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# Intelligent and Secure Seagull Optimization-Based Routing Framework for Energy-Efficient Mobile Ad Hoc Networks

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**ABSTRACT:** Mobile Ad hoc Networks (MANETs) are unstructured and dynamic wireless networks. Efficient routing in MANETs is difficult due to node mobility which affect the flow and integrity of data within a MANET. A routing framework, which incorporates an intelligent and secure routing protocol which adapts the Seagull Optimization Algorithm (SOA) is developed through natural seagull migrations and attacking behaviours to identify the routing path with the lowest energy consumption is discussed in this paper. The intelligent routing framework allows for the efficient routing of packets through MANETS while dealing with frequent topology changes, so the identified routes are appropriate at each topology change. The enactment advance of the offered routing framework is demonstrated through the simulation of increased throughput, decreased energy consumption and decreased end-to-end delay related to existing methods. Therefore, the proposed routing framework is applicable to a broad range of uses, including disaster management, military operations and Internet of Things (IoT).

**Keywords:** Routing framework, Seagull Optimization Algorithm, MANET, existing methods, evaluation metrics.

## 1. Introduction

The use of mobile or wireless devices has increased significantly in recent years, greatly altering the communication and interaction with the world. Modern mobile and wireless devices, including smartphones, wearable technology, drones and self-driving cars are designed to work without a fixed infrastructure and are therefore reliant upon networks that adapt to changing conditions and the movement of nodes which allow for variable link quality and conserve battery power [1-2]. MANET are one possible solution to these problems and they provide a decentralized, self-organizing means of communication where all nodes in a MANET act as hosts and routers, thus provide communications across multiple domains to meet the requirements [3].

As this expertise has grown, existing methods such as Ad Hoc On-Demand Distance Vector (AODV) and Dynamic Source Routing (DSR) rely on distinct ways and do not work well with frequently changing topologies or identify security attacks like wormhole and black hole attacks that have a serious impact on the integrity of the data. In a MANET, wormhole attacks is one of the most serious threats [4]. Attackers produce a tunnel amongst dual distant nodules in the network. Therefore, routing is interrupted and permits the invaders to take the routing of packets, which then allows the attackers to eavesdrop on all network activity, monitor delays in communication and drop packets, thereby worsening the performance of the network. This is illustrated in Figure 1 by using two colluding malicious nodes (Node A and Node B) to form a high-speed tunnel and direct most of the network traffic and leave the network open to manipulation. It is very difficult to detect such attacks because of limited resources and means of communication [5-6].

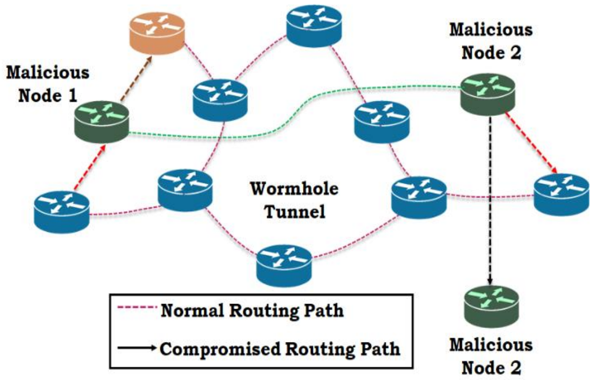


**Figure 1:** *Wormhole attack in MANET*

Most current countermeasures for such attacks use trusted methods, however, both the methods impose a significant amount of additional computation and communication overhead on the network. Advanced routing techniques that use Reinforcement Learning (RL) such as Deep Reinforcement Learning (DRL) are used to accommodate high-dimensional state spaces [7]. This allows for adaptive routing to be performed in changing topologies when traditional routing protocols fail. The use of mobile devices along with the extensive dynamics of MANETs exhibit the urgent necessity for a routing practice that is secure, intelligent and energy proficient. Current solutions primarily tackle the issue; however, each option requires an unnecessary computational or communication overhead that results in the solutions which is unsuitable for deployment within large scale resource arranged MANETs [8-9].

As a result, there exists an essential for a light weight clarification that stabilizes safety, enactment and efficiently scale to support enormous active MANET arrangements. Another area of concern is securing MANET networks. Existing techniques utilize trusted methods; however, these methods add important message and are impractical for highly dynamic MANET networks [10]. To address these challenges this paper introduces an intelligent and secure SOA based routing framework for energy-efficient MANET. By establishing effective routing paths that optimize energy consumption, the framework assists with energy efficiency and ultimately increases the life of the entire network. The framework is able to adjust scientific or dynamic changes due to node mobility and continue to provide reliable communication [11].

### 1.1 Related works

**Hood Almutairi *et al* [2024] [12]** have proposed a Particle swarm optimization (PSO)-based frameworks for MANETs which provide an intelligent and secure routing framework, resulting in numerous benefits, including fast convergence, improved energy efficiency and simple implementation. However, PSO requires fine-tuning of parameters and does not provide a strong level of security by itself unless it is combined with other mechanisms. **Ramanpreet Kaur *et al* [2025] [13]** have developed a Unified Energy aware Link Auto-configuration Routing model (UELARM) for MANETs which provides improved energy balancing, reduced hotspot formation, increased overall network lifetime and greater routing stability. Nevertheless, UELARM has higher computational complexity, more overhead associated with its routing in mobile networks and has limited scalability when mobile networks become highly mobile. **Minal Patil *et al* [2025] [14]** have established a grey wolf optimization (GWO) for MANETs for an intelligent and secure routing basis, resulting in good global searching capabilities, improved energy efficiency and stable routing. Nonetheless, there is a potential for premature convergence when networks become highly dynamic with GWO. **N. Naveen *et al* [2025] [15]** have implemented the use of secure bio-inspired optimization which provide MANETs with an intelligent and secure routing structure, resulting in improved energy efficiency, adaptive routing and enhanced security. Though, optimization and security mechanisms caused an increase in the algorithm's complexity.

### 1.2 Contributions

The major involvement of this paper includes,

- The SOA is used to determine the most efficient routes for maintaining a long-lasting network in MANETs
- The method provides a trust mechanism that detects malicious nodes and protecting data transfer.
- Optimizes key factors such as energy usage, delay time and packet delivery ratio to compensate for changing network conditions.

## 2. Proposed System Description

An intellectual and safe transmitting structure for MANETs is developed by utilizing the SOA. The block diagram of proposed system is depicted in figure 2.

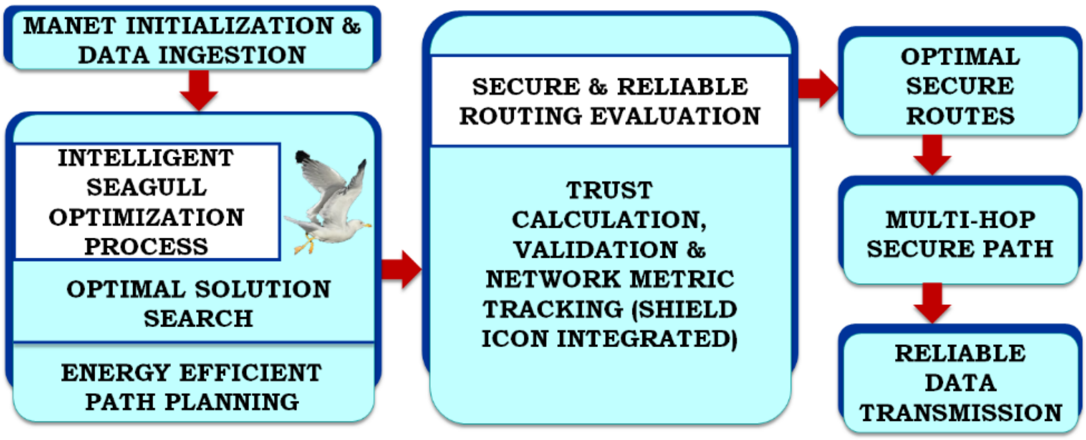


**Figure 2:** *Proposed block diagram*

This new routing structure provides energy-efficient and stable routes through the identification of optimal routes determined by various factors, including nodes' energy levels, nodes' mobility and link quality. The selection of optimal routes extends the lifetime of the overall network. During the route formation process, a trust evaluation mechanism identifies and eliminate malicious nodes so that secured data transmission occurs. The proposed system continuously evaluates the changes within a MANET's topology and updates its routing decisions in real time, enhancing the overall system stability, reducing power consumption, and improving reliable communication in dynamic environments.

## 3. Proposed system modelling

### 3.1 SOA-Based Routing Framework

The proposed SOA is an intelligent and secure routing framework to select and optimize routing paths for energy-efficient MANETs. The SOA is used in a dynamic MANET environment during the global exploration phase to explore multiple candidate routing paths on the network. Each candidate route is a potential routing path, where the program of collision avoidance helps to prevent overlapping route selections and is modelled as,

$$C_i(t) = A \times X_i(t) \qquad (1)$$

Where, $C_i(t)$ is a preventing overlapping routes and $A$ is defined to be the inertia weight and is expressed as follows,

$$A = f_c - \left(t \times \frac{f_c}{MaxIter}\right) \qquad (2)$$

Here, $f_c$ is constant and $MaxIter$ is the limit on maximum iterations allowed. This decreasing factor causes the transition from exploration through exploitation to occur gradually as the routing stabilizes. Flowchart of SOA is shown in figure 3.

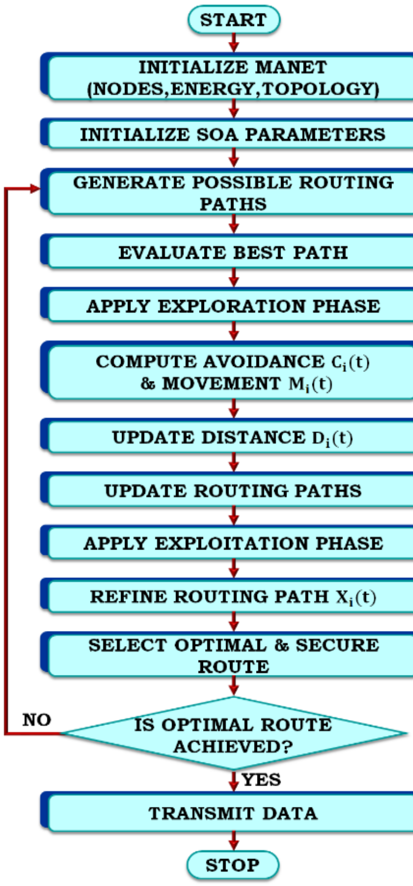


**Figure 3:** *Flowchart of SOA*

This transition towards better possible routing paths is controlled by the subsequent calculation,

$$M_i(t) = B \times \left(X_{best}(t) - X_i(t)\right) \quad (3)$$

$$B = 2 \times A^2 \times r + and \quad (4)$$

In the above equation, $M_i(t)$ represents movement towards that best route, $X_{best}(t)$ represents the best-known solution (route) and $rand$ represents a random number in the range of 0 to 1 to ensure balanced exploration. In addition, nodes are attracted towards the best route according to energy consumption and stability of the link. The overall update to routing during exploration is performed through,

$$D_i(t) = |C_i(t) + M_i(t)| \quad (5)$$

Where, $D_i(t)$ is the distance to the proposed route from the best route, which calculates the distance from each proposed route to the best-known solution. During local exploitation phase of SOA, the selected route is refined using a spiralling-based optimization method, which increase routing efficiency or performance. The spiral motion is defined as using the following equations,

$$r = u \times e^{\theta v} \quad (6)$$

$$x' = r \times cos(\theta) \quad (7)$$

$$y' = r \times sin(\theta) \quad (8)$$

$$z' = r \times \theta \quad (9)$$

In this equation, $r$ is radius for the spiral. The final optimized path is then updated using the following expression,

$$X_i(t) = (D_i(t) \times x' \times y' \times z') + X_{best}(t) \quad (10)$$

Here, $X_i(t)$ is the refined path solution, again providing an optimized, energy-efficient and stable routing path back into the mesh. The adaptive routing framework in the proposed routing system helps to find the best paths for MANET by allowing for real-time adaptation to the network's topological changes. Stable, reliable routes are selected in these environments as opposed to unstable and unreliable routes or links, which help to conserve battery power, provide sufficient, consistent delivery of packets, improve reliability and performance of the route in a dynamic MANET.

## 4. Result And Discussion

The intelligent and secure SOA based routing framework for energy efficient MANET improves the performance of routing through the effective determination of energy-efficient and stable paths in dynamic environments. The experimental results from the simulations demonstrate that the proposed routing framework significantly reduces the total energy consumed by a MANET and consequently extends the lifetime of the network. In addition, the proposed routing framework is capable of ensuring the security of the data being transmitted by avoiding the use of unreliable nodes during routing. Thus, the proposed routing framework result in reduced packet loss and improved reliability in communication. Parameter specification is depicted in table 1.

**Table 1:** *Parameter specifications*

| Parameters | Values |
|---|---|
| Field area | $1500 \times 1500\ m^2$ |
| Number of sensor nodes | 50 |
| Number of mobile nodes | 100 |
| Initial energy of sensor node | 0.5 *Joules* |
| Packet size | 500 *bytes* |
| Initial energy of MANET | 1.25 *Joules* |
| Simulation tool | Network simulator (NS-3) |

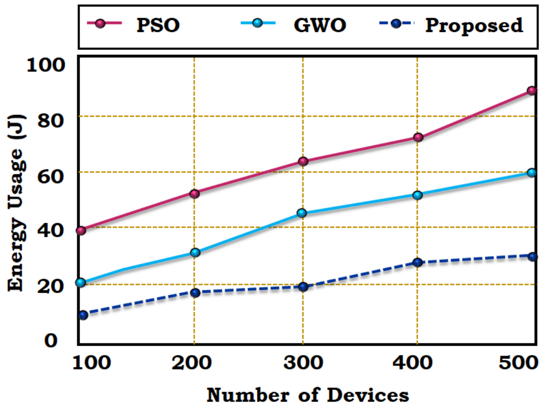


**Figure 4:** *Energy consumption*

In figure 4, the quantity of devices increases for every technique. The proposed technique produces the least amount of energy consumed, while GWO [14] has moderate amount of energy consumed and PSO [12] has the highest amount of energy consumed. Therefore, it appears that the proposed method is the most efficient method.

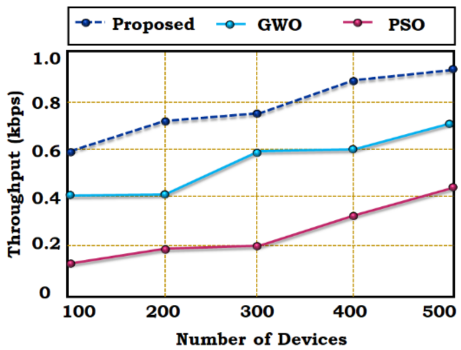


**Figure 5:** *Throughput*

In figure 5, throughput grows with an increase in device presence, demonstrating that the proposed method provides the greatest throughput compared to GWO and PSO, indicating the proposed method is the most scalable and efficient method.

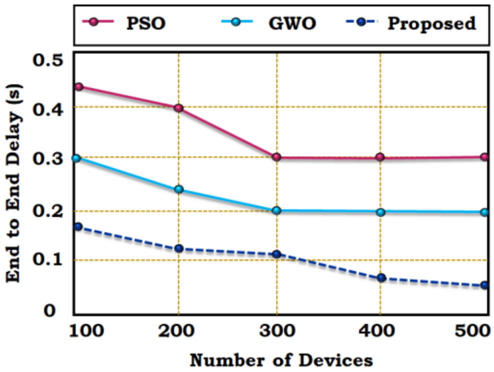


**Figure 6:** *End-End delay*

Figure 6 demonstrates as the quantity of devices develops the amount of end to end (E2E) delay decreases. The proposed method has the shortest delay followed by GWO with a moderate delay and PSO having the largest E2E delay. Consequently, it performs that the proposed method has the least amount of E2E delay overall compared to both GWO and PSO and is therefore the best performing method with a lower level of E2E delay.

## 5. Conclusion

The proposed system describes an innovative intelligent and secure SOA based routing framework to resolve recurring problems faced by MANETs. The SOA used in this proposed framework allows for the discovery of optimal and stable routes for minimally consuming energy from the total network, therefore increasing the length of time before the network becomes unfeasible due to a complete depletion of energy. In this routing mechanism, there is a mechanism for node evaluation that allows for reliable routing. As a result of this mechanism, the proposed routing framework achieves increased throughput, decreased energy usage and decreased E2E delay, making it a viable and reliable solution for routing requirements within the MANET environment.

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