

Comparative Study and Performance Enhancement of Reactive Routing Protocols for Mobile AD HOC Networks

Shashank Khare ¹, Dr. Anand Dubey ²

¹Research Scholar, Department of Computer Science & Engineering,
School of Engineering and Technology Vikrant University, Gwalior, (M.P.), India

²M.Tech Guide, Department of Computer Science & Engineering,
School of Engineering and Technology Vikrant University, Gwalior, (M.P.), India

Abstract

Mobile Ad Hoc Networks (MANETs) are decentralized wireless communication systems in which mobile nodes dynamically establish communication links without relying on fixed infrastructure. Due to node mobility, limited bandwidth, changing network topology, interference, packet loss, and constrained energy resources, routing remains one of the major challenges in MANETs. Reactive routing protocols establish routes only when communication is required and are therefore widely used in dynamic network environments. This study presents a comparative analysis of three prominent reactive routing protocols: Ad hoc On-Demand Distance Vector (AODV), Dynamic Source Routing (DSR), and Ad hoc On-Demand Multipath Distance Vector (AOMDV). The protocols are examined using important performance indicators, including Packet Delivery Ratio (PDR), average end-to-end delay, routing overhead, throughput, and route recovery capability. The study further proposes an adaptive performance-enhancement framework that combines mobility awareness, route-quality assessment, link-break prediction, and multipath route selection. The proposed approach aims to improve communication reliability while reducing unnecessary routing overhead and delay. The comparative framework demonstrates that no single reactive routing protocol is optimal under all MANET conditions; instead, performance depends strongly on network density, mobility, traffic load, and route stability. The proposed enhancement provides a basis for developing more adaptive and resilient routing mechanisms for dynamic MANET applications.

Keywords: MANET, reactive routing, AODV, DSR, AOMDV, routing protocol, packet delivery ratio, throughput, network performance, routing overhead, adaptive routing.

Introduction

The rapid development of wireless communication technologies has resulted in increasing demand for communication systems capable of operating without fixed infrastructure. A Mobile Ad Hoc Network (MANET) is a collection of mobile wireless nodes that communicate with one another through dynamically established wireless links. Each node can act simultaneously as a host and a router, allowing packets to travel through multiple intermediate nodes before reaching the destination.

MANETs are useful in emergency response, disaster management, military communication, temporary networking, vehicular environments, collaborative sensing, and remote-area communication. However, the dynamic nature of MANETs creates significant routing challenges. Nodes may move unpredictably, resulting in frequent changes in network topology. Wireless links may also experience interference, congestion, signal attenuation, and packet loss.

Traditional routing protocols designed for fixed networks are not always suitable for such dynamic environments. Consequently, several specialized MANET routing protocols have been developed. These protocols can broadly be categorized into proactive, reactive, and hybrid approaches.

Reactive or on-demand routing protocols do not maintain complete routing information for all destinations continuously. Instead, they discover a route when a source node has data to send. AODV and DSR are representative reactive protocols, while AOMDV extends the on-demand approach by maintaining multiple loop-free paths.

Although reactive protocols can reduce unnecessary routing traffic, they can introduce route-discovery delays and may suffer from route failures under high mobility. Therefore, comparative performance evaluation and enhancement of reactive routing mechanisms remain important research areas.

This research focuses on comparative evaluation of AODV, DSR, and AOMDV and proposes an adaptive framework for improving reactive routing performance in MANET environments.

Objectives of the Study

The major objectives are:

1. To study the architecture and operational principles of reactive routing protocols in MANETs.
2. To analyze the working mechanisms of AODV, DSR, and AOMDV.
3. To compare their performance using standard network-performance metrics.
4. To examine the effect of node mobility, network density, and traffic load on routing performance.
5. To identify the major limitations of conventional reactive routing protocols.
6. To develop an adaptive framework for performance enhancement.
7. To improve packet delivery ratio and throughput.
8. To minimize end-to-end delay and routing overhead.
9. To enhance route stability and recovery capability.
10. To establish a framework suitable for future simulation-based validation.

Literature Review

Reactive Routing in MANETs

Reactive routing protocols follow an on-demand philosophy. Instead of maintaining routes to all possible destinations, a source initiates route discovery when a route is required.

The general process includes:

1. Route requirement identification.
2. Route request generation.
3. Route request propagation.
4. Route reply generation.
5. Route establishment.
6. Data transmission.
7. Route maintenance.
8. Route repair or rediscovery after route failure.

This approach can significantly reduce periodic control traffic compared with proactive routing, particularly when only a limited number of destinations are actively communicating.

AODV

AODV is a distance-vector-based on-demand routing protocol. A source node initiates route discovery by broadcasting a Route Request (RREQ). An intermediate node can respond if it has a sufficiently fresh route to the destination; otherwise, it forwards the request.

AODV uses destination sequence numbers to help maintain loop-free routes and to identify fresh routing information.

Its major advantages include:

- Simple routing mechanism
- Reduced periodic control traffic
- Destination sequence-number mechanism
- Good suitability for dynamic networks

Its limitations include:

- Route-discovery delay
- Broadcast-based route discovery
- Route failures under high mobility
- Potential control overhead during frequent topology changes

DSR

DSR uses source routing, where the complete route is carried within the packet header. It generally consists of Route Discovery and Route Maintenance mechanisms.

A significant feature of DSR is route caching. A node may store previously discovered routes and use them when needed.

Advantages include:

- Route caching
- Multiple known routes may be available through cached information
- No periodic routing advertisements required

Limitations include:

- Increased packet-header size as path length increases
- Route-cache staleness
- Potential inefficiency in larger networks

AOMDV

AOMDV extends the AODV approach by establishing multiple loop-free paths between source and destination during route discovery.

Instead of depending on a single route, the source can maintain alternate paths. If the primary route fails, another route may be used without immediately initiating a new route-discovery process.

This can improve route recovery under mobility, although maintaining multiple routes may introduce additional routing overhead and resource requirements.

Comparative Characteristics of Reactive Protocols

Parameter	AODV	DSR	AOMDV
Routing approach	On-demand	On-demand	On-demand multipath
Routing information	Next-hop based	Source route	Multiple next-hop paths
Route discovery	RREQ/RREP	RREQ/RREP	Multipath RREQ/RREP
Route caching	Limited/route based	table Strong route caching	Multiple routes
Route redundancy	Low	Moderate through cache	High
Mobility tolerance	Moderate	Moderate	High
Packet-header overhead	Relatively low	Can increase with path length	Moderate
Route recovery	Route repair/rediscovery	Cached route/rediscovery	Alternate path
Major advantage	Simplicity	Route cache	Fast recovery
Major limitation	Frequent rediscovery	Large headers/stale cache	Additional route-management overhead

Proposed Methodology

The proposed study follows a simulation-oriented comparative methodology.

Network Model

A MANET simulation environment can be created using a network simulator such as NS-3 or OMNeT++.

The network consists of:

- Mobile wireless nodes
- Source nodes
- Destination nodes
- Intermediate forwarding nodes
- Wireless communication links

Each node is assumed to have the capability of transmitting, receiving, forwarding, and routing packets.

Experimental Parameters

A representative simulation configuration can include:

Parameter	Representative Setting
Number of nodes	25–100
Simulation area	1000 × 1000 m
Routing protocols	AODV, DSR, AOMDV
Mobility model	Random Waypoint
Traffic	CBR/UDP
Packet size	512–1024 bytes
Mobility	Low, medium, high
Node speed	Variable
Simulation duration	300–600 seconds
MAC layer	IEEE 802.11
Propagation	Wireless channel
Performance metrics	PDR, delay, throughput, overhead

These parameters should be replaced with actual simulation settings before publication.

Performance Metrics

Average End-to-End Delay

Average end-to-end delay represents the average time required for packets to travel from source to destination.

$$D_{\text{avg}} = \frac{\sum_{i=1}^N (T_{\text{receive},i} - T_{\text{send},i})}{N}$$

Lower delay indicates better real-time communication performance.

Routing Overhead

Routing overhead indicates the amount of control traffic generated to establish and maintain routes.

A simplified measure can be represented as:

$$RO = \frac{\text{Routing Packets}}{\text{Successfully Delivered Data Packets}}$$

Lower routing overhead generally indicates more efficient utilization of network resources.

Route Recovery Time

Route recovery time is the time required to restore connectivity following a route failure.

A lower route recovery time is particularly important in highly mobile environments.

Comparative Performance Analysis

The expected behavior of the three protocols can be analyzed under different network conditions.

Low Mobility

Under low mobility, topology changes are relatively infrequent. Existing routes can remain valid for longer periods.

AODV can perform effectively because route discovery does not occur frequently. DSR can also benefit from route caching. AOMDV may provide limited additional benefits because route failures are relatively infrequent.

Medium Mobility

With increasing node movement, route failures become more frequent.

AODV may experience increased route-discovery operations. DSR can sometimes utilize cached alternatives, but stale cache entries may become problematic. AOMDV is expected to benefit from maintaining alternate paths.

High Mobility

High mobility produces rapid topology changes. Single-path routing becomes more vulnerable to route failure.

AOMDV is expected to demonstrate better route resilience because alternate routes can be used when the primary route becomes unavailable.

However, multipath maintenance may generate additional routing traffic.

The table suggests an important observation: **AOMDV may provide better reliability and route recovery in highly dynamic networks, while AODV and DSR can remain competitive under relatively stable conditions.**

Proposed Performance Enhancement Framework

A major contribution of this research is an adaptive enhancement framework that improves conventional reactive routing by incorporating additional route-selection parameters.

The proposed framework is called the:

Adaptive Route Stability and Link Quality Framework (ARSLQF)

The framework evaluates potential routes according to:

1. Link stability
2. Node mobility
3. Residual energy
4. Hop count
5. Packet loss
6. Link quality
7. Historical route reliability
8. Current congestion

Route Quality Score

A route-quality score can be defined as:

$$[RQS = w_1LS + w_2LQ + w_3RE + w_4HR - w_5HC - w_6PL]$$

where:

- (LS) = Link Stability
- (LQ) = Link Quality
- (RE) = Residual Energy
- (HR) = Historical Reliability
- (HC) = Hop Count
- (PL) = Packet Loss
- ($w_1, w_2, \dots, w_6$) = weighting factors

The weights can be optimized experimentally according to the desired application.

Proposed Routing Procedure

The proposed approach can follow the following sequence:

Step 1: Route Request

The source generates a route request when a destination route is unavailable.

Step 2: Route Assessment

Intermediate nodes collect information related to:

- Signal quality
- Link stability
- Node mobility
- Congestion
- Residual energy

Step 3: Route Quality Calculation

Each candidate route receives a Route Quality Score.

Step 4: Route Selection

The route with the highest suitable score is selected instead of simply selecting a route based on minimum hop count.

Step 5: Link Monitoring

The selected route is continuously monitored.

Step 6: Predictive Route Repair

If the link-quality indicator falls below a predefined threshold, an alternate route is selected before complete route failure.

Step 7: Multipath Backup

Where appropriate, one or more alternative paths are maintained to minimize route-discovery delay.

This mechanism aims to shift reactive routing from **failure-based recovery** toward **predictive and adaptive route management**.

Expected Performance Enhancement

The proposed framework is expected to improve performance in the following areas:

Packet Delivery Ratio

By selecting more stable routes and activating alternate paths before complete failure, packet loss can potentially be reduced.

End-to-End Delay

Predictive route repair may reduce the time required for complete route rediscovery.

Throughput

Reduced packet loss and fewer communication interruptions can improve effective throughput.

Routing Overhead

Although additional monitoring information introduces some overhead, intelligent route selection can potentially reduce repeated route-discovery operations.

Network Reliability

Multipath and predictive routing mechanisms can improve communication continuity.

Discussion

The comparative analysis demonstrates that reactive routing protocols exhibit different strengths depending on network conditions.

AODV provides a relatively simple and scalable on-demand routing mechanism. Its use of sequence numbers supports loop-free routing and route freshness. However, frequent mobility can lead to repeated route discovery and increased control traffic.

DSR has the advantage of source routing and route caching. It may perform efficiently in smaller or moderately mobile networks, where cached routes remain useful. However, the source-routing mechanism can increase packet-header size as network paths become longer. Route caches may also contain obsolete information in highly dynamic environments.

AOMDV provides route redundancy by maintaining multiple paths. This characteristic can be especially useful in highly mobile environments. When one route fails, another path may be available, reducing the need for immediate route rediscovery. The trade-off is additional routing and route-maintenance complexity.

Therefore, the selection of a routing protocol should be based on application requirements and network characteristics rather than on a universal assumption that one protocol is always superior.

The proposed adaptive framework attempts to overcome this limitation by incorporating route stability, link quality, energy, mobility, and congestion into routing decisions.

Conclusion

This research presented a comparative study of reactive routing protocols for Mobile Ad Hoc Networks, with particular emphasis on AODV, DSR, and AOMDV. MANETs present unique routing challenges because of dynamic topology, wireless link instability, limited resources, and unpredictable node mobility.

AODV provides an efficient and relatively straightforward on-demand routing mechanism, whereas DSR benefits from source routing and route caching. AOMDV introduces multipath capability and can provide improved route resilience under dynamic network conditions.

The comparative analysis indicates that protocol performance is strongly dependent on mobility, network density, traffic load, and topology changes. Consequently, no individual reactive protocol can be considered universally optimal.

To address these limitations, an **Adaptive Route Stability and Link Quality Framework (ARSLQF)** was proposed. The framework considers link quality, mobility, residual energy, congestion, packet loss, and route reliability when

selecting routes. Predictive route monitoring and alternate-route activation can potentially improve packet delivery, throughput, delay, and route recovery.

For a publishable experimental study, the next stage should be to implement AODV, DSR, AOMDV, and the proposed enhanced protocol in **NS-3** or **OMNeT++**, run controlled simulations at different node densities and mobility levels, and statistically validate the resulting performance differences

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