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Hybrid optimization-based Effective Path Selection and Multipath routing in MANETs

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Abstract Mobile Adhoc Networks (MANETs) have emerged as a popular technology because of their wide application and independent mobility. Nevertheless, communication through MANETs can be effective because of their inherent nature of high mobility, which in turn results in a higher rate of data loss and delay. Therefore, for effective communication to be achieved, the MANETs' routing performance must be enhanced. Some extant routing protocols like AOMDV can yield moderate Routing Overhead (RO) during communication. The review of previous studies shows that there is a need for improvement in the following areas: Computational E2E delay: the proposed Genetic Algorithm- Ant Colony Optimization (GA-ACO) was unable to reduce the computational E2E delay that occurs during communication. RO: The schemes that were proposed failed to minimize the RO in the network. Energy consumption: the reduction energy consumed by the network was reduced, however, high throughput and PDR could not be achieved by the method. On the contrary, the EHO-based AOMDV routing protocol achieved low E2E delay and RO but was unable to decrease the energy consumed by the network. Throughput and PDR: The protocol proposed failed to achieve high Quality of Services (QoS). Consequently, this paper aims to provide a solution to this communication problem by proposing a Hybrid Optimization-based Effective Path Selection and Multipath routing (HOEPSM) approach for MANETs. The proposed approach, which is HOEPSM is made up of two parts: Elephant Herding Optimization (EHO)-based AOMDV routing protocol, which makes use of EHO for the identification of the shortest path from the source to the destination. The second part which is the Hybrid optimization using Genetic Ant Optimization (GAO) algorithm, involves finding the best solution through the use of a GAO-based hybrid optimization algorithm. The results of the study revealed that the use of the HOEPSM causes a significant decrease in routing RO while enhancing the network's Quality of Forwarding (QoF) of the network. Also, the simulation of the proposed approach was carried out in NS2, and afterward, compared with earlier proposed methods like DRARP and MDRARP. Based on the simulation results, the HOEPSM outperformed the other methods, with high Energy Efficiency (EE) (91%), Packet Delivery Ratio (PDR) (95%), RO (155), and End to End (E2E delay) (102ms). These results can be attributed to the HOEPSM's choice of the best and steady route from the source nodes and destination nodes.

Index Terms mobile ad-hoc network, AOMDV, elephant herding optimization, quality of services, genetic ant Optimization

I. Introduction

Mobile Adhoc Networks (MANETs) are the communication standard that is equipped with dynamic infrastructure, whereby wireless network and routing protocols are used for the transmission of data. The transfer of data in MANETs is carried out from one node to another node that is present within the coverage area, whereby it is impossible for nodes that are within areas with no coverage to communicate with those in the coverage area. It is for this reason that multi-hop communication is required for the transfer of data from nodes to nodes to achieve high performance in terms of communication. The network is self-organized, and characterized by complex prediction and dynamic mobility which gives room for the emergence of setbacks within the network, thereby resulting in data loss, link failure, RO, and E2E delay [1]–[8]. Communication in the extant routing protocols like DSR, AODV, and TORA becomes ineffective within the dynamically changing topology. To address the issue of multipath communication in MANETs, Adhoc Multipath On Demand Vector (AOMDV) routing protocol is employed, resulting in relatively improved performance in terms of throughput and PDR. However, the resulting E2E delay and RO from the network during communication between source and destination nodes does not improve [9]–[14]. AOMDV protocol has been used to improve the overall Quality of Service (QoS) of the network, but more enhancement needs to be made in terms of RO [15]–[18]. It is for this reason that a hybrid optimization-based effective path selection for the AOMDV routing protocol is proposed in this study. The following are the contributions of the current study:

- The HOESPM method is proposed to enhance the performance of the AOMDV routing protocol. The HOESPM approach is combined with Elephant Herding Optimization (EHO) based routing protocol and hybrid optimization through the use of the Genetic Ant Optimization (GAO) algorithm.
- The choice of the optimal path is made by the deployment of the EHO-AOMDV routing protocol through the use of the weighing factor as well as residual energy of the nodes, and this allows better performance as compared with the standard AOMDV protocol.
- Through the use of the GAO algorithm, the verification of the EHO-AOMDV process is realized, while the best optimal solution is obtained for data communication between the source and destination nodes.
- By using this routing protocol, significant improvements were noted in the network's EE and PDR. On the other hand, significant reductions in RO and end E2E delay were observed.

This paper is organized based on the following sections. Section 2 contains a review of previous works on MANETS routing protocol. Section 3 presents a discussion on the proposed HOEPSM. Section 4 presents the results of the performance analysis carried out on the proposed approach. Section 5 presents the evaluation of the results as well as the comparison of the results of the proposed approach with those of previous approaches like Dynamic Reverse Address Resolution Protocol (DRARP) and Multi metric Decision Adaptive Routing Protocol (MDARP). In the last section 6, the conclusion of the study is illustrated.

II. Related Work

In the study conducted by Madhavan, [19], a genetic algorithm-ant colony optimization method (GA-ACO) was proposed. In their method, the quality-of-service parameters are optimized, while the transmission routing method is secured. Also, optimization occurs based on hybrid GA and ACO methods. However, the method was unable to reduce the computational E2E delay that occurs during communication. In another work, [20], the authors, Riaz et al., introduced two schemes that can enable the improvement of the lifetime of the network, as well as the reduction of link breakages during the process of selection for the routing path. The first scheme is based on ad-hoc on-demand routing protocol, while the second scheme is based on reactive routing protocol. Their results showed that RO was observed in their proposed method.

Pariselvam et al., [21] proposed a novel method that is energy efficient with the aim of increasing the lifespan of the network. The authors applied their proposed method in RSSI. In the study, the MANET was deployed under low-energy ad-hoc on-demand distance vector routing protocol. Their proposed method achieved a significant reduction in energy consumption, however, it was observed that it was unable to realize high PDRn and high throughput.

Sharma and Ramkumar in the study [22] proposed a parallel routing mechanism for the selection of a routing path. The proposed method which is a work-based load balancing method was evaluated using MIMO devices because the MIMO system is characterized by multipath in the network for the delivery of payload. A comparison was carried out between their proposed mechanism and the unicast routing algorithm. It was observed that their proposed method was unable to reduce the RO. In another study [23], the authors, Sarhan and Sarhan, presented a hybrid approach, which combines an Elephant Herding Optimization (EHO) algorithm with an Ad-hoc On-Demand Multipath Distance Vector routing protocol. The approach proposed in their work possesses two categories. The first involves the discovery of the path based on the fittest node and the best node that can facilitate transmission so that path failure can be controlled, while the second category involves the use of residual energy for the selection of each transmission node. The proposed method was simulated, and the results revealed that the proposed method facilitates the reduction of RO and E2E delay, but fails to minimize the consumption of energy. Using the Markovian mobility model combined with the relay-assisted multicast scheme, a method in MANET was proposed by Gan et al., [24]. In order to enable the discovery of the exact E2E delay value, the authors made use of a two-hop relay algorithm. Also, they developed an algorithm that uses minimum energy for the calculation of the actual energy consumed by the network.

In the study carried out by Dhawan and Singh, [25], a routing protocol-based optimization in the MANET was proposed, with the aim of increasing the network's EE. In order to achieve this objective, the use of the ant colony optimization and protocol-based method was employed. However, the results showed that the method was unable to minimize the network's RO. Mahamune and Chandane, [26] introduced the EXata stimulator in order to achieve a more realistic simulation. These authors combined AODV and DSR routing protocols that are characterized by efficient routing functionality. A novel protocol labeled Dynamic MANET On-demand routing protocol was designed. Afterward, a comparison was done between the newly proposed method and DSR as well as AODV. Results of the simulation revealed that RO was demonstrated by the method during the process of data transmission.

A method of resource allocation was proposed in the study carried out by Liu et al., [27]. The proposed method is based on two-tuple and enhances communication effectiveness using storage resources and transmission resources. This group of researchers also developed an analytical framework for the dynamic network model and queuing process based on the throughput, PDR, and E2E delay of each node. Nevertheless, the proposed method failed to minimize the RO.

In an attempt to enhance the efficiency of Multi-Path Dynamic Address Routing, a multi-interface and multi-channel was proposed by Alshaikh and Morie [28]. In the work, the distributed Hash tables were included. In a similar study, a protocol was proposed by Sathyaraj with the aim of improving MANET's Quality of Service (QoS). A comparison was done between the proposed protocol and those of DSR and AODV, using throughput, delivery rate, and E2E delay as parameters for the comparison. The results of the comparison showed that the proposed protocol demonstrated moderate throughput, delivery rate, and E2E delay. Overall, the performance was moderate. Based on the results of the previous studies reviewed in this paper, it can be concluded that there is a need to improve the MANET in terms of the effectiveness of communication. Consequently, this paper aims to address this problem by proposing a HOEPSM routing protocol. This protocol is described in detail in the subsequent sections.

III. Proposed Hoepsm Approach

The proposed HOEPSM method carries out an effective process of path selection through the use of hybrid optimization combined with Genetic Ant Optimization and Elephant Herding Optimization in the multipath routing protocol. This proposed work is subdivided into three sections they are, (3.1) AOMDV routing protocol, (3.2) EHO-AOMDV routing protocol, and (3.3) HOEPSM routing protocol.

A. AOMDV routing protocol

AOMDV is the Multipath Ad-hoc On Demand Vector routing protocol which extends its routing with multipath routing table. Through AOMDV, the source is provided with several options for the transmission and reception of RREQ or RREP to the destination. In the multipath routing table, every detail including minimum hop count to maximum hop count measured from the source to the destination is recorded. The selection of the minimum hop count is carried out at the initial stage and the secondary optimal paths are often available for (best alternatives). In the event of the occurrence of link failure, the data is moved to the optimal option to enable its arrival at the desired destination.

B. EHO-AOMDV routing protocol

The purpose of using the Elephant Herding Optimization (EHO) is to enhance the AOMDV so that a better multipath traffic balancing routing model can be achieved. Fundamentally, EHO achieves energy optimization through the use of node classification, whereby the creation of several clans occurs based on node energy. The formation of the nodes occurs based on the weight (100 Joules) of the nodes as well as the residual energy of the nodes. Thus, only the nodes that possess the aforementioned qualities can transfer a higher amount of data, and as such, it is regarded as a high-priority clan. The nodes found in the second class are regarded as modest priority, while the nodes that have the least weight and residual energy are referred to as least priority nodes. The choice of the intermediate nodes that will carry out the transfer of the data from the source to the destination nodes is done

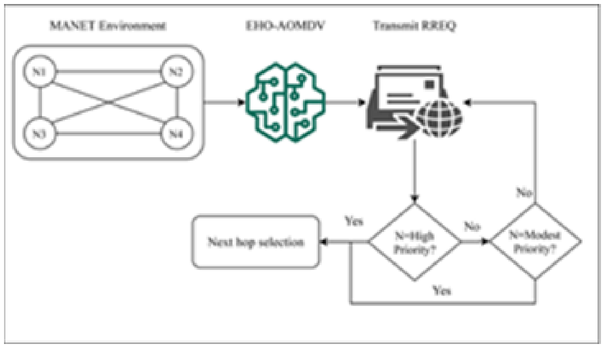

Figure 1: EHO-AOMDV routing protocol

in a hierarchical manner, starting from the high priority and followed by the modest priority clans where the nodes that are present in the least priority can serve as either a source or destination, depending on the data transmission, but that is not a consideration for the process of path selection.

The design of the AOMDV protocol is done in a manner that it can discover the multilink disjoint route through which the RREQ packets can be broadcasted. Also, in this protocol design, the use of intermediate nodes that are found at the High Priority (HP) and Modesty Priority (MP) clans is employed in generating multiple overturns. Once the optimal path is discovered, the transmission of the load is carried out in a manner that is balanced in order to avoid the occurrence of traffic congestion while the data is transmitted from multiple sources to multiple destinations.

n the case where path failure occurs in the process of communication, then the next optimal path is immediately considered for the transfer of data. The use of the EHO-AOMDV routing protocol for transmission involves the following steps. Nodes are divided based on priority, selection of route, traffic balancing, as well as monitoring of route. Overall, the EHO-AODMV protocol demonstrated moderate performance, and RO was recorded during the communication time. Despite the fact EHO-AOMDV protocol outperformed the AOMDV protocol, there is still room for further improvement in terms of the process of optimal path selection. For this reason, the Genetic Ant Optimization. Figure 1 below shows the flowchart for the EHO-AODMV routing protocol.

The process involved in the EHO-AOMDV routing protocol is shown in the Figure 1 above. The first stage involves the construction of the MANET network followed by the activation of the routing protocol. By means of the EHO-AODMV, the transmission of the route request by the source to the neighbor node occurs. Once the presence of the node is noticed in the high-priority or modest-priority clan, the node is selected as the next hop node, but if not, then the source node will perform the transmission of the RREQ message to other neighbors within the coverage area. It is through this process that the source node identifies its best neighbor.

Algorithm 1: Pseudo code for initial optimal path selection

```
Begin Initiate food search;
Parameter used for ant food search;
Euclidean distance, energy, high priority, modest
  priority;
while iteration (IT) = IT + 1; finish_IT = 50 do
    for V - Node count && antV - root Node do
        if antV = antV + 1; antV++ then
            The source transmits RREQ;
            Path calculation process;
            Pheromone initialization, update,
              evaporation;
            Initial optimal path selection;
            Send a reply through RREP;
            Iteration++;
        else
            Choose the next vehicle and send the
              RREQ;
        end
    end
end
End
```

C. HOEPSM routing protocol

The HOEPSM routing protocol is a combination of the Genetic Ant Optimization (GAO) algorithm and the EHO-AOMDV routing protocol. Through the use of the GAO duel stage, the selection of the optimal path is done, thereby increasing the stability and scalability of the network. As a result of this process, alternative paths are provided during the process of data transmission based on the calculation of pheromone and fitness function which results in the reduction of RO during transmission. The pseudo-code below describes the process through which the initial optimal path is selected.

Once the process of initial optimal path selection is completed, the best solution identified gets preceded through the use of GAO optimization. The output produced by the optimal path selection is applied to the fitness calculation through the use of three operations which are, Selection, Crossover, and Mutation operations. The aim of this is to enable the selection of the final refined optimal path. The selection process supports the verification of the nodes' trustworthiness from the first stage. The next operation which is crossover, involves determining novel paths based on that while the residual energy of those nodes is considered. Lastly, in the mutation operation, the paths are recombined with the aim of finding the optimal solution. By calculating the fitness, the worst shortest paths are ignored. One benefit of using this process of path selection is that it results in a significant improvement of the QoF, which in turn causes the EE as well as the PDR to increase. In addition, the process helps in reducing the end-to-end E2E delay and RO that can occur in the network. Figure 2 below shows the process through which the best solution is discovered through the use GAO algorithm.

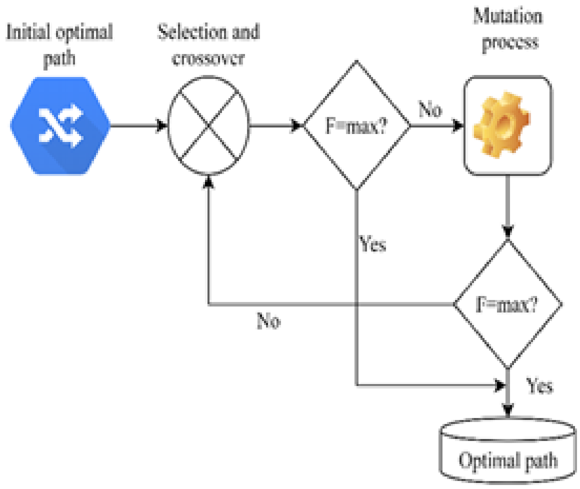

Figure 2: Process of best path selection using GAO algorithm

Input Parameters	Values a
Running Time	100 ms
Dimension	1000m2
No of Nodes	100
Antenna Type	Omni-directional Antenna
Propagation Model	TwoRay Ground Model
Queue Type	DropTail
Traffic Flow	CBR
Initial Energy	100 Joules
Transmission Power	0.500 Joules
Receiving Power	0.50 ules

Table 1: Simulation parameters

The process of finding the optimal path from the initial selection paths using the GAO algorithm is shown in Figure 2. The initial stage involves two processes which are selection and crossover processes, as well as the measurement of the fitness. In the next stage, the mutation process is carried out alongside the measurement of the best fit. Based on the two-stage process, the selection of the best optimal path occurs so that the data can be transferred from the source to the destination. The above-described steps are the steps involved in the HOEPSM routing protocol.

IV. Performance Analysis

In this section, the computation of the performance analysis of the proposed HOEPSM method is presented, and the results are compared with those of previous studies like MDARP, and DRARP methods. The estimation of the result of the approaches is carried out using performance parameters such as E2E delay, PDR, EE, and RO. The use of the NS2 software under the Ubuntu Operating system with SUMO is employed in the execution of the implementation. Table 1 below presents the simulation settings.

A. Energy efficiency calculation

Energy-efficient methods like MDARP, DRARP, and the proposed HOEPSM are presented in Figure 3. The EE is calcu-

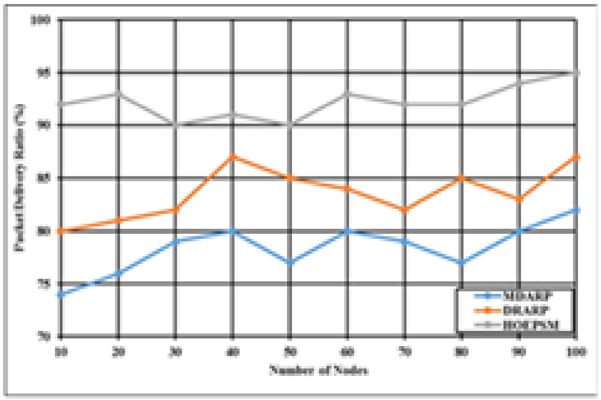

Figure 3: Energy Efficiency

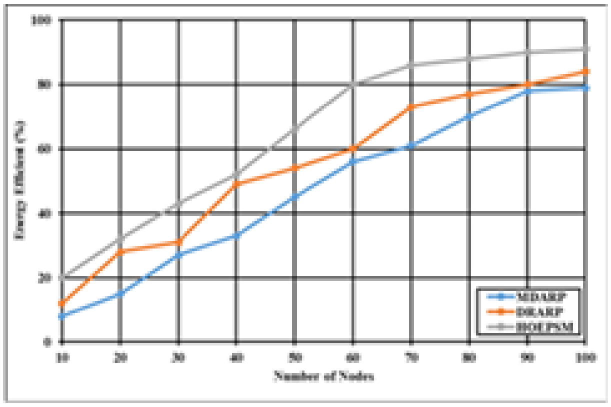

Figure 4: Packet Delivery Rate

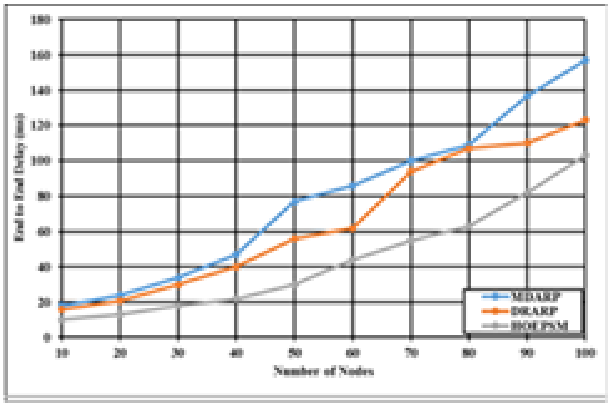

Figure 5: E2E delay

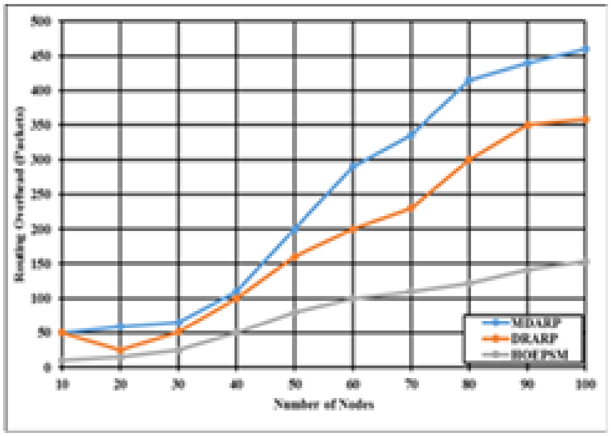

Figure 6: Routing Overhead

lated by summing up the residual energy of the network for 100 nodes in the network.

Based on Figure 3, it can be seen that the proposed HOEPSM approach demonstrated a higher level of EE as compared with the other methods. This was achieved through the aid of the duel stage optimization, which enabled the significant reduction of the RO and E2E delay during communication which is reflected in the increase in the residual energy of each node within the network.

B. Packet delivery rate calculation

Figure 4 shows the result for the packet delivery rate of the HOEPSM approach proposed in this paper, as well as those of the other methods like MDRAP and DRARP. The delivery rate of the network is described as the amount of data received from the sender.

Based on the illustration in Figure 4, it can be observed that the proposed HOEPSM approach demonstrated higher effectiveness as compared to the previously proposed ones in terms of PDR. The effectiveness of the routing process was increased by the EHO-AOMDV routing protocol as compared with the earlier methods. This implies that the EHO-AOMDV routing protocol enhanced the PDR of the network during the process of communication.

C. End-to-End delay calculations

Figure 5 represents the E2E delay of methods such as the MDARP, DRARP, and the proposed HOEPSM. It can be seen from the figure that the performance results of the HOEPSM in terms of E2E delay are better than those of the MDARP and DRARP methods, as the HOEPSM demonstrated lower E2E delay.

In a situation where link failure occurs in the proposed routing process, the best alternative paths are discovered immediately for the continuation of data transmission, which in turn reduces the delay that occurs during communication between the nodes in the network.

D. Routing overhead calculation

Figure 6 below presents the RO of methods such as MDARP, DRARP, and the proposed HOEPSM approach the RO is described as the amount of packets that progress to the source without being transmitted to the endpoint.

Basically, the design of the proposed HOEPSM is done in a manner that enables the reduction of the RO. The results showed that in the two stages of EHO-AOMDV routing and GAO optimization, the RO is concentrated and decreases.

Parameters / Methods	MDARP	DRARP	HOEPSM
EE	79%	85%	91%
PDR	82%	88%	95%
E2E Delay	154ms	125ms	102ms
RO	457 packets	369 packets	155 packets

Table 2: Results analysis and measurements

V. Results and Discussion

This section presents the discussion on the results of the MDRAP, DRARP, and the proposed HOEPSM in terms of PDR, E2E delay, EE, RO, and the values for all the parameters for the three approaches are presented in Table 2.

The proposed HOEPSM approach achieved an EE score of 91%, while MDARP and DRARP achieved EE of up to 79% and 85% respectively. This implies that the proposed EPMSA-CHAG approach is 12% higher than MDARP and 6% higher than DRARP, which is an indication that the proposed HOE-SPM outperformed the MDARP and DRARP. With regards to the PDR, the proposed HOEPSM achieved a packet delivery rate of 95%, while the MDARP and DRARP achieved up to 82% and 88% respectively. This implies that the HOEPSM approach achieved a score that is 13% higher than MDRARP and 7% higher than DRARP. With regards to the E2E delay of the proposed HOEPSM approach, a value of 102ms was achieved while values of 154ms and 125ms were recorded for MDARP AND DRARP, respectively. The results for the E2E delay showed that the proposed HOEPSM approach achieved a value of 52ms, which is less than MDARP and 23ms lower than DRARP. In terms of RO, 155 packets were recorded for the HOEPSM approach while for the earlier methods such as MDARP, and DRARP up to 457 packets and 369 packets were recorded, respectively. The RO of the proposed HOEPSM approach is 300 packets lower than MDARP and 200 packets lower than DRARP. Based on the results presented above, the overall performance of the proposed HOEPSM approach is better than those of the MDARP and DRARP. The better performance of the proposed HOEPSM can be attributed to the use of the EHO-AOMDV routing protocol together with the GAO optimization process.

VI. Conclusion

Mobile Ad-hoc Network is defined as wireless networks that are characterized by dynamic infrastructure, multi-hop communication, data transmission, and self-organization. Some of the challenges associated with MANETS include loss of data, link failures, delays, and RO that occur due to mobility and complex predictions. To this end, this paper focuses on improving the routing performance of this kind of wireless network. The use of AOMDV routing protocols has been employed in several works, but it fail to perform optimally in terms of achieving high EE with low delay. Thus, this study proposed a method that uses the weight and residual energy of the node to discover the optimal path through which data can be transferred from the source to the destination nodes, with the aim of addressing the issue highlighted above. The method utilizes the Elephant Herding Optimization (EHO)-based AOMDV. Afterward, the performance of the EHO-AOMDV is verified, and the best optimal solution is sought after using the Genetic Ant Optimization (GAO) algorithm. Through the use of this method, the overall performance was significantly improved. The proposed HOEPSM was simulated in NS2 and. The performance of the proposed method was compared with that of earlier studies using parameters like EE, packet delivery rate, E2E delay, and RO. To perform comparative analysis, the results are compared with the earlier works such as MDARP and DRARP. The results showed that the proposed approach was better as it achieved 12% higher EE, 13% higher PDR, 52ms lower E2E delay, and 300 packets lower RO in comparison with the earlier works. The HOEPSM routing protocol enabled the realization of a stable and optimal route for data transmission from source to destination nodes, thereby enhancing the routing performance Conflicts of interest The authors declare no conflicts of interest.

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