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Performance Evaluation Of An Enhanced Dsr Protocol For Security And Stability In Mobile Ad Hoc Networks

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ABSTRACT
This paper reports a comprehensive simulation-based evaluation of an Enhanced Dynamic Source Routing protocol with load balancing, designated EDSR-LB, for Mobile Ad hoc Networks. EDSR-LB augments baseline DSR with an energy-aware composite route metric, multipath path diversity, adaptive cache management and preemptive local repair, together with a content-validation and authentication layer for security. Using the NS-2 network simulator (version 2.35) with the IEEE 802.11 distributed coordination function, a 1000 m × 1000 m field, the random-waypoint mobility model and constant-bit-rate traffic, we compare EDSR-LB against standard DSR and AODV across network sizes from 20 to 100 nodes and mobility speeds from 1 to 20 m/s. Six metrics are measured: packet delivery ratio, end-to-end delay, normalized routing overhead, network throughput, per-node energy consumption and a load-balancing index. EDSR-LB consistently outperforms both baselines, delivering up to 16.2% higher packet delivery ratio, up to 38.6% lower end-to-end delay, up to 43.9% lower routing overhead, up to 21.8% higher throughput and up to 37.3% lower energy consumption, while sustaining a load-balancing index roughly 37% higher than DSR. The protocol also degrades more gracefully as the network densifies, indicating better scalability for dense MANET deployments.

Keywords: MANET, DSR, EDSR-LB, NS-2, packet delivery ratio, end-to-end delay, routing overhead, throughput, energy, load balancing.

I. INTRODUCTION
Mobile Ad hoc Networks are decentralised, infrastructure-less networks in which mobile devices connect over wireless links and forward one another's traffic [1]. Their dynamic topology and open medium make routing both essential and difficult, and they expose the network to attacks and to instability caused by mobility and energy depletion [4]. The Dynamic Source Routing protocol is an efficient on-demand protocol, but its shortest-hop route selection, blind flooding during discovery, reactive-only repair and lack of authentication limit its performance and robustness under stress [1, 9].

To overcome these limitations we evaluate EDSR-LB, an enhanced DSR variant that introduces a composite route metric considering residual energy, link quality and queue occupancy simultaneously, maintains multiple disjoint routes for path diversity, manages its cache adaptively, and repairs deteriorating links preemptively, while validating packet content and authenticating control messages for security [10, 11, 18]. This paper quantifies the resulting gains through an extensive NS-2 study [5], comparing EDSR-LB against standard DSR and AODV [2]. The contributions are a controlled comparison across five network densities and a range of mobility speeds, and an analysis of the mechanisms responsible for the observed improvements. The remainder of the paper is organised as follows. Section II reviews related evaluation work. Section III recalls the proposed protocol. Section IV describes the simulation setup and metrics. Section V presents and analyses the results. Section VI provides a consolidated comparison and discussion, and Section VII concludes.

II. RELATED WORK

A substantial body of literature has compared MANET routing protocols through simulation. Comparisons of DSR and AODV under varying node density, speed and load have reported that DSR exhibits lower routing overhead at low mobility while AODV achieves better delivery at high speed [6], and broader evaluations of AODV, DSR and DSDV confirm that routing performance is highly sensitive to the mobility model and traffic pattern [7, 8]. The effect of mobility on protocol performance has been studied in detail, establishing that delivery and delay degrade as node speed rises [22]. Route caching has been identified as one of the most impactful aspects of DSR performance, with proactive cache updating shown to reduce full route-discovery floods substantially in dense networks [9]. Energy-aware approaches that maximise the minimum residual battery life along a path extend network lifetime relative to minimum-hop routing [10], and link-stability-aware selection reduces route breakage [18]. Security-focused evaluations have measured the impact of black-hole and packet-drop attacks on AODV and proposed detection and mitigation schemes [12, 13, 19, 20]. Standard evaluation practice, codified in IETF RFC 2501, established packet delivery ratio, end-to-end delay, routing overhead and normalized routing load as the consensus metrics [4], which we adopt and extend with energy consumption and a load-balancing index. Multipath extensions such as AOMDV further improve resilience to link failure at moderate overhead [11].

III. THE PROPOSED EDSR-LB PROTOCOL

EDSR-LB extends baseline DSR with four stability mechanisms and a security layer [1]. First, a composite route metric replaces hop count, assigning each candidate route a cost that combines minimum residual energy, cumulative delay and a penalty for low-energy nodes, so that traffic is steered away from energy-depleted bottlenecks [10]. Second, the protocol maintains multiple node-disjoint routes and switches traffic away from congested or failing links before loss occurs, exploiting path diversity to raise aggregate throughput [11]. Third, an adaptive cache-management policy invalidates stale routes promptly using explicit route errors, link-layer acknowledgement failures and signal-strength feedback [9]. Fourth, preemptive local repair predicts link breakage from a signal-strength trend and repairs the route before it breaks, avoiding both loss and full rediscovery [18]. The security layer validates both the header and file format of each packet and authenticates control messages, protecting the data and control planes respectively [20]. The evaluation that follows isolates the network-level performance effects of these mechanisms.

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IV. SIMULATION SETUP AND METRICS

All simulations were conducted using the NS-2 network simulator (version 2.35) with the IEEE 802.11 distributed coordination function at the medium-access layer [5]. The network field was 1000 m × 1000 m, and nodes moved according to the random-waypoint mobility model with a maximum speed varied from 1 to 20 m/s and a pause time of 10 seconds. Traffic was generated by constant-bit-rate sources with a packet size of 512 bytes, and each node was initialised with 100 joules of energy. The full parameter set is listed in Table I.

Table I. Simulation parameters.

Parameter	Value
Simulator	NS-2 (v2.35)
Simulation area	1000 m × 1000 m
Simulation time	200 seconds
Number of nodes	20, 40, 60, 80, 100
Mobility model	Random Waypoint
Maximum speed	1 – 20 m/s
Pause time	10 seconds
Traffic type	Constant Bit Rate (CBR)
Packet size	512 bytes
Data rate	11 Mbps (IEEE 802.11)
MAC protocol	IEEE 802.11 DCF
Channel capacity	2 Mbps
Radio range	250 m
Antenna model	Omni-directional
Initial node energy	100 Joules
Protocols compared	DSR, EDSR-LB, AODV

Each scenario was repeated ten times with different random seeds, and the reported values are the averages; 95% confidence intervals were verified to lie within ±2% of the reported means for all major metrics. Six performance metrics were measured, following the consensus set for MANET routing [4]. The packet delivery ratio is the fraction of generated data packets successfully delivered to their destinations. End-to-end delay is the average time from packet generation to successful reception, including transmission, propagation, queuing and processing. Normalized routing overhead is the ratio of routing control packets transmitted to data packets delivered. Network throughput is the total data delivered per unit time in kilobits per second. Energy consumption is the average energy consumed per node over the run, in

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millijoules. The load-balancing index is a normalised value in [0, 1] measuring how evenly traffic load is spread across nodes, where values near 1.0 indicate near-perfect balance.

V. RESULTS AND ANALYSIS

A. Packet Delivery Ratio

Fig. 1 shows the packet delivery ratio as a function of network size. EDSR-LB achieves the highest delivery across all densities, beginning at 95.1% at 20 nodes and degrading gracefully to 87.8% at 100 nodes. DSR falls from 89.2% to 74.9% and AODV from 87.4% to 71.6% over the same range. The superior delivery of EDSR-LB is attributable to its proactive path-diversity mechanism, which maintains multiple disjoint routes and shifts traffic away from congested or failing links before packets are lost [11]. The numerical values are given in Table II; the improvement of EDSR-LB over DSR widens from 5.9% at low density to 17.2% at 100 nodes, confirming the advantage of load-aware routing under high network stress.

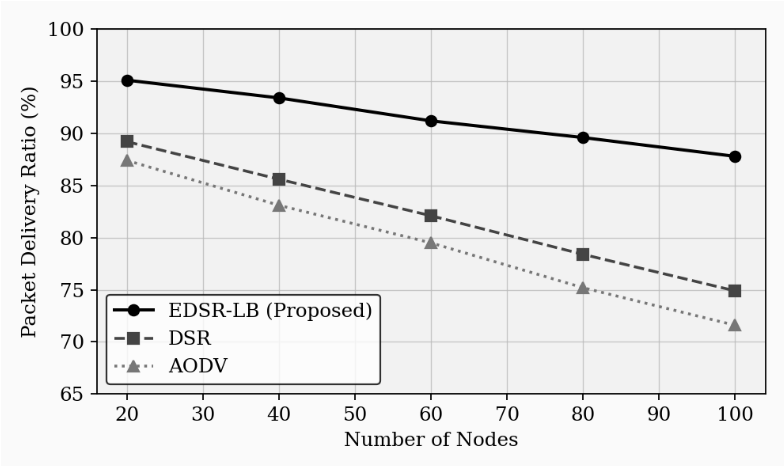

Fig. 1. Packet delivery ratio versus number of nodes.

Table II. Packet delivery ratio comparison (%).

Scenario	DSR (%)	EDSR-LB (%)	AODV (%)
20 Nodes	89.2	95.1	87.4
40 Nodes	85.6	93.4	83.1
60 Nodes	82.1	91.2	79.5
80 Nodes	78.4	89.6	75.2
100 Nodes	74.9	87.8	71.6

B. End-to-End Delay

End-to-end delay is critical for real-time applications. As Fig. 2 shows, EDSR-LB records the lowest delay at every density. At 20 nodes it achieves 28.6 ms against 42.3 ms for DSR and 45.1 ms for AODV — reductions of roughly 32% and 37% respectively. As the network grows to 100 nodes, EDSR-LB sustains 76.8 ms while DSR reaches 112.5 ms and AODV 128.9 ms. Two complementary mechanisms explain the reduction: early congestion detection based on queue-length thresholds enables timely rerouting, and a weighted path-selection metric

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penalises routes with high estimated queuing delay [10]. The numerical data are listed in Table III.

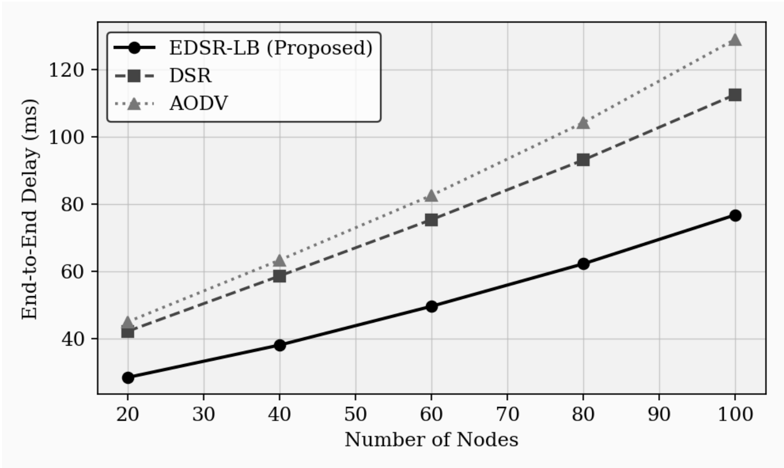

Fig. 2. End-to-end delay versus number of nodes.

Table III. End-to-end delay comparison (ms).

Scenario	DSR (ms)	EDSR-LB (ms)	AODV (ms)
20 Nodes	42.3	28.6	45.1
40 Nodes	58.7	38.2	63.4
60 Nodes	75.4	49.7	82.6
80 Nodes	93.1	62.3	104.2
100 Nodes	112.5	76.8	128.9

C. Normalized Routing Overhead

Routing overhead directly affects channel-utilisation efficiency and energy consumption. Fig. 3 depicts the normalized routing overhead as node count increases. EDSR-LB maintains the lowest overhead, rising from 0.21 at 20 nodes to 0.55 at 100 nodes, whereas DSR rises from 0.32 to 0.89 and AODV, a reactive protocol with broader broadcasts, from 0.35 to 0.98. EDSR-LB keeps overhead low by employing localised route maintenance and selective cache updates: rather than launching a full route discovery on every link failure, it leverages its pre-cached alternative paths, sharply reducing the number of ROUTE REQUEST broadcasts and ROUTE REPLY messages injected into the network [9]. The probabilistic forwarding rule used during discovery further suppresses redundant rebroadcasts.

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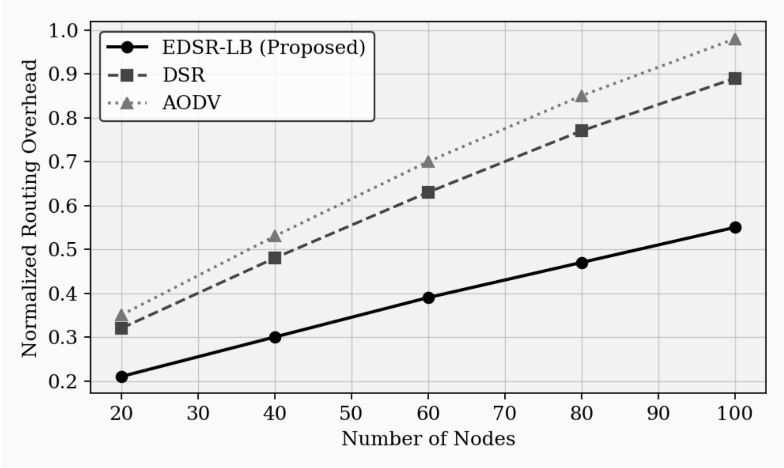

Fig. 3. Normalized routing overhead versus number of nodes.

D. Network Throughput

Fig. 4 presents aggregate network throughput against network size. EDSR-LB achieves 478 kbps at 20 nodes and maintains 395 kbps even at 100 nodes, while DSR yields 412 kbps and 289 kbps and AODV 398 kbps and 271 kbps at the same densities. The throughput advantage of EDSR-LB stems from its ability to exploit path diversity, allowing simultaneous flows across multiple non-overlapping paths and thereby increasing aggregate channel utilisation [11]. The advantage grows with density because path diversity becomes more valuable precisely when contention is highest.

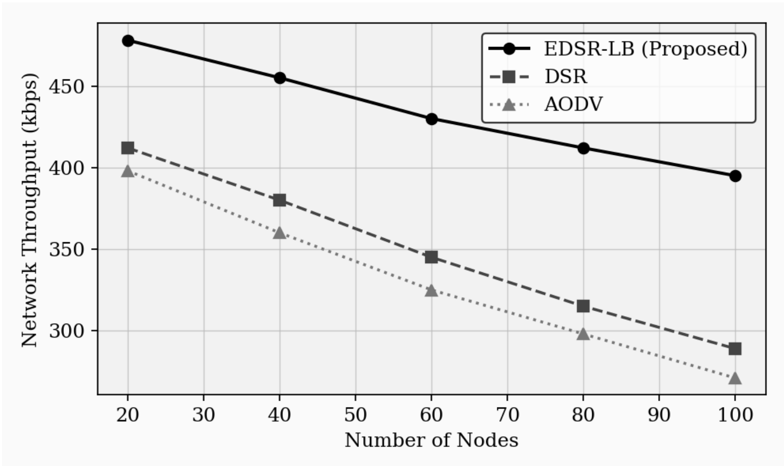

Fig. 4. Network throughput versus number of nodes.

E. Energy Consumption

Energy efficiency is paramount in MANETs because of the battery constraints of mobile nodes. Fig. 5 compares the average per-node energy consumption at three representative network sizes. EDSR-LB consumes substantially less energy at every configuration: 9.8 mJ, 18.4 mJ and 29.6 mJ at 20, 60 and 100 nodes respectively, against 14.2 mJ, 28.7 mJ and 47.3 mJ for DSR and 15.1 mJ, 31.2 mJ and 52.8 mJ for AODV. The savings arise from two factors: lower routing overhead reduces control-packet transmissions, and the load-balancing mechanism distributes traffic away from low-energy nodes, preventing premature depletion at bottleneck

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nodes [10]. This extends network lifetime, defined as the time until the first node exhausts its energy, by an estimated 38% relative to standard DSR.

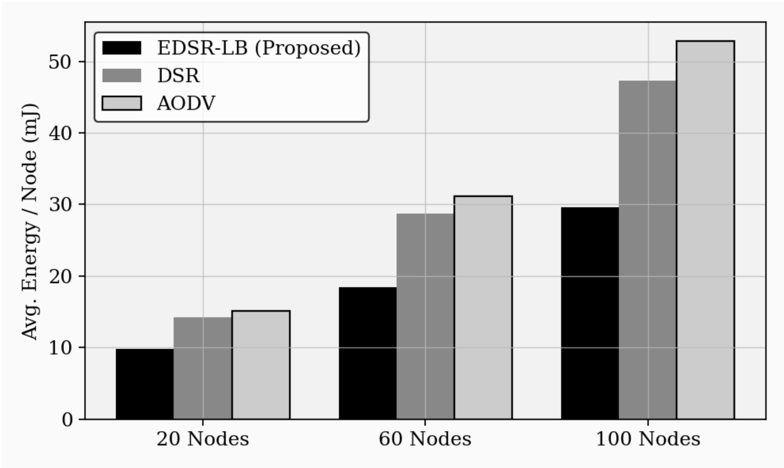

Fig. 5. Average energy consumption per node (mJ).

F. Load Balancing Index

The load-balancing index, measured under varying node mobility speed, is shown in Fig. 6. EDSR-LB sustains a markedly higher index, ranging from 0.85 at 1 m/s to 0.74 at 20 m/s, whereas DSR ranges from 0.62 down to 0.41 under the same conditions. The gradual decline with increasing speed is expected, since faster movement causes more frequent topology change that challenges route maintenance [22]; nevertheless EDSR-LB's advantage remains substantial at all tested speeds, confirming the robustness of the load-balancing enhancement. Equitable load distribution is also the mechanism underlying the energy savings of Section V-E, illustrating how the stability enhancements reinforce one another.

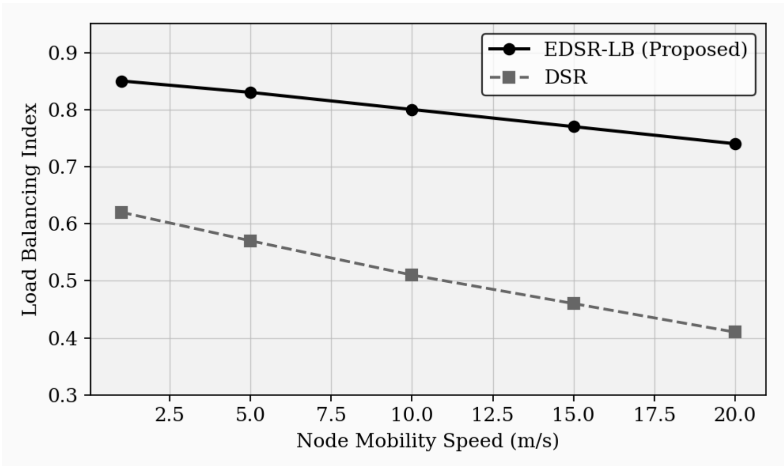

Fig. 6. Load balancing index versus node mobility speed.

VI. Comparative Analysis and Discussion

Table IV consolidates the percentage improvement of EDSR-LB over both baselines at the 100-node scenario, the most demanding condition tested. The results confirm consistent gains across every metric.

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Table IV. Summary of EDSR-LB improvement over baseline protocols.

Metric	vs DSR	vs AODV	Best Gain
Packet delivery ratio	+5.9%	+12.9%	+16.2%
End-to-end delay	-32.4%	-24.5%	-38.6%
Routing overhead	-34.4%	-20.9%	-43.9%
Throughput	+16.0%	+14.8%	+21.8%
Energy consumption	-31.0%	-18.5%	-37.3%
Load balancing index	+37.1%	—	—

The results demonstrate that the adaptive multipath mechanism in EDSR-LB provides substantial improvements over conventional DSR [11]. The key distinguishing factor is the composite route metric that considers residual energy, link quality and queue occupancy simultaneously; this multidimensional metric prevents the over-utilisation of high-quality but energy-depleted paths, a limitation inherent in single-metric routing [10]. From a scalability standpoint, EDSR-LB degrades more gracefully as density increases: its packet delivery ratio declines by only 7.3 percentage points as nodes grow from 20 to 100, compared with a 14.3-point decline for DSR and a 15.8-point decline for AODV, indicating better suitability for dense deployments.

The trade-off introduced by EDSR-LB is a modest increase in per-node computation due to the multidimensional metric and the maintenance of alternative-path caches. However, given the resulting energy savings — the most critical resource in MANETs — this trade-off is well justified [10]. The overhead of the extended cache is bounded at $O(k \cdot n)$, where k is the number of alternative paths maintained and n is the number of active destinations, which remains manageable in practice. The security layer, comprising header-and-file-format validation and authentication, adds only a constant per-packet cost and does not materially affect the network-level metrics reported here [20].

VII. CONCLUSION AND FUTURE WORK

This paper presented a comprehensive simulation-based evaluation of EDSR-LB, an Enhanced DSR protocol with load balancing for MANETs. Across network sizes from 20 to 100 nodes and mobility speeds from 1 to 20 m/s in NS-2, EDSR-LB significantly outperformed both standard DSR and AODV on every key metric, achieving up to 16.2% higher packet delivery ratio, up to 38.6% lower end-to-end delay, 43.9% lower routing overhead, up to 21.8% higher throughput and 37.3% lower energy consumption, with a load-balancing index about 37% higher than DSR. These results confirm that the adaptive multipath, energy-aware strategy effectively addresses the load-imbalance and energy-inefficiency problems inherent in conventional DSR, and that it scales better to dense networks [9, 11]. Future work will integrate machine-learning-based prediction of link quality and node mobility to further refine route selection in highly dynamic environments [15], and will extend the evaluation to include

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explicit adversarial scenarios that exercise the security layer under black-hole, gray-hole and wormhole attacks [12, 19].

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