

# Wired for Mobility: Investigating Routing Protocols and AI Integration in MANETs

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## Abstract

*Nodes in Mobile Ad Hoc Networks (MANETs), which operate without a fixed infrastructure, communicate wirelessly in a dynamic and demanding environment. In these kinds of situations, routing becomes essential to guaranteeing effective data transfer. The dynamic topology and shifting network conditions of MANETs present challenges for traditional routing protocols. The blending of routing protocols with Artificial Intelligence (AI) techniques has become a viable way to improve MANET performance in recent years. The integration of AI techniques and routing protocols in MANETs is the subject of this research article. We assess different routing protocols and AI-based techniques through a thorough review and analysis, outlining their advantages, disadvantages, and suitability for various MANET scenarios. In addition, we go over the difficulties and potential avenues for future research in this area with the goal of enlightening practitioners and researchers who are interested in enhancing the resilience and effectiveness of MANETs.*

**Keywords:** MANETs, AI, Nodes, Environment, OLSR

## INTRODUCTION

The capacity of Mobile Ad Hoc Networks (MANETs) to establish communication without depending on a fixed infrastructure has garnered a great deal of attention. Traditional routing protocols, however, face difficulties due to the dynamic nature of MANETs, which can result in problems like poor throughput, high overhead, and unstable routes. In order to improve the performance of MANETs, researchers have looked into integrating Artificial Intelligence (AI) techniques with routing protocols. We present an overview of AI integration with routing protocols in MANETs in this article, emphasizing the advantages and disadvantages of this strategy. A key component of MANETs is routing, which creates effective routes for data transfer between source and destination nodes. Proactive, reactive, and hybrid protocols are the three main categories into which traditional routing protocols in MANETs can be divided. High control overhead results from proactive protocols like Optimized Link State Routing (OLSR), which keep all network nodes' routing information current. Ad Hoc On-Demand Distance Vector (AODV) and other reactive protocols create routes on-demand, which lowers control overhead but may cause latency during route discovery. Zone Routing Protocol (ZRP) is one example of a hybrid protocol that combines the benefits of proactive and reactive methods [1].

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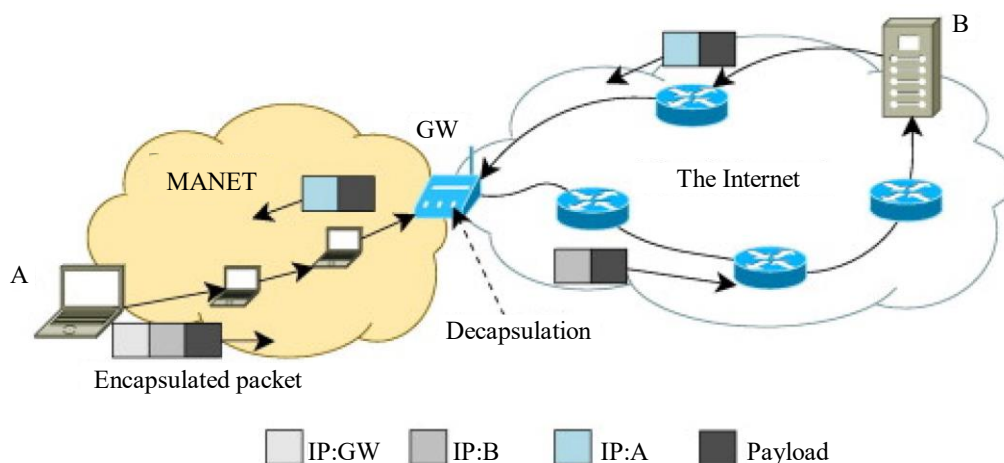
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Traditional routing protocols, although widely used, suffer from a number of problems in MANETs, such as high overhead, unstable routes, scalability problems, and susceptibility to node failures and network partitions. The dynamic nature of MANETs, where nodes may join or leave the network frequently and the network topology can change quickly, makes these difficulties worse. To overcome the drawbacks of conventional methods and improve the efficiency of MANETs, researchers



**Figure 1.** Integrating IP mobility management.

have recently investigated the integration of Artificial Intelligence (AI) techniques with routing protocols. AI techniques have the potential to adaptively optimize routing decisions based on traffic patterns, application requirements, and dynamic network conditions. Examples of these techniques include machine learning algorithms and swarm intelligence-based approaches. The integration of AI techniques and routing protocols in MANETs is the focus of this research article. We assess the efficacy of AI-enhanced routing protocols in enhancing the scalability, efficiency, and robustness of MANETs through a thorough review and analysis [2]. We aim to shed light on the potential advantages and difficulties of this approach by analyzing the design principles, implementation techniques, and performance of AI-integrated routing protocols (Figure 1).

### MANET ROUTING PROTOCOLS

The absence of fixed infrastructure, node mobility, and dynamic topology are the defining characteristics of mobile ad hoc networks, or MANETs. In MANETs, routing protocols are essential for creating effective channels of communication between nodes. Proactive, reactive, and hybrid protocols are the main categories into which these protocols can be divided; each has unique qualities, benefits, and drawbacks.

1. *Routing protocols that are proactive:* Table-driven protocols, commonly referred to as proactive routing protocols, update all network nodes' routing tables on a regular basis to ensure consistent routing information. By taking this proactive measure, routes are guaranteed to be available when needed, which lowers data transmission latency. But constant routing information sharing raises control overhead, so it might not be appropriate for MANETs with a lot of dynamic traffic. The Optimized Link State Routing (OLSR) protocol is one of the most well-known proactive routing protocols for MANETs. OLSR employs a proactive strategy to preserve links and routes throughout the network by routinely exchanging topology data with nearby nodes. To reduce routing overhead and boost route discovery efficiency, OLSR keeps a consistent perspective of the network topology.
2. *Protocols for reactive routing:* When a source node needs to communicate with a destination node, reactive routing protocols—also known as on-demand protocols—create routes only then. This reactive strategy aids in lowering control overhead and adjusting to the dynamic MANET topology. Reactive protocols, however, might take longer than proactive protocols to find a route, particularly in large-scale networks or situations with high mobility. The Ad Hoc On-Demand Distance Vector (AODV) protocol is one of the most popular reactive routing protocols. When a node needs a route to a destination, AODV starts the route discovery process. Up until a route to the destination is found, control packets are broadcast to find nearby nodes during the route discovery process. Routes are kept active by AODV, which invalidates them when they stop being used [3].



**Figure 2.** Ad-Hoc connection attack.

3. *Routing protocols hybrid:* The Zone Routing Protocol (ZRP) is an illustration of a hybrid routing protocol. To effectively maintain local routing information, ZRP partitions the network into zones and uses proactive routing within each zone. Reactive route discovery is the method ZRP uses to create routes across zones when a route is unavailable within the local zone. ZRP seeks to minimize overhead and achieve efficient routing in MANETs by combining proactive and reactive strategies. To maximize each strategy's advantages, hybrid routing protocols incorporate components of both proactive and reactive strategies. The goal of these protocols is to minimize control overhead while maintaining current routing information. The network is frequently divided into zones or clusters by hybrid protocols, and depending on the properties of each zone, various routing strategies may be used.

Communication is made possible in dynamic and mobile environments thanks in large part to MANETs. While proactive protocols like OLSR may have more overhead, they maintain current routing data. On-demand route establishment is a feature of reactive protocols like AODV, which lower overhead but may cause latency [4]. ZRP and other hybrid protocols seek to combine the benefits of both strategies. The size of the network, the mobility patterns, and the needs of the applications all influence the routing protocol selection (Figure 2).

## COMPARATIVE ANALYSIS

This section compares and assesses the effectiveness of AI-integrated and conventional routing protocols in Mobile Ad Hoc Networks (MANETs). The goal is to evaluate their performance across a range of scenarios and network conditions in terms of important metrics like packet delivery ratio, end-to-end delay, routing overhead, and network throughput. Our goal is to offer an understanding of the advantages, disadvantages, and appropriateness of various routing strategies for various MANET implementations by contrasting their performance [5].

1. *Packet delivery ratio (PDR)*: PDR calculates the proportion of all generated packets that are successfully delivered to their destinations. Improved network efficiency and dependability are indicated by higher PDR.
  - i. *Conventional protocols*: Because proactive protocols, such as OLSR, guarantee the availability of current routing information, they usually maintain higher PDR. But there could be more control overhead because of this.
  - ii. *AI-integrated protocols*: By choosing more dependable routes, AI techniques can adaptively optimize routing decisions based on changing network conditions, potentially increasing packet loss rate (PDR). Machine learning algorithms are able to learn from the past to improve their routing decisions.
2. *End-to-end delay*: The duration of a packet's network journey from its source to its destination is referred to as the end-to-end delay. To reduce latency, a lower end-to-end delay is preferable, particularly for real-time applications.
  - i. *Conventional protocols*: Because they rely on on-demand route discovery, reactive protocols such as AODV typically have lower end-to-end delays for route establishment. On the other hand, in highly dynamic networks, if route discovery is triggered frequently, the delay might grow.
  - ii. *AI-integrated protocols*: By choosing paths with less congestion or shorter transmission delays, AI techniques can optimize routing decisions to minimize end-to-end delay. Ant colony optimization is one example of a swarm intelligence-based method that can find effective routes with the least amount of delay [6].
3. *Routing overhead*: The quantity of control traffic produced by routing protocols for the sharing of routing data is referred to as routing overhead. To preserve network resources and reduce bandwidth usage, lower routing overhead is preferred.
  - i. *Conventional protocols*: Because proactive protocols, such as OLSR, periodically exchange routing information among nodes, they usually result in higher routing overhead. The size and density of the network may cause this overhead to rise.
  - ii. *AI-integrated protocols*: By optimizing routing decisions based on localized information instead of global routing tables, AI techniques can minimize routing overhead. It is possible for machine learning algorithms to anticipate the best routes ahead of time without requiring regular routing information exchange [7].
4. *Network throughput*: The rate at which data is successfully transferred over a network is measured by network throughput. Improved data transfer efficiency and better use of network resources are indicated by higher throughput.
  - i. *Conventional protocols*: By preserving stable routes and reducing route discovery delays, proactive protocols can increase network throughput. But there's a chance that this will result in higher routing overhead.
  - ii. *AI-integrated protocols*: In response to shifting network conditions, AI techniques can dynamically adjust routing decisions to maximize network throughput. Swarm intelligence-based methods can increase throughput by taking advantage of node cooperation and parallelism.

The comparison analysis draws attention to the trade-offs that traditional and AI-integrated routing protocols in MANETs have. In dynamic and unpredictable environments, artificial intelligence (AI) techniques can offer efficiency and adaptability, while traditional protocols might offer stability and reliability. The requirements of the application, the size of the network, mobility patterns, and resource limitations all influence the routing strategy selection. To verify the effectiveness of AI-integrated routing protocols in various MANET scenarios and to determine the best configurations for deployment scenarios, more research and simulation studies are required [8].

## CHALLENGES AND FUTURE DIRECTIONS

While it creates new opportunities for research and development, the integration of Artificial Intelligence (AI) techniques with routing protocols in Mobile Ad Hoc Networks (MANETs) also poses a few challenges. This section outlines the main obstacles that AI-integrated routing protocols in MANETs must overcome and suggests possible future paths to solve these obstacles and further the field [9].

1. *Scalability*: Scalability is one of the main issues AI-integrated routing protocols in MANETs face. The computational and communication overhead associated with AI techniques may become unaffordable as network size and density increase. The main goal of future research should be to create scalable AI algorithms and optimization strategies that can manage large-scale MANETs effectively without compromising performance.
2. *Energy efficiency*: Since most MANET nodes are powered by small-capacity batteries, energy efficiency is essential. By optimizing routing choices and taking individual node energy constraints into account, AI-integrated routing protocols should strive to reduce energy consumption. Novel AI methods and strategies for energy-aware routing in MANETs, such as reinforcement learning-based methods that adaptively modify routing parameters to save energy, could be the subject of future research.
3. *Security and privacy*: MANETs are susceptible to denial-of-service attacks, eavesdropping, and node impersonation, among other security risks. Routing protocols that incorporate AI may create new security holes and privacy issues, such as hostile attacks against AI systems or illegal access to private routing data. Subsequent investigations ought to concentrate on augmenting the security and confidentiality of AI-incorporated routing protocols via methods like anomaly identification, cryptographic procedures, and safe AI model development.
4. *Adaptability to changing environments*: The dynamic topology, node mobility, and fluctuating network conditions of MANETs are their defining features. To ensure effective communication, AI-integrated routing protocols should be able to quickly adjust to these changing environments. Subsequent investigations may delve into approaches based on reinforcement learning, which facilitate nodes in perpetually acquiring and modifying their routing tactics through immediate input from the surroundings.
5. *Cognitive MANETs*: In the long run, the idea of cognitive MANETs—nodes with the capacity for learning, reasoning, and decision-making—has a great deal of promise to advance the field of AI-integrated routing protocols. Subsequent studies may examine cognitive architectures and algorithms that facilitate autonomous behavior adaptation and optimization by MANET nodes in accordance with overarching goals and objectives [10].

To fully realize the potential of AI-integrated routing protocols in Mobile Ad Hoc Networks, it will be imperative to address the challenges and investigate future directions mentioned above. We can improve the dependability, efficiency, and resilience of MANETs in a variety of application scenarios, from emergency response and disaster recovery to IoT deployments and military operations, by creating scalable, energy-efficient, secure, and adaptive routing solutions.

## CONCLUSION

A viable path toward enhancing the dependability, effectiveness, and resilience of wireless communication in dynamic and unpredictable environments is the integration of AI techniques with routing protocols in MANETs. AI-integrated routing protocols have the potential to open new avenues for research and development in MANETs, enabling a variety of scenarios from military operations and IoT deployments to emergency response and disaster recovery.

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