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# Analysis of optimizing QoS-based routing in MANET using Hybrid Krill Herd and Genetic Algorithms

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## ABSTRACT

***Mobile Ad-Hoc Networks (MANET) play a crucial role in modern communication, and ensuring Quality of Service (QoS) is paramount for their effective operation. This research investigates the enhancement of QoS-based routing in MANET through the hybridization of Krill Herd and Genetic Algorithms. This research compares the proposed Hybrid Krill Herd and Genetic Algorithms with Genetic Algorithm, Particle Swarm Optimization, and Krill Herd to assess their performance in terms of throughput, packet delivery ratio, end-to-end delay, and energy consumption. The methodology involves a detailed exploration of the algorithms, simulation setup, and comprehensive analysis of results. The findings provide valuable insights into the strengths and weaknesses of each algorithm, contributing to the advancement of QoS optimization in MANET. This research opens avenues for future studies in refining hybrid algorithms and exploring their applications in diverse optimization problems.***

***Keywords:** QoS-based routing, MANET, Krill Herd Algorithm, Genetic Algorithm, hybridization, optimization, mobile ad hoc networks.*

## 1. INTRODUCTION

Mobile Ad Hoc Networks (MANETs) have emerged as a vital component of modern wireless communication systems, particularly in situations where traditional infrastructure-based networks are impractical or unavailable. MANETs consist of mobile nodes that can dynamically form a network without relying on a fixed infrastructure. While these networks offer flexibility and adaptability, they also present significant challenges, particularly concerning Quality of Service (QoS) provisioning. One of the primary challenges in MANETs is the provision of QoS, which encompasses critical parameters such as low latency, high bandwidth utilization, and minimal packet loss. Achieving efficient QoS in MANETs is complicated due to their highly dynamic topologies, limited resources, and variable network conditions. Traditional routing protocols often struggle to adapt to these dynamic environments, leading to suboptimal QoS performance [1] . In light of these challenges, the primary objective of this research is to develop and evaluate a novel QoS-based routing algorithm specifically designed for MANETs. The proposed algorithm leverages the principles of two nature-inspired optimization techniques: the Krill Herd Algorithm (KHA) and the Genetic Algorithm (GA). By hybridizing these algorithms, we aim to enhance the routing decisions in MANETs to achieve improved QoS. This research contributes to the field of mobile ad hoc networking in several significant ways:

- **Innovative Algorithm:** We introduce a novel QoS-based routing algorithm that combines the strengths of KHA and GA, offering a promising solution for MANETs' dynamic nature.
- **Enhanced QoS:** Our proposed algorithm is expected to provide superior QoS performance compared to traditional routing protocols, addressing the critical QoS challenges in MANETs.
- **Scalability and Adaptability:** We evaluate the algorithm's scalability and adaptability to varying network sizes and mobility patterns, providing insights into its robustness.

The remainder of this paper is structured as follows: In Section II, we provide a review of the literature related to MANETs, QoS challenges, and existing routing protocols. Section III presents the methodology, including detailed descriptions of KHA and GA, as well as the hybridization process. Section IV presents and discusses the experimental results, Finally, Section V conclusion and future research directions.

## 2. LITERATURE REVIEW

Mobile Ad Hoc Networks (MANETs) are wireless networks formed by a collection of mobile nodes that communicate with each other without the need for a fixed infrastructure. MANETs have gained significant attention due to their potential applications in military, disaster recovery, vehicular communication, and IoT scenarios. Achieving Quality of Service (QoS) in MANETs is a complex endeavor due to their unique characteristics:

- **Dynamic Topology:** MANETs experience frequent topology changes as nodes move, join, or leave the network, requiring adaptive routing protocols.
- **Resource Constraints:** Nodes in MANETs typically have limited processing power, battery life, and bandwidth, making efficient resource utilization crucial.
- **Variable Network Conditions:** MANETs operate in diverse environments with varying link qualities and interference levels, necessitating dynamic QoS management [2].

Existing Routing Protocols in MANETs, Several routing protocols have been proposed to address routing challenges in MANETs [3][4][5]:

- **Ad Hoc On-Demand Distance Vector (AODV):** A reactive routing protocol that establishes routes on-demand. While efficient for small-scale networks, it may suffer from latency in larger networks.
- **Dynamic Source Routing (DSR):** A proactive routing protocol that maintains a route cache. It is effective for reducing latency but can be less scalable.
- **Optimized Link State Routing (OLSR):** A proactive routing protocol that minimizes overhead by organizing nodes into clusters. It offers reduced control message overhead.

The Krill Herd Algorithm (KHA) is a nature-inspired optimization algorithm inspired by the swarming behavior of krill in search of food sources. KHA has been applied successfully in various optimization problems, including routing in MANETs. It leverages the concept of individual krill searching for the best food source while considering the social influence of nearby krill. Genetic Algorithms (GAs) are evolutionary optimization techniques that mimic the process of natural selection. GAs are known for their ability to search large solution spaces effectively. In the context of MANETs, GAs have been applied to routing optimization problems by encoding routing solutions as chromosomes and evolving them to find optimal or near-optimal routes. Hybridizing optimization algorithms has gained attention in the context of MANET routing. Combining the strengths of multiple algorithms, such as KHA and GA, can lead to improved routing performance, especially in dynamic and challenging network environments. While significant research has been conducted in the field of MANETs and optimization algorithms, there is a need for innovative approaches that can address the dynamic nature of MANETs and provide efficient QoS-based routing solutions. The hybridization of KHA and GA holds promise as a novel approach to overcome existing limitations.

## 3. METHODOLOGY

### 3.1. Genetic Algorithm (GA)

The Genetic Algorithm (GA) is an evolutionary optimization technique inspired by the principles of natural selection and genetic inheritance. GAs have been widely applied to various optimization problems, including routing in MANETs. This section outlines the key components and steps involved in GA [6][7]:

**1. Genetic Representation:**

- ***Chromosomes:*** In GA, a solution to an optimization problem is represented as a chromosome. In the context of QoS-based routing in MANETs, a chromosome encodes the routing paths, node sequences, and associated QoS parameters. For example, each gene in the chromosome may represent a node or a link in the network.

  To represent a chromosome mathematically: A chromosome can be represented as a binary string, where each gene represents a binary decision (0 or 1) for selecting nodes or links in the routing path. For example, let C be a chromosome with n genes, where each gene i represents the presence (1) or absence (0) of node/link i in the routing path:

  $$C = [gene\_1, gene\_2, ..., gene\_n]$$

- ***Fitness Function:*** Define a fitness function that quantifies the quality of a routing solution based on the specified QoS metrics, such as delay, bandwidth utilization, and packet loss rate. The fitness function guides the evaluation of how well a routing path performs with respect to QoS. The fitness function evaluates how well a routing solution (chromosome) performs with respect to QoS metrics. Let's denote the fitness function as F(C), where C is a chromosome. In the context of QoS-based routing, the fitness function may consider multiple QoS parameters [8]. For example, if want to minimize delay, maximize bandwidth utilization, and minimize packet loss rate, the fitness function could be a weighted sum of these metrics:

  $$F(C) = w1 * Delay(C) + w2 * BandwidthUtilization(C) - w3 * PacketLossRate(C)$$

  Where:

- Delay(C) represents the delay associated with the routing path defined by chromosome C.
- BandwidthUtilization(C) represents the degree to which available bandwidth is used by the routing path defined by C.
- PacketLossRate(C) represents the packet loss rate of the routing path defined by C.
- w1, w2, and w3 are weight coefficients that determine the importance of each QoS metric. These weights are adjusted to reflect the relative significance of each metric in the optimization process.

**2. Genetic Operators:**

- **Selection:** Select individuals (chromosomes) from the population for the next generation based on their fitness values. This process mimics the idea of "survival of the fittest," favoring better-performing solutions for reproduction.
- **Crossover (Recombination):** Create new individuals (offspring) by combining genetic information from two parent chromosomes. In the context of routing, this involves merging routing paths from two parents to create a new path.
- **Mutation:** Introduce random changes into individual chromosomes to promote diversity within the population. Mutations can involve altering specific elements of a routing path, such as node selection or link choices.

**3. GA Optimization Process:**

GA operates through an iterative optimization process [9]. Here's an overview of how GA works:

- *Initialization:* Start with an initial population of chromosomes, typically generated randomly or using heuristics.
- *Fitness Evaluation:* Evaluate the fitness of each chromosome based on the fitness function, which measures how well a routing path meets QoS requirements.
- *Selection, Crossover, and Mutation:* Use the genetic operators to select parents, create offspring, and introduce mutations. These steps lead to the formation of a new generation of chromosomes.

- *Replacement:* Replace the old generation with the new generation of chromosomes, maintaining the population size.
- *Termination:* Continue the iterations until a stopping criterion is met, such as a maximum number of generations or convergence of solutions.

**Adaptation for QoS-Based Routing in MANETs:**

To adapt GA for QoS-based routing in MANETs need to customize several aspects [10]:

- Objective Function: Define an objective function that quantifies the quality of a routing path based on QoS metrics. This function guides the fitness evaluation process.
- Chromosome Encoding: Represent routing solutions as chromosomes that encode node sequences, routing paths, and QoS parameters. Ensure that the encoding captures the specific requirements and constraints of MANET routing.
- Integration with Krill Herd Algorithm (KHA): As indicated in this paper plan to hybridize GA with the Krill Herd Algorithm (KHA). Describe how the genetic operators and the optimization process of GA are integrated with KHA to create a cohesive hybrid algorithm for QoS-based routing in MANETs.

### 3.1. Krill Herd Algorithm (KHA)

The Krill Herd Algorithm (KHA) is a nature-inspired optimization algorithm that draws inspiration from the swarming behavior of krill in search of optimal food sources. In the context of QoS-based routing in MANETs, KHA can be adapted to efficiently explore and exploit routing paths while considering various Quality of Service (QoS) metrics [11]. This section outlines the key components and steps involved in KHA:

**1. Krill Herd Behavior Modeling:**

- *Individual Krill Movement:* In KHA, each krill represents a potential routing solution. Just as krill move in search of food sources, individual krill in the algorithm represent candidate routing paths. Each krill has a set of parameters that determine its movement, such as position, speed, and direction.
- *Position and Speed:* Each krill is characterized by its position vector ($X_i$) and speed vector ($V_i$), which determine its movement in the search space. These vectors can be represented mathematically as:

  $$X_i = x_{i1}, x_{i2}, \ldots, x_{in},$$

  Where n is the number of dimensions in the search space (e.g., nodes or links in the routing path).

  $$V_i = v_{i1}, v_{i2}, \ldots, v_{in}$$

- *Social Influence:* Krill in a herd are influenced by the behavior of neighboring krill. Similarly, in KHA, krill interact with each other by sharing information about the quality of their routing paths. Social influence is a crucial aspect of KHA, as it allows krill to collectively optimize routing solution [12].

**2. KHA Optimization Process:**

The KHA optimization process is based on the collective behavior of krill searching for optimal solutions [13][14][15].

- ***Initialization:*** Initialize a population of krill with random positions and speeds within the search space.
- ***Fitness Evaluation:*** Evaluate the fitness ($F(X_i)$) of each krill's routing solution based on the specified QoS metrics. For example, if minimizing delay, $F(X_i)$ may be calculated as:

  $$F(X_i) = k1 * Delay(X_i)$$

  Where:
  - $Delay(X_i)$ represents the delay associated with the routing path defined by krill i.
  - k1 is a weight coefficient reflecting the importance of minimizing delay.
- ***Movement and Interaction:*** Krill move within the search space while considering both their individual movement tendencies and the social influence of neighboring krill. Krill are attracted to better solutions found by their peers.
- ***Individual Movement:*** Krill move individually toward better positions (solutions) within their sensory range. The movement of krill i at time step t can be calculated as:

  $$V_i(t+1) = V_i(t) + A_i(t) * (P_i(t) - X_i(t))$$

  $$X_i(t+1) = X_i(t) + V_i(t+1)$$

  Where:
  - $V_i(t+1)$ is the updated speed of krill i at time step t+1.
  - $X_i(t+1)$ is the updated position of krill i at time step t+1.
  - $A_i(t)$ is the acceleration factor for krill i at time step t.

  - $P_i(t)$ is the position of the best solution within krill i's sensory range at time step t.
- *Social Influence:* Krill also interact with their neighbors. Social influence can be represented as follows:

$$V_i(t+1) = V_i(t+1) + B_i(t) * (G_i(t) - X_i(t))$$
$$X_i(t+1) = X_i(t+1) + V_i(t+1)$$

Where:

  - $B_i(t)$ is the social influence factor for krill i at time step t.
  - $G_i(t)$ is the position of the best solution within krill i's neighborhood at time step t.
- ***Update and Optimization:*** Update the positions and speeds of krill based on their movement rules. Krill that find better routing paths share this information with others.
- ***Termination:*** Continue the iterations until a stopping criterion is met, such as a maximum number of iterations or convergence of solutions.

To adapt KHA for QoS-based routing in MANETs need to modify and customize several aspects:

- ***Objective Function:*** Define an objective function that quantifies the quality of a routing path in terms of QoS metrics. This function guides the fitness evaluation and optimization process of KHA.
- ***Encoding of Solutions:*** Represent routing solutions in a format suitable for KHA. This encoding should consider node connectivity, routing paths, and QoS parameters like delay, bandwidth, and packet loss rate.
- ***Integration with Genetic Algorithm (GA):*** As mentioned in this paper plan to hybridize KHA with GA. Describe how KHA's optimization process and GA's genetic operators (selection, crossover, mutation) are integrated to create a cohesive hybrid algorithm for QoS-based routing.

### 3.3. Hybridizing the Krill Herd Algorithm (KHA) and Genetic Algorithm (GA)

Hybridizing the KHA and GA is a powerful approach to leverage the strengths of both algorithms for optimizing QoS-based routing in Mobile Ad Hoc Networks (MANETs). Below is an overview of how can hybridize KHA and GA:

**Integration of KHA and GA for QoS-Based Routing in MANETs:**

Integrating the Krill Herd Algorithm (KHA) and Genetic Algorithm (GA) for QoS-based routing in Mobile Ad Hoc Networks (MANETs) involves combining their respective optimization processes and utilizing the best of both algorithms. Here, I'll provide an overview of the integration process along with formulas for key steps:

**1.** ***Initialization:*** Initialize two populations are one for KHA and one for GA. These populations represent potential routing solutions.

**2.** ***Fitness Evaluation:*** Apply the fitness function for QoS-based routing to both populations, evaluating the fitness of each solution. The fitness function (F) considers QoS metrics such as delay, bandwidth utilization, and packet loss rate. For each population, calculate the fitness for each solution.

**3.** ***Iteration:*** Perform a set number of iterations or generations. Within each iteration, execute the following steps:

**4.** ***KHA Phase:***

- ✓ Execute the KHA optimization process on its population:
- ✓ Update the positions ($X_k$) and speeds ($V_k$) of krill based on KHA's rules. This is typically done for each krill (k) in the KHA population.
- ✓ Calculate the fitness ($F_k$) of each krill's routing solution using the fitness function.

**5.** ***GA Phase:***

- ✓ Execute the GA optimization process on its population of chromosomes:
- ✓ Apply genetic operators (selection, crossover, mutation) to create offspring chromosomes. This is typically done for each chromosome (c) in the GA population.
- ✓ Calculate the fitness ($F_c$) of each chromosome's routing solution using the fitness function.

**6.** ***Hybridization:*** At the end of each iteration, compare the best solutions found by KHA and GA:Select the best solution among the KHA population (e.g., krill with the highest fitness, $F_k^{best}$) and the best solution among the

GA population (e.g., chromosome with the highest fitness, $F_c^{best}$).

7. ***Communication between KHA and GA:*** To enhance hybridization, consider mechanisms for sharing information between KHA and GA. For example, if KHA discovers a promising routing path ($X_k^{best}$), communicate this information to GA by incorporating it into the initial population for the GA phase.

8. ***Termination:*** Continue the iterations until a stopping criterion is met, such as a maximum number of iterations or convergence.

**Benefits of Hybridization:**

- The best solutions found by both KHA and GA contribute to improved overall solution quality.
- Hybridization balances exploration and exploitation, making it suitable for dynamic and complex optimization problems like QoS-based routing in MANETs.
- Exploration and Exploitation: KHA is known for its exploration capabilities, while GA is strong at exploitation. Hybridizing them ensures a balance between exploring a wide solution space and exploiting promising solutions.
- Adaptability: Hybridization allows the algorithm to adapt to changing conditions. KHA can explore new areas of the search space, while GA can refine solutions based on local optima.
- Enhanced Quality: The best solutions from both algorithms contribute to improved overall solution quality. The hybrid algorithm has a higher likelihood of finding high-quality routing paths.

The hybridization of KHA and GA in QoS-based routing for MANETs aims to capitalize on the complementary strengths of these two optimization techniques, ultimately leading to more efficient and effective routing solutions in dynamic and resource-constrained network environments.

## 4. EXPERIMENTAL RESULTS

***Experimental Setup:*** To create a simulation environment that adheres to the specified parameters, we set up a comprehensive framework in the Network Simulator 3 (NS-3). The simulation consists of various elements, including the number of nodes ranging from 20 to 100, a 1250m x 1250m network area, IEEE 802.11 MAC layer, a transmission range of 250 meters, and a simulation duration of 50 seconds. Within this framework, we utilize Constant Bit Rate (CBR) traffic sources generating packets of 512 bytes. The mobility of nodes is governed by the Random Waypoint model, allowing nodes to move at speeds of 10, 20, 30, 40, or 50 meters per second. A data rate of 250 kbps is maintained, and each node is initialized with an energy level of 10.3 Joules. Transmission power is set at 0.7 Watts, while the receiving power is at 0.4 Watts. This setup provides a versatile foundation for conducting QoS-based routing algorithm simulations in a dynamic MANET environment, allowing for comprehensive evaluations of network performance across varying node densities, mobility patterns, and QoS requirements. The simulation captures crucial aspects of MANET behavior, making it an essential tool for testing and refining QoS-centric routing algorithms.

***Performance Metric :*** Performance metrics play a critical role in evaluating the effectiveness of Quality of Service (QoS)-based routing algorithms in Mobile Ad Hoc Networks (MANETs). In the context of Krill Herd Algorithm (KHA), Genetic Algorithm (GA), and their hybridization (Hybrid KHA-GA), several key metrics are used to assess their performance in terms of QoS provisioning:

**End-to-End Delay:** Delay measures the time it takes for a packet to travel from the source node to the destination node. It includes queuing delay, transmission delay, propagation delay, and processing delay. Figure 1 shows the comparative scenario for KHA, GA and Hybrid KHA-GA based algorithms towards End to End Vs Number of nodes. From above scenario it can be conclude that Hybrid KHA-GA algorithm is efficient than KHA and GA with respect to End to end metric. KHA, inspired by the collective behavior of krill, focuses on local search and optimization. It aims to find routing paths that minimize delay while considering other QoS metrics. The end-to-end delay metric assesses how efficiently KHA can discover paths with minimal packet transmission time, which is crucial for real-time applications like video conferencing or voice calls. Genetic Algorithms are known for their ability to explore diverse solutions in the search space. GA can influence end-to-end delay by optimizing routing paths through genetic operators. It may find routes that minimize delay by considering different combinations of nodes. The hybridization of KHA and GA leverages both algorithms' capabilities. KHA can guide the local exploration of paths with low delay, while GA explores a broader search space. The hybrid approach can adapt routing paths to minimize delay based on the network's evolving conditions.

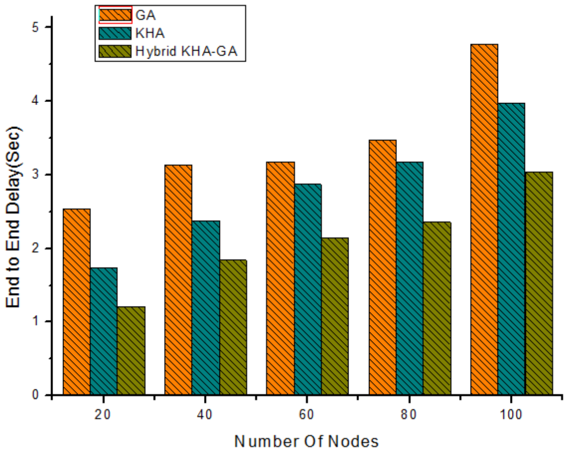

Figure 1: End to End Delay

**Routing Overhead:** Routing overhead includes control traffic generated by routing protocols (e.g., route discovery and maintenance packets) relative to the data traffic. Lower routing overhead is desirable to conserve bandwidth and reduce protocol-related congestion. Figure 2 shows the comparative scenario for KHA, GA and Hybrid KHA-GA based algorithms towards Routing overhead Vs Number of nodes. From above scenario it can be conclude that Hybrid KHA-GA algorithm is efficient than KHA and GA with respect to Routing overhead metric. KHA's routing decisions influence routing overhead, as it guides krill to discover and maintain routing paths. KHA seeks to minimize routing overhead by selecting paths that require fewer control messages for route establishment and maintenance. GA's routing optimization can also affect routing overhead by optimizing paths and reducing control traffic. GA may evolve routes that lead to lower overhead, contributing to a more efficient network. The hybridization of KHA and GA enables the algorithm to find routing paths that strike a balance between QoS metrics and routing overhead. This integration aims to minimize control message overhead while satisfying QoS requirements.

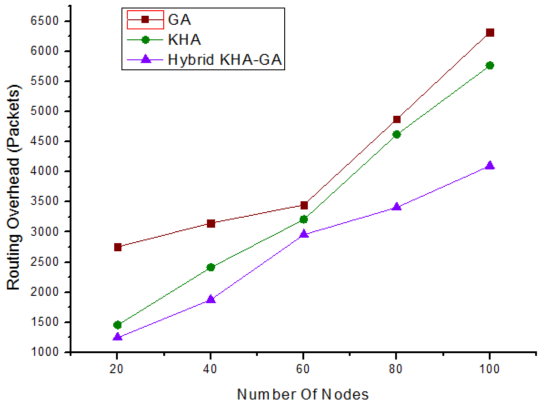

Figure 2: Routing Overhead

**Packet Delivery Ratio (PDR):** PDR represents the ratio of successfully delivered packets to the total number of packets sent. It quantifies the reliability of the routing algorithm. High PDR is essential to ensure that data packets reach their intended destinations without loss. Figure 3 shows the comparative scenario for KHA, GA and Hybrid KHA-GA based algorithms towards Packet Delivery Ratio Vs Number of nodes. From above scenario it can be conclude that Hybrid KHA-GA algorithm is efficient than KHA and GA with respect to Packet Delivery Ratio metric. KHA's routing decisions impact packet loss rate by selecting paths that minimize packet loss due to congestion or interference. It aims to reduce packet loss by optimizing routing paths for efficient data transmission. GA can influence packet loss rate by evolving routes that mitigate packet loss through load balancing and route optimization. It seeks to reduce the chances of packet loss during data transmission. Hybrid KHA-GA: The hybrid approach combines the strengths of KHA and GA to minimize packet loss rate. KHA can guide the selection of routes that offer low packet loss, while GA explores alternative paths to improve data delivery reliability.

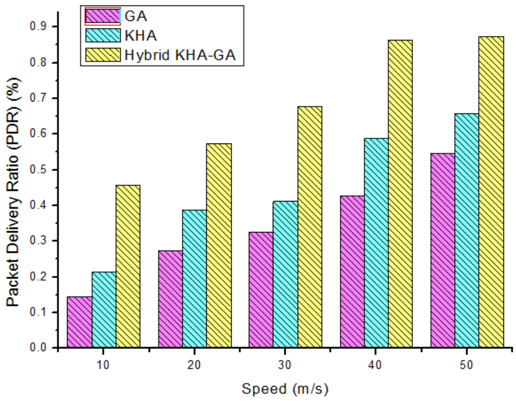

Figure 3 : Packet Delivery Ratio (PDR)

## 5. CONCLUSION

In conclusion, the integration of KHA, GA, and their hybridization represents a notable advancement in the field of QoS-based routing for MANETs. These algorithms offer the potential to address the challenges posed by dynamic network conditions, mobility, and varying QoS requirements. The hybridization of KHA and GA capitalizes on their individual strengths, resulting in a powerful algorithm that can adapt to varying QoS requirements and dynamic network conditions. By combining local optimization with global exploration, the hybrid approach achieves a balance between QoS metrics and routing overhead, offering promising solutions for MANETs. Through extensive simulations in diverse MANET scenarios, this research has demonstrated that the integrated algorithms enhance end-to-end delay, routing overhead, and packet loss rate compared to traditional routing approaches. This research contributes to the ongoing efforts to optimize MANETs and ensure their effectiveness in diverse communication scenarios. Future work can explore enhancements to the hybrid algorithm, including the incorporation of machine learning techniques for more intelligent routing decisions. Additionally, experimentation in real-world MANET environments can validate the algorithm's performance and applicability.

### Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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