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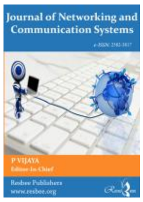

Enery-Aware routing in MANET: Hybrid Genetic and Group Search Algorithm

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Abstract: MANET is the infrastructure-less, self-organized wireless network. Here, the mobile nodes can join the group or leave from the network group dynamically. As the mobile ad hoc network (MANET) is established with the battery power nodes, reducing the power consumption of mobile node poses a major complex in the network system. Efficient and robust secure routing protocols are required in MANET due to the quickly changing network topology such that the overhead incurred in the track is excessive. To achieve the secure routing path mechanism with less delay and minimum energy consumption of the nodes, a multi-objective based optimization algorithm is introduced in this research work. Here, the best optimal route is chosen for routing the data packets from the source to the destination on the basis of defined multi-objectives like: energy, delay, distance and link state stability. The secure path energy efficient path is identified by the Crossover of GA with GSO Algorithm (CGA-GSO). This is the hybridized form of standard Genetic Algorithm (GA) and the Group search Optimization (GSO) algorithm. The performance of the proposed model will be analyzed over the traditional approaches concerning Energy and Delay as well.

Keywords: MANET routing; Optimal Path Selection; Defined Mult-Objectives; Proposed CGA- GSO.

1. Introduction

MANET has a gathering of versatile hubs, which makes a powerful autonomous system through completely movable framework. The hubs speak with one another without the contribution of concentrated base stations or the passageways [4].However, the MANET regularly contains remote hubs, which works with no fixed framework [3][5]. The hub, which are available in these systems make the application traffic and client traffic for playing out the directing conventions and system control. The fast changes in the collision, higher error rates, power control, network partitions, connectivity, interference makes the issues in the structure of more elevated level conventions, such as routing and actualizing the nature of service[15] [8]. For the most part, the MANET has different applications in the field of military activities, portable systems and calamity help process. Different systems confinements in the MANET are visit connect instability because of the versatility, restricted transmission capacity, and the low battery intensity of nodes [9] [6] [10] [11] [12]. The rotation in the radio recurrence geography allows the system administrations to help the particular nature of administrations and capacities [2] [14]. In MANET, there are for the most part two methods for geography management, to be specific clustering and power control. Further, the power control technique manages the force based on per hub, in this way one hop neighbour availability is adjusted to guarantee the organize network [7] [4]. The wireless ad-hoc network and the profoundly powerful geography build up the trouble in the management of gathering participation in light of the fact that the associations are impermanent [7].

The geography control component is utilized to deal with certain measurements, similar to hub versatility, power the executives and the frequency management [2]. In MANET, the fundamental objective of power control approach is to achieve the network connectivity. The power control strategy upgrades the system ability, yet additionally improves the battery limit of hubs [1]. In the hub, the power is devoured at the hour of transmission, “routing, receiving and processing packets” of information [10]. Along these lines, the power control strategy is the huge concern for the MANET [1]. Also, different power control approaches are used for the power management, like Power Aware Routing Optimization (PARO) [8] [10] [15].

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A portion of the difficulties looked by the protected directing in MANET are depicted underneath: To discover and identify the system assaults in the system while the administration is missing represents an incredible test, because of the mistaken observing of traffic in versatile system. Asset accessibility represents a significant test in MANET, as giving the safe transmission in the changing condition and ensuring against the dangers requires the improvement of security components. Because of the versatility and the changing geography structure, adaptability represents a mind boggling issue in MANET [8]. Thus, there is a necessity to develop an energy-efficient approach with an optimization concept [18] [19] [20] [21] for enhancing the power consumption and life span of the network.

The rest of the paper is organized as: Section II depicts the most fascinating works undergone in literature regarding the MANET routing. Section III portrays about the secured proposed power-aware routing protocol in MANET: system model and multi-objective function. Section IV addresses about the proposed multi-objective based optimization: CGA- GSO approach. The resultant acquired with the presented work is discussed in Section V. Finally, a strong conclusion is provided to this research work in Section VI.

2. Literature Review

2.1 Related works

In 2014, Manickavelu and Vaidyanathan [1] have introduced "a particle swarm optimization (PSO)-based lifetime prediction algorithm" for MANET routing. Here, on the basis of the relative constraints like the energy drain rate as well as node mobility, the node link life time of nodes was predicted. Further, the node status was decided by the fuzzied parameter (relative mobility and energy drain rate of nodes) and fuzzy rules. Then, with the PSO prediction, the communication overhead and the data loss was minimized.

In 2015, AJAN and SHANTHI [2] have proposed “a Hybrid Genetic Based Optimization for Multicast Routing algorithm" in MANET. The multiple nodes that send packets at the same time were fed as solution to the proposed model that uses the best features of Genetic Algorithm (GA) and particle swarm optimization (PSO) to find the optimal path. As a consequence, there was upgrading in the end to end delay and jitter with quick convergence.

In 2017, Rajadurai et al. [3] have utilized the genetic algorithm (GA) for best path selection in MANET on the basis of the objectives like the "packet deliver ratio, latency and energy consumption ". Further, with the backup paths of the network structure, the tree based multicast protocols validity was improved. The proposed GA model improved the tree structure efficiency and hence routed the data in the optimal path.

In 2019, Kandan and Sabari [4] have developed fuzzy hierarchical ant colony optimization routing in MANET for maintaining the cluster head sustainability within the clusters. On the basis of the nodes quality of service, the cluster head was selected. The authors have selected the optimized cluster head on the basis of the fuzzy hierarchical ant colony optimization routing. Further, in the proposed FHACO protocol, the processes were involved: "Ant colony optimization, Fuzzy Rules for Cluster Head Selection Process and Cluster’s Gateway".

In 2020, Babu and Balasubramanie [5] have developed fuzzy logic with hybrid optimization approach in MANET for optimal route selection. The authors have developed this approach on the basis of the "2-Opt algorithm and Artificial Bee Colony (ABC)". Further, when a node tends to leave from the network, the several packets might get lost and different route requests might be generated. The fuzzy rule system was based on the end-to-end delay and this approach had enhanced the network lifetime.

3. Secured Proposed Power-Aware Routing Protocol in MANET: System Model and Multi-Objective Function

The significant exploration destinations are clarified in this area:

(i) To locate the ideal way among different system courses utilizing the power aware security routing protocol.

(ii) To find the most feasible path among the best selected paths.

3.1 System Model of MANET

The system model of MANET is illustrated in Fig. 1. The optimal path utilized for the transmission of data is depicted here. In between the neighbouring nodes of the network, the gateways act as the interface to increase the coverage and connectivity. The energy-aware routing mechanism contains three different phases, like discovering the path, optimization framework, and establishing the optimal path. The graph structure of the MANET is denoted as $S(X,Y)$, in which the node set $X=\{x_1,x_2,\ldots x_a,\ldots x_q\}$ and Y represents the link set. Here, the notation q denotes the total number of nodes and $1\le a\le q$. The mobile nodes of $Y=\{y_1,y_2,\ldots,y_j\}$ that connect between x_p and x_s such that $1\le p\le s\le q$. Initially, the paths available in the network are selected such that the optimal path used to transfer the data from source to destination is selected using the proposed optimization algorithm. The best secured path can be selected in tersm of multi-objective factors like delay, distance, energy (or power) and link maintenance. To reduce the data loss and to transmit the information securely in the mobile network, it is highly essential for secure routing approach for data transmission without path conjunction. The nodes x_p and x_s are selected as the source and destination and the links exist in the mobile network uses the above specified multi objective factors for packet transmission.

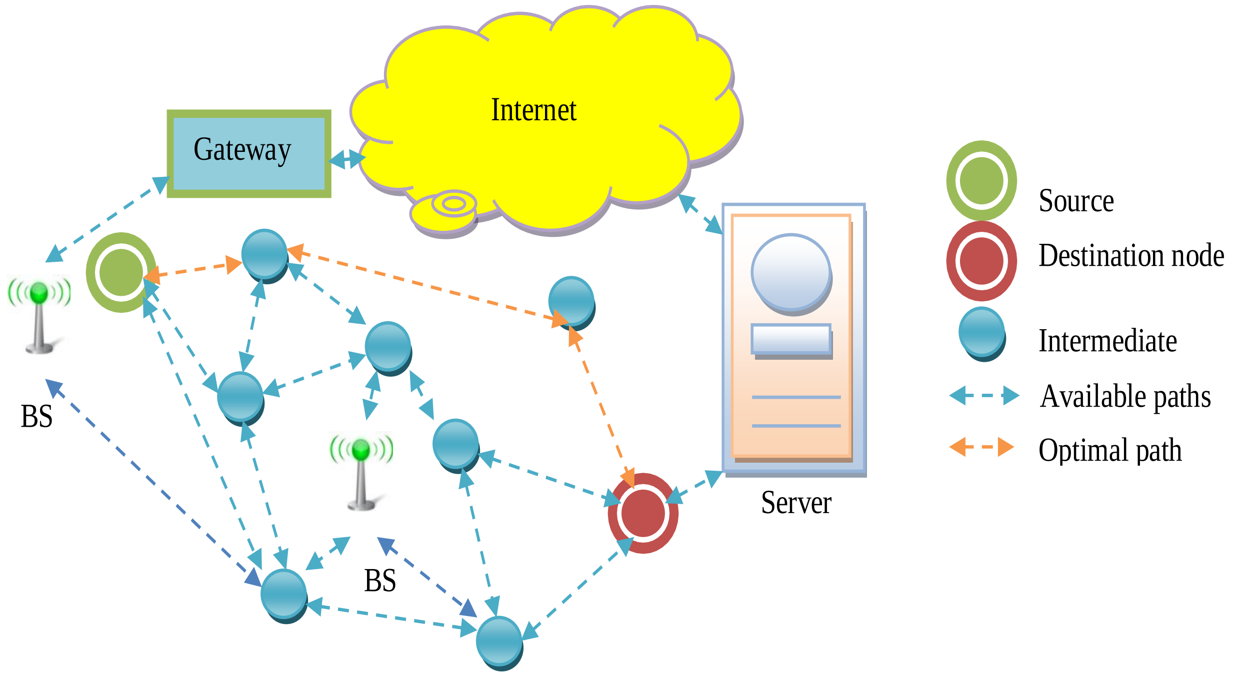


***Fig. 1.** System Model of MANET*

3.2 Defined Multi-objectives

To achieve a power-aware routing mechanism, the multi-objective factors like delay (D), distance (G), power (P) and link maintenance (S) are considered as a key in this research work. These multi-objectives (Ob) are together represented mathematically as per Eq. (1).

$$Ob=\sum_{i=1}^{|k|}L_i \quad (1)$$

Here, the count of intermediary nodes are denoted as i and the total nodes in the network is denoted as k and node factor is symbolized as L_i .Mathematically, the node factor can be expressed as per Eq. (2).

$$L_i=\frac{1}{4}\times\left[S+[1-D]+[1-P]+[1-G]\right] \quad (2)$$

Power: The nodes used to send and receive the data require high power in MANET. However, the total power (TP) is expressed as,

$$TP=P^T+P^R+P^I+P^O \quad (3)$$

where, P^T specifies the transmission power and it is expressed mathematically in Eq. (4).

$$P^T=\frac{E_{Tx}}{t} \quad (4)$$

Here, E_{Tx} denotes the transmission energy and the time for transmitting the packets is denoted as t .

In Eq. (3), P^R indicates the reception power and it is expressed as per Eq. (5). Here, E_{Rx} denotes the reception energy

$$P^R = \frac{E_{Rx}}{t} \tag{5}$$

Further, P^I in Eq. (2) represents the power consumed in the idle mode and it is mathematically shown in Eq. (6).

$$P^I = P^R \tag{6}$$

In addition, P^O In Eq. (2) indicates the power consumed in the overhearing mode. It is expressed mathematically in Eq. (7).

$$P^O = P^R \tag{7}$$

Delay: The delay exhibits how quicker the data reaches the destination from the source. In case of lower delay, the transmission becomes slower and hence the system becomes inefficient for routing. such that the delay must be minimal in the network. The delay is computed as the "ratio of nodes in the selected path with the total number of nodes" and is represented mathematically as per Eq. (8).

$$\beta_i = \frac{\tau}{k} \tag{8}$$

Here, τ specifies the number of nodes present in the respective path, and k denotes the total nodes.

Distance: The distance is the ratio of the distance between the i^{th} and $(i-1)^{th}$ node to the normalization factor (κ) and it is computed as per Eq. (9).

$$\alpha_i = \frac{dist(i, i-1)}{\kappa} \tag{9}$$

Link stability: The link breakage between the nodes reduces the reliability of the nodes as they might leads to information loss. Hence, the security of the system gets affected.

$$\xi = \frac{-(\tau\mu + \vartheta\omega) + \sqrt{(\tau^2 + \vartheta^2)r^2 - (\tau\omega - \vartheta\mu)^2}}{(\tau^2 + \vartheta^2)} \tag{10}$$

where, $\tau = a_u^s \cos\theta_{a_u} - a_v^s \cos\theta_{a_v}$, $\mu = a_u^{c_1} - a_v^{c_1}$, $\vartheta = a_u^s \sin\theta_{a_u} - a_v^s c \sin\theta_{a_v}$, and $\omega = a_u^{c_2} - a_v^{c_2}$, respectively.

All these objectives are fed as input to the proposed CGA- GSO approach.

4. CGA- GSO Approach for Routing

4.1 CGA- GSO

In GSO [17], a group of glowworms is distributed in search space in a random manner. It includes a special luminescent quantity named luciferin that has a decision domain. Generally, GSO encompasses a vibrant decision range and therefore the effect of distant glow-worms is minimized when a glow worm has sufficient neighbors. The GA [16] has higher convergence, but gets trapped in local optima. The benefits of GA and GSO are significantly integrated in this research work to achieve the multi-objective function defined in Eq. (1).

The steps followed in the CGA- GSO approach [22] is depicted below:

Step 1 (Initialization): Initially, the search agents of both glow worm and genetic algorithm are initialized. The dimension count d and count of search agents n is allocated. The step size is initialized as size .

Step 2: At T time, the the position of j search agent is denoted as $X_j(T)$. Then, the search agents are ranked arbitrarily.

Step 3: for j =1 to n do $L_j(0) = L_0$, in which $L_j(T)$ addresses the level of luciferin as given by Eq. (11).

$$L_j(T) = (1-\upsilon)L_j(T-1) + \gamma(M(X_j(T))) \tag{11}$$

Here, υ signifies the luciferin decay constant $(0 < \upsilon < 1)$, γ addresses the luciferin improvement constant. Then, set $R_e^j(0) = R_0$. The decision domain of the luciferin is denoted as $R_e^j(0 < R_e^j \le R_u)$. The utmost iteration is set as max^{it} .

Step 4: while T=1, the random solutions are generated and fitness function is computed for these solutions. Further, on the basis of the best fitness, the best solution is discovered.

Step 5: while $(T \le max^{it})$ do

For every j glow worm, calculate $L_j(T)$ as given in Eq. (11) and the mathematical formula for $W_j(T)$ is expressed as per Eq. (12).

$$W_j(T) = \{k : e_{jk}(T) < R_e^j(T) : L_j(T) < L_k(T)\}; \quad (12)$$

During the movement phase, all glowworms select its respective neighbour and follow the direction of it with a certain probability, thereby it includes 2 properties: first is, k have to be within the decision domain of j; and second one is the luciferin value that should be superior than the luciferin value of j glow worm. Also, if j goes in the direction of neighbour k neighbor that comes from $W_j(T)$ within certain probability $P_{jk}(T)$, it is evaluated as per Eq. (13).

$$P_{jk}(T) = \frac{L_k(T) - L_j(T)}{\sum_{l \in W_j(T)} L_l(T) - L_j(T)} \quad (13)$$

Step 6: For every $j \in W_j(T)$, Compute $P_{jk}(T)$ as given by Eq. (14). Here, k = select glow worm ($\vec{P}$).

Step 7: update $X_j(T+1)$ as per Eq. (13)

$$X_j(T+1) = X_i(T) + size * \left(\frac{X_k(T) - X_j(T)}{|| X_k(T) - X_j(T) ||} \right) \quad (14)$$

Step 7: Compute the fitness of the solutions and explore the optimal solution.

Step 8: Discover the distance among $X_j(T+1)$ with global best solution. Among them, choose eight solutions with utmost distance. Then, Carry out crossover of GA for 2 remaining solutions. In general, the Crossover of the GA allows the permutation of two or more factual solutions. Indeed, the majority of the species includes two parents. In addition, specific exemption doesn't know varied sexes, and as a result there is only a single parent. Crossover employs an application that relates the genetic life of the parents.

Step 9: Further, processed with the process by discovering the highest distance with global best solution.

Step 10: Then, Calculate the nneighborhood range update $R_e^j(T+1)$ as per Eq. (15). In which β symbolizes the constant parameter, n_T is a constraint for balancing the count of neighbors.

$$R_e^j(T+1) = \min\{R_u, \max\{0, R_e^j(T) + \beta \mid W_j(T) \mid\}\} \quad (15)$$

Step 10: Terminate

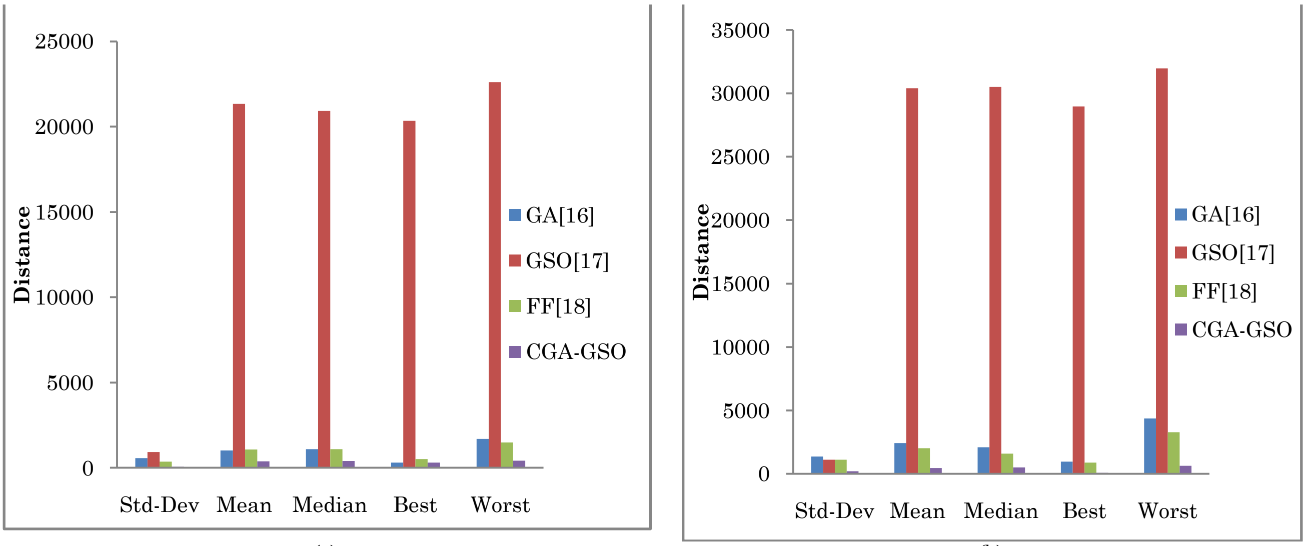
5. Results and Discussion

5.1 Simulation Procedure

The proposed energy-efficient routing in MANET was implemented in MATLAB and the experimented outcome will be analyzed. The performance of the presented work (CGA-GSOPSO) is analyzed over the traditional approaches like GA [16], GSO [17] and FF [18] with respect to Energy and Delay as well. This evaluation is done by varying the count of nodes viz. 100 and 150, respectively. Sine, the optimization algorithm being stochastic in nature, the presented work as well as existing models are executed 5 times and the best results are acquired in terms of mean, median, best, worst and standard deviation(std-dev).

5.2 Statistical Evaluation on Distance

During the selection of the best path for data transmission from the source to destination, it is crucial to select the nodes that are closer. If the intermediate nodes are far away from each other, there is chance for the network linkage to break up and hence results in information loss. Thus, lesser the distance between the intermediate, higher is the information security. The distance based statistical evaluation is undergone and the resultant acquired is graphically for nodes=100 and 150 in Fig. 2(a), Fig. 2(b), Fig. 2(c) and Fig. 2(d), respectively. The mean of the presented work for 100 count of nodes is 367.17, which is lower than the extant models like GA=1084.45, GSO=2093.61 and FF=1063.21. On the other hand, from Fig. 2(b), the best distance is recorded as 509.3, which is 90.98%, 98.6% and 90.2% better than the extant models like GA, GSO and FF, respectively.

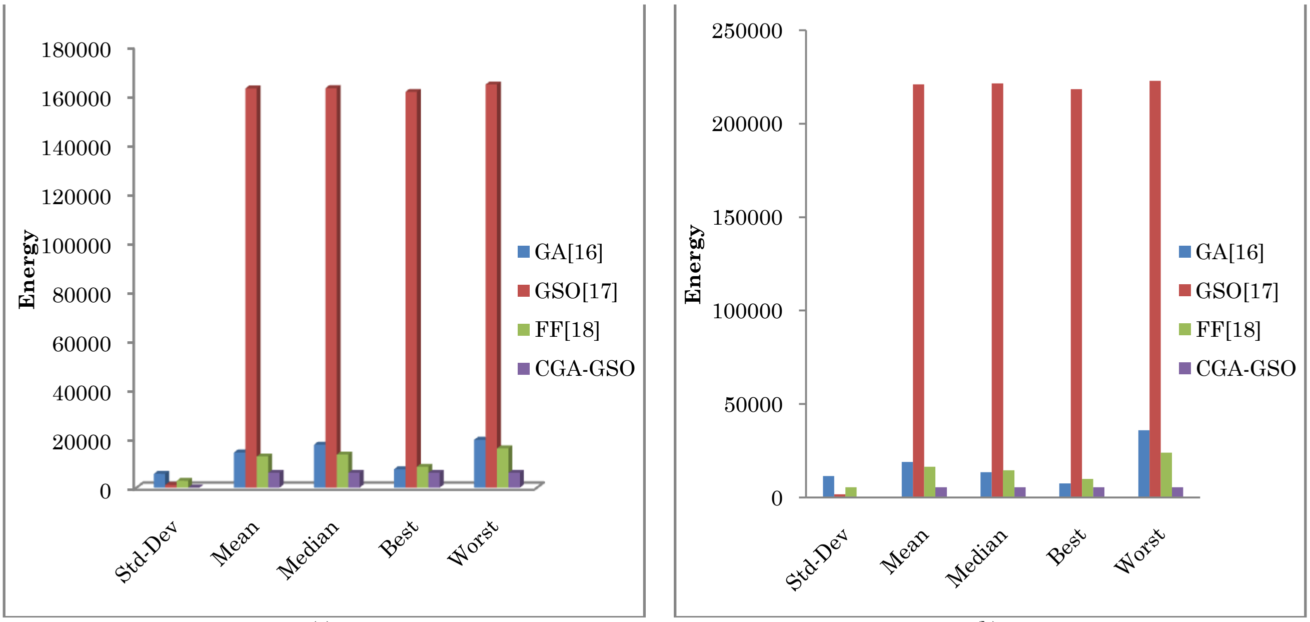


(a) (b)

Fig. 2. *Statistical Evaluation on Network Distance: Proposed versus Conventional Models for (a) 100 count of nodes and (b) 150 count of nodes*

5.3 Statistical Evaluation on Energy

The energy required for data packet transmission need to be lower for better network life span. The resultant acquired in terms of energy is shown in Fig. 3(a) and Fig. 3(b) for 100 and 150 counts of nodes. The mean energy of the presented work from Fig. 3(a) is 6000 and it 58.04%, 96.31% and 52.75% better than the existing models like GA, GSO and FF, respectively. In Fig. 3(b), the best energy of the presented work is lower and it is 26.6%, 97.4% and 45% better than the existing models like GA, GSO and FF, respectively. Thus, from the evalution, it is more obvious that the presented work consumes less energy during the path selection as well as data packet transmission.



(a) (b)

Fig. 3. *Statistical Evaluation on Network Energy: Proposed versus Conventional Models for (a) 100 count of nodes and (b) 150 count of nodes*

6. Conclusion

This paper had established and maintained an energy-efficient optimal route in MANET is the major concern to enhance the lifetime of network. The selection of optimal path is made with the determined fitness like minimum distance, minimum power, minimum delay, and maximum link state stability as well. A novel optimization Algorithm referred as CGA- GSO was used for routing on the basis of these multi-objectives. The performance of the proposed model will be analyzed over the traditional approaches with respect to Energy and Delay by varying the count of nodes. The mean energy of the presented work is 6000 and it 58.04%, 96.31% and 52.75% better than the existing models like GA, GSO and FF, respectively.

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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