Adaptive enhancements to AODV and DSDV for post-disaster networks

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Abstract: In post-disaster scenarios, the failure of conventional communication infrastructure often necessitates the deployment of Mobile Ad Hoc Networks (MANETs) for emergency communication. However, traditional MANET routing protocols such as Ad hoc On-Demand Distance Vector (AODV) and Destination-Sequenced Distance Vector (DSDV) have well-documented performance limitations in highly dynamic environments, leading to frequent link failures, increased end-to-end delay, and excessive energy consumption. To address these challenges, this study introduces adaptive enhancements to AODV and DSDV by incorporating link stability-based route selection and energy-aware routing mechanisms. These modifications are designed to improve reliability by dynamically optimizing routing decisions based on real-time network conditions. The performance of the proposed enhancements was evaluated through extensive NS-3 simulations in a post-disaster network scenario. Simulation results demonstrate that the enhanced AODV and DSDV protocols outperform their standard counterparts, achieving a packet delivery ratio (PDR) improvement of 17%–19%, a 30%–35% reduction in end-to-end delay, and a 40%–50% increase in network lifetime. These improvements underscore the viability of the proposed approach in providing resilient, energy-efficient communication for emergency response teams and first responders. Furthermore, the study explores the potential integration of advanced technologies, such as artificial intelligence (AI)-based predictive routing and blockchain-enabled secure communication, to further enhance MANET capabilities. Future research directions include developing hybrid routing protocols that can dynamically switch between proactive and reactive strategies, and implementing lightweight consensus mechanisms for secure and decentralized MANET operation. These findings contribute to the advancement of robust and efficient MANET architectures, addressing critical challenges in post-disaster recovery efforts.

Keywords: Mobile Ad Hoc Networks (MANETs), Ad hoc On-Demand Distance Vector (AODV), Destination-Sequenced Distance Vector (DSDV), Energy-Aware Routing, Resilient Networks, NS-3 Simulation.

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1 Introduction

In disaster-stricken regions, conventional fixed communication infrastructures such as cellular networks, telephone lines, and internet backbones often become severely damaged or completely inoperable. This infrastructure failure critically impedes emergency response activities by disrupting information flow among first responders, rescue teams, and affected populations. As a resilient alternative, Mobile Ad Hoc Networks (MANETs) have emerged

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as a powerful communication paradigm capable of providing rapid, infrastructure-less wireless connectivity in such challenging environments. MANETs consist of autonomous mobile nodes that self-organize into a wireless multi-hop network without relying on centralized control or existing infrastructure, making them well-suited for deployment in disaster recovery and emergency scenarios (Al-kahtani et al., 2020; Nizamuddin et al., 2024).

Traditional MANET routing protocols, notably Ad hoc On-Demand Distance Vector (AODV) and Destination-Sequenced Distance Vector (DSDV), have been long deployed in various mobile environments [(Lakshmi et al., 2024). Despite their adaptability, these protocols experience significant challenges in post-disaster contexts characterized by high node mobility, erratic network topology changes, limited node energy, and unpredictable wireless links (Pathan et al., 2019). Although these protocols have proven adaptable in various contexts, their performance deteriorates significantly in highly mobile and energy-constrained post-disaster scenarios, suffering from frequent route failures, substantial end-to-end delay, and disproportionate energy consumption due to persistent route discovery and maintenance overheads (Bai et al., 2024; Benatia et al., 2021). Recent research efforts reflect a growing consensus that traditional MANET routing protocols require fundamental enhancements to meet the stringent demands of post-disaster communications. One promising direction is the incorporation of energy-aware routing mechanisms, wherein routing decisions consider residual battery levels of nodes to balance the energy load and prolong network lifetime (Tarus et al., 2023). Concurrently, link stability has surfaced as another key metric in enhancing routing reliability. Traditional hop-count based route selections often lead to unstable paths prone to frequent breakages. Alsaeedi et al. (2023) demonstrated that incorporating link stability metrics alongside node mobility predictions can significantly reduce route failures and improve network efficiency through hybrid optimization methods. These approaches facilitate the selection of longer-lasting routes, decreasing the need for frequent rediscoveries which otherwise increase delay and energy use.

Artificial intelligence (AI) and machine learning (ML) techniques are increasingly being integrated into MANET routing to further optimize dynamic and uncertain network environments. Deep reinforcement learning has been applied to predict network conditions and autonomously adapt routing decisions, thereby addressing challenges of node mobility and varying traffic loads (Bai et al., 2024; Baumgartner et al., 2024). Although highly promising, these intelligent routing solutions often introduce computational complexity and scalability issues, particularly significant in resource-limited disaster scenarios.

Despite these considerable advancements, there remains a gap in developing an integrated MANET routing solution that simultaneously addresses energy efficiency, link stability, adaptive intelligence, and security within the confines of post-disaster constraints. Most existing works focus on optimizing one or two aspects, often overlooking the interplay between energy consumption and route stability or the practical limitations of embedding AI and blockchain in constrained mobile nodes. Advanced routing strategies integrating link stability estimation, adaptive energy-aware mechanisms, and lightweight security frameworks are in nascent stages and often suffer from high overhead or scalability issues. Consequently, there is an urgent need for integrated, adaptive routing protocols designed specifically to mitigate these challenges by dynamically optimizing routing decisions in real time, balancing network reliability, energy efficiency, and security, thus enabling sustained and robust communication for emergency responders and affected populations in post-disaster environments.

2 Literature review

Mobile Ad Hoc Networks (MANETs) serve as a cornerstone for emergency communication after disasters sever conventional infrastructure. The effectiveness of MANETs depends heavily on the performance of routing protocols which must handle dynamic topologies, resource constraints, and security threats. Despite their utility, traditional protocols like AODV and DSDV face significant challenges in dynamic, resource-constrained environments, manifesting as frequent link failures, increased latency, and suboptimal energy use (Al-kahtani et al., 2020).

Energy efficiency remains a critical design criterion to prolong network lifetime in MANETs. Recent studies focus on adaptive routing mechanisms that balance energy consumption across nodes. Alotaibi and Assiri (2010) proposed an energy-efficient multipath routing protocol incorporating a robust transmission mechanism (FF-AOMDV) to improve connectivity and reduce packet loss, demonstrating extended network lifetimes and improved QoS under mobility and congestion conditions. Similarly, Nizamuddin et al. (2024) introduced an optimized packet loss routing scheme that dynamically adjusts path selection based on residual energy levels and link quality, leading to lower energy consumption and enhanced network stability. These approaches align with your work's emphasis on energy-aware mechanisms but may lack integration with real-time link stability estimation.

The dynamic nature of MANETs calls for routing protocols that predict and adapt to link failures. Alsaeedi et al. (2023) applied a hybrid extended particle swarm optimization (EPSO) model to improve routing by optimizing node mobility and identifying stable routes, emphasizing reliability in varying network densities. Your method's incorporation of real-time link stability metrics concurs with this focus but advances it further by fusing with classical AODV and DSDV protocols for wider applicability.

The application of artificial intelligence (AI) and machine learning (ML) to MANET routing has amplified the adaptability and intelligence of routing decisions (Baumgartner et al., 2024), Bai et al. (2024) demonstrated the use of deep reinforcement learning to achieve a MANET routing method that mitigates route failures and dynamically optimizes paths, offering significant improvements in packet delivery ratio and network lifetime. While powerful, such AI-based techniques often face scalability and resource usage challenges that your proposed approach mitigates by combining adaptive but computationally tractable enhancements to established protocols.

Security in MANETs is a growing concern given the susceptibility to attacks such as black hole and gray hole. Recent work by Pathan et al. (2019) presented an efficient scheme to detect and prevent black hole attacks in AODV-based MANETs using modified routing request packets, improving detection accuracy while limiting overhead. Other works examine blockchain-based decentralized authentication frameworks to securely validate routes, reducing trust-related vulnerabilities (Teotia, 2025). However, these solutions sometimes impose high computational burden on mobile nodes. Emerging intelligent routing models using bio-inspired algorithms and symbiotic search optimization (SOS) have shown potential in balancing efficiency and reliability. Tabatabaei (2023) proposed an SOS-based intelligent routing scheme which significantly enhances route discovery and robustness in MANETs. Efforts like these complement traditional methods and highlight hybridization as a promising path forward, which your method embodies by combining classic protocols with advanced link stability and energy-awareness.

Despite significant progress in routing protocol development, MANETs still face critical challenges in dynamic and resource-constrained environments like post-disaster scenarios. Existing protocols, including enhancements in energy-aware and link stability mechanisms, often struggle to maintain high packet delivery ratios and low latency under rapid topology changes. The trade-off between energy efficiency and increased computational or signaling overhead remains unresolved, with many energy-aware methods imposing burdens that reduce gains in practical deployments. Additionally, security solutions such as blockchain and machine learning–based anomaly detection often lack lightweight implementations suitable for resource-limited MANET nodes, hindering seamless adoption. Furthermore, there is a noticeable lack of integrated approaches that jointly optimize energy efficiency, route stability, adaptive decision-making, and robust security in a unified framework, leaving networks vulnerable and inefficient in real-world, highly dynamic conditions. Lastly, scalability and interoperability with existing communication systems, as well as long-term sustainability of MANET deployments, are still open areas needing effective solutions.

These persistent gaps highlight the pressing need for adaptive routing protocols that can dynamically balance energy consumption and link reliability, incorporate intelligent prediction for route selection, ensure secure communications without excessive overhead, and maintain high performance under the extreme mobility and connectivity disruptions characteristic of post-disaster MANET environments.

3 Methodology

This section outlines the methodology adopted to enhance the performance of Mobile Ad Hoc Networks (MANETs) by addressing critical limitations in existing routing protocols. Traditional protocols often fall short in dynamic environments due to their lack of adaptability to changing link conditions and energy constraints (Kang and Chung, 2020; Naseem et al., 2021; Tahboush et al., 2023; Tabatabaei, 2023). To overcome these shortcomings, the proposed approach introduces adaptive modifications to two widely used protocols—Ad hoc On-Demand Distance Vector (AODV) and Destination-Sequenced Distance Vector (DSDV)—by incorporating link stability and energy awareness into the route selection process. The methodology includes protocol-level enhancements, simulation-based evaluation using the NS-3 network simulator (Singh and Bhambri, 2023) and performance comparisons with standard versions as shown in Figure 1.

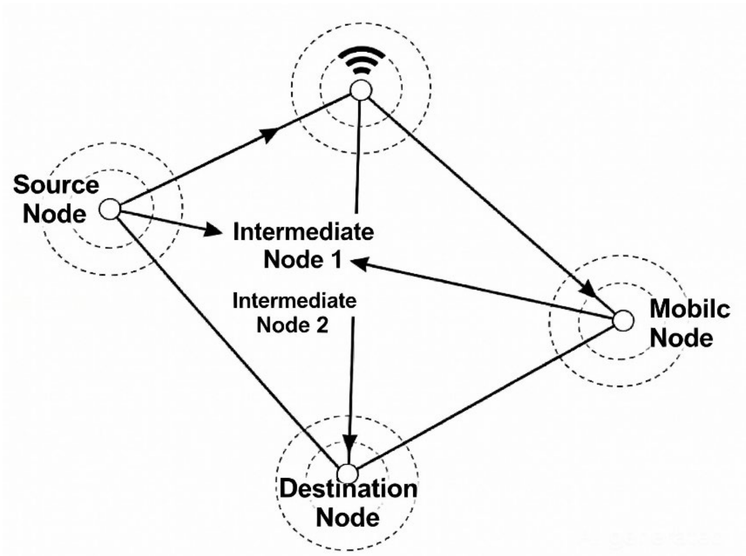

Figure 1 Simulated MANET network topology

In the envisioned post-disaster MANET environment, it is assumed that all participating nodes are mobile, battery-powered devices capable of establishing direct wireless communication with nearby nodes. The network operates in the absence of conventional infrastructure, making it fully self-organizing and decentralized, as is typical in emergency response scenarios where base stations and fixed access points are unavailable. Each node is equipped to estimate its residual energy and periodically track its connectivity history for predictive link stability calculations. Nodes use location and mobility models, such as the Random Waypoint Model, to mimic realistic movement patterns of responders and vehicles in a disaster zone. Communication occurs within a predefined area, with transmission ranges and node densities selected to emulate field deployment conditions and stress-test network performance under varied topological changes. The network is initialized such that each node can serve both as a data source and as an intermediate router, ensuring multi-hop communication is possible when direct transmission to the destination is not feasible. All data exchanges are subject to fluctuating signal qualities and frequent topology updates due to continuing mobility and environmental disruption, requiring routing algorithms to adapt proactively to ensure reliable, energy-efficient, and robust packet delivery throughout the dynamic emergency scenario.

The flowchart illustrates the decision-making process in the proposed adaptive AODV and DSDV routing protocols, which integrate link stability and residual energy as key routing metrics shown in Figure 2. The process begins with the reception of a route request (RREQ), followed by the computation of link stability using a Link Stability Factor (LSF) (Sebestyen and Kopjak, 2024). Based on a predefined threshold, nodes assess their eligibility to participate in routing. If the link stability is sufficient, the node proceeds to check its residual energy. Nodes with energy levels above the threshold participate in routing and help forward route replies (RREP), while nodes with insufficient energy are dropped from the routing path to conserve resources (Verma et al., 2023). The selected stable path is then used for data transmission. Throughout the process, link stability and energy levels are continuously monitored to allow dynamic adjustments, ensuring optimal route reliability and energy efficiency in the network.

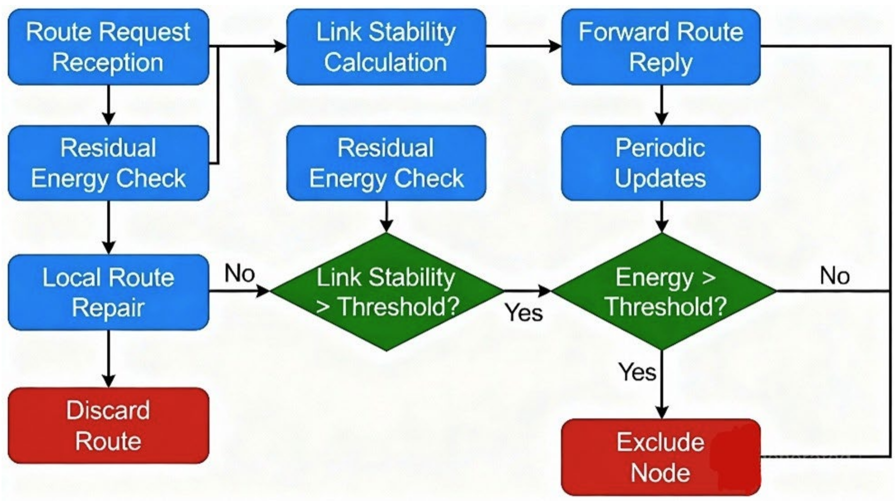

Figure 2 Flowchart of the proposed algorithm

3.1 Link stability-based route selection

In traditional AODV and DSDV, route selection is based on hop count, which does not ensure path stability. To enhance route reliability, we introduce the Link Stability Factor (LSF) that predicts how long a wireless link between two nodes is likely to remain available. This prediction helps in selecting routes less prone to breakages, minimizing route discovery overhead.

The link stability factor LSF between two nodes i and j is computed as:

$$LSF_{i,j} = \frac{1}{1 + e^{-(\Delta t - T_{th})}}$$

where:

Δt is the estimated link lifetime or predicted duration the link remains connected;

T_{th} is a predefined threshold to distinguish stable from unstable links;

The sigmoid function maps this estimate to a normalized probability-like value between 0 and 1.

Only links with $LSF_{i,j} > \theta$ (where θ is a stability threshold typically set around 0.8) qualify for route construction, filtering out likely unstable paths.

3.2 Energy-aware adaptive routing

Energy depletion in MANET nodes can lead to network failures to optimize network longevity, the routing protocol incorporates node residual energy into route selection:

$$E_{res}(i,t) = E_{init} - \sum_{k} P_k \times T_k$$

where:

$E_{res}(i,t)$ is the residual energy of node i at time t;

E_{init} is the node's initial energy capacity;

P_k is the power consumption for the k -th transmission or reception event;

T_k is the duration of the k-th transmission event.

Nodes with residual energy below E_{th} (an energy threshold) are excluded from participating in routing paths to avoid network partitioning due to node failures.

3.3 Routing process

The routing process in the proposed adaptive MANET protocol begins with the source node broadcasting a Route Request (RREQ) packet throughout the network to discover a path to the desired destination. As each intermediate node receives the RREQ, it dynamically evaluates the link stability of the connection to the previous node using a Link Stability Factor (LSF), which predicts how long the wireless link will remain active based on prior connectivity and signal conditions. Nodes further assess their current residual energy levels to ensure they possess sufficient power reserves for forwarding data packets. Only those nodes whose link stability exceeds a predefined threshold and whose residual energy is above an established minimum continue to propagate the RREQ, effectively pruning unstable or energy-depleted paths early in the discovery process. Once the destination node receives the RREQ(s), it generates a Route Reply (RREP) packet, which traverses the reverse route back to the source, establishing a viable, stable, and energy-efficient path. During ongoing data transmission, nodes continuously monitor link conditions and their energy metrics. In case a link failure is detected, a localized route repair mechanism is activated to recompute alternative paths using updated stability and energy parameters, minimizing delays associated with global route rediscoveries. This adaptive, metric-aware routing approach ensures that established communication paths balance quality and sustainability, significantly enhancing packet delivery rates, reducing latency, and extending network lifetime in the face of post-disaster dynamics and constraints.

3.4 Local route repair

Local route repair is a critical mechanism employed in the proposed routing protocol to maintain communication continuity and enhance reliability in dynamic MANET environments typical of post-disaster scenarios. When a node involved in data forwarding detects a link failure to its next hop—often due to node mobility or environmental disruptions—it immediately initiates a local repair process to find an alternate path without involving the source node. This localized approach drastically reduces the latency and control overhead associated with re-initiating a full route discovery from the source, which is especially beneficial in resource-constrained and time-sensitive emergency networks. The node first updates its knowledge of link stability and residual energy for neighboring nodes and then examines potential substitute routes that meet or exceed predefined thresholds for link durability and node energy availability. If a suitable local route is found, data forwarding resumes seamlessly through this rerouted path. If local repair attempts fail, the node informs the source of the failure, triggering a broader route rediscovery process. By confining repair procedures to nearby nodes and adapting dynamically to real-time network conditions, the local route repair mechanism significantly improves the robustness and efficiency of the MANET, ensuring sustained data transmission despite the challenges imposed by mobility and node energy limitations.

The following algorithm outlines the decision-making process for selecting stable and energy-efficient paths in Enhanced AODV and Enhanced DSDV. This algorithm is designed to ensure that only nodes with stable links and sufficient energy participate in routing, thereby improving reliability and prolonging network lifetime.

Algorithm: Adaptive Link Stability-Based and Energy-Aware Routing

Input: Source node S, Destination node D

Parameters: Link Stability threshold θ, Residual Energy threshold E_th

// Initialization

For each node i in network:

Initialize residual energy $E_{res}(i)$

Periodically calculate Link Stability Factor $LSF_{i,j}$ with neighbors j.

// Route Discovery

S broadcasts Route Request (RREQ)

// Intermediate Node Handling of RREQ

Upon receiving RREQ at node i from node j:

Compute $LSF_{i,j}$ based on predicted link duration

If $LSF_{i,j}$<= θ then

Discard RREQ

Exit

End If

Check residual energy $E_{res}(i)$

If $E_{res}(i)$ <= E_{th} then

Discard RREQ

Exit

End If

Forward RREQ to neighbors

// Destination Node Handling of RREQ

Upon receiving RREQ, destination D sends Route Reply (RREP) along reverse path

// Data Transmission

Source S sends data packets along selected stable and energy-efficient route

// Continuous Monitoring

Periodic update of LSF and residual energy at intermediate nodes

// Local Route Repair Mechanism

If node k detects broken link to next hop during data forwarding then

For each neighbor m of node k:

Compute $LSF_{k,m}$ and check $E_{res}(m)$

If $LSF_{k,m}$ > θ and $E_{res}(m)$ > E_{th} then

Forward packets via m (local repair success)

Exit local repair

End If

End For

If no alternate path found then

Notify source S to initiate new route discovery

End If

End If

This algorithm ensures that routing adapts dynamically to changing network conditions by considering real-time link stability and energy availability, reducing route failures, overhead, and energy depletion, thus improving reliability and lifetime of MANET communication in post-disaster scenarios.

3.5 Simulation setup and parameters

To evaluate the effectiveness of the proposed adaptive routing enhancements, we conducted extensive simulations using the NS-3 (Network Simulator-3) framework. The simulation environment was designed to replicate post-disaster communication scenarios, where MANETs are deployed in infrastructure-less environments to provide emergency connectivity. The proposed enhancements were implemented and evaluated using the NS-3 simulator. This section details the experimental configurations, protocol modifications, and simulation environment settings.

3.5.1 Custom enhancements in NS-3

In the NS-3 simulation environment, the AODV and DSDV routing protocols were modified to incorporate link stability factors, enabling more reliable route selection in dynamic network conditions. Adaptive energy-aware metrics were also implemented to optimize routing decisions based on the residual energy of nodes. Additionally, the handling of control messages was refined to minimize unnecessary retransmissions and reduce communication overhead. The wireless interface was configured using IEEE 802.11 standards to ensure realistic network behavior. while the Random Waypoint Mobility Model was employed to simulate dynamic node movement patterns. The energy consumption model was based on a constant power usage per packet transmission, providing a consistent framework for evaluating energy efficiency.

3.5.2 Programming environment

Modifications were implemented using C++ in the NS-3 simulator. Python scripts were used for performance data extraction and statistical analysis, while graphs and result visualizations were generated using the Matplotlib library.

3.5.3 Simulation environment

The Random Waypoint Model (RWM) was used to mimic the movement of rescue personnel and autonomous devices.

Constant Bit Rate (CBR) traffic with the User Datagram Protocol (UDP) was used to maintain a steady data flow (Baccelli et al., 2008). Table 1 shows the key parameters used in the simulation.

Table 1 The key parameters used in the simulation

Parameter	Description	Value
Simulation Area	Disaster communication range	1000 m × 1000 m
Number of Nodes	Mobile nodes in MANET	50–100
Mobility Model	Movement pattern of nodes	Random Waypoint Model
Traffic Model	Type of data flow	Constant Bit Rate (CBR)
MAC Protocol	Medium Access Protocol	IEEE 802.11
Packet Size	Data packet size	512 Bytes
Transmission Range	Maximum wireless range	250 m
Simulation Time	Duration of the experiment	300 s
Energy Model	Initial node energy	2 J
Performance Metrics	Evaluated parameters	PDR, Delay, Energy, Lifetime

Table 2 The comparative performance of standard and enhanced AODV and DSDV protocols

Performance Metric	Standard AODV	Standard DSDV	Enhanced AODV	Enhanced DSDV
Packet Delivery Ratio (PDR) (%)	78.3	74.5	92.1	88.7
End-to-End Delay (ms)	150.3	142.8	98.5	110.2
Energy Consumption (J)	18.4	19.1	12.6	13.2
Network Lifetime (s)	170.8	160.4	250.5	230.7

4 Performance analysis and comparison

The effectiveness of the proposed adaptive enhancements is evaluated through extensive simulations in a post-disaster MANET environment. A comparative analysis between standard and enhanced AODV/DSDV demonstrates significant improvements in network reliability, energy efficiency, and stability.

To conduct this evaluation, the performance of Enhanced AODV and Enhanced DSDV protocols was compared against their respective standard versions. The analysis focused on four key performance metrics: Packet Delivery Ratio (PDR), End-to-End Delay, Energy Consumption, and Network Lifetime.

Packet Delivery Ratio (PDR) measures the percentage of successfully delivered packets, where higher values indicate improved network reliability.

End-to-End Delay represents the average time taken for data packets to reach their destination, with lower delay indicating faster communication.

Energy Consumption accounts for the total energy used by all nodes in the network, and lower values signify better energy efficiency.

Network Lifetime is defined as the time until the first node exhausts its energy, where longer lifetimes reflect sustainable communication and better energy distribution.

The results of the comparative analysis reveal that the proposed adaptive enhancements significantly improve routing efficiency, communication stability, and overall energy conservation in dynamic MANET environments.

4.1 Performance comparison

Table 2 presents the comparative performance of standard and enhanced AODV and DSDV protocols.

The results clearly show that the enhanced AODV and DSDV protocols achieve significant improvements across all metrics, particularly in PDR (+17%–19%), reduced delay (-30%–35%), and extended network lifetime (+40%–50%).

4.2 Graphical performance analysis

Figure IV presents the graphical representation of the performance improvements achieved by the enhanced routing protocols. Each graph highlights the relative gains in Packet Delivery Ratio (PDR), reduction in end-to-end delay, improvement in energy efficiency, and extension in network lifetime. These visual comparisons help illustrate the superiority of the enhanced AODV and DSDV protocols over their standard counterparts under dynamic MANET conditions.

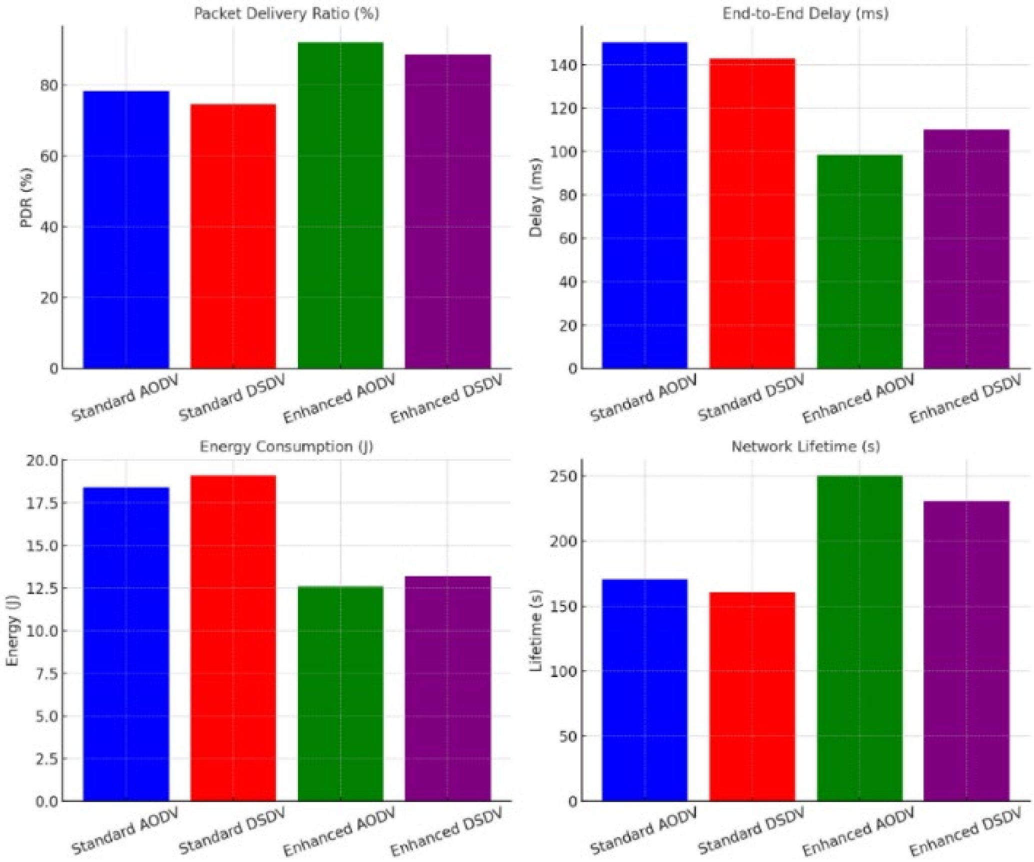

Figure 3 Graphical comparison of these results, highlighting the efficiency of the proposed adaptive enhancement

4.3 Discussion and interpretation of results

The results presented in Figure 3 demonstrate the effectiveness of the proposed adaptive enhancements in improving MANET performance. This section provides a detailed interpretation of each performance metric, highlighting the key improvements achieved.

4.3.1 Packet Delivery Ratio (PDR) improvement

Enhanced AODV achieved a PDR of 92.1%, while Enhanced DSDV reached 88.7%. Compared to standard AODV (78.3%) and DSDV (74.5%), this represents a 17%–19% improvement. The improvement is attributed to link stability-based route selection, which reduces frequent route failures and adaptive path selection, which ensures higher packet delivery success rates.

4.3.2 End-to-end delay reduction

Enhanced AODV reduced end-to-end delay to 98.5 ms, and Enhanced DSDV achieved 110.2 ms. This marks a 30%–35% reduction compared to standard AODV (150.3 ms) and DSDV (142.8 ms). The delay reduction is due to faster route maintenance that prevents delays from broken links as well as energy-aware routing mechanisms that avoid congested or overloaded nodes.

4.3.3 Energy consumption optimization

Enhanced AODV consumed 12.6 J, and Enhanced

DSDV consumed 13.2 J. These figures represent a 35% reduction in energy usage compared to standard AODV (18.4 J) and DSDV (19.1 J). This optimization is attributed to adaptive energy-aware routing, which avoids overuse of low-energy nodes and efficient path selection, which reduces retransmissions and minimizes control overhead.

4.3.4 Network lifetime extension

Enhanced AODV extended network lifetime to 250.5 seconds, while Enhanced DSDV achieved 230.7 seconds. This is a 40%–50% improvement over standard AODV (170.8 seconds) and DSDV (160.4 seconds). The improvement results from even energy distribution across nodes, preventing early failures and balanced traffic load management, ensuring no single node depletes energy rapidly.

These results indicate that the proposed adaptive enhancements significantly improve overall MANET performance. The combination of link stability-based route selection and energy-aware routing contributes to higher PDR, lower latency, optimized energy usage, and extended network lifetime. These improvements make the proposed approach a highly effective and practical solution for post-disaster communication networks. Simulation results validate the effectiveness of the approach, with a notable increase in PDR by 17%–19%, a reduction in end-to-end delay by 30%–35%, a decrease in energy consumption by 35%, and an extension in network lifetime by 40%–50% as shown in Figure 3. These findings form a strong foundation for future innovations in developing resilient, sustainable, and intelligent MANET routing architectures.

5 Conclusion

The conclusion of this research highlights that the proposed adaptive routing enhancements to AODV and DSDV protocols significantly improve MANET performance in post-disaster scenarios. The simulation results demonstrate a packet delivery ratio (PDR) improvement of 17%–19%, a 30%–35% reduction in end-to-end delay, and a substantial 40%–50% increase in network lifetime compared to the baseline protocols. These improvements confirm the method's effectiveness in ensuring reliable, low-latency, and energy-efficient communication under the dynamic and resource-constrained conditions typical of disaster recovery environments.

Nonetheless, the study acknowledges limitations such as increased computational and signaling overhead due to continuous link stability and energy metric monitoring, which may impact scalability in very large or dense networks. Additionally, the approach assumes accurate real-time availability of these metrics, which can be challenging in noisy or harsh real-world conditions. Security integrations using blockchain, while promising, introduce added complexity and resource demands requiring further optimization.

Future research directions involve integrating machine learning for predictive routing to reduce overhead while maintaining adaptability, developing lightweight blockchain-based security mechanisms for decentralized trust, and designing hybrid routing protocols that dynamically switch between proactive and reactive modes to balance overhead and responsiveness. Extensive real-world deployments and interoperation with next-generation IoT and 5G networks will further validate and extend the applicability of the proposed methodology for robust post-disaster communication.

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