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Penguin Optimized Intelligent Routing Protocols in MANET

Ebby Darney P[3], Vasmitha R I[4]

[3]Professor, Department of Electrical and Electronics Engineering,
Rajarajeswari College of Engineering, Bangalore, India- 560074. pebbydarney@gmail.com

[4]Assistant professor, Department of Civil,
Cape Institute of Technology, Tamil Nadu, India. rivasmitha@gmail.com

ABSTRACT: Mobile Adhoc Networks (MANETs) have become a desirable communication paradigm as they facilitate dynamic communication through their decentralized infrastructure. Problems such as frequent changes in network topology, high mobility of nodes, and routing overhead have become extremely difficult in MANET. Additionally, to extend the network's lifetime, conserving node energy is crucial. To address these issues, this paper proposes the Penguin Search Optimization (PeSO) approach for reliable and energy-efficient routing in MANET. In PeSO, the nodes operate as a group and perform simultaneous route discovery and energy updation for enhancing the optimal path selection. Moreover, this approach ensures effective exploration of the potential candidate solution and faster convergence under high node mobility areas. The OMNet++ simulator is used as the evaluation tool. The proposed PeSO achieves an enhanced Packet Delivery Ratio (PDR) of 93.1%, minimal energy consumption of 1370 J, and a reduced throughput of 925 kbps at 100 nodes.

Keywords: Mobile Adhoc Networks, routing, Penguin Search Optimization, Packet Delivery Ratio, faster convergence.

1. Introduction

In recent years, wireless networks have gained huge importance as they support fast and simultaneous exchange of data across dynamic environments. The topology of these networks keeps modifying as the nodes enter and exit the network frequently. MANETs play a vital role in managing the continuous flow of nodes in the network. With the aid of dynamic network topology, the nodes move freely in the network and also interact with each other without any third-party assistance, i.e., a centralized architecture. It is prevalent in areas where fixed infrastructure is not dependable.

An enormous number of routes are available to route the data between source and destination. Moreover, finding the optimal path among the available routes is tedious. Therefore, routing protocols are important in finding the optimal path and enhancing routing efficiency and reliability in MANETs. Traditional routing protocols for MANET are categorised into three divisions: reactive, proactive and hybrid [1]. In a proactive routing protocol, each node possesses a routing table and exchanges information among the neighbouring nodes at regular intervals. In a reactive routing protocol, route discovery occurs only at the time of data forwarding. It is more scalable than the proactive protocol since it doesn't maintain a routing table. The hybrid protocol combines the above two protocols; it uses proactive routing protocols for nodes within the local zones and reactive protocols for nodes away from the local zones. There are several drawbacks with the traditional routing protocols. Proactive routing protocols create network overhead in fast-

changing networks and require higher bandwidth and maintenance of routing tables. In reactive routing protocol retransmission of route takes longer time, in case of route failure. Moreover, these protocols fails to address the challenges faced by the MANET like routing overhead, limited battery power, limited bandwidth etc. In [1], an Enhanced Particle Swarm Optimization (EPSO) algorithm was introduced to enhance route selection by considering path distance, energy consumption, and end-to-end delay. In [2], a Genetic algorithm was explored to improve route selection and routing performance in MANETs. Furthermore, an adaptive hybrid Ant Colony Optimization (ACO) algorithm was proposed in [3] to address multi-constrained Quality of Service (QoS) routing. Although these approaches address different routing requirements, designing an efficient routing strategy that balances energy consumption, end-to-end delay, and network lifetime remains an important challenge.

This paper introduces a novel nature-inspired penguin Search Optimization Algorithm to overcome the struggles in MANETs. Penguins hunt for food in groups. Every penguin in the group hunts for food separately and updates the amount of food it gathers with its location to the peers in the group. This collaborative behaviour of penguins allows them to find the path with an abundant food source, and preserve their oxygen supply and energy. Likewise, PeSO is an effective optimization approach for finding an optimal route, and also for preserving the nodes' energy, which increases the lifetime of networks.

This paper is organised as follows: Section 2: Recent Works, which discusses the bio-inspired optimization algorithms utilized in various research papers. Section 3: Covers the proposed PeSO algorithm. Section 4: Results and discussion, followed by Section 5: Conclusion.

2. Recent Works

Adaptive Ant Colony Optimization (AACO) [4] allows adaptive route discovery by dynamically modifying the parameters in Ant Colony Optimization (ACO). This approach gained an increased PDR, lower end-to-end delay, and minimized routing overhead. However, it fails in considering energy consumption of the nodes, which helps to increase the network's lifetime.

Particle Swarm Optimization (PSO) routing algorithm [5] is utilized to enhance routing in MANET. PSO finds an optimized routing path by dynamically exploring all possible routes. This method attains an increased Packet delivery ratio, throughput, and assures global route optimization. However, this method fails to adjust energy consumption in nodes dynamically.

Secure Bio optimization (Sec-Bio) approach [6] solves the complex routing problem by performing energy-aware routing, and routes are made only at the time of data transmission. Because of the reduced energy drop, the network's lifetime is increased. However, the performance of the system is reduced when more nodes enter the network.

Adaptive Actor Optimization Algorithm (AAOA) [7] is a hybrid model that combines the adaptive concept with the Actor Optimization Algorithm (AOA) for providing energy-efficient routing by selecting suitable paths in dynamic environments. This approach provides fault tolerance and minimizes the node death rate. However, the end-to-end packet delay is not addressed.

Serial Exponential Coati Optimization Algorithm (SECOA) [8] uses Recurrent Neural Networks to find the Link Life Time (LLT). The nodes having high LLT are chosen for routing. With the aid of SECOA, more reliable and uninterrupted communication is created. The calculation of LLT requires more time, which makes the model more complex.

[9] Uses the Genetic Algorithm (GA), the natural selection principle of GA, to help in finding optimal routes. It addresses the dynamic routing problems in MANET. However, it fails to perform

adaptive learning in changing networks and also it is not evaluated for heterogeneous nodes.

In [10], a hybrid approach is proposed, which integrates Ant Colony Optimization (ACO) and Particle Swarm Optimization (PSO). The local adaptive character of ACO and the global convergent behavior of PSO together make this approach more robust and scalable in dynamic environments. Moreover, energy conservation is not considered, which leads to node death in a shorter duration.

3. PeSO Algorithm

The PeSO optimization technique is inspired by the collective and collaborative hunting behaviour of penguins. Penguins always hunt in groups. They follow an approach that includes synchronized dives and communication for finding and capturing fish. Each penguins of the group is involved in search for food separately, and then they communicate their findings in the group, which enables the group to find out highest concentration of food and allows the remaining members to be aware of the paths which is already discovered.

3.1 Rules of PeSO

- The penguin population is divided into several groups and each group contains a varying number of penguins depending on the availability of fish at the particular hunting area.
- According to the energy gain and the cost to attain it, each penguin in the group begins hunting.
- They hunt as a group, by following the leading one which finds most food in the previous dive.
- Penguins search for fish inside the water until their energy level gets drained.
- After several dives, they reach the surface and share the location and the ample food with the neighbours through intra-group communication.
- The entire group or a section of the group is shifted to another group via inter-group communication if the food finding becomes inadequate for the members.

3.2 Proposed Work Explanation

Fig. 1 shows the workflow of the proposed Penguin Search Optimization Algorithm (PeSO) which is discussed below

3.2.1 Data Collection

The process starts with data collection. Here, the data is collected from the mobile nodes such as laptops, Mobile Phones, and wireless devices at regular intervals.

The collected data contains

- Node position
- Energy consumption
- Neighbour information
- Link quality

3.2.2 PeSO

The gathered data is forwarded to the destination node through the shortest path with minimal cost. This is achieved using PeSO, it contains several methodologies for routing the data.

Overview

PeSO begins with the Candidate Path update, which is used to update the node's position. Followed by Energy Updation, where the energy consumption of the nodes is monitored and updated to avoid node death and to increase the network lifetime. Then, In intra-Group Communication: nodes share the routes explored and the energy level with the other nodes in that group. In the Route Abundance degree section, the quantity of routes discovered by the group is evaluated. Continued by Group Membership

Update where the nodes switches to other groups if the optimal solution can't be found with the existing group.

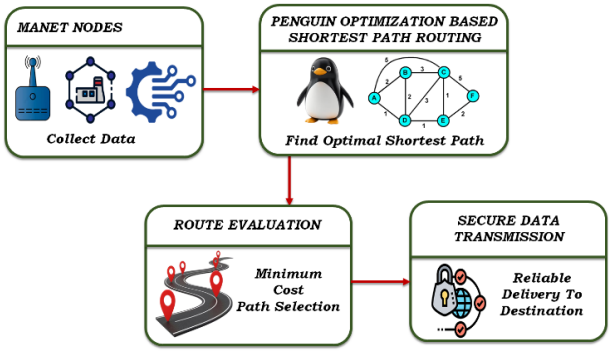

Figure 1: *Proposed System Workflow*

Candidate Path Update

Candidate paths represent possible routes, the quality of these routes is assessed using network parameters like energy consumption, delay, and routing efficiency. At first, the candidate solutions are divided into groups, and each group contains varying number of nodes according to the available routes.

Consider S sets of nodes which are scattered in a random manner in the solution space. Consider the set Si having m_i nodes such that the node j belonging to Si is assigned to a solution at the time a + 1 as follows.

$$u_h^g(a+1) = u_h^g(a) \times r(\,) \times | u_{Lbest}^g - u_h^g(a) | \quad (1)$$

Where $u_h^g(a+1)$ is the position of node h in the gth group at the ath instant, u_{Lbest}^g is the best solution found by the gth group, r () is the random number between (0, 1).

Table 1: *Notations and Description*

Notations	Descriptions
S	Number of Groups
d	Objective Function
$u_h^g(a)$	node h's position, assigned to the gth group at ath instance
u_{Lbest}^g	Best local solution of gth group
$E_h^g(a)$	Residual energy of hth node at the gth group
$NRDi\ (a)$	Number of routes Discovered by the group i at the instance a
$Mi\ (a)$	Probability of finding optimal path by the group i at instance a
r	Random number between 0 and 1

At each iteration, the candidate path is modified using the gathered information regarding the best path in the group, along with the search process being used to explore the possible routes. The modified path must satisfy MANET routing requirements, including connectivity of the source and destination.

Energy Updation

After each hop, the node's energy consumption is monitored and the residual energy is updated as follows.

$$E_h^g(a+1) = E_h^g(a) + (d(u_h^g(a+1)) - d(u_h^g(a))) \times \| u_h^g(a+1) - u_h^g(a) \| \quad (2)$$

Where $E_h^g(a)$ is the residual energy of the hth node in the gth group and the objective function for resolving the MANET network's routing optimization problem is denoted by d.

To find an effective route between the source node and the destination node, the objective function takes into account network metrics such as energy consumption, throughput and packet delivery ratio (PDR), end-to-end delay, and network lifetime.

The energy level of the nodes depends on the time taken for one hop and the number of hops covered. The energy level increases if a new solution is better than the previous one and it decreases in the other case. Longer paths with more hops will have higher energy consumption and delays. To maintain energy consumption, network connectivity and to increase network lifetime, another path or node may be taken into consideration when a node has insufficient energy for communication. The amount of energy used during data transmission and efficiency of the chosen route, determine how much energy each mobile node uses. The nodes migrate to other networks if the existing network's energy supply is inefficient.

Intra-group Communication

In intra-Group Communication: nodes share the routes explored and the energy level with the other nodes in that group. The Intra-group communication is managed well by the nodes as they perform route discovery as a group and share the gathered information with their peers. The nodes in the group follow the local best solution from the previous route discovery as discussed in Eqn (1). At every instance of time the node finds the new route and becomes the best local solution.

Route Abundance Degree

The route abundance degree associated with a group denotes the residual energy available from each node in the group. It is calculated using network evaluation metrics such as PDR, remaining energy, delay, and link quality. The route abundance degree can be estimated by the Number of Route Discovered (NRD), which is calculated by the following expression.

$$NRD^{g}(\text{a}+1) = NRD^{i}(\text{a}) + \sum_{h}^{g_k}(E_h^g(\text{a}1) - E_h^g(\text{a})) \quad (3)$$

In order to ensure efficiency in route selection and prevent any unnecessary operations linked to the group shift, this measure will aid in the selection and migration of groups. A greater value of NRD indicates improved routing performance in the group.

Group Membership Update

The node switches to the other group if the optimal route is not attained with the group it belongs. The node updates its group membership by reference to a function relating to the Route abundance degree of various groups. It enters another group based on the group's route abundance degree. The region explored by the group is restricted if all the nodes in that group are shifted to other groups.

The membership value of joining a group g is given by the probability of

$$\text{M}_\text{i}(\text{a}+1) = \frac{\text{NRDi (a)}}{\sum_{i=1}^{h} NRD^{g}(\text{a}+1)} \quad (4)$$

3.2.3 Route Evaluation

In order to find the optimal path with minimum cost, evaluation metrics such as PDR, throughput, network lifetime, energy consumption and end-to-end delay are used.

Packet Delivery Ratio: PDR is the ratio of the total number of packets successfully received at the receiver end to the total number of packets transmitted by the source.

$$\text{PDR} = \frac{\sum_{\text{i}=0}^{\text{n}} \text{K}}{\sum_{\text{j}=0}^{\text{m}} \text{L}} \quad (5)$$

Where K is the count of received packets and L is the count of sent packets.

Energy Consumption: Energy Consumption of a node indicates the total amount of energy required for transmitting and receiving data.

$$E = \sum E_{trans} + E_{rec} \quad (6)$$

Where E_{trans} is the energy used for transmitting the data and E_{rec} is the energy used for receiving the data.

Throughput: Rate at which the data is delivered through a network within a specific time.

$$\text{T} = \frac{\sum_{\text{i}=0}^{\text{n}} \text{A}}{\text{D}} \quad (7)$$

Where A is overall data received by every node and D is the duration.

Network Lifetime: The time period for which the node remains alive.

End-to-End delay: Time taken by the data packet to travel from the source to its destination in the network.

$$\text{D} = \frac{1}{\text{A}\sum(\text{T}_{\text{rec}} - \text{T}_{\text{sent}})} \quad (8)$$

3.2.4 Secure Data Transmission

The data has to reach the destination securely without exposing to vulnerable attacks during transmission. PeSO ensures energy-efficient,

reliable and trust-based secure data forwarding. It uses trust based route path selection, which effectively mitigates all attacks during data transmission.

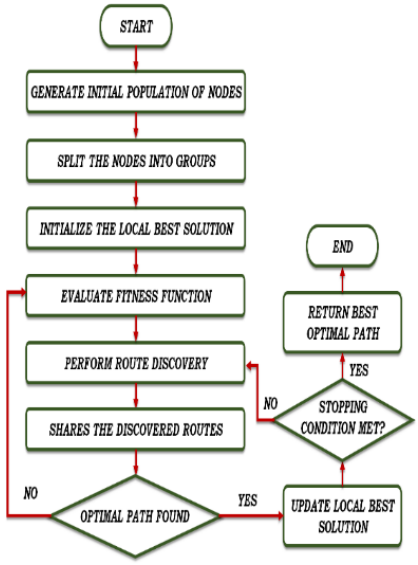

Figure 2: *Flowchart of PeSO Algorithm*

The working of the PeSO approach is presented in the flowchart in Fig. 2.

Algorithm of PeSO

1: Generate the initial population of nodes u_h^g(h=1, 2, 3.. N (total nodes)) for every group g.
2: While stopping condition is met do
3: Initialize the energy for each node;
4: For each group g do
5: For each node h in the group g do
6: Update the node position and best local solution with eqn 1.
7: Update energy E_h^g by eqn 2
8: End
9: Update the Route abundance degree of that group by eqn 3.
10: End
11: For each group update its membership value by eqn 4.
12: Disperse the nodes to different groups based on membership function.
13: Remove the group with no nodes.
15: end while;
16: End.

In PeSO, the first population initiation of candidate solutions has huge importance, because this acts as the entry point to discover routes for other candidates. Here, a random strategy is utilized for population initiation. Then the candidate solution is divided into several groups. Each node in the group routes separately by following the best local solution obtained from the previous route. After several routes, the nodes share the location and the route discovered with their neighbouring nodes. This helps in conserving the nodal energy by avoiding the route visited by its peers. The best local solution gets updated every time a better route is discovered. The node's status is represented by its location and the residual energy. When the energy is reduced, the node returns and shares the group information with the nodes of other groups. Then, it gets redistributed based on the updated group membership function. Also, after an entire cycle of intra-group communication, the entire group or a part of the group migrates to the neighbouring group, if the optimal route is not found in the current group. This process is repeated until it reaches maximum iteration.

4. Results and Discussion

This section presents the simulation results obtained from the OMNet++ simulator for evaluating the performance of the proposed PeSO algorithm with varying numbers of nodes such as 20, 40, 60, 80, and 100. The performance of PeSO is compared with several bio-inspired optimization algorithms like Sec-Bio, SECOA, and GA. Performance metrics such as PDR, Energy consumption, Network lifetime, end-to-end delay and Throughput are used as evaluation metrics.

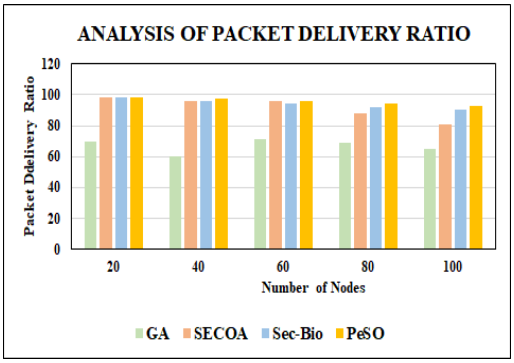

Figure 3: *Packet Delivery Ratio Analysis*

Fig. 3 shows the performance of different optimization techniques in terms of PDR. PDR is one of the most important metrics in analysing the network performance. From the comparison results, it is inferred that the proposed method outperforms all other methods such as GA, SECOA and Sec-Bio and also ensures that it has more reliable and enhanced packet delivery ratio. The PDR for the proposed method with 100 nodes is 93.1%. This increased PDR shows that the proposed PeSO technique has more reliable performance even in dynamic environments.

Table 2: *Performance comparison in terms of Throughput*

No of nodes	GA	Sec-Bio	SECOA	PESO
20	930	935	986	990
40	920	930	961	980
60	911	925	944	967
80	890	920	929	942
100	882	915	895	925

Table 2 shows the performance of different optimization techniques in terms of throughput (kbps). From the table, it is clear that there is a significant improvement in throughput when using PeSO (925 kbps) at even 100 nodes. At 20 nodes the throughput of PeSO is 990 Kbps which is much higher than using GA and Sec-Bio. This shows that PeSO has higher efficiency in data transfer.

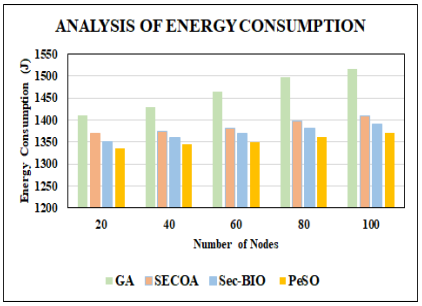

Figure 4: *Analysis of Energy Consumption*

Fig. 4 depicts the comparison of different optimization techniques in terms of Energy Consumption (J). Energy is also an important evaluation metrics in evaluating the efficiency of the model in dynamic environments. The proposed technique uses minimal utilization of energy among all other techniques at 100 nodes. This shows that the nodes in PeSO remain alive for a longer time.

Table 3 depicts the end-to-end delay (ms) comparison of different optimization techniques. The results indicate that PeSO routes the packets by finding the shortest path with minimal delay.

Table 3: *Performance comparison in terms of end-to-end delay*

No of nodes	GA	SECOA	Sec-BIO	PeSO
20	58	66	55	50
40	65	72	60	59
60	72	84	70	67
80	85	96	80	74
100	91	108	90	85

At 20 nodes the end-to-end delay of PeSO is 50ms and it shows gradual increase with increase in nodes, finally at 100 nodes it reached an end-to-end delay of 85ms which is comparatively lesser than other methods.

Table 4*: Performance comparison in terms of lifetime*

No of nodes	GA	SECOA	Sec-BIO	PeSO
20	710	700	500	750
40	688	670	480	715
60	664	630	460	685

80	639	610	440	640
100	600	590	420	615

Table 4 shows the comparison of network lifetime (s) against the number of nodes. From the results, the proposed method has the highest network lifetime, which indicates that the nodes in the network remain alive for a longer time span.

5. Conclusion

In this paper, a collaborative, energy-efficient secure routing approach is developed using the nature-inspired Penguin Search Optimization. This proposed approach is compared with several bio-inspired algorithms like GA, Sec- Bio, and SECOA. The results show improved values in PDR (93.1%), throughput (925 kbps), network lifetime (615 s) and minimal values in Energy consumption (1370 J), and end-to-end delay (85 ms). This enhanced performance is due to the unique collaborative hunting behaviour of the Penguins. Overall, the results reveal that PeSO outperforms existing techniques by effectively handling dynamic network topologies, energy consumption and network lifetime.

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