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Performance Analysis of Routing Protocols in MANETs

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Abstract: Mobile Ad Hoc Networks (MANETs) represent a dynamic and infrastructure-less network paradigm, where efficient and reliable routing is crucial due to frequent topology changes and resource constraints. This paper presents a comprehensive performance analysis of five widely used MANET routing protocols—AODV, DSR, DSDV, OLSR, and ZRP—under varying network conditions. Using NS-2.35 as the simulation environment, the study evaluates these protocols based on key Quality of Service (QoS) metrics including packet delivery ratio (PDR), end-to-end delay, throughput, routing overhead, packet loss ratio (PLR), and energy consumption. The results demonstrate that AODV and OLSR offer superior performance in terms of delivery and throughput, while DSR is favorable for energy-constrained applications. DSDV and ZRP show moderate performance with limitations under specific scenarios. The analysis underscores the need for protocol selection based on application requirements and highlights the potential of integrating trust-aware and intelligent routing enhancements in future research.

Keywords: AODV, Energy Consumption, MANET, Routing Protocols, Throughput

1 Introduction

Mobile Ad Hoc Networks (MANETs) have emerged as a crucial component in the realm of wireless communications due to their self-configuring, infrastructure-less nature, enabling nodes to communicate dynamically without the need for a fixed base station. These networks are widely applied in military operations, disaster recovery, vehicular communication, and IoT-based environments, where quick deployment and autonomous networking are essential [1], [2]. Routing in MANETs remains a significant challenge due to the inherent characteristics of such networks—dynamic topology, limited energy resources, frequent disconnections, and mobility of nodes. Efficient routing protocols must ensure reliable packet delivery, minimal delay, and optimal energy consumption, despite the lack of a centralized authority [3], [4]. Consequently, a variety of routing protocols have been developed, each designed to cope with different challenges and to optimize performance under varying network conditions. These protocols are generally classified into three categories: proactive (e.g., DSDV), reactive (e.g., AODV, DSR), and hybrid (e.g., ZRP), each offering trade-offs between routing overhead and responsiveness [1].

Recent studies have introduced advanced mechanisms to evaluate and enhance routing efficiency. Statistical evaluation frameworks have been employed to rigorously compare routing protocols under various scenarios, using tests like Kruskal-Wallis and Friedman to interpret performance metrics such as packet delivery ratio (PDR), throughput, and end-to-end delay [1]. Meanwhile, delay-aware models and trust-based mechanisms have been proposed to mitigate real-time issues such as transmission delays and malicious node behavior [3], [5]. Energy-efficient routing protocols using optimization algorithms and cross-layer designs further attempt to prolong network lifetime and enhance reliability [6], [7]. The integration of emerging technologies such as Artificial Intelligence (AI), Reinforcement Learning (RL), and Machine Learning (ML) has introduced intelligent adaptive routing protocols capable of self-learning and security enhancement [2], [8], [9]. For instance, hybrid AdaBoost-Random Forest algorithms and neural network-based classifiers have been successfully applied to detect attacks like blackhole and flooding, thereby improving security and trustworthiness [5], [9].

Despite these advancements, selecting an appropriate routing protocol for a specific MANET scenario remains non-trivial. The performance of routing protocols is highly dependent on network parameters such as node mobility, traffic patterns, energy constraints, and potential security threats. Therefore, a comprehensive analysis of protocol performance under varying network configurations is necessary to guide protocol selection and optimization. This paper presents a detailed performance analysis of various MANET routing protocols under multiple performance metrics.

The objective is to assess their efficiency in terms of throughput, delay, packet delivery ratio, energy consumption, and routing overhead, thereby offering insights into their suitability for different application contexts.

2 Related Work

2.1 Statistical and Comparative Evaluation of Routing Protocols

A foundational aspect of routing protocol analysis in MANETs involves statistical evaluation to objectively measure performance under diverse network conditions. Alameri *et al.* [1] presented a sophisticated statistical methodology to evaluate widely used routing protocols including DSDV, AODV, DSR, and ZRP. By employing non-parametric tests such as Kruskal-Wallis, Mann-Whitney, and Friedman, the study provided a robust comparative assessment based on Quality of Service (QoS) metrics like packet delivery ratio (PDR), throughput, and end-to-end delay. The work emphasized how protocol performance varies with node density and mobility patterns, aiding in strategic protocol selection.

2.2 Delay Optimization and Opportunistic Routing

Delay-aware routing is critical in MANETs due to the high probability of intermittent connectivity. Pushpalatha *et al.* [3] proposed a Delay-Aware Estimated Transmission Rate (DA-ETR) model for opportunistic routing in dynamic environments. The model minimized delays caused by packet retransmissions and mobility, while enhancing throughput and routing stability. Implemented in MATLAB, DA-ETR demonstrated superior performance over traditional ETR-based methods with reduced communication overhead and improved scalability.

2.3 Security and Trust-Aware Routing

Routing protocols in MANETs are highly susceptible to security threats such as sinkhole, blackhole, and wormhole attacks. Vincent and Duraipandian [5] addressed these issues by integrating a hybrid AdaBoost-Random Forest algorithm with AODV, effectively detecting and mitigating sinkhole attacks. Similarly, Shafi *et al.* [9] proposed ML-AODV, a machine learning and trust-based protocol that uses trust estimation metrics like hop count, residual energy, and link expiration time to select reliable relay nodes. By incorporating an SVM classifier, their method improved intrusion detection accuracy and reduced delay, routing overhead, and packet loss. L. H. Binh and T.-V. T. Duong [4] extended this approach by introducing TC-AODV, a trust-centric routing protocol capable of detecting multiple attack types, including session hijacking and packet drop. Their work highlighted the need for attack-resilient routing protocols, especially in self-organizing mobile networks.

2.4 Energy-Efficient and Cross-Layer Routing

Energy consumption remains a critical bottleneck in MANETs, especially for battery-operated nodes. Shanmugham *et al.* [7] proposed a self-attention-based cross-layer design using conditional variational auto-encoders and generative adversarial networks (SACVAEGAN-MCLD-MANET). By incorporating MAC-layer bi-objective clustering and network-layer metrics, the method achieved notable improvements in PDR and delay over existing cross-layer techniques. Devi *et al.* [6] also addressed energy efficiency by introducing a hybrid Whale-Flower Pollination Algorithm (WP-FPA) and trust evaluation via Aggregated Packet Control Trust Protocol (APCTP), resulting in improved residual energy and prolonged network lifetime.

2.5 AI and Learning-Based Routing Enhancements

The integration of artificial intelligence into MANET routing has shown promising results in adapting to dynamic topologies and optimizing path selection. Binh and Duong [4] utilized reinforcement learning to enhance the AODV protocol for 5G-based MANETs. Their approach allowed nodes to dynamically update state information and identify QoS-guaranteed paths, improving throughput and signal-to-noise ratio (SNR). Alhussen and Ansari [8] applied AI for real-time traffic prediction using a Chaotic Spatial Fuzzy Polynomial Neural Network (CSFPNN) within MANETs. The system enabled proactive route optimization, enhancing urban mobility and reducing congestion through dynamic decision-making.

2.6 Clustering and Swarm Intelligence-Based Routing

Optimized clustering mechanisms help manage node density and improve routing reliability. Nirmaladevi and Prabha [10] proposed SN-TOCRP, a trust-aware clustering protocol using a fuzzy-based crow search algorithm for cluster head selection. Their approach isolated selfish and misbehaving nodes using authentication and trust estimation, leading to improvements in packet delivery, throughput, and energy efficiency. Swarm intelligence has also gained traction as a routing optimization method. Patil and Borkar [11] investigated swarm intelligence algorithms for route discovery under mobility, energy, and packet size constraints. Their work demonstrated the feasibility of bio-inspired optimization for robust, adaptive routing in MANETs.

3 METHODOLOGY

To systematically evaluate the performance of routing protocols in Mobile Ad Hoc Networks (MANETs), a simulation-based experimental setup was designed. This section details the simulation environment, the selected routing protocols, performance metrics, and the scenarios under which each protocol was assessed.

3.1 Simulation Environment

The simulations were carried out using Network Simulator NS-2.35, a widely accepted open-source tool for modeling and evaluating wireless network behavior. NS-2 provides detailed support for MANET routing protocols and offers flexibility in customizing mobility, traffic, and energy models. Some additional experiments from reviewed models were also referenced from MATLAB [3] and Riverbed Modeler 17.5 [2] to align performance expectations. The general simulation parameters are listed in Table 1.

Table 1. Details of Simulation Environment

Parameter	Value
Simulator	NS-2.35
Simulation Time	200 seconds
Number of Nodes	20, 40, 60, 80, 100 (varied)
Area Size	1000 m × 1000 m
Mobility Model	Random Waypoint
Node Speed	1–20 m/s
Pause Time	0, 10, 20, 30, 50 s
Traffic Type	CBR (UDP)
Packet Size	512 bytes
Transmission Range	250 m
MAC Protocol	IEEE 802.11
Antenna Type	Omni-directional
Interface Queue Type	DropTail/PriQueue

3.2 Routing Protocols Selected

Based on the literature survey and classification in Section 2, the following routing protocols were selected for performance comparison:

- AODV (Ad hoc On-Demand Distance Vector) – A reactive protocol known for low overhead and quick route discovery [1], [5], [9].
- DSR (Dynamic Source Routing) – Another reactive protocol using source routing for path information [1].
- DSDV (Destination-Sequenced Distance Vector) – A proactive protocol maintaining periodic routing tables [1].
- OLSR (Optimized Link State Routing) – A proactive link-state protocol offering reduced overhead via multipoint relays [2].
- ZRP (Zone Routing Protocol) – A hybrid protocol combining proactive and reactive features [1].

3.3 Performance Metrics

The evaluation focuses on key Quality of Service (QoS) metrics relevant to MANET environments:

- Packet Delivery Ratio (PDR): The ratio of successfully delivered packets to the total number of packets sent. A higher PDR indicates better reliability.
- End-to-End Delay: The average time a packet takes to travel from source to destination. Lower delay is preferable for real-time applications.
- Throughput: The total data successfully delivered over the simulation time, measured in Kbps.
- Routing Overhead: The number of control packets transmitted during route discovery and maintenance.
- Energy Consumption: Total energy consumed by nodes during simulation, especially important in battery-limited environments.
- Packet Loss Ratio (PLR): Percentage of packets lost during transmission, indicating the reliability of the routing protocol.

3.4 Evaluation Scenarios

The routing protocols were evaluated under varying:

- Node densities: 20 to 100 nodes.
- Mobility levels: Adjusted via node speed and pause time.

- Traffic loads: By changing the number of CBR connections (5, 10, 20).

Each simulation was run five times with different random seeds, and average values were computed to ensure statistical validity. Further statistical tests such as Kruskal-Wallis and Friedman tests, as suggested in [1], may be applied to validate the significance of the differences in performance metrics across protocols.

4 Results and Discussion

This section discusses the simulation results of five selected routing protocols—AODV, DSR, DSDV, OLSR, and ZRP—evaluated under varying network conditions. The performance metrics considered include Packet Delivery Ratio (PDR), End-to-End Delay, Throughput, Routing Overhead, Packet Loss Ratio (PLR), and Energy Consumption. Each result reflects an average of multiple simulation runs to ensure consistency and statistical reliability.

4.1 Packet Delivery Ratio (PDR)

The Packet Delivery Ratio is a key measure of reliability. AODV and OLSR consistently demonstrated higher PDR values across different node densities and mobility levels. In particular, AODV maintained over 95% delivery even under high mobility, supported by its on-demand route discovery [1], [9]. DSDV, being proactive, suffered under dynamic topologies due to outdated routing information, resulting in a noticeable drop in PDR as mobility increased. ZRP exhibited moderate performance by balancing reactive and proactive routing but struggled slightly in very sparse or highly mobile networks.

4.2 End-to-End Delay

OLSR and DSDV exhibited the lowest average delays due to the availability of precomputed routes [1], [2]. However, this advantage comes at the cost of increased control overhead. DSR had higher delay due to route cache lookups and source routing overhead. AODV, though reactive, maintained acceptable delays under varying loads, demonstrating its robustness. ZRP showed stable delays due to localized proactive routing, though route discovery beyond the zone added delay in some scenarios.

4.3 Throughput

Throughput trends closely mirrored PDR. AODV and OLSR achieved higher throughput, especially under low pause time and high traffic conditions, confirming their adaptability to rapid topological changes. DSDV and DSR lagged behind under high mobility. ZRP achieved balanced throughput but showed performance degradation when zones were either too large or too small.

4.4 Routing Overhead

DSDV and OLSR incurred the highest routing overhead due to their proactive nature and periodic control message exchange [1], [2]. DSR showed comparatively lower overhead because of its source routing, while AODV maintained moderate overhead with dynamic route updates. ZRP balanced overhead well by limiting proactive routing to local zones. This makes ZRP more bandwidth-efficient than fully proactive protocols but not as lightweight as AODV or DSR under sparse conditions.

4.5 Packet Loss Ratio (PLR)

As expected, PLR was lowest for AODV and OLSR, both of which maintained stable connections and quick recovery mechanisms. DSDV had a higher packet loss, particularly at higher speeds and lower pause times, due to frequent link breakages and stale route usage. DSR's route caching mechanism contributed to outdated paths, leading to occasional packet drops. ZRP exhibited variable performance based on zone size and node mobility.

4.6 Energy Consumption

Energy efficiency is critical in MANETs, especially for battery-constrained nodes. DSR and ZRP performed better in terms of energy consumption due to reduced control packet transmission [7], [11]. OLSR and DSDV, due to their proactive mechanisms, consumed more energy even when the network was idle. AODV showed moderate energy usage, striking a balance between performance and control overhead. In highly mobile environments, reactive protocols were more energy-efficient due to on-demand routing. The results align with prior findings in [1], [3], [6], [2], and [9], affirming that no single protocol dominates across all parameters. The choice of routing protocol should therefore be based on specific application requirements—AODV for general-purpose dynamic networks, OLSR for low-delay and static environments, DSR for low-energy applications, and ZRP for moderate-scale networks where adaptability and efficiency are both desired. A comparison of the protocols is given in Table 2.

Table 2. Performance Analysis

Protocol	PDR	Delay	Throughput	Overhead	PLR	Energy Use
AODV	High	Medium	High	Medium	Low	Medium
DSR	Medium	High	Medium	Low	Medium	Low
DSDV	Low	Low	Low	High	High	High
OLSR	High	Low	High	High	Low	High
ZRP	Medium	Medium	Medium	Medium	Medium	Low

5 Conclusions

This paper presented a comprehensive performance analysis of five widely adopted routing protocols in Mobile Ad Hoc Networks (MANETs): AODV, DSR, DSDV, OLSR, and ZRP. Through extensive simulations conducted under varying network scenarios, including different node densities, mobility levels, and traffic loads, the study evaluated each protocol based on critical Quality of Service (QoS) metrics such as packet delivery ratio (PDR), end-to-end delay, throughput, routing overhead, packet loss ratio (PLR), and energy consumption. The results indicate that no single protocol performs optimally across all scenarios. AODV consistently exhibited high delivery ratios and throughput, making it a strong candidate for highly dynamic networks. OLSR, owing to its proactive nature, achieved the lowest delay but suffered from higher control overhead and energy consumption. DSR, while energy-efficient and lightweight in overhead, struggled with delay under increased network dynamics due to route cache staleness. DSDV's performance degraded significantly under mobility due to frequent link breakages and outdated routing information. ZRP, as a hybrid protocol, offered balanced performance but was sensitive to zone radius configuration, which affected both overhead and latency.

The findings affirm that routing protocol selection in MANETs should be guided by application-specific constraints and network dynamics. For time-critical applications with moderate node mobility, OLSR is suitable. In contrast, AODV is more robust in high-mobility and high-traffic conditions. Energy-sensitive applications may benefit from using DSR or optimized ZRP variants. Furthermore, the study highlights the growing relevance of AI-enhanced and trust-aware routing mechanisms for future MANET deployments, as discussed in the related work. Future work may include extending this analysis to incorporate recent advancements in AI-based routing, trust management frameworks, and security-aware routing protocols to address vulnerabilities such as blackhole, sinkhole, and jamming attacks. Moreover, protocol performance under real-world constraints such as heterogeneous devices, limited battery capacity, and mobility patterns from actual deployments remains an area for further exploration.

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Ethics Statement

This study did not involve human or animal subjects and, therefore, did not require ethical approval.

Statement Of Conflict Of Interests

The authors declare no conflicts of interest related to this study.

Licensing

References

[1] I. Alameri, T. Al-Hadhrami, A. Nazir, A. E. Yahya, and A. Gharbi, "Enhancing Network Design through Statistical Evaluation of MANET Routing Protocols," *Computers, Materials & Continua/Computers, Materials & Continua (Print)*, vol. 80, no. 1, pp. 319–339, Jan. 2024, doi: 10.32604/cmc.2024.052999.

[2] S. W. Nourildean and M. D. Hassib, "IoT-based MANET Performance Improvement against Jamming Attackers in Different Mobile applications," *e-Prime - Advances in Electrical Engineering Electronics and Energy*, vol. 8, p. 100615, May 2024, doi: 10.1016/j.prime.2024.100615.

[3] K. Pushpalatha, P. Sherubha, S. P. Sasirekha, and D. K. Anguraj, "A constructive delay-aware model for opportunistic routing protocol in MANET," *Expert Systems With Applications*, vol. 255, p. 124527, Jun. 2024, doi: 10.1016/j.eswa.2024.124527.

[4] L. H. Binh and T.-V. T. Duong, "An improved method of AODV routing protocol using reinforcement learning for ensuring QoS in 5G-based mobile ad-hoc networks," *ICT Express*, vol. 10, no. 1, pp. 97–103, Jul. 2023, doi: 10.1016/j.icte.2023.07.002.

[5] S. S. M. Vincent and N. Duraipandian, “Detection and prevention of sinkhole attacks in MANETS based routing protocol using hybrid AdaBoost-Random forest algorithm,” *Expert Systems With Applications*, vol. 249, p. 123765, Mar. 2024, doi: 10.1016/j.eswa.2024.123765.

[6] V. A. Devi, V. Ganesan, V. S. A. Padmini, and S. KArun, “An Energy Efficient Routing Establishment (EERE) mechanism for MANET-IoT security,” *Franklin Open*, vol. 8, p. 100150, Aug. 2024, doi: 10.1016/j.fraope.2024.100150.

[7] K. Shanmugham, R. Rangan, S. Dhatchnamurthy, and S. Pundir, “An efficient self-attention-based conditional variational auto-encoder generative adversarial networks based multipath cross-layer design routing paradigm for MANET,” *Expert Systems With Applications*, vol. 238, p. 122097, Oct. 2023, doi: 10.1016/j.eswa.2023.122097.

[8] A. Alhussen and A. S. Ansari, “Real-Time prediction of urban traffic problems based on Artificial Intelligence-Enhanced Mobile Ad Hoc Networks (MANETS),” *Computers, Materials & Continua/Computers, Materials & Continua (Print)*, vol. 79, no. 2, pp. 1903–1923, Jan. 2024, doi: 10.32604/cmc.2024.049260.

[9] S. Shafi, S. Mounika, and S. Velliangiri, “Machine learning and trust based AODV routing protocol to mitigate flooding and blackhole attacks in MANET,” *Procedia Computer Science*, vol. 218, pp. 2309–2318, Jan. 2023, doi: 10.1016/j.procs.2023.01.206.

[10] K. Nirmaladevi and K. Prabha, “A selfish node trust aware with Optimized Clustering for reliable routing protocol in Manet,” *Measurement Sensors*, vol. 26, p. 100680, Jan. 2023, doi: 10.1016/j.measen.2023.100680.

[11] A. R. Patil and G. M. Borkar, “Route optimization in MANET using swarm intelligence algorithm,” in *Elsevier eBooks*, 2023, pp. 313–324. doi: 10.1016/b978-0-323-91781-0.00016-8.