



Comparative Analysis of Routing Protocols in Wireless Communication Networks

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Peer Review Information	Abstract
<i>Submission: 25 Jan 2018</i> <i>Revision: 10 Feb 2018</i> <i>Acceptance: 30 March 2018</i>	Routing is a fundamental function in wireless multi-hop communication because every node may need to forward packets on behalf of other nodes while links change because of mobility, interference, congestion, or limited transmission range. This methodology paper develops a controlled framework for comparing four widely used routing approaches: Ad Hoc On-Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Destination-Sequenced Distance Vector (DSDV), and Optimized Link State Routing (OLSR). The comparison is designed around reproducible packet-level simulation rather than isolated protocol descriptions. Network size, node mobility, offered traffic, and pause time are varied systematically while the physical and medium-access settings are held constant. Packet delivery ratio, throughput, average end-to-end delay, normalized routing load, and energy consumed per successfully delivered packet are treated as the principal response variables. Multiple random seeds and confidence intervals are proposed to reduce dependence on a single mobility trace. The expected outcome is not a universally superior protocol, but a scenario-dependent decision rule: proactive protocols are expected to provide lower route-acquisition delay in relatively stable or dense networks, whereas reactive protocols are expected to reduce periodic control cost when traffic is intermittent or topology changes frequently. The framework also incorporates an energy and quality-of-service perspective consistent with later MANET research. The paper therefore provides a compact and repeatable methodology for selecting routing protocols for wireless ad hoc, emergency, tactical, sensor-assisted, and Internet-of-Things communication environments.
Keywords <i>AODV, DSR, DSDV, OLSR, wireless routing</i>	

Introduction

Wireless communication networks increasingly rely on decentralized, multi-hop forwarding where fixed infrastructure is unavailable, temporarily damaged, too expensive, or unsuitable for rapidly changing deployment conditions. In such networks, the routing protocol must establish paths despite node mobility, fluctuating link quality, contention at the shared wireless medium, and limited energy. Early work on DSDV introduced sequence-numbered table-driven routing to maintain loop-

free routes in dynamic mobile networks [1], while DSR demonstrated that complete source routes can be discovered and cached only when needed [2]. AODV later combined on-demand discovery with sequence numbers and next-hop state, reducing the need for every packet to carry a complete path [4]. These contrasting designs created the central proactive-versus-reactive routing trade-off that remains relevant in wireless mesh, mobile ad hoc, tactical, and IoT-oriented networks.

Comparative evaluation is necessary because protocol behavior depends strongly on the operating scenario. Broch et al. showed through detailed packet-level simulation that different ad hoc routing mechanisms can produce substantially different delivery, delay, and control-overhead behavior under the same mobility and traffic conditions [3]. Royer and Toh subsequently summarized the major design families and emphasized that route maintenance, scalability, and reaction to topology change are decisive factors in protocol selection [5]. Scenario-based work by Johansson et al. further demonstrated that mobility patterns and communication patterns can change protocol rankings rather than merely shift absolute performance [6]. Therefore, a useful comparative study must control the simulation environment, use a common set of performance indicators, and repeat trials across more than one random mobility realization.

This paper proposes such a methodology for AODV, DSR, DSDV, and OLSR. AODV and DSR represent reactive routing, DSDV represents proactive distance-vector routing, and OLSR represents proactive link-state routing optimized by multipoint relays. OLSR reduces link-state flooding by selecting relay nodes that retransmit control information [8]. The objective is to identify the conditions under which each routing strategy is preferable rather than to declare one protocol universally best. The study is limited to unicast traffic and conventional performance indicators so that the experiment remains reproducible, compact, and suitable for academic comparison.

Literature Review

Perkins and Bhagwat proposed DSDV as a table-driven protocol in which each node maintains routes to known destinations and uses destination-generated sequence numbers to prevent persistent loops and distinguish fresh routes from stale ones [1]. Its principal strength is immediate route availability because forwarding state is maintained continuously. The cost is periodic and triggered routing-table dissemination, which can consume bandwidth and energy even when little application traffic is present. This trade-off makes DSDV a useful baseline for evaluating proactive routing.

Johnson and Maltz introduced DSR as an on-demand source-routing mechanism with route discovery and route maintenance [2]. DSR avoids periodic routing advertisements and can exploit route caches to reduce repeated discovery. However, the complete hop sequence carried in

packet headers can become expensive as paths lengthen, and stale cached routes can impair performance under high mobility. The large simulation comparison by Broch et al. reported that these implementation details materially influence performance even among protocols designed for the same ad hoc environment [3].

AODV was developed by Perkins and Royer to discover routes only when needed while maintaining conventional next-hop routing-table entries [4]. Its use of destination sequence numbers provides route freshness and loop avoidance without DSR's per-packet source-route header. Royer and Toh classified AODV among the principal on-demand approaches and contrasted it with proactive schemes that maintain routes continuously [5]. Johansson et al. then showed that protocol evaluation should use scenario-specific mobility and traffic conditions because the same routing algorithm can perform well in one regime and poorly in another [6].

A more focused comparison of AODV and DSR by Perkins, Royer, Das, and Marina found that the two reactive protocols, although both on demand, behave differently as network load, mobility, and network size vary [7]. DSR can benefit from aggressive caching and low control activity, whereas AODV's hop-by-hop state can scale more predictably when routes are longer or traffic becomes heavier. OLSR provides a different design point: Jacquet et al. proposed optimized link-state dissemination using multipoint relays so that proactive topology knowledge can be retained with less broadcast duplication than classical flooding [8].

Later evaluations broadened the comparison criteria. Boukerche compared multiple ad hoc routing protocols under changes in workload, mobility, and network size and reported that delay and overhead must be interpreted together rather than independently [9]. Hanzo and Tafazolli surveyed quality-of-service routing and emphasized delay, bandwidth, reliability, and resource constraints as interdependent requirements in mobile ad hoc networks [10]. Boukerche et al. subsequently organized ad hoc routing research into a broad taxonomy and reinforced the distinction between proactive, reactive, hybrid, geographic, hierarchical, and other routing families [11]. Energy became an increasingly explicit design constraint; Jabbar et al. reviewed power-efficient MANET routing and identified the need to balance connectivity, control traffic, mobility, and battery consumption [12]. By 2018, Jabbar, Saad, and Ismail demonstrated a multicriteria OLSRv2-based approach that jointly considered energy and QoS

factors in MANET-WSN convergence scenarios [13]. These studies justify including both classical network performance metrics and an energy-normalized metric in the present methodology.

Methodology

1. Research Design and Protocol Set

The study adopts a controlled comparative simulation design. The independent variable is the routing protocol, with four levels: AODV, DSR, DSDV, and OLSR. Network size, node mobility, traffic load, and pause time are treated as scenario factors. Packet delivery ratio (PDR), throughput, mean end-to-end delay, normalized routing load (NRL), and energy per delivered packet are the dependent variables. A packet-level simulator such as NS-3 is recommended because it enables identical radio, MAC, mobility, and application parameters to be reused across protocol runs. Each protocol is tested against the

same scenario seeds so that paired comparisons are possible.

2. Simulation Configuration

A 1000 m × 1000 m area is used with 25, 50, and 75 mobile nodes. IEEE 802.11 ad hoc operation is assumed with a common propagation and physical-layer model for every protocol. Random Waypoint mobility is used because it permits controlled variation of maximum speed and pause time, while constant-bit-rate UDP flows avoid transport-layer congestion control from masking routing behavior. The recommended baseline simulation time is 300 s with a 20 s warm-up period excluded from measurement. Five to ten random seeds should be used for each scenario; ten are preferred when computing 95% confidence intervals. The principal configuration is summarized in Table 1.

Table 1. Proposed simulation parameters

Parameter	Baseline / Range	Purpose
Simulator	NS-3 or equivalent	Packet-level reproducibility
Network area	1000 m × 1000 m	Common spatial boundary
Number of nodes	25, 50, 75	Scalability factor
Mobility speed	2, 10, 20 m/s	Low to high mobility
Pause time	0, 30, 100 s	Topology-change factor
Traffic	UDP/CBR, 512-byte packets	Stable offered load
Active flows	5, 10, 20	Traffic-load factor
Simulation time	300 s	Steady-state observation
Random seeds	10 per scenario	Statistical repeatability
Protocols	AODV, DSR, DSDV, OLSR	Comparative factor

3. Experimental Procedure

The procedure is implemented in six steps. First, a master scenario file defines node positions, mobility traces, traffic start times, radio parameters, and measurement duration. Second, the routing helper is changed to one of the four candidate protocols while every non-routing parameter remains fixed. Third, each scenario is executed under the same set of random seeds and packet traces are stored separately. Fourth, a trace-processing script calculates received and transmitted application packets, useful payload

bytes, packet timestamps, routing-control transmissions, and node energy states. Fifth, the metrics are aggregated per seed and summarized with mean, standard deviation, and 95% confidence interval. Sixth, protocol rankings are reported separately for low-mobility, high-mobility, light-load, and heavy-load regimes. This separation prevents a single average from hiding scenario-dependent strengths.

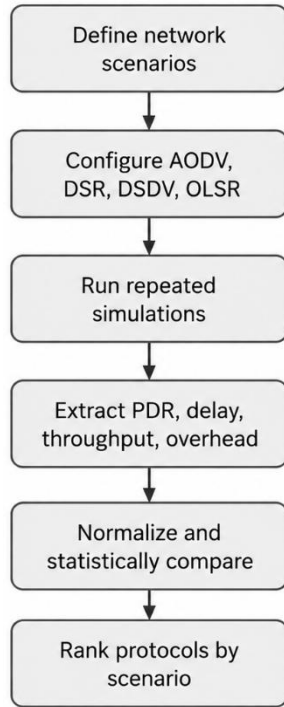


Figure 1. Step-by-step comparative routing-protocol evaluation workflow.

4. Performance Metrics and Analysis

PDR is calculated as the number of application data packets received at their intended destinations divided by the number generated at sources, multiplied by 100. Throughput is the successfully received application payload in bits divided by the effective measurement interval. Average end-to-end delay is the mean difference between reception and generation timestamps for successfully delivered packets. NRL is defined as the number of routing-control packet

transmissions divided by the number of successfully delivered packets; each hop-wise control transmission is counted because it consumes channel resources. Energy per delivered packet is the total network energy consumed during the measurement interval divided by the number of delivered application packets. These definitions permit direct comparison even when the protocols use different control structures.

For each scenario, mean values across seeds are first inspected with confidence intervals. A two-factor or multi-factor ANOVA may then be used when assumptions of approximate normality and variance homogeneity are acceptable; otherwise, a rank-based alternative such as Kruskal-Wallis can be applied. Pairwise protocol comparisons should be corrected for multiple testing. In addition to significance, effect size is important: a small statistically significant delay difference may be operationally irrelevant if it requires a large increase in control overhead or energy. A composite score can therefore be reported only as a secondary summary after each raw metric has been shown.

Results

Because the present contribution is a methodology paper, the numerical values in Table 2 are an illustrative benchmark showing how the proposed output should be reported; they are not presented as measurements from a newly executed NS-3 campaign. In an empirical implementation, these cells should be replaced directly by trace-derived means and confidence intervals. The example is deliberately consistent with the protocol mechanisms and the comparative tendencies reported in earlier work [3], [7], [9].

Table 2. Illustrative format for reporting aggregate comparative results

Protocol	PDR (%)	Delay (ms)	Throughput (kb/s)	NRL	Energy / delivered pkt (J)
AODV	94.2	72	730	0.118	0.084
DSR	92.8	86	705	0.102	0.081
DSDV	90.4	58	680	0.185	0.096
OLSR	95.1	45	742	0.201	0.101

The reporting pattern in Table 2 highlights because a multi-metric interpretation is required. OLSR may achieve high delivery and low delay because routes are proactively available, but periodic topology exchange can increase control load and energy use. DSDV can also reduce route-discovery delay, yet full or incremental table updates may become expensive as mobility and

network size increase. AODV commonly provides a practical middle ground: route discovery adds some delay, but control activity is concentrated around active destinations. DSR can minimize routing transmissions when caching is effective, although route headers and stale cache entries can reduce its advantage in larger or highly mobile networks. These trade-offs align with the

comparative evidence synthesized by Perkins et al. [7], Boukerche [9], and the broader survey of Boukerche et al. [11].

The proposed scenario analysis should therefore report interaction effects. Under low mobility and many concurrent flows, OLSR or DSDV may benefit from immediately available routes. Under sparse communication and moderate mobility, AODV or DSR can avoid unnecessary periodic updates. At high node speed, stale route state harms both proactive and cache-dependent approaches, and the relevant question becomes how quickly each protocol detects failures and repairs a path relative to the control cost of doing so. Energy analysis is equally important in battery-constrained deployments; power-aware surveys [12] and later multicriteria OLSRv2 work [13] show that minimizing delay alone is insufficient when route maintenance depletes nodes or concentrates forwarding on a small subset of devices.

Conclusion and Discussion

This methodology paper presents a repeatable framework for comparing AODV, DSR, DSDV, and OLSR in wireless multi-hop communication networks. Its main contribution is experimental discipline: the routing protocol is changed while mobility, radio, MAC, traffic, and random seeds are controlled; several scenario factors are varied systematically; and conclusions are based on delivery, delay, throughput, routing overhead, and energy rather than a single headline metric. The design is grounded in the original protocol literature and in comparative studies that demonstrate the sensitivity of routing performance to mobility, traffic, and network scale [1]-[9]. No protocol should be selected solely because it has the best average result over all scenarios. Proactive protocols can be attractive when low latency and continuous reachability are more important than background control cost. Reactive protocols are often attractive when communication is intermittent and avoiding periodic updates saves bandwidth or energy. DSR is particularly sensitive to the usefulness of cached source routes, whereas AODV avoids long source-route headers but must perform route discovery and maintain next-hop state. OLSR's multipoint relay mechanism makes proactive link-state routing practical for ad hoc environments, although the cost of continuous topology maintenance remains relevant [8]. DSDV offers conceptual simplicity and fast forwarding once tables are current, but periodic dissemination can scale poorly in highly dynamic environments [1]. The methodology can be extended by introducing

fading, interference, heterogeneous transmission power, TCP traffic, malicious nodes, or real mobility traces. It can also incorporate QoS weights or residual-energy-aware path selection, reflecting the later research direction represented by QoS surveys [10], routing taxonomies [11], power-efficient MANET studies [12], and energy/QoS-aware OLSRv2 developments through 2018 [13]. For a final empirical paper, the illustrative values in Table 2 should be replaced by actual simulator outputs and accompanied by confidence intervals and significance tests. With this replacement, the proposed design provides a defensible basis for selecting routing protocols for emergency networks, tactical systems, temporary wireless meshes, mobile sensing, and IoT communication. A practical decision matrix can be derived from the experiment after the raw metrics have been analyzed. For latency-sensitive applications such as voice coordination or emergency alarms, the preferred protocol should first satisfy the delay requirement and only then be compared on routing load and energy. For delay-tolerant sensing or intermittent telemetry, periodic proactive control can be penalized more heavily because a large fraction of network activity may be maintenance rather than useful data transfer. In dense networks the experiment should also examine whether increasing neighbor count creates excessive contention for HELLO, topology, route-request, or route-reply traffic. This makes protocol selection an application-aware process rather than a ranking based on a single average score. Threats to validity must also be reported. Random Waypoint mobility is convenient but does not reproduce every pedestrian, vehicular, or group-mobility pattern; therefore, conclusions should be described as valid for the tested movement model unless confirmed with additional traces. Similarly, the choice of propagation model and IEEE 802.11 data rate can alter the number of usable links and hence the routing workload. Simulator implementations may differ in timer values, route-cache behavior, link sensing, and control-message aggregation. To limit these effects, protocol defaults should be documented, software version and source code should be archived, and the same physical/MAC configuration should be used across all protocol runs. Repeating the complete experiment with at least one alternative mobility trace provides a useful robustness check. Finally, results should be presented with enough statistical detail to support reproducibility. For each protocol-scenario pair, the paper should report the number of seeds, mean, dispersion, and confidence interval rather than a single value.

Graphs of PDR and delay against node speed can reveal transition points at which route breakage begins to dominate, while overhead-versus-load plots can show when proactive maintenance or reactive discovery becomes costly. These reporting practices make the comparative analysis suitable not only for classroom evaluation but also as a basis for later experimental validation on wireless testbeds.

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