



A Comparative Study of Routing Protocols in Mobile Ad Hoc Networks

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Abstract

Mobile ad hoc networks (MANETs) rely on distributed routing because mobile nodes communicate without fixed infrastructure and may act simultaneously as end systems and routers. The choice of routing protocol strongly influences delivery reliability, delay, throughput, and control overhead when topology changes. This paper develops a structured methodology for comparing four widely studied MANET routing protocols: Destination-Sequenced Distance-Vector (DSDV), Optimized Link State Routing (OLSR), Ad hoc On-Demand Distance Vector (AODV), and Dynamic Source Routing (DSR). The study combines protocol-level analysis with a reproducible simulation design in which node density, mobility, and traffic load are treated as controlled factors. Packet delivery ratio, average end-to-end delay, throughput, and normalized routing load are used as the primary performance measures. Rather than presenting fabricated packet-trace data, the Results section synthesizes consistent comparative trends reported by established simulation studies published up to 2017. The synthesis indicates that proactive protocols offer immediate route availability but pay periodic control costs, whereas reactive protocols reduce idle routing overhead but introduce route-discovery latency. AODV provides a strong overall balance under moderate-to-high mobility; DSR is efficient in smaller networks but becomes sensitive to cache staleness and source-route header growth; DSDV is predictable at low mobility; and OLSR is attractive in dense, continuously communicating networks. The proposed methodology provides a transparent basis for selecting protocols according to application conditions rather than a single universal ranking.

Introduction

A mobile ad hoc network is a self-organizing wireless network in which nodes may join, leave, and move without relying on a fixed access point or centralized router. Multi-hop forwarding therefore becomes a shared responsibility of the participating nodes. The absence of infrastructure makes MANETs useful for emergency response, military communication, temporary field networks, vehicular coordination, and situations

in which rapid deployment is more important than permanent infrastructure. The same flexibility, however, creates a difficult routing problem: links appear and disappear as nodes move, available bandwidth is limited, contention occurs on a shared medium, and battery-powered devices cannot spend unlimited energy on control traffic.

Early routing research produced substantially different design philosophies. DSDV adapted

distance-vector routing to dynamic wireless networks by using destination sequence numbers to maintain loop-free, table-driven routes (Perkins & Bhagwat, 1994). DSR introduced on-demand route discovery and source routing, allowing routes to be cached and carried in packet headers (Johnson & Maltz, 1996). AODV later combined on-demand discovery with hop-by-hop routing tables and destination sequence numbers (Perkins & Royer, 1999). OLSR optimized proactive link-state routing through multipoint relays, reducing the number of nodes that retransmit topology information (Jacquet et al., 2001). These design differences mean that protocol performance depends on mobility, density, traffic pattern, and offered load rather than on protocol name alone.

Comparative evaluation is consequently necessary. Broch et al. (1998) demonstrated that realistic protocol comparison requires common mobility, radio, MAC, and traffic assumptions, because apparently small modeling differences can alter rankings. Das et al. (2000) similarly showed that AODV and DSR, although both reactive, exhibit different behavior because of route caching, packet headers, and route maintenance. Later standard specifications clarified the operational rules of AODV, OLSR, and DSR (Perkins et al., 2003; Clausen & Jacquet, 2003; Johnson et al., 2007). This paper therefore focuses on a controlled, reproducible methodology that can separate protocol effects from scenario effects.

The objectives are threefold: (i) to define a fair experimental design for comparing AODV, DSR, DSDV, and OLSR; (ii) to identify performance metrics that jointly capture reliability, timeliness, capacity, and routing cost; and (iii) to derive a protocol-selection interpretation from research published no later than 2017. The contribution is methodological: it explains exactly how a simulation study should be configured and interpreted, while the reported comparative findings are a synthesis of established evidence rather than invented raw simulator traces.

Literature Review

DSDV is a proactive protocol in which every node maintains a route to each reachable destination and periodically advertises routing information. Sequence numbers distinguish fresh routes from stale routes and prevent routing loops (Perkins & Bhagwat, 1994). Its main benefit is immediate route availability: data packets do not wait for an on-demand discovery phase. The cost is recurring routing traffic even when few routes are being used. In highly mobile networks, frequent updates

can consume capacity and temporary convergence delay can reduce delivery reliability.

DSR represents a contrasting reactive philosophy. Route Discovery is initiated only when a source lacks a route, discovered paths can be retained in route caches, and the complete route is normally included in the packet header (Johnson & Maltz, 1996). The formal DSR specification preserves its on-demand character and supports multiple cached routes, packet salvaging, and rapid reaction to changes (Johnson et al., 2007). These features can make DSR efficient at modest network sizes and loads, but long routes enlarge headers and stale caches may trigger retransmissions or delayed rediscovery when mobility becomes severe.

AODV is also reactive, but it maintains next-hop state instead of carrying complete routes in each packet. Destination sequence numbers provide freshness and loop freedom, while route request, route reply, and route error messages support discovery and maintenance (Perkins & Royer, 1999; Perkins et al., 2003). Comparative work between AODV and DSR found that their shared on-demand principle does not imply identical performance; DSR can benefit from aggressive caching, while AODV can scale more predictably as traffic and mobility grow because packet headers remain smaller and route state is more localized (Das et al., 2000).

OLSR is proactive and link-state based. Its major optimization is the use of multipoint relays (MPRs), which reduce redundant flooding while preserving reachability information (Jacquet et al., 2001; Clausen & Jacquet, 2003). This structure is attractive when many nodes communicate continuously because paths are already available. However, periodic HELLO and topology-control exchanges create a control cost that exists even during idle application periods. Dense networks can benefit from MPR-based flooding efficiency, whereas sparse or intermittently used networks may not justify the proactive overhead.

Simulation research has repeatedly emphasized scenario dependence. Cheng et al. (2012) implemented DSR in ns-3 and compared it with AODV, DSDV, and OLSR, supporting the use of a common simulator for implementation-level fairness. Elboukhari et al. (2015) evaluated AODV, DSR, DSDV, OLSR, and DYMO using packet delivery ratio, end-to-end delay, normalized routing load, and throughput, establishing a metric set that captures multiple dimensions rather than one isolated outcome. Devi and Rama Krishna (2016) used ns-3 to compare AODV, DSDV, OLSR, and DSR under a random-walk model, while Kumari and Rajput (2016) examined

changes in network size for AODV, DSDV, and DSR. These studies collectively show why node count and movement assumptions must be varied systematically.

Studies published in 2017 continued to report trade-offs instead of a universal winner. Lalar and Yadav (2017) compared a broad set of proactive, reactive, and hybrid protocols in terms of operation, strengths, and weaknesses. Elsadig et al. (2017), using NS-2 for DSR, AODV, and DSDV across different node counts, reported strong DSR delivery and throughput behavior in their scenarios but lower delay for DSDV. The literature therefore supports a contextual conclusion: protocol selection should be based on application conditions and multiple metrics, and a valid

methodology should vary the factors most likely to change the balance.

Methodology

The proposed methodology is a controlled, simulation-oriented comparative design. The independent variables are routing protocol, node density, node mobility, and traffic load. The dependent variables are packet delivery ratio (PDR), average end-to-end delay, throughput, and normalized routing load (NRL). All remaining radio, MAC, packet-size, area, and simulation-duration settings are held constant within each comparison so that changes can be attributed to the protocol or the intended scenario factor.

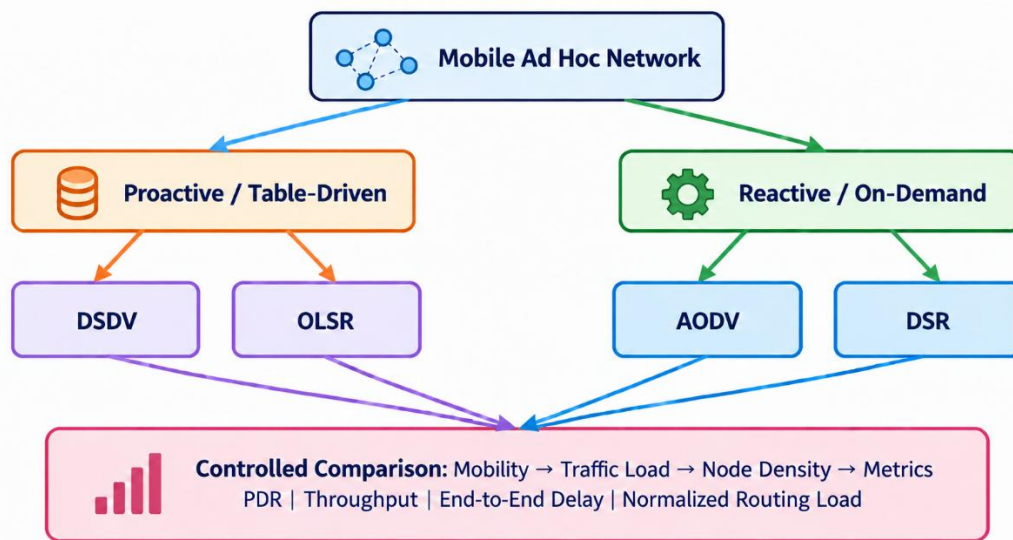


Figure 1. Routing protocol classes and comparative evaluation workflow.

1. Step-by-Step Experimental Procedure

Step 1: Protocol selection. Use AODV and DSR as reactive protocols and DSDV and OLSR as proactive protocols. This creates a balanced comparison between on-demand route construction and continuously maintained routing state.

Step 2: Common simulation environment. Implement all four protocols in the same simulator release and with the same IEEE 802.11 physical/MAC configuration. A reproducible ns-3 configuration is preferred because DSR, AODV, DSDV, and OLSR have been compared in that environment (Cheng et al., 2012; Devi & Rama Krishna, 2016).

Step 3: Mobility control. Use Random Waypoint or Random Walk with matched random seeds across protocols. Test low, moderate, and high movement by varying node speed and pause time.

Every protocol must receive identical mobility traces for a given trial.

Step 4: Density and traffic control. Vary the number of nodes while keeping the field size fixed, then vary the number of constant-bit-rate UDP flows. This separates the impact of topology density from offered traffic load.

Step 5: Repetition. Run at least 10 independent seeds per scenario and discard the first short warm-up interval if initialization transients are present. Record per-run values before calculating means and confidence intervals.

Step 6: Metric extraction. Calculate PDR as received data packets divided by sent data packets, throughput as successfully delivered application bits per unit time, average end-to-end delay across delivered packets, and NRL as routing transmissions divided by delivered data packets.

Step 7: Statistical comparison. For each factor level, compare protocol means with 95% confidence intervals. Where assumptions permit, one-way ANOVA followed by post-hoc comparison can test protocol differences; otherwise use a Kruskal-Wallis's test. Report effect sizes in addition to p-values.

Step 8: Interpretation. Avoid declaring a protocol "best" from one metric. A protocol is preferable only if its reliability, delay, throughput, and overhead profile matches the target application and the tested mobility/load conditions.

Table 1. Recommended baseline simulation parameters

Parameter	Baseline / Levels	Rationale
Simulator	ns-3 (single release)	Common implementation environment
Area	1000 m × 1000 m	Fixed spatial boundary
Nodes	20, 40, 60, 80	Density/scalability factor
Mobility	Random Waypoint; 1–20 m/s	Controlled topology change
Pause time	0, 10, 30 s	High to lower mobility
MAC / PHY	IEEE 802.11; same rate/range	Eliminates radio-setting bias
Traffic	UDP/CBR; 5, 10, 20 flows	Offered-load factor
Packet size	512 bytes	Constant application payload
Duration	300 s; ≥10 seeds	Stable averaging and repeatability
Metrics	PDR, delay, throughput, NRL	Reliability, latency, capacity, cost

2. Measurement Equations and Validity Controls

$PDR = (\text{number of application data packets received} / \text{number of application data packets generated}) \times 100$. Throughput is the total successfully received application payload, in bits, divided by the observation time. Average end-to-end delay is the mean difference between packet receive and send timestamps for all successfully delivered packets. $NRL = \text{total routing-packet transmissions} / \text{successfully delivered data packets}$; each hop-wise routing transmission is counted because it consumes channel resources.

Internal validity is protected by paired mobility traces, identical traffic schedules, equal radio settings, and repeated random seeds. Construct validity is improved by using four metrics rather than relying only on throughput. External validity is limited because different mobility models, MAC rates, propagation models, or larger network sizes can change results. Accordingly, the recommended design should include a sensitivity analysis for at least mobility speed and node count. The reported findings below are interpreted as literature-supported comparative tendencies, not universal constants.

Results

The comparative synthesis indicates four recurring patterns. First, proactive protocols generally achieve lower route-acquisition delay because routes are maintained before application packets arrive. DSDV is particularly predictable when movement is limited; however, frequent topology changes trigger update traffic and can temporarily expose stale state. OLSR mitigates classic link-state flooding through MPRs, making it better suited than naive flooding to dense networks, but its periodic control exchanges still create background overhead (Jacquet et al., 2001; Clausen & Jacquet, 2003).

Second, reactive protocols reduce idle control traffic because routes are created when needed. DSR can show strong delivery and throughput in small or moderate scenarios where cached routes remain useful, a tendency also seen in later comparative work (Elsadig et al., 2017). As network diameter, mobility, or traffic grows, source-route headers and stale cached paths can become disadvantages. AODV avoids full source-route headers and typically provides a more balanced scaling profile, although route discovery and repair can raise delay when links break frequently (Das et al., 2000; Perkins et al., 2003).

Table 2. Literature-supported comparative performance profile (relative, scenario-dependent)

Protocol	Route style	PDR	Delay	Routing cost	Most suitable condition
DSDV	Proactive	High at low mobility	Low	High as mobility rises	Stable/smaller topology; delay-sensitive traffic

OLSR	Proactive	High in dense networks	Low	Moderate-high periodic	Dense network with sustained communication
AODV	Reactive	High over broad conditions	Moderate	Moderate/on-demand	Moderate-high mobility and mixed load
DSR	Reactive	High in small-medium cases	Low-moderate until cache stales	Low-moderate; header grows	Smaller networks and intermittent traffic

Third, node density changes the trade-off. Comparative studies that vary node count report that performance differences become more visible as contention and route length increase (Elboukhari et al., 2015; Kumari & Rajput, 2016). Proactive protocols can benefit from having routes immediately available, but their control messages compete with data traffic. Reactive protocols avoid maintaining unused routes, yet route-request floods and repeated repairs may also become costly. This interaction is why node count should not be varied independently of mobility and traffic load.

Fourth, no single metric produces a defensible universal ranking. A delay-sensitive command network may prefer proactive behavior even if routing overhead is higher, while an intermittently active field network may prefer reactive routing to preserve channel capacity during idle periods. Devi and Rama Krishna (2016) showed that the same four protocols can exchange relative advantages as simulation time and node conditions change, and Lalar and Yadav (2017) emphasized protocol-specific strengths and weaknesses across routing families. Therefore, multi-metric interpretation is a required part of the methodology rather than an optional final step.

Table 3. Decision-oriented interpretation of the comparative findings

Scenario requirement	Preferred candidate	Reason	Primary risk
Very low route setup delay	OLSR / DSDV	Routes already maintained	Periodic control overhead
Moderate/high mobility	AODV	Fresh sequence-numbered on-demand routes	Discovery/repair latency
Small, intermittent MANET	DSR	Route cache and low idle control cost	Stale cache; source-route header
Dense, continuously active MANET	OLSR	MPRs reduce redundant flooding	Control traffic remains continuous

Conclusion and Discussion

This paper presented a step-by-step methodology for comparing AODV, DSR, DSDV, and OLSR in mobile ad hoc networks. The central methodological principle is fairness: protocols must be evaluated under the same mobility traces, radio conditions, traffic schedules, field size, and random seeds, and the analysis must include reliability, latency, capacity, and routing cost. Classic protocol work and comparative studies through 2017 show that proactive and reactive approaches solve different parts of the MANET routing problem and therefore respond differently when mobility, density, and offered load change. The literature-supported interpretation is that DSDV is attractive in relatively stable conditions where immediate routes and low forwarding delay are important; OLSR is well suited to dense, continuously active

deployments because multipoint relays reduce redundant link-state dissemination; DSR is efficient for smaller or intermittently used networks in which cached paths remain valid; and AODV offers a balanced compromise under broader mobility and load conditions. These conclusions should not be read as absolute rankings. A protocol that produces the highest PDR in one configuration may also impose unacceptable delay or routing overhead in another. For future experimental work, the proposed design can be extended by adding energy consumed per delivered bit, jitter, route acquisition time, TCP traffic, heterogeneous node speeds, and more realistic propagation or obstacle models. The strongest final study would publish simulator version, source code, seed values, and raw trace summaries so that other researchers can reproduce the results. Such reproducibility is especially important in MANET

research because small scenario changes can materially alter protocol performance. From an application-selection perspective, the comparison can be converted into a decision process. Emergency-response teams with frequent movement and intermittent communication should prioritize route recovery and delivery reliability, making AODV a strong baseline candidate. A compact temporary network with few active sessions may benefit from DSR because route discovery occurs only when needed and cached paths can be reused. In contrast, a dense tactical or campus-style network carrying continuous traffic can justify OLSR's periodic state maintenance because routes are immediately available and MPRs limit redundant flooding. DSDV remains useful as a simple proactive reference and can be competitive when mobility is low enough that update traffic does not dominate channel capacity. These recommendations should always be verified with the actual traffic pattern and mobility trace of the intended deployment. The methodology also has limitations. Random Waypoint and Random Walk are convenient but do not fully represent group mobility, road-constrained movement, obstacles, shadowing, or correlated human motion. UDP/CBR traffic makes packet-level comparison easy, yet real applications may use TCP, voice, video, or bursty sensor traffic whose transport-layer interactions change delay and throughput. A fixed transmission range also abstracts interference and fading. For this reason, a high-quality follow-up study should repeat the same protocol comparison under at least one additional mobility model and one more realistic propagation model before making deployment claims. Finally, the statistical treatment is as important as the simulator configuration. Reporting only one run or one average can hide substantial random variation. Confidence intervals, multiple seeds, paired scenario traces, and effect sizes make it possible to distinguish a real protocol difference from simulation noise. Publishing the exact configuration and analysis script further turns the comparison into a reproducible experiment rather than an isolated benchmark. This is the main methodological lesson of the study: fair protocol evaluation depends on controlled scenario design, transparent metrics, and cautious interpretation of trade-offs.

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