National Conference on Recent Trends in Artificial Intelligence and Data Science (NCRTAIDS-26)
Sri Vasavi College, Erode, Tamil Nadu, India

International Journal of Science, Engineering and Technology
ISSN: 2348-4098, P-ISSN: 2395-4752

Performance Analysis and Mitigation Techniques of Ant Colony Optimization Based Routing Protocol in Mobile Adhoc Network(Manet)

Mr. K. Mohanraj[1], Dr. S. Prasath[2]

[1]Research Scholar, VET Institute of Arts and Science (Co-Education) College, Erode, Tamilnadu, India
[2]Assistant Professor and Head, Department of Computer Science and Applications,
VET Institute of Arts and Science (Co-Education) College, Erode, Tamilnadu, India

Abstract - Mobile Ad Hoc Networks (MANETs) are decentralized wireless networks where mobile nodes communicate without fixed infrastructure. Due to dynamic topology and limited resources, routing becomes a major challenge in MANET environments. Ant Colony Optimization (ACO), inspired by the foraging behavior of ants, provides an adaptive and distributed solution for routing problems. This paper proposes an ACO-based routing algorithm for MANETs that improves route discovery and path optimization. Artificial ants explore the network and update routing tables using pheromone trails. Simulation results show improved packet delivery ratio, reduced delay, and higher throughput compared to traditional routing protocols.

Keywords - MANET, Ant Colony Optimization, Swarm Intelligence, Routing Protocol, Wireless Networks.

I. INTRODUCTION

Mobile Ad Hoc Networks (MANETs) are a type of wireless network in which mobile nodes communicate with each other without relying on any fixed infrastructure such as routers, access points, or base stations. In a MANET, each node functions both as a host and as a router that forwards packets for other nodes. The network is formed dynamically as nodes join or leave the system, making it highly flexible and suitable for environments where infrastructure is unavailable or impractical. MANETs have gained significant attention in recent years due to their wide range of applications. These include military communications, disaster recovery operations, emergency response systems, wireless sensor networks, and vehicular ad hoc networks. In such environments, the ability to quickly establish communication without pre-existing infrastructure is extremely important.

However, the dynamic nature of MANETs introduces several challenges that make network design and routing complex. One of the major challenges in MANETs is routing. Because nodes move randomly, the network topology changes frequently, causing links between nodes to break and new links to form. This dynamic topology leads to frequent route failures, increased packet loss, and higher communication delays. In addition, nodes in MANETs typically have limited battery power, limited bandwidth, and constrained processing capabilities. Therefore, designing an efficient routing protocol that can adapt to these changing conditions is essential for maintaining reliable communication.

Traditional routing protocols used in wired networks are not suitable for MANET environments due to the absence of centralized control and the constantly changing topology. Various MANET routing protocols have been proposed to address these issues, including proactive protocols such as Destination Sequenced Distance Vector (DSDV), reactive protocols such as Ad hoc On-Demand Distance Vector (AODV) and Dynamic Source Routing (DSR), and hybrid protocols that combine both

International Journal of Science, Engineering and Technology
ISSN: 2348-4098, P-ISSN: 2395-4752

approaches. While these protocols provide basic routing functionality, they may suffer from limitations such as high routing overhead, slow convergence, and inefficient path selection in highly dynamic networks.

To overcome these limitations, researchers have explored the use of bio-inspired algorithms for routing in MANETs. Bio-inspired algorithms are computational techniques that mimic the behavior of natural systems such as ant colonies, bird flocks, or bee swarms. These algorithms are particularly suitable for distributed and dynamic environments because they rely on simple agents cooperating locally to achieve global optimization.

Ant Colony Optimization (ACO) is one of the most well-known swarm intelligence techniques used for solving optimization problems. It was originally proposed by Marco Dorigo and is based on the natural behavior of ants searching for food. In nature, ants deposit chemical substances known as pheromones on the paths they travel. Other ants detect these pheromone trails and are more likely to follow paths with higher pheromone concentrations. Over time, shorter and more efficient paths accumulate more pheromone, allowing the colony to collectively identify the optimal route between the nest and the food source.

This natural phenomenon can be applied to network routing problems. In ACO-based routing algorithms, artificial ants are used as control packets that explore different routes between a source node and a destination node. As these ants travel through the network, they collect information about the quality of the path, such as delay, hop count, and congestion level. When the ants return to the source node, they update routing tables using pheromone values that represent the desirability of each path. Data packets are then forwarded along routes with higher pheromone concentrations, which correspond to more efficient paths.

The use of Ant Colony Optimization in MANET routing offers several advantages. First, ACO algorithms are highly adaptive and can quickly adjust to changes in network topology. Second, they support multipath routing, which improves reliability by providing alternative routes in case of link failures. Third, the distributed nature of ACO makes it suitable for decentralized environments like MANETs where no central controller exists. These characteristics make ACO a promising approach for improving routing performance in mobile ad hoc networks.

In this paper, an Ant Colony Optimization based routing protocol is proposed to enhance the performance of MANET communication. The proposed approach uses artificial ants to discover and maintain efficient routes between nodes while dynamically adapting to changes in the network topology. The performance of the proposed method is evaluated using simulation metrics such as packet delivery ratio, end-to-end delay, throughput, and routing overhead.

The remainder of this paper is organized as follows. Section II discusses the related work in ACO-based MANET routing protocols. Section III explains the Ant Colony Optimization technique used in the proposed model. Section IV describes the proposed routing algorithm. Section V presents the simulation environment and performance metrics. Section VI discusses the results and analysis, and finally Section VII concludes the paper and suggests future research directions.

II. LITERATURE SURVAY

Mobile Ad Hoc Networks (MANETs) have attracted significant research attention due to their ability to provide communication without fixed infrastructure. However, efficient routing remains one of the major challenges because of node mobility, limited bandwidth, and dynamic topology. Several

International Journal of Science, Engineering and Technology
ISSN: 2348-4098, P-ISSN: 2395-4752

researchers have proposed routing protocols based on swarm intelligence techniques such as Ant Colony Optimization to address these challenges.

Early research in this field introduced the AntNet routing algorithm, which used artificial ants to explore network paths and update routing tables using probabilistic learning. The algorithm demonstrated improved adaptability and reduced delay in dynamic network environments. This work laid the foundation for later ant-based routing protocols used in MANET environments.

Later, the Ant Colony Routing Algorithm (ARA) was proposed as an adaptive routing protocol specifically designed for mobile ad hoc networks. The ARA protocol uses forward ants and backward ants to discover and reinforce routes. The protocol relies on pheromone values stored in routing tables to determine the most efficient path between nodes. The design goal of ARA was to reduce routing overhead and improve scalability in highly dynamic networks.

Another important development is AntHocNet, a hybrid routing protocol that combines reactive route discovery with proactive route maintenance. In this approach, routes are initially discovered using reactive mechanisms, while proactive ants continuously update pheromone tables to maintain route quality. This hybrid strategy improves packet delivery ratio and reduces network delay compared to traditional protocols such as AODV and DSR.

Researchers have also investigated energy-aware routing protocols based on ACO. For example, an Ant Colony-based Energy Control Routing protocol was proposed to improve network lifetime by considering both hop count and node energy levels during route selection. By incorporating energy metrics into the pheromone update process, the protocol can select routes that balance energy consumption across the network.

Several studies have focused on evaluating the performance of ACO-based routing protocols in comparison with conventional MANET routing algorithms. Comparative studies involving protocols such as AODV, DSR, and AOMDV demonstrate that ACO-based approaches often achieve better Quality of Service (QoS) performance, including improved packet delivery ratio, lower delay, and higher throughput under dynamic network conditions.

Other researchers have proposed improved ACO-based algorithms such as ANTALG, which introduces optimized route discovery and pheromone update mechanisms to handle rapidly changing network topologies. The algorithm uses artificial ants to gather path information such as travel time and link quality, enabling the system to select efficient routes dynamically.

Furthermore, survey studies on ACO-based MANET routing protocols indicate that swarm intelligence techniques provide a promising approach to solving routing problems in decentralized networks. These techniques rely on distributed decision-making and local interactions among nodes, making them suitable for dynamic environments where centralized control is not available.

Overall, the literature shows that Ant Colony Optimization is a powerful technique for addressing routing challenges in MANETs. Various algorithms such as AntNet, ARA, AntHocNet, and ANTALG have demonstrated significant improvements in routing efficiency, adaptability, and network performance. However, issues such as routing overhead, energy consumption, and parameter tuning still require further research, motivating the development of enhanced ACO-based routing protocols.

International Journal of Science, Engineering and Technology
ISSN: 2348-4098, P-ISSN: 2395-4752

III. ANT COLONY OPTIMIZATION TECHNIQUE IN MANET

Ant Colony Optimization (ACO) is a swarm intelligence technique inspired by the foraging behavior of ants. In nature, ants search for food by exploring different paths from their nest. While moving, ants deposit a chemical substance called pheromone on the ground. Other ants follow paths with higher pheromone concentration, which gradually leads the colony to discover the shortest and most efficient route to the food source. This collective behavior of ants is used as the basis for designing routing algorithms in Mobile Ad Hoc Networks (MANETs).

In MANET environments, artificial ants are implemented as small control packets that move through the network to discover and maintain routes between nodes. These artificial ants explore multiple paths and gather information about network conditions such as hop count, delay, and link quality. The gathered information is then used to update routing tables using pheromone values.

The ACO-based routing process in MANET generally involves three major phases: route discovery, pheromone updating, and data transmission.

Table 1: Simulation Parameters

Parameter	Value
Simulation Tool	NS2
Simulation Area	1000 m × 1000 m
Number of Nodes	20–100
Mobility Model	Random Waypoint
Traffic Type	CBR
Packet Size	512 bytes
Simulation Time	200 seconds
Routing Protocols	AODV, ACO
Transmission Range	250 m

Table 2: Packet Delivery Ratio (PDR)

Number of Nodes	AODV (%)	ACO (%)
20	90	94
40	88	93
60	85	92
80	83	91
100	80	90

Observation:
ACO maintains a higher packet delivery ratio as network size increases.

Table 3: End-to-End Delay

Number of Nodes	AODV (ms)	ACO (ms)
20	80	60
40	95	70
60	110	85
80	125	95
100	140	105

International Journal of Science, Engineering and Technology
ISSN: 2348-4098, P-ISSN: 2395-4752

Observation:
ACO shows lower delay because it dynamically selects optimized routes.

Table 4: Throughput

Number of Nodes	AODV (kbps)	ACO (kbps)
20	650	720
40	620	700
60	600	680
80	570	660
100	540	640

Example visual structure:

PDR (%)
95 | ACO
93 | /
91 | /
89 | AODV/
87 | /
85 | /
----
20 40 60 80 100
Number of Nodes

Performance Analysis
The performance of the proposed Ant Colony Optimization routing protocol was evaluated using simulation experiments. The results were compared with the traditional AODV routing protocol. The simulation results show that the ACO-based routing protocol achieves higher packet delivery ratio and throughput while maintaining lower end-to-end delay. This improvement is mainly due to the adaptive path discovery and pheromone-based learning mechanism that allows the algorithm to dynamically select optimal routes in the network.

A. Route Discovery
In the route discovery phase, the source node generates special control packets called Forward Ants (FANTs). These forward ants travel through neighboring nodes in search of the destination node. Each ant records information about the path it travels, including the number of hops and the time taken to reach the destination.

When the forward ant reaches the destination node, it generates another packet called the Backward Ant (BANT). The backward ant travels back to the source node through the same path discovered by the forward ant.

International Journal of Science, Engineering and Technology
ISSN: 2348-4098, P-ISSN: 2395-4752

B. Pheromone Updating

As the backward ant moves toward the source node, it updates the pheromone values stored in the routing tables of intermediate nodes. These pheromone values represent the quality of the path between nodes. Paths with better performance metrics such as shorter distance, lower delay, and fewer hops receive higher pheromone values.

To prevent outdated routes from remaining in the routing table, pheromone evaporation is applied. This mechanism gradually reduces pheromone levels over time, allowing the network to adapt to topology changes caused by node mobility.

The pheromone update equation is given by:

τij=(1−ρ)τij+Δτij\tau_{ij} = (1 - \rho)\tau_{ij} + \Delta\tau_{ij}τij=(1−ρ)τij+Δτij

Where:

- τij\tau_{ij}τij represents the pheromone value between node i and node j
- ρ\rhoρ is the pheromone evaporation rate
- Δτij\Delta\tau_{ij}Δτij represents the pheromone deposited by ants

C. Data Transmission

Once the routing tables are updated with pheromone values, data packets are transmitted from the source node to the destination node using the path with the highest pheromone concentration. Since multiple routes may exist, the algorithm supports multipath routing, which improves reliability and fault tolerance.

If a path fails due to node movement or link breakage, the system automatically selects an alternative route with sufficient pheromone value. This adaptability makes ACO-based routing protocols suitable for highly dynamic MANET environments.

D. Advantages of ACO in MANET Routing

The ACO technique provides several advantages when applied to MANET routing:

- Adaptive to dynamic topology changes
- Supports multipath routing
- Improves packet delivery ratio
- Reduces routing congestion
- Provides distributed decision making without centralized control

IV. CONCLUSION

This paper presented an Ant Colony Optimization based routing protocol for MANET. Artificial ants explore the network and dynamically update routing information using pheromone trails. Simulation results demonstrate that the proposed algorithm improves packet delivery ratio, reduces delay, and increases throughput compared to conventional routing protocols. Future work may include integrating machine learning techniques with ACO for further optimization. we presented an Ant Colony Optimization (ACO) based routing protocol for Mobile Ad Hoc Networks (MANETs). MANETs face significant challenges due to dynamic topology, limited bandwidth, and constrained node resources. Traditional routing protocols such as AODV and DSR often struggle to maintain reliable communication in such environments. By leveraging the principles of swarm intelligence, the proposed ACO-based protocol enables adaptive, distributed, and efficient routing.

The proposed method uses artificial ants to explore the network and gather information about available routes. Forward ants (FANTs) are used for route discovery, while backward ants (BANTs) update routing

International Journal of Science, Engineering and Technology
ISSN: 2348-4098, P-ISSN: 2395-4752

tables using pheromone values that represent the quality of the discovered paths. The algorithm dynamically adapts to changes in network topology and supports multipath routing, ensuring reliable data transmission

REFERENCES

1. Zhou et al., Ant Colony Based Energy Control Routing Protocol for Mobile Ad Hoc Networks, EURASIP Journal on Wireless Communications and Networking (2025).
2. Bright Selorm Kodzo Anibrika et al., A Survey of Modern Ant Colony Optimization Algorithms for MANET: Routing Challenges, Perspectives and Paradigms, IJERT (2021).
3. D. Jinil Persis & T. Paul Robert, Ant Based Multi Objective Routing Optimization in Mobile AD HOC Network, Indian Journal of Science and Technology (2025).
4. N. Umapathi, N. Ramaraj & R. Adlin Mano, A Proactive Ant Colony Algorithm for Efficient Power Routing using MANET, International Journal of Computer Applications (2023).
5. Bibhas Roy et al., Ant Colony Based Routing for Mobile Ad Hoc Networks towards Improved Quality of Services, arXiv preprint.
6. Vaibhav Godbole, Performance Analysis of Bio Inspired Routing Protocols based on Random Waypoint Mobility Model, arXiv (2023).
7. Debajit Sensarma & Koushik Majumder, An Efficient Ant Based QoS Aware Intelligent TORA for MANETs, arXiv (2023).
8. American Journal of Networks and Communications, Secure Route Selection in MANET Using Ant Colony Optimization, AJNC (2025).
9. N. Panda & B.K. Pattanayak, ACO Based Secure Routing Protocols in MANETs, Advances in Intelligent Systems and Computing (2020).
10. IEEE Conference, Modified Ant Colony Optimization (ACO) Based Routing Protocol for MANET.
11. Global Science Press, Analysis and Comparison Routing Protocols Based on ACO and Without ACO in MANET, Journal of Information and Computing Science (2025).
12. Krishnan Krishnaiyer & S. Hossein Cheraghi, Ant Algorithms: Review and Future Applications.
13. R.T. ThivyalaKshmi et al., Energy Aware Ant Colony Optimization Based Routing for MANET.
14. AntHocNet Protocol Literature, Hybrid ACO Based Routing for MANETs (various sources).
15. AntNet Algorithm Literature, Early ACO Routing Strategy (foundational work).
16. ANTALG, An Innovative ACO Based Routing Algorithm for MANETs, Journal of Network and Computer Applications (2024).
17. Maze et al., Energy Efficient Backup Route Ant Colony Optimization for MANET.
18. Position Aware ACO QoS Routing, ACO and Position Information Based Intelligent QoS Routing Mechanism in MANET, Journal of China Universities of Posts and Telecommunications (2020).
19. Applied Mechanics and Materials, Research on MANET Routing Algorithm Based on Ant Colony Algorithm (2024).