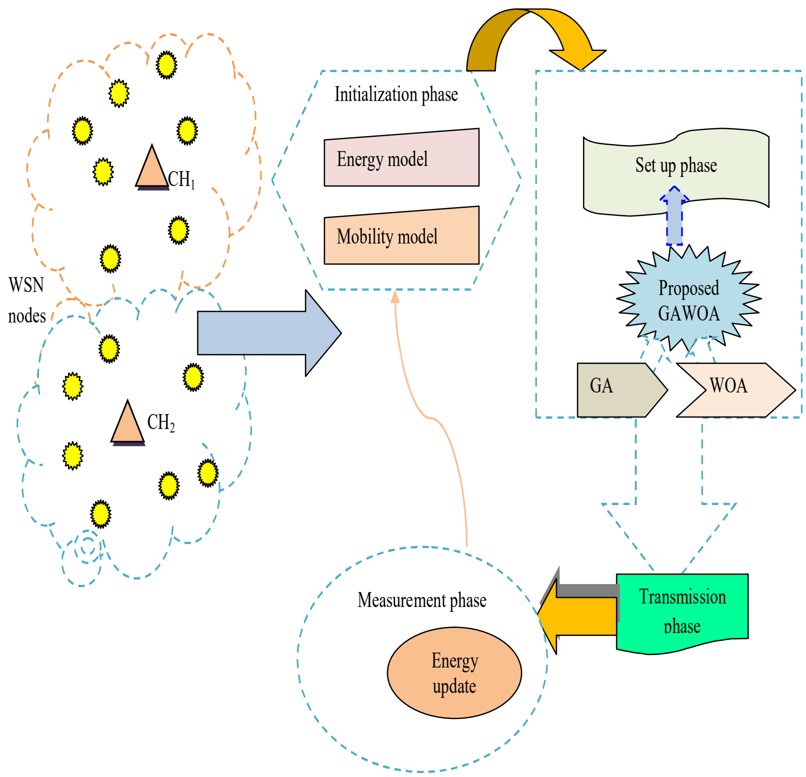

Fig. 1. *Architecture model of adopted GA-WOA for optimal CHS*

3.1. Initialization Phase

In this phase, the system model of the WSN is shown that involves the mobility and energy model. The most important problem seen in the WSN is energy shortage that is exhausted out as the amount of rounds is maximized. In order to resolve this problem, the WSN is partitioned into 3 levels on the basis of the energy levels. The shortest level is nearer to the Base Station comprises normal nodes with minimum energy, where the in-between level comprises the very good nodes with intermediate energy, and the final level is the far-away from the Base Station comprises the progress nodes, it attains the maximum energy. Hence, these Sensor Nodes are legally responsible for information sensing and transmitting sensed information to Base Station. In order to minimize the broadcast and reception energy of S Sensor Nodes N, the clustering algorithm is formulated. In clustering, on basis of the remaining energy chosen of the CH is performed. From all the SN, the CH gathers data and forwards data to the BS. Let a WSN by means of a total of g nodes that S indicates the number of normal nodes, and T indicate the number of CHs, and BS, be a base station that activates in energy-effectual chosen of the CH.

3.1.1 Energy Model

The energy model [7] [8] of WSN is discussed in this section. In this model, by exploiting the batteries, the WSN is operated, which comprises numerous sensor nodes. Here, energy is considered as a significant aspect in order to participate in data transmission so each node requires considerable energies. The sensor nodes are operated based on the battery, using the batteries the nodes exploit the energy that residuals totally charged in the first phase. Subsequently, at the time of the transmission of the data, the energy is decreased gradually. Moreover, the energy utilization model is described in this section. In addition, to generate the radio waves the transmitter is responsible so as to transmit the data by exploiting the antenna. Likewise, to run the radio electronics, the receiver exploits the energy. While the transmitter node transfer message of M bits over a distance h, the subsequent node distributes energy and it is stated in eq. (1).

$$G_t(M,h) = \begin{cases} MG_e + MH_a h^2 & h \le h_o \\ MG_e + MH_r h^4 & h > h_o \end{cases} \tag{1}$$

In eq. (1), G_e signifies electronics energy, $G_t(M,h)$ signifies transmitter energy, h signifies distance, M signifies message, h_o signifies threshold distance, H_a signifies amplifier energy in free space, and H_r signifies radio amplifier energy. The energy is excluded out while the receiver node receives the message and it is stated in eq. (2), $G_e(M)$ signifies the transmitter energy.

$$G_r(M) = MG_e \tag{2}$$

3.1.2 Mobility Model

To illustrate the sensor node movements and to evaluate the alter in the location of the nodes on the basis of the acceleration, velocity, and position in an exact instant, the mobility model is formulated in [8]. To decide the routing performance of the method, the mobility model is changed and it is exploited to imitate the movement among the node. At time $z = 0.$ presume nodes b_f and b_l positioned at (u,v) and (u^*,v^*). To new location, the nodes b_f , and b_l moves with a variable velocities based on the 2 angles $\phi_{b,f}$ and $\phi_{b,l}$. Moreover, at time $z = 0.$ node b_f moves a distance $D_{b,f}$, and a node, b_l moves a distance $D_{b,l}$. Let (u_f,v_f) and (u_l,v_l) signifies the updated locations changed by nodes b_f and b_l at time $z = 1$. Meanwhile, the node resides in 2 novel locations and this procedure is continued until each node is included in the transmission however, efficient transmission is attainable only for nodes possessing minimum distance that is formulated based on the Euclidean distance. Hence, Euclidean distance among nodes b_f and b_l at a time $z = 0$ is stated as,

$$D(b_f, b_l, 0) = \sqrt{|u - u^*|^2 + |v - v^*|^2} \tag{3}$$

In eq. (3), (u,v) and (u^*,v^*) indicates the new location of nodes b_f and b_l at $z = 0.$ Let nodes b_f and b_l moves by means of a velocity $x_{b,f}$ and $x_{b,l}$ creating an angle $\phi_{b,f}$ and $\phi_{b,l}$ with the x-axis. Hence, distance covered by a node in a precise time z is stated as,

$$D_{b,f} = x_{b,f} \times z \tag{4}$$

$$D_{b,l} = x_{b,l} \times z \tag{5}$$

At the time $z = 1,$ while node b_f moves at distance $D_{b,f}$ and angle $\phi_{b,f}$, subsequently novel location of node b_f at a time z is stated as eq. (6).

$$u_f = u + x_{b,f} \times z \times \mathrm{Cos}(\phi_{b,f}) \tag{6}$$

$$v_f = v + x_{b,f} \times z \times \mathrm{Cos}(\phi_{b,f}) \tag{7}$$

In eq. (7), $\phi_{b,f}$ indicate angle in that node b_f moves to a novel location. Likewise, while node b_l moves at distance $D_{b,l}$ at an angle $\phi_{b,l}$, subsequently novel location of node b_l at a time z is stated as follows:

$$u_l = u^* + x_{b,l} \times z \times \mathrm{Cos}(\phi_{b,l}) \tag{8}$$

$$v_l = v^* + x_{b,l} \times z \times \mathrm{Cos}(\phi_{b,l}) \tag{9}$$

At time instant $z,$ distance among nodes at b_f positioned at the location (u_f, v_f) and (u_l, v_l) is stated as below,

$$D(b_f, b_l, z) = \sqrt{|u_f - u_l|^2 + |v_f - v_l|^2} \tag{10}$$

In eq. (10), (u_f, v_f) and (u_l, v_l) indicates the novel location of nodes b_f and b_l.

(i) Set Up Phase

The optimal Cluster head is selected on the basis of the developed O-SEED clustering approach. On the basis of the developed GA-WOA and SEED model the adopted model is formulated.

(ii) Fitness Evaluation

On the basis of definite parameters such as energy, threshold, the distance among nodes, and cluster head available in the WSN, the fitness is evaluated. The fitness on the basis of the GA-WOA approach is adapted to determine the optimal cluster head. The fitness is calculated on the basis of the below fitness formula:

$$N = \{Y(b_q) + (1 - G_Q) + (1 - G_{Q'}) + (1 - G_P) + (1 - Z)\} \tag{11}$$

In eq. (11), $Y(b_q)$ indicate the node threshold b_q , G_Q indicate the energy utilization of CHs, $G_{Q'}$ defines the energy utilization of non-CH nodes, G_P indicate energy utilization in TDMA, and Z defines the distance from nodes to Cluster Head.

a) Threshold: For the selection of CH, every node has to determine if to turns out to be a Cluster Head or not by choosing a value among (0, 1). If the selected amount is lesser than the threshold $Y(b_q)$, subsequently node b_r becomes the Cluster Head. Here, the threshold is selected on the basis of the following equation:

$$Y(b_q) = \begin{cases} \dfrac{K_n}{1 - K_n (y \bmod \frac{1}{K_n})} \\ \dfrac{K_o}{1 - K_o (y \bmod \frac{1}{K_o})} \\ \dfrac{K_s}{1 - K_s (y \bmod \frac{1}{K_s})} \\ 0 \end{cases} \tag{12}$$

In eq. (12), K_o indicates favored+ percentage of CH in advanced nodes, K_n indicates the favored percentage of Cluster Head in normal nodes, and K_s signifies the preferred percentage of CH in supernodes, I signifies node-set that haven't been CH, and y signifies current round.

b) Energy Utilization of non-CH Nodes: After completing the selection of the CH subsequently, every non-CH node creates a choice for that the CH is combined in the conventional round. The CH is chosen by exploiting suggestions concerning the strong point of the received signal. Hence, utilization of energy for a non-CH node in creating a cluster is stated as below:

$$G_{Q'} = 2M_1 G_e + M_1 H_a h_c^2 \tag{13}$$

The total energy used to create a cluster is stated as follows:

$$G_Q^{all} = l\left[G_Q + \left(\frac{g}{l} - 1\right) G_{Q'}\right] \tag{14}$$

In eq. (14), G_Q indicate energy utilization of Cluster Head, l indicate the number of clusters, $G_{Q'}$ indicate energy utilization of non-CH, g indicate total nodes, and G_Q^{all} indicates total energy utilization.

c) Energy Utilization of Cluster Head Nodes: The CH used energy from any areas is calculated as,

$$G_Q = M_1 G_e \left(\frac{g}{l} - 1\right) + M_1 H_r h_{BS}^4 + M_1 H_a h_c^2 \tag{15}$$

d) Energy Utilization for TDMA: After the connection of the non-cluster node to CH, subsequently every cluster head allocates the TDMA slots to every sensor node. The cluster sensors can swap the data packets with connected CH's at the assigned time. Hence, the energy used by Cluster Head to allocate the TDMA slot is indicated as below,

$$G_P = l\left[G_P + \left(\frac{g}{l} - 1\right) G_{P'}\right] \tag{16}$$

whereas,

$$G_P = 2M_1 G_e + M_1 H_a h_c^2 \tag{17}$$

$$G_{P'} = M_1 G_e \tag{18}$$

The total energy utilization to assign the TDMA scheduling is stated as below:

$$G_P^{all} = l\left[G_P + \left(\frac{g}{l} - 1\right) G_{P'}\right] \tag{19}$$

The total energy utilization is devised as below,

$$G_W = G_Q^{all} + G_P^{all} \tag{20}$$

e) Distance: The distance is represented as a significant model, while data is to be transferred from one node to another node. By exploiting network topology the distance is computed which is in charge of the node mobility on the basis of their velocities, positions, and accelerations. Moreover, the distance among the CH m_i is stated as follows:

$$Z = \left\{ \frac{1}{|m| \times g} \sum_{i=1}^{|m|} \sum_{\substack{k=1 \\ i \in k}}^{g} \frac{z(m_i) g_k}{g} \right\} \tag{21}$$

iii) Transmission Phase

Subsequent to chosen optimal CH by the developed GA-WOA, data transmission is initiated from Cluster Head to Base Station. Conversely, the communication between a Cluster Head and a sink happens exploiting certain parameters that are modeled based upon the threshold, energy, and distance.

iv) Measurement Phase

Finally, the residual energies presented in the nodes are updated. Subsequently, the process is continued until the transmission of data to the CH terminates in the measurement phase

4. Proposed GA-WOA Algorithm

The process of the proposed algorithm procedures are stated as below:

WOA imitates the social behavior of humpback whales [9]. They are stated as below:

i) Initialization Population

Whales population is produced in an $X -$ dimension vector to solve s_p problem [9]. Moreover, X signifies the total variable and s_p signifies the total population:

$$Q_k = S_{task} + q_{min} + ran(1, X)(q_{max} - q_{min}) \; (k = 1, 2, \ldots\ldots, S_P) \tag{22}$$

whereas, q_{max} and q_{min} signifies the limits of q_k in X directions, S_{task} signifies the sub-task set, and $ran(1, X)$ states uniformly scattered random number in the range [0, 1].

ii) Encircling Prey

After identifying optimal search agent, the remaining agent will there subsequently attempt to update the location for an optimum search agent and it is indicated as below:

$$\vec{X} = \left|\vec{U}.\vec{Q}(m) - \vec{Q}(m)\right| \tag{23}$$

$$\vec{Q}(m+1) = \vec{Q}(m) - \vec{V}.\vec{X} \tag{24}$$

$\vec{Q}$ signifies the vector indicating the location of the superior solution is attained so far., m signifies the current iteration, $\vec{X}$ and! $\vec{Q}$ signifies vector locations and $\vec{U}$ & $\vec{V}$ signifies the vectors of co-efficient. In every iteration, $\vec{Q}$ is fed to obtain the update if a superior optimal solution is attained and vectors $\vec{U}$ and $\vec{V}$ states change over iterations.

$$\vec{V}. = 2\vec{v} \cdot \vec{r} - \vec{v} \tag{25}$$

$$\vec{U}. = 2\vec{r} \tag{26}$$

$\vec{r}$ signifies an arbitrary vector in [0, 1], and $\vec{v}$ signifies linearly minimized from 2 to 0.

iii) Bubble Net Attacking

While a prey tries to attack for the bubble net behavior, the humpback whale possesses distinctive path movement that is attacked by prey.

a) Shrinking Encircling Mechanism

The $\vec{v}$ is minimized to (27), to apply the shrinking mechanism. Therefore, the range of oscillation $\vec{V}$ will be minimized to $\vec{v}$.

$\vec{V}$ is treated as the interval among (-a and a), and here over each iteration v value is decreased from 2 towards 0. Selecting arbitrary values for $\vec{V}$ in (1, 1), updated location in any stated search agent is decided. This is in the middle of any of the ranges between the initial location and the current location of the agent.

b) Spiral Updating Position

For the updating, a stated spiral formulation in a position is therefore produced between the whales on the basis of their position and the victim's position to mimicker the spiral structured humpback whales and they indicated as:

$$\vec{Q}(m+1) = \vec{X} \cdot e^{sn} \cdot \cos(2\pi n) + \vec{Q}(m) \tag{27}$$

$$\vec{X} = \left|\vec{Q}^{*}(m) - \vec{Q}(m)\right| \tag{28}$$

Whereas, s signifies helix structured constant and it is typically allocated value 1 and s signifies arbitrary amount among intervals -1 and 1. Arbitrary number selection G among [0,1] possesses a 50% possibility to switch among the modes to update the whale's location as below

$$\vec{Q}(m+1)=\begin{cases}\vec{Q}^*(m)-\vec{V}\cdot\vec{X} & \text{if } G<0.5\\ \vec{X}\cdot e^{sn}\cdot\cos(2\pi n)+\vec{Q}^*(m) & \text{if } G\geq 0.5\end{cases} \tag{29}$$

iv) Exploration Phase

If stated values are higher than 1 and minimum than 1, it subsequently forces the agent from sending out of way from a whale which is represented as objective. A similar term is stated as

$$\vec{X}=\left|\vec{U}.\vec{Q}_{rand}(m)-\vec{Q}(m)\right| \tag{30}$$

$$\vec{Q}(m+1)=\vec{Q}^*(m)-\vec{V}.\vec{X} \tag{31}$$

So as to the whale optimization to present the best solution for the convergence problem, the hybrid GA [10] is exploited in this paper in the WOA. Hence the aforementioned formula exploited the crossover and mutation operators before location updating of the GW. The two-point crossover is exploited and shown as

$$\vec{Q}(m+1)=\vec{Q}_{rand}(m)\oplus C_1\oplus C_2 \tag{32}$$

$$C_1=\frac{\left|\vec{Q}(m)\right|}{3} \tag{33}$$

$$C_2=C_1+\frac{\left|\vec{Q}(m)\right|}{3} \tag{34}$$

where, C_1 and C_2 states the two points that are used as points of crossovers and then mutation is performed by location of 5 new genes as a swap to the genes of each chromosome. The genes which are restored are randomly chosen with no replication of chromosome.

5. Result and Discussion

In this section, the outcomes of the adopted technique and its efficiency were shown through the relative analysis regarding the conventional techniques. The illustration outcomes of the experimentation were shown for both the proposed and conventional models such as PSO, ABC, WOA, and GA.

Tables 1 and 2 reveals a comparative analysis of the proposed model and conventional models based on the throughput, alive nodes, and energy using 50 and 100 nodes. The overall analysis shows that the adopted technique performs superior to existing models.

Table1. *Performance analysis of proposed method exploiting 50 nodes*

Techniques	ABC	PSO	GA	WOA	Proposed method
Alive nodes	3	1	7	6	8
Energy (J)	0.1	2	0.03333	0.03333	0.1222
Throughput (%)	68.707	67.5	70.33	70.19	78.22

Table 2. *Performance analysis of proposed method exploiting 100 nodes*

Techniques	ABC	PSO	GA	WOA	Proposed method
Alive nodes	15	10	11	20	21
Energy (J)	0.099	0.009	0.022	0. 1000	0.11
Throughput (%)	67.470	0	55.33	34.222	78.75

6. Conclusion

This work set up a platform for data communication by adopting GA-WOA approach to initiate the communication in sensor nodes in WSN. In the WSN node, CH's were formed by the developed technique, which was the combination of the GA and WOA method, and CH's help the communication, and the optimal CH was determined by exploiting the fitness function. Moreover, the developed technique was processed in 3 stages, namely the setup, transmission, and measurement phase. Initially, the the network was initialized using initial energy, and the mobility model was used to manage the mobility of the nodes. In the setup phase, CHs were selected for transmission of data from nodes to BS by exploiting O-SEED clustering, which was recently adopted by discovering the optimal threshold and

CH's exploiting the developed GA-WOA approach. Moreover, the threshold, and CHs, was chosen on basis of multi-objective constraints, like energy, distance, and delay. Subsequent to the selection of CH's, data transmission starts from CH to BS. Finally, residual energies available in nodes are updated in the measurement phase. The analysis of approaches was performed by exploiting the performance measures such as throughput (%), energy (J), and alive nodes and performance analysis shows that efficiency of the developed algorithm with maximum energy, throughput, and the number of alive nodes correspondingly.

Compliance with Ethical Standards

Conflicts of interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows the ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

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