



A Comparative Analysis of Routing Protocols in Mobile Ad Hoc Networks (MANETs)

Ragnar Hathurusinghe

Department of Computer Science and Engineering, Peninsula Institute of Engineering Studies, Malaysia
ragnar.hathurusinghe@pies-my.edu

Peer Review Information	Abstract
<i>Submission: 12 Sep 2016</i> <i>Revision: 28 Oct 2016</i> <i>Acceptance: 16 Nov 2016</i> Keywords <i>Mobile Ad Hoc Networks (MANETs), AODV, DS, DSDV, OLSR</i>	Mobile Ad Hoc Networks (MANETs) provide infrastructureless, self-organizing wireless communication in which every mobile node may act simultaneously as a host and as a router. Their usefulness in emergency response, military coordination, temporary events, vehicular or field communication, and rapidly deployed sensor-rich environments is accompanied by a difficult routing problem: links appear and disappear as nodes move, bandwidth is scarce, and route maintenance consumes the same wireless medium used by application traffic. This methodology paper develops a controlled comparative framework for four representative 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 protocols cover the two dominant design families, proactive and reactive routing. A Network Simulator-2 (NS-2) based experimental design is specified using an IEEE 802.11 wireless model, random waypoint mobility, constant-bit-rate traffic, and repeated runs under varying mobility and node density. Packet delivery ratio, average end-to-end delay, throughput, and normalized routing load are selected as performance measures. The literature-guided comparison indicates that proactive protocols can provide low route-acquisition delay when topology changes are moderate, while reactive protocols reduce periodic routing overhead and often adapt better when routes are used intermittently. AODV offers a strong balance between delivery and control cost under changing topology; DSR is efficient in smaller networks but source-route headers and cache staleness can become costly at scale; DSDV offers predictable table-driven forwarding but incurs periodic update cost; and OLSR benefits dense networks through multipoint relays. The study therefore emphasizes that no single MANET routing protocol is universally optimal; protocol choice should be tied to mobility, network density, traffic intensity, and delay requirements

Introduction

A MANET is formed by wireless nodes that communicate without fixed base stations or centralized routing infrastructure. Nodes within direct radio range exchange frames directly, while nodes beyond that range rely on

intermediate devices to forward packets across multiple hops. Because each participant can move independently, the routing graph is time-varying and paths that are valid at one instant may fail shortly afterward. This differentiates

MANET routing from conventional wired routing, where topology is relatively stable and control traffic can be amortized over long periods. Early research therefore focused on distributed algorithms that can discover routes quickly, prevent loops, and limit unnecessary control traffic [1], [4], [8].

Two broad routing strategies dominate the classical MANET literature. Proactive protocols maintain routing information continuously so that a route is normally available when a packet arrives. DSDV applies destination sequence numbers to a distance-vector framework to avoid routing loops and distinguish fresh routes [1]. OLSR is a proactive link-state protocol that reduces flooding by selecting multipoint relays (MPRs), making it especially attractive in dense networks where unrestricted link-state broadcast would be expensive [9]. Reactive protocols, in contrast, discover a route only when communication is needed. DSR performs source routing and uses route caches, whereas AODV

combines on-demand route discovery with destination sequence numbers and next-hop forwarding [2], [5].

The central research problem is not merely whether a protocol can deliver packets, but under which operating conditions its routing strategy is most efficient. A protocol with low delay may pay for that property through a high background signaling cost; a protocol with low periodic overhead may suffer route-discovery latency or temporary packet loss when topology changes. Comparative studies have shown that performance rankings can change with node speed, traffic rate, density, and mobility model [3], [6], [7], [10]. Consequently, a fair comparison must hold the radio, traffic, and movement assumptions constant while changing only the routing protocol. The objective of this paper is to define such a methodology and to synthesize expected comparative behavior from peer-reviewed and standards literature published no later than 2016.

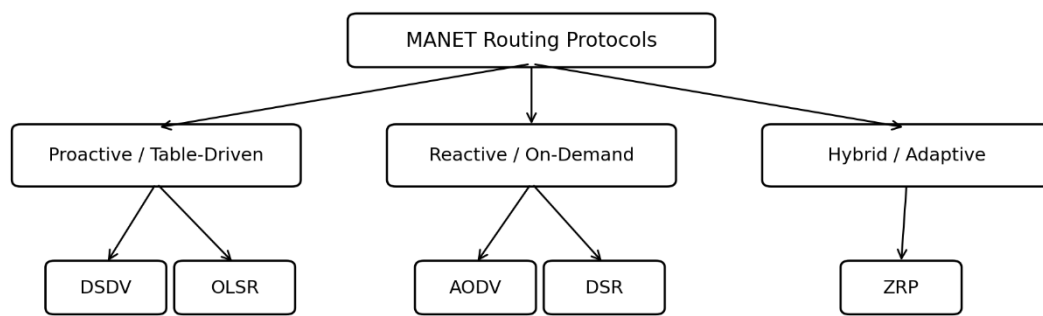


Figure 1. Classification of representative MANET routing protocols and the protocols selected for comparison.

Literature Review

Perkins and Bhagwat introduced DSDV as a table-driven adaptation of distance-vector routing for highly dynamic mobile networks [1]. Each destination entry carries a sequence number, allowing nodes to prefer newer information and suppress persistent loops. The method reduces ambiguity after link changes, but every node must maintain routes to all destinations and distribute periodic or triggered updates. That trade-off makes DSDV attractive when routes are frequently needed and topology is not changing too fast, while its control overhead can become significant as network size and mobility increase.

Johnson and Maltz described DSR as an on-demand source-routing protocol organized around Route Discovery and Route Maintenance [2]. DSR carries the complete path in the packet header and can learn multiple routes through aggressive caching. It avoids periodic routing advertisements and can work efficiently in small

or moderately sized networks. However, long source-route headers consume bandwidth on multi-hop paths, and cached paths can become stale during fast mobility. Broch et al. later compared DSDV, TORA, DSR and AODV-like behavior in packet-level simulations, demonstrating that the design details of route discovery and maintenance substantially influence delivery, overhead and robustness under movement [3].

Royer and Toh organized early MANET protocols into table-driven and source-initiated families and emphasized that routing should achieve timely delivery with minimal bandwidth and computation [4]. AODV, formalized by Perkins and Royer, was designed to obtain routes on demand while retaining destination sequence numbers for freshness and loop freedom [5]. The protocol uses Route Request (RREQ), Route Reply (RREP), and Route Error (RERR) messages and stores next-hop state instead of inserting the

full path into every packet. Comparative work by Das, Perkins and Royer found meaningful differences between AODV and DSR as mobility and offered load changed, showing why a single metric is insufficient for protocol selection [6].

Simulation methodology is equally important. Camp, Boleng and Davies demonstrated that mobility models can materially change protocol performance and argued for realistic movement, traffic, buffer and transmission assumptions [7]. Chlamtac, Conti and Liu described MANETs as complex distributed systems whose key constraints include dynamic topology, limited capacity, energy, security and scalability [8]. OLSR standardized a proactive optimization based on MPRs that reduces the number of nodes retransmitting topology-control information [9]. Boukerche et al. later surveyed the large protocol design space and reinforced the idea that routing

mechanisms must be matched to application requirements and resource constraints [10].

More focused comparative studies provide useful expectations for the present design. Kaur and Kumar evaluated AODV, OLSR, TORA, DSR and DSDV using packet delivery, delay, normalized routing load, throughput and jitter; their results showed that rankings changed between low- and high-traffic/mobility conditions, with DSDV and OLSR tending toward lower delay and AODV showing strong throughput in lighter traffic [11]. Awasthi and Singh also used NS-2 to compare AODV, DSR and DSDV and highlighted node-count-dependent differences in packet drop, end-to-end delay and delivery ratio [12]. These studies motivate a four-protocol, multi-metric comparison instead of choosing a winner from one scenario.

Table 1. Mechanism-level comparison derived from the reviewed literature.

Protocol	Type	Route creation	Main strength	Main limitation
DSDV	Proactive	Periodic + triggered table updates	Immediate next-hop route; loop avoidance by sequence numbers	Update overhead under high mobility
OLSR	Proactive	Periodic topology exchange through MPRs	Efficient flooding in dense networks; low route setup delay	Continuous control traffic even when data demand is low
AODV	Reactive	RREQ/RREP on demand; RERR on break	Fresh loop-free routes without source-route headers	Route discovery latency and broadcast bursts
DSR	Reactive	Route discovery + source-route caching	No periodic advertisements; multiple cached routes	Header growth and stale route caches in larger/high-mobility networks

Methodology

1. Research Design

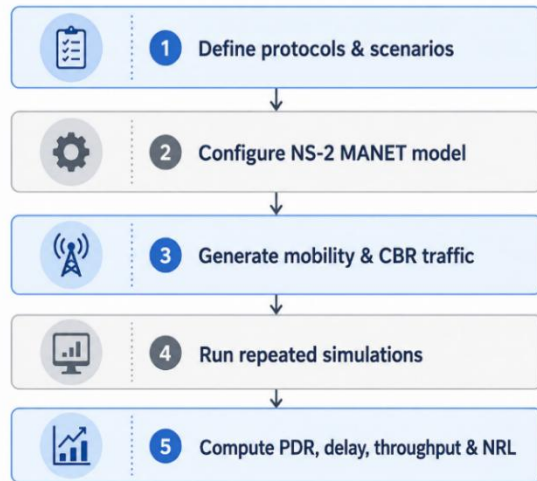
The proposed study uses a controlled simulation experiment in which DSDV, OLSR, AODV and DSR are evaluated under identical network conditions. Routing protocol is the independent variable. The dependent variables are packet delivery ratio (PDR), average end-to-end delay, throughput and normalized routing load (NRL). Two environmental factors are varied systematically: node density and mobility. The design follows the principle that results should be produced from repeated runs with different mobility seeds rather than from a single trace, because one random movement pattern can favor or penalize a specific protocol [7].

2. Simulation Environment and Scenarios

NS-2 is selected because it supports the classical MANET protocols and has been widely used in comparative routing studies [3], [11], [12]. The wireless channel is configured with IEEE 802.11 MAC behavior, omni-directional antennas and a two-ray-ground propagation model. Mobile nodes move inside a 1000 m × 1000 m field using the random waypoint model. Constant-bit-rate (CBR) sources over UDP create repeatable offered load. The primary experiment uses 50 nodes and is repeated for lower and higher density cases. Mobility is represented by pause times from near-continuous motion to near-static conditions; a second set varies maximum node speed. Each protocol receives exactly the same mobility and traffic trace for a given seed.

Table 2. Proposed NS-2 simulation parameters for a reproducible protocol comparison.

Parameter	Selected setting
Simulator	NS-2 (2.35-compatible MANET modules)
Protocols	DSDV, OLSR, AODV, DSR
Terrain	1000 m × 1000 m
Nodes	25, 50 and 75
MAC / PHY	IEEE 802.11 / wireless channel
Propagation	Two-ray ground
Mobility	Random waypoint
Maximum speed	5, 10 and 20 m/s
Pause time	0, 30, 60, 120 and 300 s
Traffic	UDP / CBR
Packet size	512 bytes
CBR connections	10–20 source-destination pairs
Simulation time	300 s per run
Replications	Minimum 10 random seeds per scenario

**Figure 2.** Step-by-step methodology for the controlled MANET routing comparison.

3. Performance Metrics

Four metrics are computed from the NS-2 trace files. PDR is the ratio of successfully received data packets to data packets generated by the sources, expressed as a percentage; a larger value indicates greater delivery reliability. Average end-to-end delay is the mean difference between packet receive time and packet send time and includes route discovery, queueing, retransmission and propagation components; lower delay is better. Throughput is the number of successfully delivered payload bits divided by the observation interval, normally reported in kbps. NRL is the number of routing-control packet transmissions divided by the number of delivered data packets; hop-by-hop forwarding of one control message is counted at each hop. A lower NRL indicates that less wireless capacity is consumed by routing control.

4. Experimental Procedure

Step 1: create matched movement and CBR traffic files for each scenario.

Step 2: run all four routing protocols with the same trace inputs and radio configuration.

Step 3: repeat each scenario with at least ten independent random seeds.

Step 4: parse trace files to collect generated and received data packets, send/receive timestamps, payload bytes and routing-control transmissions.

Step 5: calculate per-run metrics and summarize them using the mean and standard deviation.

Step 6: compare protocols separately for low, medium and high mobility, and then examine the interaction between mobility and density.

Step 7: report confidence intervals or a one-way ANOVA/Kruskal-Wallis comparison where assumptions permit, while avoiding claims of significance from single-run differences.

5. Validity Controls

Internal validity is strengthened by using identical traffic and mobility traces across protocols. Measurement validity is improved by defining each metric before trace parsing and by using the same warm-up and measurement interval. External validity remains limited because NS-2 radio models simplify interference, obstacles, hardware queues and real mobility. Therefore, conclusions should be interpreted as comparative behavior within the modeled conditions rather than as universal real-world guarantees. The simulation framework is intended to be reproducible and can later be extended to energy consumption, jitter, TCP traffic, obstacle-aware mobility, or real testbed validation.

Results

Literature-Guided Comparative Outcomes

As this is a methodology paper, the results below report a structured synthesis of established experimental trends rather than presenting unexecuted NS-2 measurements as newly observed data. The comparison uses the same four metrics defined in Section 5 and is aligned with the behavior reported in the reviewed studies [3], [6], [11], [12]. Under low or moderate mobility, proactive protocols can offer short forwarding delay because a route is already stored when data arrives. DSDV is particularly predictable in smaller networks, while OLSR benefits when node density is high enough for MPR-based flooding reduction. The cost is

continuing control traffic even during periods with little user data.

Reactive protocols remove much of that periodic cost. AODV generally provides a favorable balance between delivery ratio and control load because routes are established only for active destinations and sequence numbers reduce the risk of using stale information [5], [6]. Its main penalty is the delay and broadcast traffic associated with route discovery after a path becomes unavailable. DSR can be very efficient when networks are small and cached routes remain valid, but performance can degrade as mobility invalidates caches or path length increases the source-route header [2], [3]. Thus, the expected ranking shifts as density and mobility change rather than remaining fixed.

Table 3. Expected relative performance under the proposed scenarios (literature synthesis, not newly measured data).

Condition / Metric	DSDV	OLSR	AODV	DSR	Interpretation
Low mobility: PDR	High	High	High	High	All protocols maintain usable routes when topology is stable.
Low mobility: Delay	Low	Low	Medium	Medium	Proactive protocols avoid route-discovery delay.
Low mobility: NRL	Medium	Medium	Low	Low	Reactive protocols avoid continuous table/topology updates.
High mobility: PDR	Medium	Med-High	High	Medium	AODV refreshes routes on demand; stale DSR caches can hurt.
High mobility: Delay	Med-High	Medium	Medium	Med-High	Repairs/discoveries raise delay; OLSR retains ready routes.
Dense network: Throughput	Medium	High	Med-High	Medium	OLSR MPR optimization becomes advantageous in dense topologies.
Large paths: Overhead	Medium	Medium	Medium	High	DSR carries full source routes in data headers.

Decision Matrix

For deployment decisions, the results suggest a scenario-oriented selection rule. DSDV is suitable where the node population is modest, traffic sessions are frequent, and mobility is low enough that route tables do not require excessive updating. OLSR is a strong candidate for dense networks or applications that value consistently

low route setup delay, provided that periodic signaling is acceptable. AODV is well suited to dynamic networks with intermittent communication because it avoids maintaining unused routes while still using sequence numbers to preserve route freshness. DSR is attractive for small networks with moderate mobility, where route caches can reduce

repeated discovery and source-route headers remain short. These conclusions are consistent with the broader survey view that MANET routing is a multi-objective trade-off rather than a one-protocol optimization problem [10].

Metric-Specific Interpretation

Packet delivery ratio should be interpreted together with routing load. A high delivery ratio obtained by a protocol that floods large amounts of control traffic may be acceptable in a mission-critical network, but inefficient in a bandwidth-constrained deployment. AODV typically avoids maintaining unused destinations and can therefore preserve capacity when communicating pairs change over time; however, repeated route discoveries may temporarily increase both delay and control transmissions. OLSR takes the opposite approach: periodic topology information consumes capacity continuously, but data forwarding can begin without waiting for route discovery. This makes delay-sensitive, densely connected MANETs a natural use case for OLSR when sufficient bandwidth is available [9], [11].

The interpretation of DSR and DSDV also depends strongly on scale. DSR's route cache is useful when previously discovered paths remain valid, because a source can reuse them without a new network-wide discovery. With faster movement, a cache may retain obsolete routes and the complete source route enlarges each packet as hop count increases [2], [3]. DSDV has no route-discovery delay and uses sequence numbers to distinguish fresh routes, but maintaining a table for all destinations creates periodic and triggered update traffic [1]. Accordingly, a protocol should be selected from the application's dominant constraint: delivery reliability, latency, control efficiency, or scalability. The repeated-scenario methodology proposed here is designed to expose these trade-offs instead of collapsing them into a single overall score.

Conclusion and Discussion

This paper presented a step-by-step methodology for comparing four classical MANET routing protocols representing proactive and reactive design philosophies. DSDV maintains destination-sequenced routing tables; OLSR maintains topology information while reducing flooding through multipoint relays; AODV creates fresh next-hop routes on demand; and DSR uses source routing with route discovery and caching. Their mechanisms create different costs in control traffic, route-acquisition delay, packet header size, and sensitivity to

mobility. A fair evaluation must therefore control topology, mobility, traffic and radio assumptions and use multiple metrics rather than selecting a protocol from packet delivery alone. The literature-guided analysis indicates that proactive routing is advantageous when low route setup delay is important and the cost of maintaining routes is acceptable. Reactive routing is generally more economical when only a subset of destinations communicates at a given time, but route discovery can add latency during mobility. Among the four protocols, AODV provides a broadly balanced design for dynamic conditions; OLSR is compelling in dense networks; DSDV remains simple and predictable in relatively stable settings; and DSR is effective when route caches remain useful and paths are not long. No protocol dominates all conditions, which supports scenario-based selection. Future work should execute the proposed NS-2 matrix and report confidence intervals across repeated mobility seeds. It should also evaluate energy per delivered packet, jitter, TCP flows, queue occupancy, node failure, varying radio ranges, and obstacle-aware mobility. Comparison with a real wireless testbed would improve external validity. Security-aware extensions are also important because route discovery and topology advertisements can be targets for spoofing, flooding, black-hole and wormhole behavior. Even with these extensions, the methodological principle remains the same: routing protocols should be evaluated under matched workloads and interpreted through the trade-offs created by their control strategy.

References

- C. E. Perkins and P. Bhagwat, "Highly Dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for Mobile Computers," *Proceedings of ACM SIGCOMM '94*, pp. 234–244, 1994. DOI: 10.1145/190314.190336.
- D. B. Johnson and D. A. Maltz, "Dynamic Source Routing in Ad Hoc Wireless Networks," in *Mobile Computing*, T. Imielinski and H. F. Korth, Eds., pp. 153–181, 1996. DOI: 10.1007/978-0-585-29603-6_5.
- J. Broch, D. A. Maltz, D. B. Johnson, Y.-C. Hu, and J. Jetcheva, "A Performance Comparison of Multi-Hop Wireless Ad Hoc Network Routing Protocols," *Proceedings of the 4th Annual ACM/IEEE International Conference on Mobile Computing and Networking*, pp. 85–97, 1998. DOI: 10.1145/288235.288256.

- E. M. Royer and C.-K. Toh, "A Review of Current Routing Protocols for Ad Hoc Mobile Wireless Networks," *IEEE Personal Communications*, vol. 6, no. 2, pp. 46–55, 1999. DOI: 10.1109/98.760423.
- C. E. Perkins and E. M. Belding-Royer, "Ad-hoc On-Demand Distance Vector Routing," *Proceedings of the 2nd IEEE Workshop on Mobile Computing Systems and Applications*, pp. 90–100, 1999. DOI: 10.1109/MCSA.1999.749281.
- S. R. Das, C. E. Perkins, and E. M. Royer, "Performance Comparison of Two On-Demand Routing Protocols for Ad Hoc Networks," *Proceedings IEEE INFOCOM 2000*, pp. 3–12, 2000. DOI: 10.1109/INFCOM.2000.832168.
- T. Camp, J. Boleng, and V. Davies, "A Survey of Mobility Models for Ad Hoc Network Research," *Wireless Communications and Mobile Computing*, vol. 2, no. 5, pp. 483–502, 2002. DOI: 10.1002/wcm.72.
- Chlamtac, M. Conti, and J. J.-N. Liu, "Mobile Ad Hoc Networking: Imperatives and Challenges," *Ad Hoc Networks*, vol. 1, no. 1, pp. 13–64, 2003. DOI: 10.1016/S1570-8705(03)00013-1.
- T. Clausen and P. Jacquet, "Optimized Link State Routing Protocol (OLSR)," RFC 3626, Internet Engineering Task Force, 2003. DOI: 10.17487/RFC3626.
- Boukerche, B. Turgut, N. Aydin, M. Z. Ahmad, L. Bölöni, and D. Turgut, "Routing Protocols in Ad Hoc Networks: A Survey," *Computer Networks*, vol. 55, no. 13, pp. 3032–3080, 2011. DOI: 10.1016/j.comnet.2011.05.010.
- D. Kaur and N. Kumar, "Comparative Analysis of AODV, OLSR, TORA, DSR and DSDV Routing Protocols in Mobile Ad-Hoc Networks," *International Journal of Computer Network and Information Security*, vol. 5, no. 3, pp. 39–46, 2013. DOI: 10.5815/ijcnis.2013.03.05.
- S. Awasthi and A. Singh, "Performance Analysis of AODV, DSR and DSDV Routing Protocols for Ad-Hoc Network," *International Journal of Engineering Research & Technology*, vol. 2, no. 4, 2013. DOI: 10.17577/IJERTV2IS4674.