SinkrOn
JURNAL & PENELITIAN TEKNIK INFORMATIKA
Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 4, October 2024
DOI : https://doi.org/10.33395/sinkron.v8i4.14141
e-ISSN : 2541-2019
p-ISSN : 2541-044X

Performance Analysis of AODV and DSDV Routing Protocols for UDP Communication in VANET

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Submitted July 25, 2024 | **Accepted** : Aug 21, 2024 | **Published** : Oct 6, 2024

Abstract: In high-mobility Vehicular Ad hoc Networks (VANETs), maintaining a low Packet Loss Ratio and a high Packet Delivery Ratio (PDR) under UDP communication is crucial. This study compares the performance of Ad hoc On-Demand Distance Vector (AODV) and Destination-Sequenced Distance-Vector (DSDV) routing protocols in vehicular communications and networking using Network Simulator 3 (NS3) simulations. The research employs a simulation-based approach, leveraging NS3 and SUMO to analyze these protocols across different VANET scenarios, including free flow, steady flow, and traffic jams over varying time intervals (300 to 700 seconds). Our findings demonstrate that AODV outperforms DSDV. AODV maintained an average Packet Loss Ratio of 98% and achieved higher throughput, while DSDV experienced higher packet loss and lower throughput. Additionally, AODV exhibited lower end-to-end delay and a higher Packet Delivery Ratio compared to DSDV. These results indicate that AODV is better suited for UDP communication in VANETs, offering lower packet loss, higher throughput, and reduced delays. The study further emphasizes that AODV is preferable for UDP communication in VANETs due to its superior performance metrics. There is potential for further research in vehicular communications, such as integrating advanced hybrid routing protocols and exploring the effects of different traffic densities, vehicle types, and real-world environmental conditions. By investigating these factors, future studies can enhance the reliability and efficiency of VANET communications, contributing to the advancement of intelligent transportation systems.

Keywords: AODV; DSDV; NS3; SUMO; UDP Communication; VANETs;

INTRODUCTION

Vehicular Ad-hoc Networks or VANETs have emerged as a cornerstone of intelligent transportation systems, providing crucial support for various applications such as traffic management, road safety, and infotainment services(Tahir & Katz, 2022). These networks enable VANET direct communication between vehicles (V2V)(Mezher et al., 2023) and vehicles and infrastructure (V2I)(Bhatia et al., 2020), facilitating real-time information exchange. As the volume of vehicular communication increases, selecting efficient routing protocols becomes paramount to ensure the reliability and efficiency of data transmission. Among the various communication protocols, the User Datagram Protocol (UDP) is frequently used in VANETs due to its low overhead and suitability for real-time applications(Xu, 2023). However, UDP communication poses significant challenges, especially in high-mobility environments typical of VANETs(Keshavamurthy et al., 2020). Key performance metrics such as Packet Loss Ratio (PLR), Packet Delivery Ratio (PDR), average throughput, end-to-end delay, and end-to-end jitter are critical for evaluating the effectiveness of routing protocols in such dynamic settings(Cheong et al., 2017)(Sathya Narayanan & Joice, 2019).

LITERATURE REVIEW

Previous studies have tackled the challenges associated with the AODV routing protocol, focusing mainly on reducing routing overhead by establishing network routes only when necessary. Innovative approaches such as Node Trends Prediction and Mobility and Detection Aware AODV(Arief et al., 2016) have been proposed to enhance the protocol's efficiency. Additionally, cluster-based communication strategies(Benkerdagh, 2019),

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which integrate prediction supported by learning automata(K. Bintoro et al., 2024), have shown promise. Another noteworthy method involves the Doppler effect channel reservation and multipath routing, which aims to improve route reliability and performance. A distinct study introduces DDSLA-RPL(Homaei et al., 2021), which employs learning automata to dynamically adjust parameter weights, resulting in improved network service quality and extended node lifespan. Despite the precision and adaptability of DDSLA-RPL, further enhancements are needed to address its limitations in various scenarios.

The selection of optimization techniques should be tailored to the specific characteristics of the network, considering the limitations of methods such as fuzzy clustering(Chen et al., 2020), C-means, and K-means(Kumar et al., 2019). Another research effort applies Particle Swarm Optimization (PSO)(Rizki & Nurlaili, 2021) and basic learning automata to ensure channel availability for V2V communication in VANETs. Conversely, LA-AODV(K. B. Y. Bintoro & Priyambodo, 2024) has effectively enhanced communication in dynamically changing traffic conditions, focusing on improving Quality of Service (QoS) through modifications of relay nodes based on the AODV routing protocol. The results are promising, with LA-AODV outperforming standard AODV, achieving Packet Delivery Ratios (PDR) between 95% and 99% and Average Throughputs ranging from 36.90 Kbps to 56.50 Kbps. Although LA-AODV exhibits slightly higher end-to-end delays, it significantly reduces Packet Loss Ratios (PLR) to 1% and 4%, showing its potential for improving vehicular communications.

On the other hand, DSDV faces significant challenges in highly dynamic VANET environments due to its frequent route updates and buffering limitations(Afzal et al., 2021). This protocol also experiences increased packet loss in dense network conditions and performs poorly with many hops. AODV and DSDV encounter limitations in V2V communication within VANETs due to high traffic volumes, slow response times, and scalability issues(Gawas & Govekar, 2021). In contrast, the Dynamic Source Routing (DSR) protocol demonstrates superior average throughput, optimizing data transfer rates more efficiently than DSDV and AODV(Ketut Bayu Yogha Bintoro et al., 2024). However, DSR's performance could be improved by higher delays, likely due to its more complex source routing mechanism, which introduces variability in packet delivery times. Overall, these studies underscore the crucial role of selecting appropriate routing protocols and optimization techniques tailored to the specific conditions and requirements of VANETs. This highlights the ongoing need for innovative solutions to enhance vehicular communications, emphasizing the significant impact that the audience's work can have on the field and inspiring future researchers.

METHOD

The AODV Routing Protocol

The AODV is a routing protocol used in mobile ad hoc networks (MANETs) that establishes routes to destinations on-demand when the source node requests. It ensures efficient route discovery and maintenance by using route request (RREQ) and route reply (RREP) messages, minimizing the number of broadcasts and reducing network congestion.

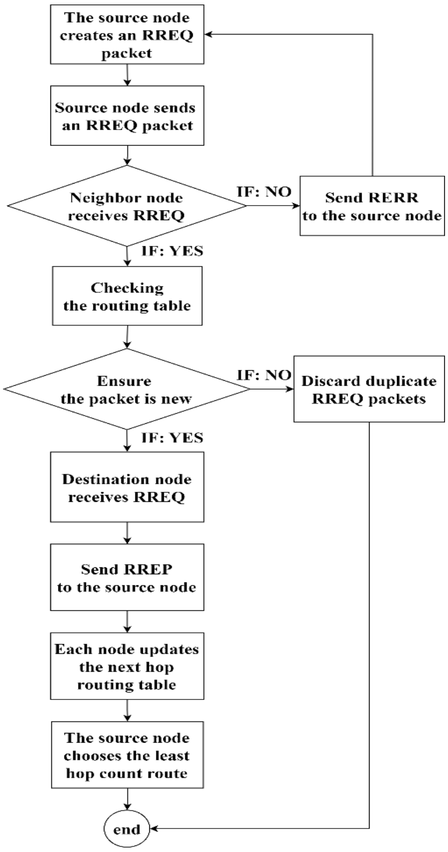

Fig. 1 The AODV Routing Protocol Flowchart

The flowchart in Figure. 1 demonstrates the reliable operation of the AODV routing protocol. The source node initiates the process by sending a Route Request (RREQ) packet. Upon receiving the RREQ, neighbor nodes check for duplicates and discard them if necessary, ensuring the protocol's reliability. The RREQ is then forwarded until it reaches the destination node. Upon receiving the RREQ, the destination node sends a Route Reply (RREP) packet back to the source, demonstrating the protocol's reliability. Each node updates its routing table based on the received RREP, contributing to the overall reliability of the protocol. The source node selects the route with the fewest hops for data transmission. Suppose any node detects an error in the route. In that case, it sends a Route Error (RERR) packet to the source node, which may prompt a new route discovery process if needed, ensuring the protocol's reliability even in error detection.

The DSDV Routing Protocol

The DSDV is a proactive routing protocol used in mobile ad hoc networks (MANETs) to maintain up-to-date routes to all destinations by periodically broadcasting routing tables. It ensures loop-free and reliable routes using sequence numbers to indicate the freshness of routing information as depict in Figure 2**.**

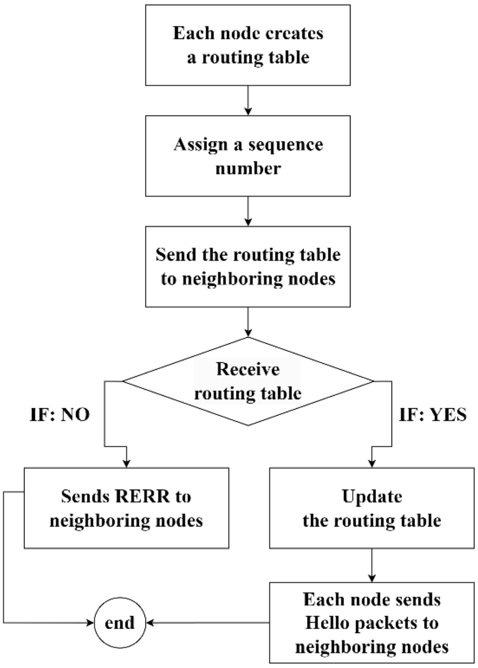

Fig. 2 The DSDV Routing Protocol Flowchart

Figure. 2 shows the process of the DSDV routing protocol. Each node begins by creating a routing table and assigning a sequence number, a crucial step that ensures the freshness of the routes and boosts the protocol's efficiency. These routing tables are then sent to neighboring nodes, who update them to reflect the new information. Each node periodically sends 'Hello' packets to its neighboring nodes to maintain connectivity. If a node detects a broken link or error in the route, it sends a Route Error (RERR) packet to neighboring nodes to notify them of the issue. This process, emphasizing sequence numbers, ensures continuous and updated routing information throughout the network, providing reliable and loop-free routes.

The User Datagram Protocol

The UDP is a fundamental communication protocol in the Internet Protocol (IP) suite that sends data with minimal protocol mechanisms. Unlike the Transmission Control Protocol (TCP), UDP is connectionless and does not provide error recovery, sequencing, or flow control. This makes it lightweight and faster, enabling rapid data transfer. It transmits self-contained packets, called datagrams, with encapsulated source and destination information, enabling rapid data transfer. Due to its low overhead, UDP is perfect for applications where speed is crucial and occasional data loss is acceptable, such as video streaming, online gaming, and Voice over IP (VoIP). However, its lack of reliability means it is typically used in scenarios where the application can handle errors and data reconstruction.

Simulation Parameter Setup and Scenario

Table 1. Parameter Setup and Value

No	Parameter	Value
1	Performances Matrix (QoS)	PDR, end to end delay, average throughput, Packet loss ratio, end to end Jitter
2	Traffic Scenario	• Freeflow, • steady flow, • traffic jam
3	Simulation time (s)	300, 400,500, 600, 700, 800, and 900 seconds
4	Total number of actual Nodes (vehicles)	Random number of vehicles
5	Type of traffic	Passenger cars only, Left-hand drive
6	Node Movement	All moving nodes

7	Route Selection	Random route selection
8	Initial node position	Random position
9	Type of protocol	AODV and DSDV(Al-Ahwal & Mahmoud, 2023)
10	Node Speed	Random speed
11	Data Packets Configuration	Data Packets Configuration
12	Internet Protocol	UDP
13	Traffic Simulator	SUMO
14	Network Simulator	NS3

Table 1 outlines the parameters and setup for a VANET study, focusing on QoS metrics such as PDR, end-to-end delay, average throughput, Packet Loss Ratio, and end-to-end jitter. The study compares AODV and DSDV routing protocols under different traffic scenarios using random node speeds and data packet configurations. A key aspect of our methodology is using NS3 simulations for data generation and analysis, which allows us to capture vehicle connectivity data in XML trace files. SUMO and NS3 are integrated for combined traffic modeling and network communication simulations. Figure 3 depict the traffic simulation in SUMO.

Fig. 3 Network Map to Simulate the Traffic Scenarios in SUMO

Figure 3 shows that the Bulaksumur Region in Yogyakarta presents complex traffic conditions with potential hazards, including dense traffic flow and congestion points at various locations. SUMO tools generate the network map to represent the actual traffic situation in the area.

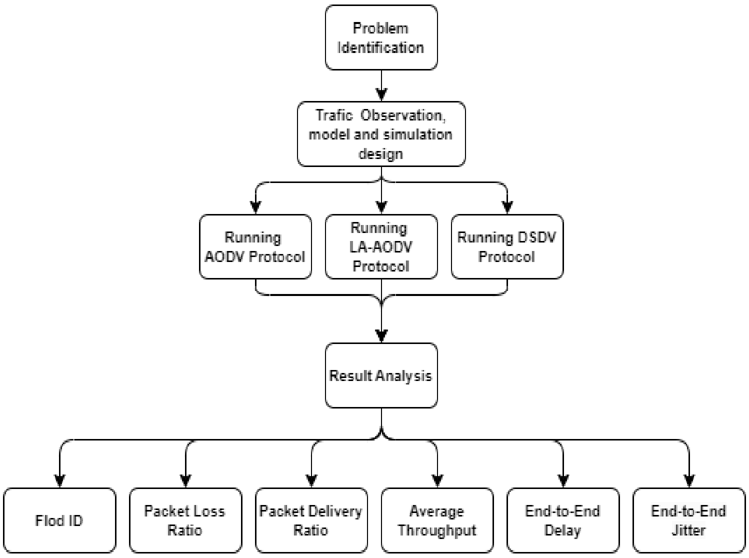

Fig. 4 Quality of Service Matrics Performances

Figure 4 visualizes the simulation matrics of performances under different V2V communication conditions, analyzing key performance metrics such as Packet Loss Ratio, Throughput, Delay, and Jitter. Using the NS3 simulation framework, this figure provides insights into the efficiency of various routing protocols, specifically AODV and DSDV across various VANET scenarios.

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RESULT

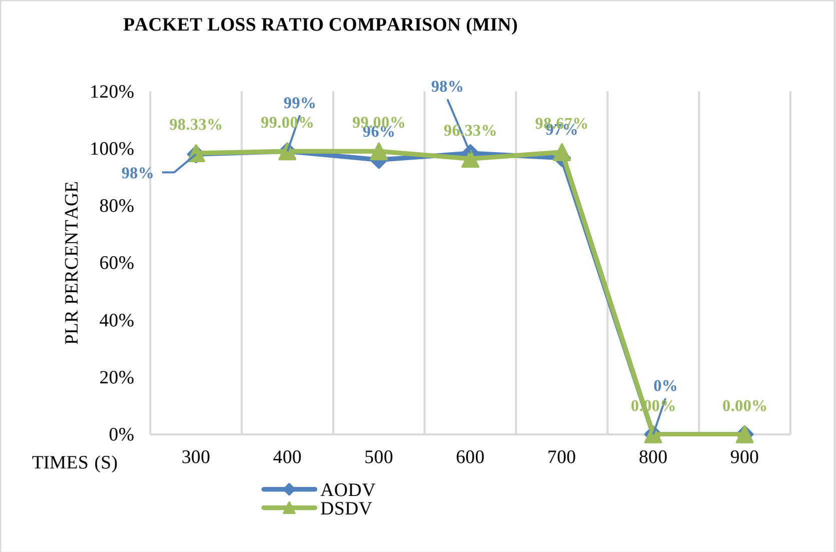

Fig. 5 The PLR Comparison between AODV and DSDV in all generated traffic scenarios

The high packet loss ratios for AODV and DSDV between 300 and 700 seconds in Figure 5 suggest that reactive and proactive protocols struggle with efficient packet delivery under typical network conditions. However, the packet loss dropping to 0% at 800 seconds shows that specific network conditions or optimizations can achieve perfect packet delivery for both protocols. The result implies that replicating these optimal conditions can enhance the reliability and performance of vehicular ad-hoc networks. Additionally, the similar performance between AODV and DSDV under these conditions suggests that both protocols are viable options, allowing for flexibility in protocol choice based on network topology, scalability, and complexity.

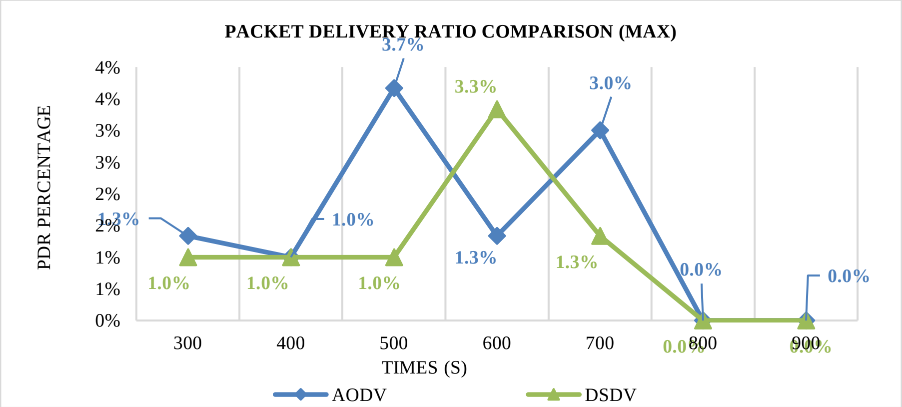

Fig. 6 The Packet Delivery Ratio Comparison Result between AODV and DSDV in all generated traffic scenarios

Figure 6. show the PDR result during the simulation. AODV starts with a PDR of 1.2% at 300 seconds, peaking at 3.7% at 500 seconds and 3.0% at 700 seconds before dropping to 0% at 800 seconds. DSDV maintains a stable PDR of 1.0% from 300 to 400 seconds, increases to 3.3% at 500 seconds, and drops to 1.3% at 600 seconds, plummeting to 0% at 800 seconds and slightly rising to 0.7% at 900 seconds. The data shows that AODV exhibits higher variability and occasional peaks in PDR, while DSDV shows more stability but lower peaks. The simultaneous drop to 0% at 800 seconds for both protocols suggests a significant event or network change impacting both. The simulation result suggests that while AODV may provide higher delivery efficiency under certain conditions, it is less consistent than DSDV.

DISCUSSIONS

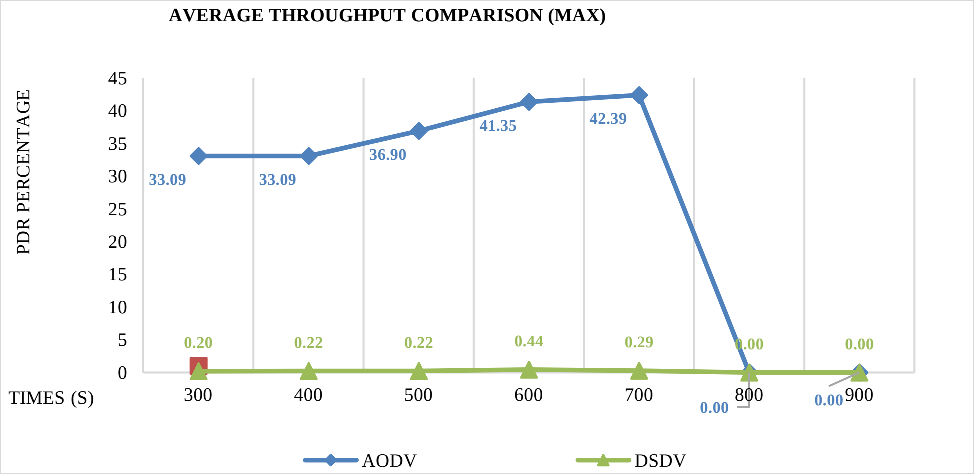

Fig. 7 The Average Throughput Comparison between AODV and DSDV in all generated traffic scenarios

The average throughput analysis for AODV and DSDV protocols reveals a stark contrast in performance, as depict in Figure 7. AODV consistently achieves significantly higher throughput, starting at approximately 33.09 Kbps at 300 and 400 seconds, then increasing to 36.90 Kbps at 500 seconds, 41.35 Kbps at 600 seconds, and peaking at 42.39 Kbps at 700 seconds. In contrast, DSDV maintains a much lower throughput, starting at 0.20 Kbps at 300 seconds, slightly increasing to 0.22 Kbps at 400 seconds, and fluctuating modestly around 0.21 to 0.44 Kbps thereafter. The average throughput analysis for AODV and DSDV protocols shows that AODV consistently achieves significantly higher throughput than DSDV. AODV is more efficient in utilizing network bandwidth, resulting in higher data transfer rates, making AODV better suited for high-throughput and efficient data transmission scenarios, especially in high-demand applications in vehicular ad-hoc networks. Conversely, DSDV's lower throughput may be more appropriate for less demanding environments where stability is prioritized over speed.

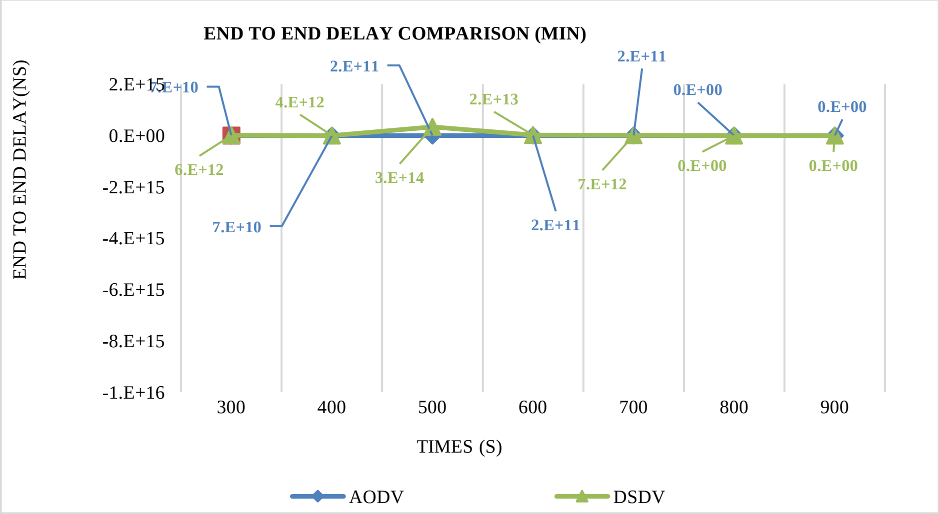

Fig. 8 The End-to-End Delay Comparison between AODV and DSDV in all generated traffic scenarios

The end-to-end delay analysis indicates in Figure 8 shows that AODV consistently has a significantly lower delay than DSDV. Specifically, at 300 and 400 seconds, AODV maintains a delay of 7.40 x 10^{10} nanoseconds, while DSDV's delay decreases from 5.92 x 10^{12} nanoseconds to 3.64. At 500 seconds, AODV's delay increases to 2.00 x 10^{11} nanoseconds, whereas DSDV spikes to 3.38 x 10^{14} nanoseconds. By 700 seconds, AODV's delay decreases to 1.64 x 10^{11} nanoseconds, while DSDV shows a higher delay of 6.81 x 10^{12} nanoseconds. This analysis indicates that AODV offers much lower and more consistent end-to-end delays, making it better suited for time-sensitive applications in vehicular ad-hoc networks. DSDV's higher and more variable delays suggest it may be less reliable for such applications, implying that AODV is preferable for scenarios requiring low latency and consistent performance. At the same time, DSDV might be more suitable for less time-critical uses where stability and predictability are less critical.

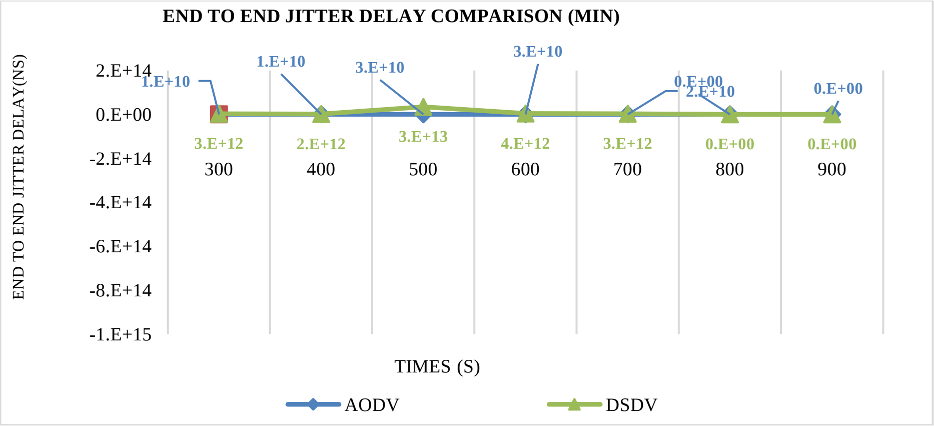

Fig. 9 The End-to-End Jitter Delay Comparison between AODV and DSDV in all generated traffic scenarios

The end-to-end jitter delay analysis in Figure 9 shows that AODV consistently has lower jitter than DSDV, indicating more stable packet delivery times. Specifically, at 300 and 400 seconds, AODV maintains a jitter delay of 1.36 x 10^{10} nanoseconds, while DSDV exhibits significantly higher jitter. At 500 seconds, AODV's jitter increases to 2.58 x 10^{10} nanoseconds, while DSDV spikes to 3.45 x 10^{13} nanoseconds. By 700 seconds, AODV's jitter decreases to 2.26 x 10^{10} nanoseconds, compared to DSDV's higher jitter of 3.49 x 10^{12} nanoseconds. This analysis indicates that AODV provides significantly lower and more consistent end-to-end jitter delays. It is better suited for applications requiring stable and predictable packet delivery times, such as real-time communications and streaming services. The higher and more variable jitter of DSDV suggests it is less reliable for such applications. This implies that AODV is preferable for scenarios where low jitter is critical to maintaining quality of service. In contrast, DSDV might be more appropriate for less time-sensitive uses where stability and predictability are less critical.

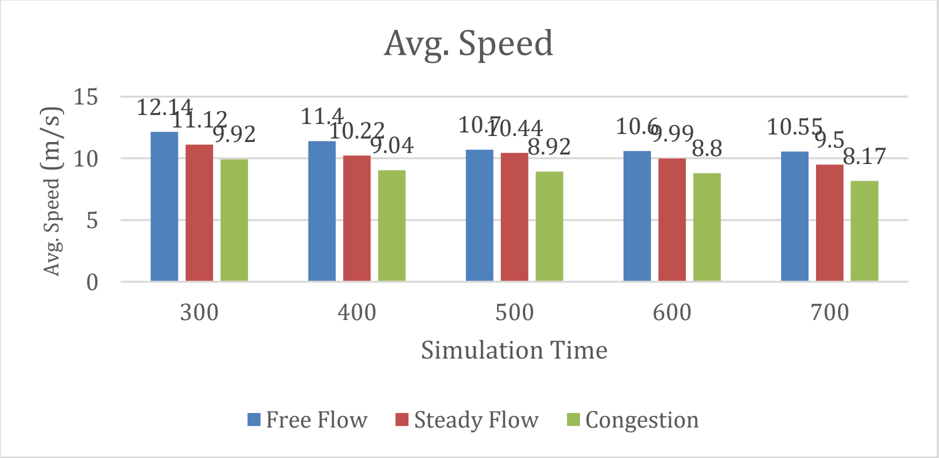

Fig. 10 The Average Speed Comparsion in all generated traffic scenarios

Figure 10 compares the average speeds in meters per second (m/s) based on different levels of traffic density: Smooth Flow, Moderately Dense, and Dense. Under Smooth Flow conditions, speeds range from 12.14 m/s at 300 m/s to 10.55 m/s at 700 m/s. In Moderately Dense scenarios, speeds decrease to 11.12 m/s at 300 m/s and 9.5 m/s at 700 m/s. Dense traffic conditions show further reductions in speed, with values like 9.92 m/s at 300 m/s decreasing to 8.17 m/s at 700 m/s. The QoS results highlight significant implications for network performance using AODV and DSDV routing protocols. Both protocols exhibit high packet loss and low packet delivery ratios across all traffic densities, indicating challenges in maintaining reliable data transmission. Despite its varying packet loss rates, AODV consistently shows higher average throughputs than DSDV. The result suggests that while AODV may achieve higher data transfer rates, the reliability of data delivery diminishes, which is especially evident in higher traffic densities where both protocols struggle with increased end-to-end delays and jitter. These implications underscore the trade-off between throughput and reliability, emphasizing the need for adaptive routing strategies and robust QoS mechanisms to mitigate performance degradation in congested network environments. Thus, optimizing QoS parameters becomes crucial for enhancing network efficiency and ensuring reliable data transmission under varying traffic conditions.

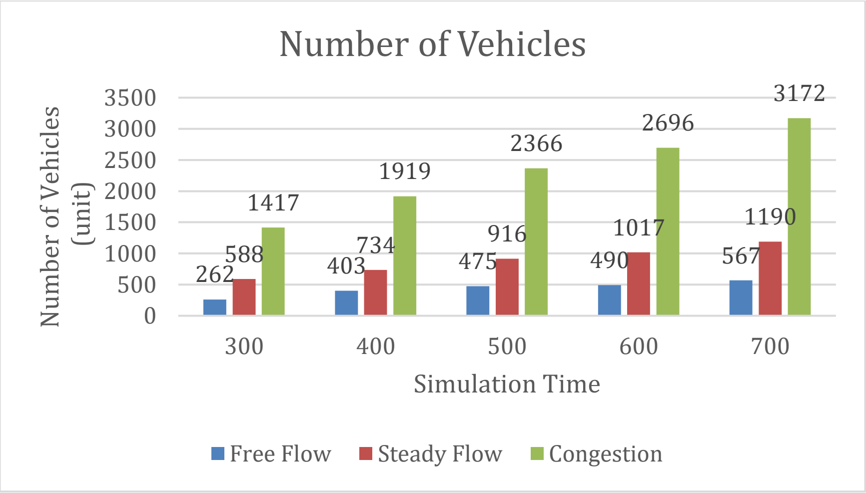

Fig. 11 The Total Number of Vehicle Comparison in all generated traffic scenarios in SUMO Simulation

The Figure 11 compares the performance metrics of AODV and DSDV routing protocols at different vehicle densities: Light, Moderate, and Heavy. Under light traffic conditions, vehicle counts range from 262 at 300 vehicles to 567 at 700 vehicles. These counts represent the number of vehicles within the network range. For moderate traffic densities, vehicle counts increase from 588 at 300 vehicles to 1190 at 700 vehicles. In heavy traffic conditions, vehicle counts are significantly higher, ranging from 1417 at 300 vehicles to 3172 at 700 vehicles. By analyzing these traffic densities with QoS metrics, we have uncovered significant trends. Higher vehicle densities (moderate to heavy) are associated with poorer QoS performance metrics, including higher packet loss ratios, lower packet delivery ratios, increased end-to-end delay, and higher jitter. The correlation underscores the substantial impact of congestion on network performance, where increased vehicle density leads to more frequent packet loss, delays, and reduced throughput efficiency. Analyzing congestion levels alongside QoS metrics shows that higher congestion leads to poorer QoS performance. The situation underscores the impact of congestion on network performance, emphasizing the need for better QoS management and infrastructure in densely populated or high-traffic areas.

CONCLUSION

This research unequivocally demonstrates the superiority of AODV over DSDV in Vehicular ad-hoc networks (VANETs) for UDP communication. The comparison of AODV and DSDV routing protocols under various conditions, focusing on metrics such as Packet Loss Ratio (PLR), Packet Delivery Ratio (PDR), average throughput, end-to-end delay, and end-to-end jitter, consistently favors AODV. The research methodology involved setting up simulated VANET environments and running extensive tests to measure the performance of both protocols. AODV's average PLR, close to 98% across different time intervals, outshines DSDV's slightly higher PLR, indicating more packet loss. AODV's higher average throughput, peaking at 42.3918 Kbps compared to DSDV's maximum of 0.4414 Kbps, further solidifies its superiority. Moreover, AODV's significantly lower end-to-end delays and jitter, with delays ranging from 7.40E+10 ns to 2.49E+11 ns and consistently lower jitter delays than DSDV's values, which peaked at 3.45E+13 ns, reinforce its dominance. The PDR for AODV reached up to 4%, while DSDV remained at 1% in most scenarios, further confirming AODV's more efficient data delivery.

Given the promising results of this study, future research has the potential to significantly enhance VANET performance. By integrating more advanced and hybrid routing protocols, we can unlock new levels of efficiency and reliability in vehicular networking. Investigating the impact of varying traffic densities, including mixed vehicle types and two-way traffic scenarios, will be crucial in understanding the robustness of these protocols. Additionally, examining the influence of real-world environmental factors and implementing machine learning techniques for adaptive routing decisions can further improve routing efficiency and reliability in highly dynamic vehicular networks, offering hope for a brighter future in this field.

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