

Comparative Performance Evaluation of MANET Routing Protocols AODV, DSR, OLSR, and DSDV under Variable Mobility and Network Density Scenarios

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ABSTRACT : The efficacy of routing protocols is crucial for optimizing performance in MANETs due to the vibrant topology and mobility of nodes. This study conducts a comprehensive comparative analysis of four prominent MANET routing protocols: Ad hoc On-Demand Distance Vector (AODV), Destination-Sequenced Distance Vector (DSDV), Dynamic Source Routing (DSR), and Optimized Link State Routing (OLSR). Using the NS-3 simulation tool, we evaluate each protocols performance across various metrics, including Packet Delivery Ratio (PDR), throughput, control overhead, and end-to-end delay, under diverse conditions of node mobility and network density. Our findings indicate that AODV and DSR, being reactive protocols, generally perform better in high mobility environments due to their on-demand route discovery. Conversely, proactive protocols like OLSR and DSDV exhibit lower delay and higher stability in static or low mobility networks but incur greater control overhead.

Keywords - DSR, AODV, OLSR, DSDV, MANET, NS-3.

I. INTRODUCTION

In mobile ad hoc networks (MANETs), mobiles act as nodes and may communicate along any path at any speed [1]. Unlike permanent infrastructure, these networks use batteries, which is an advantage. Furthermore, such nodes are seamlessly connected, which is the positive aspect of this structure. One drawback is that the amount of autonomously and seamlessly connected nodes is restricted. In the event of connectivity, such nodes link within their reach. If the transmitter wants to transfer insight to a recipient node beyond its immediate range, it first establishes a route [2]. The decade of 1990, MANETs explored the several hops framework, which allows a node to connect instantly with a neighboring node and relay data from remote nodes to an intended node [3]. WSN technology is turning into increasingly prevalent for building community networks at a reduced cost [4]. Ad hoc network nodes can travel along any route. Unlike the wired Internet, MANET nodes have a dynamic and constantly changing topology [5]. These behaviors and characteristics of MANETs present key research challenges. The flow in MANETs is difficult due to concerns such as interruption, limited legitimacy, and capacity constraints. These obstacles have attracted significant attention from network researchers [6]. MANETs are anticipated to have random several hops topologies and bandwidth constrained wireless links [7]. Therefore, advanced routing techniques should be considered when designing or updating protocols. The vibrant characteristics of ad hoc multi-hop networks makes routing demanding. Power consumption, Frequent topology changes, varying wireless link quality, and route loss propagation all contribute to routing difficulties. These challenges are particularly stressful in military situations [8]. MANETs have improves healthcare by enabling patient monitoring during disasters. Their advanced communication capabilities also make them promising for 5G networks. A 5G MANET will offer high data speeds, low cost and low latency and energy consumption [9]. MANET routing procedures are categorized as reactive, proactive, or hybrid. Proactive procedures maintain a constantly updated routing table of node positions; examples include OLSR and DSDV. Reactive routing procedures do not have preordained routes; instead, they dynamically create routes on demand from request packets. The next node is selected based on the response, and this action continues until a settled route is instituted and data packets attain their endpoint. Examples of reactive routing

procedures include TORA, DSR and AODV. Hybrid routing procedures, such as DSR, DST and ZRP, combine both proactive and reactive approaches.

It is noteworthy to perform studies on how node velocity and quantity impact the OLSR, AODV, DSDV and DSR routing procedures effectiveness to foster more successful routing methods. The performance measure, such as control overhead, throughput, PDR and delay are investigated to figure out how well OLSR, AODV, DSR and DSDV behave. The major contribution of our work includes:

- We first evaluate the suggested network modelling scenarios in NS-3 with various simulation settings. Critical performance metrics as control overhead, throughput, PDR and delay are examined. We examine 200 nodes, more than any previous study.
- Secondly, we examine how network density and node mobility impact the sustainability of the DSR, AODV, OLSR and DSDV routing protocols.

We summarize the remainder of the material. Section 2 covers literature, Section 3 covers MANET routing protocols, Section 4 covers performance metrics, Section 5 covers results and discussion, and Section 6 concludes this study.

II. LITERATURE REVIEW

Gamil Ahmed et al. (2024): This work concentrates on evaluating the effectiveness of three extensively used routing procedures OLSR, AODV and DSR in drone communication networks utilizing the NS3 simulation tool. The authors compared these approaches regarding on key execution measures under various scenarios, including different network densities, mobility patterns and node velocities. Several metrics are Energy consumption, Routing Overhead, Delay, PDR and scalability. The author concluded that OLSR was better suited for low-mobility scenarios with stable topologies, whereas AODV and DSR were more effective in dynamic environments, albeit with increased delays [10]. Ahmad Yusri Dak et al. (2024): The study concentrates on evaluating the effectiveness of non-realistic routing under the RWP model in a MANET environment. The protocols under investigation are the proactive DSDV and the reactive AODV. The authors use the NS2 to evaluate the efficacy of these protocols with regard to three metrics: throughput, PDR and EED. In their analysis, the authors observed that AODV outperformed DSDV in terms of throughput and PDR, particularly in environments with higher mobility and node density. On the other hand, DSDV showed better execution in terms of EED, with a n EED of 212.97 ms under similar conditions [11]. Al-Nasir and Mubarek (2024): The study revealed that AODV consistently surpasses DSDV and DSR addressing throughput and PDR, particularly in scenarios with high node mobility. AODV's on demand route identification mechanism allows it to adapt more efficiently to the frequent topology changes in VANETs, resulting in higher throughput and PDR. In contrast, DSDV's performance was hindered by its high overhead due to typical routing table modifications. However, DSDV demonstrated superior performance addressing average delay, which was lower contrasted to AODV and DSR. The DSR showed moderate performance, excelling in scenarios with fewer nodes owing to its source routing procedure, which minimizes the need for route discovery at intermediate nodes [12]. Khanchandani et al. (2024): This research uses the NS3 simulator to assess the performance DSDV and OLSR which are proactive in nature and AODV and DSR are reactive in nature. This study compares these protocols using PLR throughput, PDR, jitter and EED. The research found that reactive protocols work best in dynamic MANETs with frequent node mobility and topology changes. Proactive protocols are better for stable networks with known topologies that need minimal latency and constant performance [13].

Razouqi et al. (2024): This paper extends the comparison of three key routing techniques in MANETS: DSDV, DSR and AODV. The effectiveness of these routing procedures is evaluated relying on different traffic load patterns and key performance metrics, including throughput, PDF and energy consumption, using the NS3 simulator. DSR consistently outperformed DSDV and AODV in terms of throughput, particularly under irregular traffic patterns. AODV showed superior performance concerning PDF, particularly under joint traffic patterns. DSDV had the lowest energy consumption in networks with regular traffic and low mobility. DSR exhibited the highest routing overhead at lower packet rates, while AODV and DSDV had comparable overhead in high traffic scenarios due to periodic updates and routing table maintenance [14]. El-Dalalmeh et al. (2024): This paper assesses the efficacy of three well-known protocols OLSR, AODV and DSDV within the context of VANETs. The key innovation of this study is the integration of Elliptic Curve Integrated Encryption into these protocols to enhance security while evaluating their impact on performance metrics like throughput, PDR and E2E. The study utilizes OMNET++ and SUMO simulators for a comprehensive evaluation. The study concludes that ECIE-OLSR is the most adequate protocol for VANETs when high throughput and low delay are prioritized, while ECIE-AODV is more effective in highly mobile environments where PDR is crucial. ECIE-DSDV, although secure, is less efficient in dynamic VANET environments due to its higher overhead and delays [15]. Salah Abdulghani Alabady et al. (2024): A full MANET routing methods analysis includes reactive and proactive protocols. The research emphasizes routing protocol design and simulation and throughput performance. To evaluate both routing methods in vibrant and self-enabling ad hoc networks, the research may

examine network load, routing overhead, latency, and throughput. The study seeks to illuminate ad-hoc network routing strategy selection and optimization, highlighting its benefits and flexibility [16]. Baidaa Hamza Khudayer et al. (2023): This article will evaluate three MANET routing systems' scalability, latency, overhead, and other characteristics. It shows how reactive methods identify routes only when data is sent, whereas proactive methods ensure route accessibility but have adaptability and overhead [17].

Huda A. Ahmed et al. (2023): DSR, DSDV, AODV, and OLSR are extensively used traditional MANET protocols that this article evaluates. The assessment includes 10–100 wireless nodes and several performance criteria. The OLSR routing protocol outperforms the others in most video transmission measures. Traditional routing systems lack capacity for multimedia applications, causing connection failures and increasing power and bandwidth needs [18]. Dr K S Balamurugan et al. (2023): The authors suggest many routing quality improvements. Consider congestion, bandwidth, and signal intensity while improving. Choosing hosts with greater resources increases route efficiency, while nodes with more leftover energy last longer. Selected multipath protocols were enhanced and analyzed. The congestion free and bandwidth conscious AOMDV protocol determines the best route using CFT and residual bandwidth assessment [19].

Kathirvel A et al. (2023): Article authors improve MANET reactive protocol efficiency. They emphasize AODV routing protocol implementation and analysis. Four research and performance-enhancing methods are examined. These strategies are tailored to MANET use [20]. Md. Torikur RAHMAN et al. (2023): This article proposes a protocol including key governance, encryption, identification, and intrusion detection for secure routing. The protocol reduces attack risks, maintains network resources, and delivers messages to their destinations quickly and securely. Simulations show that the proposed routing system outperforms current methods in network performance and security [21]. Affandi et al. (2023): The research compared three popular routing techniques in MANETs. This study examined DSDV, DSR, and ZRP routing protocols. Analysis of key performance measures provided useful insights into these routing systems. The study analyzed routing overhead, network load, end-to-end latency, and throughput to evaluate these protocols in MANETs [22]. Jari et al. (2023): MANET routing protocols may be examined for Global Trust Management performance. This study may examine how trust management techniques affect MANET routing protocols, revealing how trust-based aspects increase network dependability and security. The research may examine MANET performance, including routing efficiency and trustworthiness [23]. Elsayed et al. (2023): They study MANET DSR protocol performance. This research emphasizes how transmission power and node mobility speed affect protocol performance. The authors want to understand how the DSR protocol operates in dynamic MANET situations via their investigation. Optimization of the protocol's routing efficacy, flexibility, and effectiveness in self-integrating and quickly changing system settings requires such insights. This study expands MANET routing protocol expertise and adaptation to transmission power and node mobility situations [24].

Amin Ullah et al. (2023): The research examined GRP, TORA, and OLSR routing approaches. We examined their throughput, network latency, and load. We used OPNET Modeler 14.5 to simulate a 1000m x 1000m office network to confirm our results. Our simulations showed that OLSR had the greatest network burden of the three protocols. The OLSR protocol outperformed the GRP and TORA protocols in network latency and throughput. TORA beat GRP and OLSR in network load. However, the GRP protocol outperformed the TORA protocol in network latency and throughput [25]. Aabid Farooq et al. (2023): The author tests wireless ad hoc network routing methods against security assaults. It evaluates routing protocols network security response and recovery. This study examines routing techniques' efficacy and durability in safeguarding wireless ad hoc networks. The research helps choose and build routing protocols in security-sensitive systems by analyzing their performance under attack [26]. Balqees AL-Hasani et al. (2022): This article assesses the most popular routing procedures in terms of delay, routing overhead, throughput, and average volatility. Changes in landscape size to portray different node density in multiple dimensions are used to evaluate these tactics in various operating circumstances. Changing the amount of bit-rate connections for the same network size changes data volume [27].

Abdul Majid Soomro et al. (2022): This study focusses on MANET routing and maintenance solutions, which include adaptable topologies and nodes for fast data transmission. The study uses route discovery to offer different methods that outperform each other. This opposing study shows MANET interaction route identification and maintenance issues and evaluates which methods work best under different network settings [28]. Sakshi Mishra et al. (2022): Predefined routing system (DSDV) is compared to on-demand routing systems in terms of effectiveness. Amount of alleviated packets, latency, PDR, forwarding overhead, node mobility, and effect of adding nodes are examined. In most cases, Dynamic Source Routing (DSR) beats the other two [29]. Sandeep Singh et al. (2022): Performance measures include packet rate size, speed, TCP types, amount of packets, and network strength. Simulations show that DSR outperforms AODV and DSDV [30]. Veepin Kumar et al. (2022): The authors briefly describe MANET and its routing protocols. These methods are then thoroughly examined using performance metrics. Performance metrics in the simulation include throughputs, energy use, PDR, and latency. Use the NS2.35 simulator to analyze performance [31]. Dr. L V Raja (2022): The authors

propose a protocol that employs node information above the core communication to fix broken routes. In case of a connection failure, the protocol switches to standby nodes, backups located near the main channel. Generalization is challenging since ad-hoc networks are used in many everyday activities [32]. M. H. Hanin et al. (2021): Retransmissions of packet loss and energy usage are minimized and assessed using NS-3 simulator to identify the routing protocol that improves MANET QoS. While the simulation area is 1000m × 1000m, the author investigated mobility speeds from 10m/s to 50m/s [33]. Walunjkar et al. (2020): The authors analyze MANET routing protocols in detail. This research compares routing methods based on routing overhead, network load, latency, and throughput. This study examines these critical factors to assess the efficacy and acceptability of alternative routing algorithms in dynamic and self-configuring MANETs [34]. Mohamed et al. (2020): MANET routing protocols are thoroughly examined in this investigation to improve network performance and reliability. The research focusses on QoS and energy-related factors for these protocols. The study examines these elements to determine how routing algorithms affect network quality and energy efficiency. This research helps better understand and optimize MANET routing protocols [35]. D. Sharma et al. (2020): MANET study on gearbox power is examined by the authors. According to the research, MANET performance under these circumstances is assessed using the AODV routing protocol. This investigation may reveal how transmission power affects network performance and efficiency, revealing AODV's efficacy [36].

H. Alani et al. (2020): For effective broadcast control packets, AODV-velocity and dynamic is recommended. The predicted method uses the AODV routing protocol. AODV-VD minimizes control messages and systems overhead. NS2.35 was used to evaluate the latency, packet transmission ratio, throughput and overhead ratio of the proposed AODV-VD strategies to the AODV routing methods [37]. S. Laqtib et al. (2019): We explored OLSR protocol mobility models. Mobile models included arbitrary direction, arbitrary walk, steady state arbitrary way-point and way-point mobility. Simulations indicate that the steady state arbitrary way-point exhibits superior performance in terms of latency, while also achieving enhanced throughput [38]. Md. Khanjahan Ali et al. (2016): This work concentrates on evaluating the effectiveness of three prominent routing procedures: AODV, DSDV and DSR. The authors use CBR traffic as a test case, providing insights into the protocols efficiency under UDP payloads, which is relevant for real-time data transmission scenarios. The effectiveness of the three protocols was evaluated using the following metrics: Throughput, PDF and EED. The study conducted simulations using NS-2 and analyzed performance across two phases: varying node mobility and varying network node density. The study concludes that DSR is the most suitable protocol for MANETs with CBR traffic. DSDV is best suited for low mobility, low density networks where consistent routes are beneficial while AODV offers a balance of performance for dynamic environments [39].

Skaggs-Schellenberg et al.: This study assesses the effectiveness of four routing approaches-OLSR, DSDV, DSR and AODV using the NS-3 simulator to test various node speeds and area sizes. The protocols are compared based on PDR and AETED, with findings that inform protocol selection for real-world applications where node speed and network are key variables. This study focuses on proactive and reactive procedures to understand their effectiveness in different mobility environments. The study concludes that AODV is the most adaptable protocol for high mobility and large are MANET applications due to its on-demand route identification, which efficiently manages dynamic topologies. OLSR is suitable for low mobility scenarios, where its proactive approach reduces delay and ensures consistent data delivery. DSDV, while stable in low mobility, low density networks, is less effective in highly dynamic environments due to its high control overhead [40]. Bhatia et al. (2015): The paper conducts a contrasted examination of hybrid, reactive and proactive routing approaches, namely OLSR, DSDV, AODV, ZRP and DSR. The analysis is based on QoS parameters, specifically focusing on how network size, node mobility and system load influence protocol efficacy. The study uses the NS-2 simulator to evaluate these protocols under different scenarios, providing guidance on protocol selection based on network requirements. The study concludes that AODV is the most adaptable protocol where DSR is suitable for smaller and stable networks. OLSR performs well in low mobility scenarios with dense topologies, while DSDV is the most effective in static or low mobility environments where frequent updates are feasible [41].

2.1 Problem Statement and Hypotheses

From the above literature review analysis, we identify the following research gaps. Many studies use idealized or non-realistic models, such as the Arbitrary Waypoint Model, which might not accurately represent real-world conditions in MANET environments. This limits the practical applicability of their findings. Most of the literature emphasizes traditional performance metrics like throughput, delay, and PDR, often overlooking other critical factors such as energy efficiency in varied environmental conditions and security aspects under different attack models. Various studies employ different simulators without standardized parameters, making direct comparisons challenging and possibly affecting the reproducibility of results. While some protocols perform well in static environments, they may not adapt efficiently in highly dynamic scenarios with frequent topology changes, a challenge often underrepresented in existing studies. A few studies incorporate security mechanisms like encryption, but the impact of these mechanisms on overall network performance is rarely

analyzed. As MANETs are susceptible to security threats, this remains a critical gap. Routing overhead and scalability are significant issues in MANETs, especially as the number of nodes increases. However, many protocols do not address scalability effectively, leading to higher overhead in dense networks. Whereas our analysis concentrates on vital performance metrics such as PDR, throughput, control overhead and delay and we also consider a maximum 200 nodes, which is more than any other paper has considered. We investigate how node mobility and network density affect the scalability of the DSR, AODV, OLSR and DSDV routing protocols.

Here are some hypotheses that could predict the effectiveness of each MANET protocol in the testing scenarios, based on the comparative analysis provided.

- H1 (Hypotheses for AODV): AODV will maintain high packet delivery ratios and throughput in high mobility environments due to its on-demand route discovery mechanism, which enables quick adaptation to topology changes. As node mobility increases, delay and overhead for AODV will rise due to frequent route discoveries and maintenance requests.
- H2 (Hypotheses for DSDV): DSDV will exhibit high PDR and low delays in low mobility, stable system environments, as its proactive nature keeps routing tables updated for consistent path availability. In high mobility environments, DSDV's performance will degrade significantly, with increased control overhead and reduced PDRs, due to the frequent updates required for route maintenance in rapidly changing topologies.
- H3 (Hypotheses for DSR): DSR will achieve high PDRs and moderate throughput in low to moderate mobility conditions due to its use of route caches and source routing, which minimize the need for frequent route discoveries. As node mobility and density increase, DSR will experience reduced performance with increased overhead and delay, owing to the need for frequent route cache updates and route discoveries.
- H4 (Hypotheses for OLSR): OLSR will perform best in low mobility, dense network scenarios, with minimal end-to-end delay and high PDRs due to its proactive routing and multipoint relay mechanisms. In high mobility networks, OLSR's control overhead will increase, leading to decreased throughput and PDRs as the protocol struggles to save current route information under frequent topology alterations.

III. MANET ROUTING PROTOCOLS

Many MANET routing protocols and methods exist. Routing protocols provide optimal paths between source and destination nodes to avoid self-looping and information redundancy [42]. Most MANET routing systems fall into two categories: proactive and reactive. Hybrid Routing procedures integrate the aspects of both proactive and reactive strategies. They fully utilize the reduced network congestion overhead and proactive methods and the decreased communication latency of proactive strategies [44]. The next section discusses proactive methods DSDV and OLSR, as well as the reactive methods AODV and DSR.

3.1. Proactive Routing Protocol

Every node in proactive routing methods holds one or more routing tables and propagates their information via the network. Route information is always accessible, reducing communication delays. These protocols are useless in big, dynamic networks because they need more memory and maintenance.

3.1.1 Destination Sequenced Distance Vector (DSDV):

Pravin Bhagwat and Charles Perkins proposed DSDV in 1994. DSDV routing protocol development relies on the traditional Bell-man Ford shortest route routing method. To avoid count to infinity, bounce effect, and routing loop difficulties, DSDV was proposed [43]. This routing protocol requires every node to have a navigation table containing data pertaining to all other nodes in the MANET. DSDV transmission tables list destinations, next hop, hop count and sequence number [45]. Current routing table attributes now include sequence number. Destination node coined sequence number to prevent loops. Routes with the latest sequence number are new [46]. Update messages are broadcast or multicast to every Mobile Ad-hoc Network node when topological changes are detected [47]. Most update messages are complete dump packets or incremental packets. DSDV ensures loop-free packet transmission routes. DSDV takes greater battery power, making it unsuitable for big networks. DSDV is too traffic-intensive for highly dynamic MANETs.

3.1.2 Optimized Link State Routing (OLSR):

OLSR protocol proposed by Clausen and Jacquet [43]. The main objective for developing OLSR routing protocol is to provide topology information without flooding [42]. Every Mobile Ad-hoc Network node in OLSR exchanges link status messages to maintain network topology data. OLSR uses Multipoint Relaying (MPR) to relay link status messages to decrease network overhead and flooding. Some MPRs allow just certain nodes to broadcast network messages. The MPRs minimize message overhead compared to a pure flooding system. Hello, Topology manage, MID, and HNA messages manage routing in OLSR protocol. Obtaining neighbor information from hello messages helps frame the MPR selection set. Only MPR nodes may broadcast topology control messages throughout the network to calculate the route [48]. MID messages indicate that a

for this analysis.

Table 1. Parameter values for varying mobility speeds

Parameter	Value
Network Simulator	Network Simulator – 3.38
Simulation time	900 seconds
Simulation Area	300m × 300m
Number of nodes	200
Protocol used	AODV, DSR, OLSR, and DSDV
Model	Random Way Point
Quantity of seeds	15
Transmission range	50m
Transport protocol	UDP
Internet Protocol	IPv4
Method of Physical layer	PHY 802.11n
MAC Protocol	IEEE 802.11
Supply power	0.0015W
Packet Size	16 kilobyte/sec
Pause time	0 seconds
Mobility speed	10, 20, 30, 40, 50, 60 and 70

5.1 Packet Delivery Ratio (PDR)

From figure 1(a) we see that AODV shows a relatively steady performance at higher mobility speeds, with a mild decrease in PDR as speed rises. Because AODV uses on-demand route finding, which helps in maintaining routes rapidly even as nodes move, but can incur delays and overhead when routes break typically at high speeds. DSR begins with a high PDR at low speeds, but its performance reduces more significantly as speed increases compared to AODV and OLSR. The explanation behind this the DSR uses source routing and keeps up route caches, which can become quickly obsolete as mobility increases, leading to more frequent route findings and lower PDR. OLSR maintains a great PDR across different speeds, but it shows a sharper degrade in very high mobility scenarios.

Because OLSR is a proactive protocol that keeps up routes by sporadically exchanging topology information. This guarantees current routing information but can be dominated by high mobility, leading to increased control overhead and reduced PDR. DSDV reveals the lowest PDR at higher speeds, with a steep decline as mobility rises. The reason behind this because DSDV is a proactive protocol that depends on maintaining consistent and current routing tables. High mobility causes frequent modifications in topology, leading to outdated routes and added control message overhead, considerably affecting performance. AODV and OLSR generally operates better than DSR and DSDV in high mobility scenarios due to their routing strategies. DSRs performance reduces due to outdated route caches at boosted speeds. DSDV experiences the most due to its proactive nature, which cannot cope well with rapid topology changes.

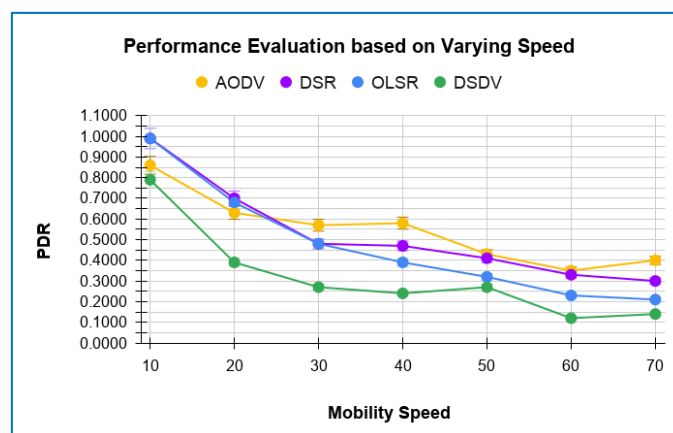


Fig. 1(a) PDR

5.2 Throughput

From figure 1(b) we see that AODV maintains relatively high throughput across all mobility speeds, showing a slight decline as speed increases. Because AODV dynamically establishes routes on-demand,

allowing it to adapt to changes in network topology due to node mobility. This adaptability helps maintain higher throughput, though the overhead from frequent route discoveries at higher speeds slightly reduces throughput. DSR also maintains high throughput, similar to AODV, with a slight decrease as mobility speed increases. Because DSR uses source routing and route caches to maintain paths. While effective at lower speeds, the increased rate of route changes at higher speeds necessitates more frequent route discoveries, leading to a minor drop in throughput. OLSR exhibits high throughput initially but shows a noticeable decline at higher speeds. The reason behind this OLSR is a proactive protocol and OLSR continuously exchanges topology information to maintain up-to-date routes. This proactive nature ensures reliable paths at lower speeds, but the increased control message overhead at higher speeds can reduce throughput. DSDV shows the lowest throughput among the protocols, with a significant decline as mobility speed increases. Because DSDV is a table-driven protocol that periodically updates routing tables. The constant need to maintain accurate routing tables in the face of high mobility leads to considerable control overhead and outdated routes, resulting in decreased throughput. AODV and DSR perform well across varying speeds due to their on-demand and source-routing mechanisms, respectively, though they experience a slight throughput reduction at higher speeds. OLSR maintains high throughput at lower speeds but suffers from control overhead at higher speeds, leading to reduced throughput. Whereas DSDV struggles with high mobility, as its proactive table-driven approach cannot keep up with rapid topology changes, resulting in the lowest throughput.

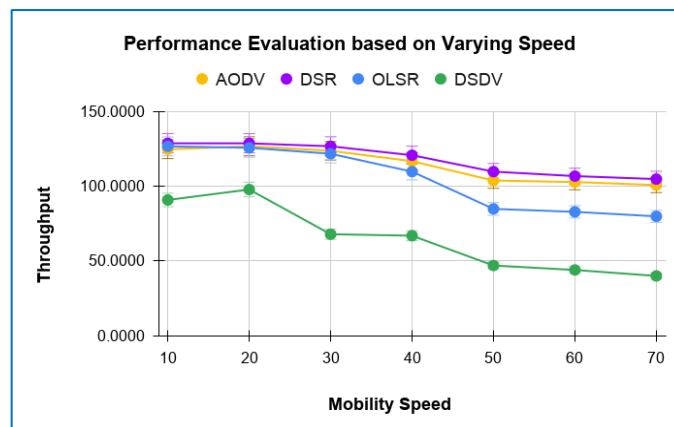


Fig. 1(b) Throughput

5.3 Control Overhead

AODV shows a moderate increase in control overhead with higher mobility speeds due to the increased frequency of route discoveries, the need for route maintenance through RERR packets, the updates required for sequence numbers, and the potentially longer paths in a rapidly changing network topology. While AODV efficiently adapts to changing conditions, the additional control messages generated to maintain accurate routing information result in a moderate increase in control overhead as node mobility increases. DSR exhibits the lowest control overhead at lower speeds, but it increases sharply at higher speeds because at lower mobility speeds, DSR benefits from stable routes and effective route caching, leading to minimal control overhead as routes remain valid for longer periods and fewer route discoveries are needed.

However, at higher speeds, the frequent changes in network topology and the resulting need for constant route discoveries and updates cause a sharp increase in control overhead. The transitions from a low to high mobility environment amplifies the need for control messages, resulting in a significant rise in overhead. OLSR’s proactive approach to routing, characterized by the periodic exchange of HELLO and TC messages, leads to a consistently high control overhead across all mobility speeds. This overhead remains constant because it is tied to the regular, scheduled dissemination of control information rather than being responsive to changes in node mobility or network topology. As a result, OLSR confirms that all nodes maintain a current and comprehensive track of the network, but at the cost of a high and relatively unvarying control overhead. DSDV displays the lowest control overhead at lower speeds, with a gradual increase as mobility increases, due to its periodic table updates. This analysis highlights that OLSR consistently generates high control overhead, making it less suitable for scenarios where minimizing control messages is crucial. In contrast, AODV and DSR adapt their control overhead based on network conditions, with AODV being more moderate and DSR showing significant increases at high speeds. DSDV’s gradual increase in overhead makes it a balanced choice for networks with varying mobility.

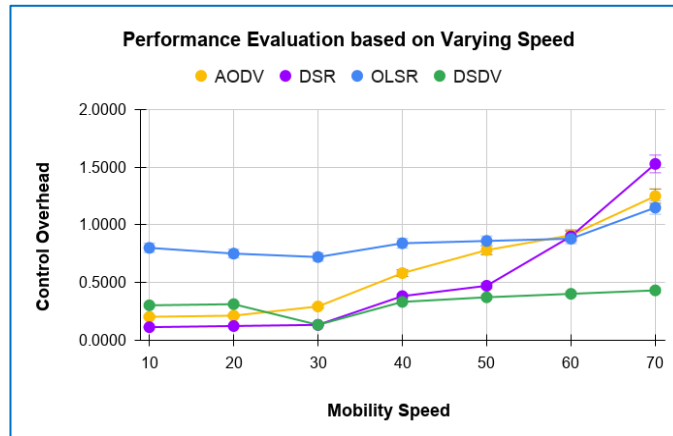


Fig. 1(c) Control Overhead

5.4 End-to-End Delay

DSR exhibits the highest and most variable end-to-end delay due to its reliance on route caches and the overhead of maintaining complete source routes, especially in highly mobile environments. AODV maintains a low and stable delay across different speeds due to its efficient on-demand route discovery mechanism.

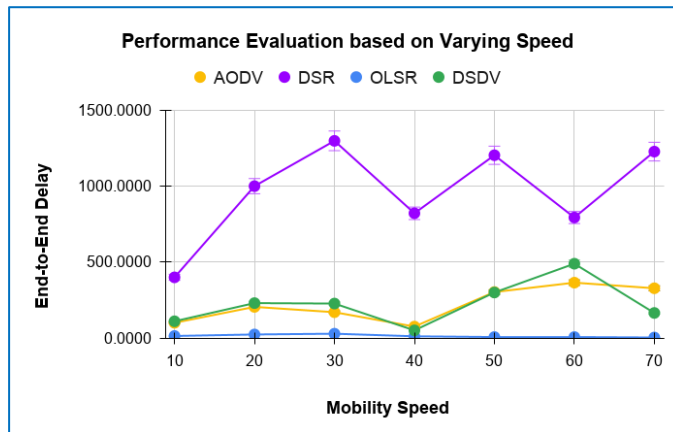


Fig. 1(d) End-to-End Delay

OLSR achieves the lowest and most consistent end-to-end delay, benefiting from its proactive approach that ensures routes are always immediately available. DSDV shows a moderate delay that increases with mobility speed, reflecting the challenges of maintaining up-to-date routing tables in a dynamic network. This analysis suggests that for applications requiring minimal delays, OLSR would be the preferred protocol, while AODV offers a good balance of low delay and adaptability to changing network conditions. DSR and DSDV may be less suitable in scenarios where low end-to-end delay is critical, especially in highly mobile environments. Table 02 represents a detailed analysis of values at varying speeds for PDR, Throughput, Control overhead and Delay.

Table 02. Detailed analysis of values at varying speeds

Metric	Protocol	Speeds (m/s)						
		10	20	30	40	50	60	70
PDR	AODV	0.86	0.63	0.57	0.58	0.43	0.35	0.40
	DSR	.99	.70	.48	.47	.41	.33	.30
	OLSR	.99	.68	.48	.39	.32	.23	.21
	DSDV	.79	.39	.27	.24	.27	.12	.14
Throughput	AODV	125	127	124	117	104	103	101
	DSR	129	129	127	121	110	107	105
	OLSR	127	126	122	110	85	83	80
	DSDV	91	98	68	67	47	44	40

Control Overhead	AODV	.20	.21	.29	.58	.78	.91	1.25
	DSR	.11	.12	.13	.38	.47	.90	1.53
	OLSR	.80	.75	.72	.84	.86	.88	1.15
	DSDV	.30	.31	.13	.33	.37	.40	.43
End-to-End Delay	AODV	100	205	170	75	303	365	328
	DSR	400	1002	1301	823	1206	795	1230
	OLSR	13	23	28	11	6	6	3
	DSDV	110	230	227	50	300	490	165

Here is a summary of the above work that evaluated the four MANET protocols based on their performance in different aspects represent in table 03.

Table 03. Summary of the above work for varying speeds

Parameters	AODV	DSR	OLSR	DSDV
Packet Delivery Ratio (PDR)	Good: Relatively stable across speeds with moderate decrease.	Bad: High at low speeds but degrades significantly at higher speeds due to outdated route caches.	Better: Maintains good PDR across speeds but declines sharply at high mobility due to control overhead.	Bad: Lowest PDR, significantly affected by high mobility due to outdated routes and control message overhead.
Throughput	Good: Maintains high throughput with slight reduction at higher speeds.	Good: High throughput, similar to AODV, with a slight decrease as mobility increases.	Bad: High at lower speeds but reduces significantly at higher speeds due to control message overhead.	Bad: Lowest throughput, significantly declining with increasing speed due to high control overhead and outdated routes.
Control Overhead	Better: Moderate increase with higher mobility due to efficient route discovery and maintenance.	Bad: Lowest at low speeds but increases sharply at high speeds due to frequent route discoveries.	Bad: Consistently high control overhead across all speeds, due to proactive nature.	Good: Low at lower speeds with a gradual increase, making it balanced for varying mobility.
End-to-End Delay	Better: Low and stable delay across speeds due to efficient on-demand route discovery.	Bad: Highest and most variable delay, especially at high speeds due to route cache maintenance.	Good: Lowest and most consistent delay, benefiting from proactive routing.	Bad: Moderate delay that increases with speed, reflecting challenges in maintaining up-to-date routing tables.

The four hypotheses (H1–H4) of Section 2.1 are now checked against the results in Table 02 and Figures 1(a)–1(d) over the 10–70 m/s mobility range. The performance evaluation highlights the strengths and weaknesses of each routing protocol as follows:

- AODV: Near-best throughput (125→101 kbps) and the highest PDR at 70 m/s; overhead and delay rise with speed, as predicted. (Meets the condition of H1)
- DSDV: The PDR and throughput degradation holds, but the predicted high overhead is contradicted and DSDV has the lowest overhead (0.13–0.43). (Meets the condition of H2)
- DSR: Provides the best low-mobility for PDR and throughput, with sharp overhead and delay increases at high speed. (Meets the condition of H3)
- OLSR: The lowest delay (3–28 ms) and high but flat overhead, matching the proactive trade-off. (Meets the condition of H4)

Overall, H1, H3 and H4 are fully supported; H2 holds for PDR and throughput but fails on overhead, as DSDV has the lowest overhead of all four protocols.

To demonstrate the efficiency of our results, we will also compare them with other papers. Table 4 represents a brief comparison report using our work along with those of Al-Nasir & Mubarek [12], Shailesh [13], Razouki [14], Khanjahan Ali [39] and Skaggs-schellenberg & Bhatia [40]. The comparative simulation analysis reveals that AODV consistently shows balanced performance across studies, with moderate to high PDR (35-95%) and throughput (101-125 kbps) across dynamic scenarios. Our work aligns with Al-Nasir & Mubarek [12] and Skaggs-Schellenberg & Bhatia [40], which also highlights AODVs adaptability in

maintaining efficient routing under high mobility. DSR demonstrates excellent throughput (105-129 kbps) and PDR (30-99%) in static and low mobility conditions, but its high control overhead (0.11-1.53 and end-to-end delay (400-1301 ms) under dynamic conditions, as observed in our work and by Razouqi [14], indicate limitations. OLSR consistently achieves high PDR (21-99%) and the lowest delay (3-28 ms) in static scenarios, supported by findings in Shailesh [13] and Skaggs-Schellenberg & Bhatia [40], but its high control overhead (0.72-1.15) limits its performance in dynamic setups. Similarly, DSDV exhibits moderate PDR (12-79%) and low delay (50-490 ms) in static networks but struggles in high mobility environments due to outdated routes, as noted in our study and by Md. Khanjahan Ali [39]. Across these studies, AODV and DSR emerge as superior choices for dynamic conditions, while OLSR and DSDV are better suited for static environments requiring minimal delay and stable performance.

Table 4. represents a brief comparison report using our work along with those of Al-Nasir & Mubarek [12], Shailesh [13], Razouki [14], Khanjahan Ali [39] and Skaggs-schellenberg & Bhatia [40]

Metric	Our Work	Al-Nasir & Mubarek [12]	Shailesh [13]	Razouki [14]	Khanjahan Ali [39]	Skaggs-Schellenberg [40]
PDR(%)	AODV: 35–86 DSR: 30–99 OLSR: 21–99 DSDV: 12–79	AODV: 85–95 DSR: 80–90 DSDV: 75–85	AODV: 65–85 DSR: 70–90 OLSR: 90–95 DSDV: 50–70	AODV: 80–90 DSR: 85–95 DSDV: 60–80	AODV: 70–90 DSR: 90–95 DSDV: 60–80	AODV: 85–95 DSR: 80–90 OLSR: 90–95 DSDV: 75–85
Throughput (Kbps)	AODV: 101–125 DSR: 105–129 OLSR: 80–127 DSDV: 40–91	AODV: 100–120 DSR: 95–115 DSDV: 80–100	AODV: 90–110 DSR: 95–120 OLSR: 100–130 DSDV: 50–80	AODV: 95–115 DSR: 110–125 DSDV: 70–90	AODV: 90–110 DSR: 110–125 DSDV: 50–80	AODV: 100–120 DSR: 95–115 OLSR: 100–130 DSDV: 80–100
Control Overhead	AODV: 0.20–1.25 DSR: 0.11–1.53 OLSR: 0.72–1.15 DSDV: 0.13–0.43	AODV: 0.3–0.6 DSR: 0.2–0.5 DSDV: 0.4–0.7	AODV: 0.2–0.5 DSR: 0.3–0.6 OLSR: 0.6–0.9 DSDV: 0.3–0.5	AODV: 0.3–0.5 DSR: 0.4–0.6 DSDV: 0.2–0.4	AODV: 0.3–0.6 DSR: 0.4–0.7 DSDV: 0.2–0.5	AODV: 0.3–0.6 DSR: 0.2–0.5 OLSR: 0.6–0.9 DSDV: 0.3–0.5
End-to-End Delay (ms)	AODV: 75–365 DSR: 400–1301 OLSR: 3–28 DSDV: 50–490	AODV: 100–300 DSR: 200–800 DSDV: 50–200	AODV: 100–200 DSR: 400–1000 OLSR: 10–50 DSDV: 50–300	AODV: 150–300 DSR: 500–1000 DSDV: 100–400	AODV: 100–200 DSR: 400–1000 DSDV: 50–300	AODV: 100–300 DSR: 200–800 OLSR: 10–50 DSDV: 50–200

VI. CONCLUSION

The study provided a comprehensive evaluation of the performance of four MANET routing protocols AODV, DSDV, DSR and OLSR under varying conditions of node mobility and network density. By employing the NS3 simulator, we assessed each protocols performance based on metrics like PDR, throughput, control overhead and end-to-end delay. The results revealed that AODV and DSR, as reactive protocols, perform better in highly dynamic environments due to their on-demand route discovery mechanisms, which adapt effectively to frequent topology changes. In contrast, proactive protocols like OLSR and DSDV demonstrated lower delays and stable performance in mobility or static scenarios, though they incur higher control overhead. This analysis provides practical insights for choosing suitable protocols tailored to different MANET applications. AODVs adaptability makes it ideal for high mobility networks, while OLSR is preferable in stable environments requiring low delay. Future research should focus on developing hybrid protocols that combine the adaptability of reactive protocols with the stability of proactive approaches, thus optimizing performance in diverse MANET scenarios.

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