Jurnal Teknik Informatika (JUTIF)
Vol. 5, No. 4, October 2024, pp. 1277-1286

DOI: https://doi.org/10.52436/1.jutif.2024.5.5.2237
p-ISSN: 2723-3863
e-ISSN: 2723-3871

THE PERFORMANCE ANALYSIS OF REACTIVE AND PROACTIVE ROUTING PROTOCOLS FOR V2V COMMUNICATION IN DYNAMIC TRAFFIC SIMULATION

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(Article received: June 7, 2024; Revision: July 29, 2024; published: October 20, 2024)

Abstract

The research problem addressed in this study arises from the urgent need to enhance Vehicle-to-Vehicle (V2V) communication in dynamic traffic scenarios. V2V communication is a critical component of intelligent transportation systems aimed at improving traffic safety and efficiency. However, existing routing protocols exhibit varying performance under different traffic conditions, such as free flow, steady flow, and congestion. Consequently, a comprehensive comparison is necessary to evaluate the effectiveness of three routing protocols—AODV, LA-AODV, and DSDV—in dynamic V2V scenarios. This research aims to address this problem by simulating realistic traffic conditions and evaluating the Quality of Service (QoS) of each protocol using metrics such as Packet Delivery Ratio (PDR), Packet Loss Ratio (PLR), Throughput, End-to-End Delay, and Jitter. The findings indicate that LA-AODV demonstrates superior performance in terms of PDR (up to 4% at 500 seconds), PLR (reaching 95.33% at 500 seconds), and Throughput (reaching 84.81 Kbps at 800 seconds). This makes it an excellent choice for applications prioritizing reliable data transfer. Conversely, AODV exhibits the lowest latency and jitter, with latency (reaching 7.40E+10 ns) and jitter (reaching 1E+10 ns) at 300 and 400 seconds, respectively. AODV is well-suited for real-time V2V communication due to its minimal delay and jitter. DSDV, while minimizing control overhead, performs less favorably in other metrics. Consequently, AODV emerges as the preferred option for real-time V2V communication. LA-AODV excels in scenarios emphasizing data delivery and high throughput. DSDV may find relevance in security-sensitive applications where minimizing control traffic is crucial.

Keywords: *V2V Communication, QoS, Reactive Routing Protocol, AODV, LA-AODV, DSDV*

1. INTRODUCTION

V2V communication technology emerges as a promising avenue for enhanced road safety by promoting improved situational awareness among neighboring vehicles[1][2]. Dynamic traffic environments necessitate robust routing protocols to ensure reliable and efficient V2V communication.[3]. AODV employs a reactive approach[4], establishing routes on-demand to minimize control message overhead in the network[5]. Triggered by a specific destination request, a node initiates route discovery by broadcasting route request (RREQ) messages[6]. Sequence numbers prevent routing loops[7] and guarantee route validity[8].

In contrast to reactive protocols, DSDV proactively disseminates routing tables throughout the network for continuous route awareness[9]. DSDV targets reliable route maintenance within the dynamic VANET environment[10]. Leverages sequence numbers to ensure loop-free routing[11], guaranteeing the use of the freshest routes[12]. DSDV's frequent updates for consistent routing information across the network can significantly increase energy consumption, especially for large deployments[13]. LA-AODV distinguishes itself by employing real-time vehicle data and learning automata to dynamically select optimal relay nodes[1].

Prior research has explored comparisons between reactive and proactive routing protocols, in [14] comparing reactive protocol by increasing the number of nodes and speed, another research [15] comparing reactive protocol based on QoS, in [16] comparative AODV and Ant Colony Optimization (ACO). Some studies comparing reactive and proactive protocols in [17] comparing reactive and proactive protocols in VANET based on QoS, another research [18] comparing AODV, DSDV and OLSR routing protocol in VANET environment. In Vehicular Ad Hoc Networks (VANETs), routing protocols fall into two main categories: proactive and reactive. Proactive protocols continuously update route information to ensure that each node has access to the latest route details for all other nodes. These protocols achieve this by broadcasting control packets containing routing table information[12]. In contrast, reactive (on-demand) protocols do not maintain routing tables on every node. Instead, they establish routes only when data transmission is necessary. Reactive protocols are particularly useful in dynamic scenarios with high mobility and changing network topologies, where maintaining fixed routing tables becomes challenging[19].

The study evaluates the effectiveness of reactive (AODV, LA-AODV) and proactive (DSDV) routing protocols in dynamic V2V communication environments with varying traffic patterns. We focus on routing efficiency and network performance using key metrics such as message redundancy, packet delivery reliability, packet loss, throughput, end-to-end delay, and jitter. The aim is to compare the performance of reactive and proactive routing protocols in dynamic V2V scenarios to identify significant network performance differences.

The study includes introduction, the research method in Section 2, the comparison between LA-AODV and AODV in the results of Section 3, discussion in Section 4. The conclusion is in Section 5.

2. RESEARCH METHOD

We extensively reviewed existing V2V communication protocols in the initial research phase to identify challenges, including network stability, data congestion, and communication delays. We then created a simulation design, as shown in Figure 1.

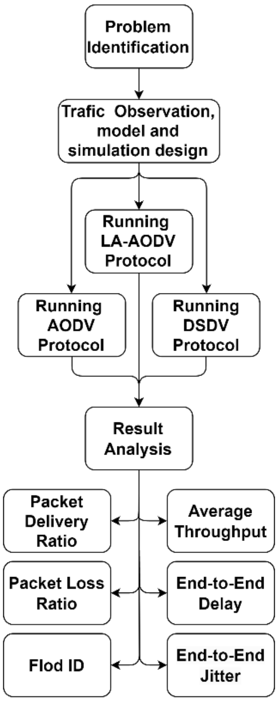

Figure 1. This study analyzes the stages of the research process.

As depicted in Figure 1, the simulation environment is crucial to our research. We use Linux Ubuntu 20.02 for simulations and generate XML trace files during NS3 simulations to capture essential connectivity data among vehicle nodes to model detailed traffic systems considering passenger-vehicle interactions across diverse traffic scenarios, we utilized SUMO-GUI[20]. Additionally, we leveraged NS3 v3.35, a reputable discrete-event simulator for network communication modeling[21]. By seamlessly integrating SUMO with NS3, we achieved successful connectivity between traffic modeling and network communication simulations.

We used the Gadjah Mada University (UGM) roundabout during data collection. This roundabout features four lanes accommodating two-way traffic flow. Its design allows vehicles to enter and exit the roundabout, including facilitating U-turns. While navigating within the roundabout, strict adherence to the ‘give way to the right’ rule and completing a full circle are essential. However, it is important to note that the study does not fully account for potential obstacles, such as pedestrians, parked vehicles, and motorized vehicles entering or exiting side roads, as illustrated in Figure 2.

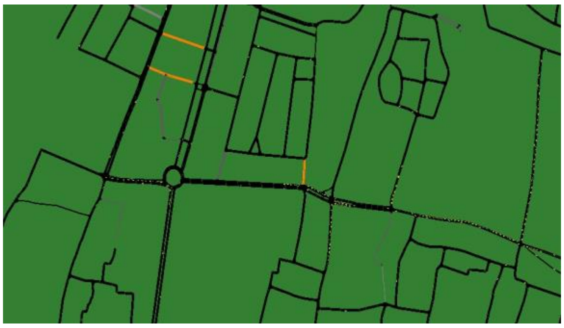

Figure 2. The UGM roundabout network map, encompassing its surroundings, reflects a real-world scenario.

In Figure 2, The UGM roundabout is near a traffic light-controlled intersection on Terban Road. Potential obstacles arise at the entrances to Mirota Kampus, SMK BOPKRI 1, and SMP BOPKRI 3. The road narrows near the roundabout, and there may be congestion on nearby roads during events. Effective coordination of vehicle movements and maintaining safe distances are crucial.

Our research utilizes SUMO for traffic modeling and NS3 for communication modeling. We evaluate our LA-AODV routing method using metrics such as Flood ID, PLR, PDR, Average Throughput, End-to-End Delay, and End-to-End Jitter, comparing them with the previous AODV routing approach. The simulation parameter configuration employed for this research is summarized in Table 1.

Table 1. This research probes V2V simulation parameters.

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 (prob 0.55) *, • steady flow (prob 0.33) *, • traffic jam (prob 0.1) * *Based on Poisson Distribution
3	Simulation time (s)	300, 400,500, 600, 700, 800, and 900 seconds
4	Total number of actual Nodes (vehicles)	Random, based on Poisson distribution Free flow
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	LA-AODV parameter Setup	fs: 0.4; fa: 0.3; fd: 0.3; α: 1; Reward: 1; Penalty: 0
10	Type of protocol	AODV, LA-AODV, and DSDV
11	Node Speed	Random speed
12	Data Packets Configuration	Data Packets Configuration

The study analyzes different traffic scenarios and evaluates the LA-AODV protocol's performance under these conditions. We consider metrics such as Packet Delivery Ratio, delay, throughput, loss ratio, and Jitter using real-time traffic data packets and realistic vehicle movement simulations. Additionally, we examine the impact of speed, acceleration, and distance on vehicular communication. The LA-AODV protocol's learning rate parameter is set to 1, facilitating optimal routing decisions. Equation 1 introduces the Poisson distribution formula to quantify the likelihood of a vehicle's appearance occurring within defined time frames across various traffic scenarios.

$$P(A=i)=\frac{b^{-\lambda}*\lambda^{-i}}{i!} \qquad (1)$$

The Poisson distribution, expressed by Eq. (1), monitors the frequency of vehicle passages at a specific location. The equation incorporates ‘b’, representing Euler’s number (approximately 2.71), and ‘λ,’ denoting the average event rate within a defined time frame. Additionally, the factorial ‘i!’ accounts for the product of positive integers up to ‘i.’ In simulation contexts, the Poisson distribution predicts the probability of observing a particular number of vehicles passing a given location, based on the mean event rate ‘λ’. Figure 3 visually depicts the operational processes of the three investigated protocols, along with the design considerations for the simulation environment.

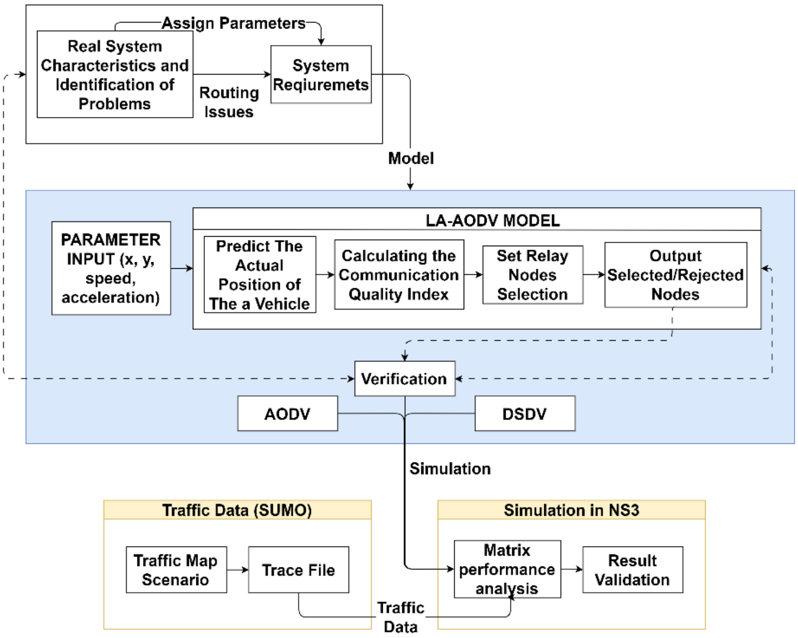

Figure 3. This study analyzes routing protocols in V2V simulation design.

DOI: https://doi.org/10.52436/1.jutif.2024.5.5.2237
p-ISSN: 2723-3863
e-ISSN: 2723-3871

Figure 3 outlines the steps for building and validating a model of a natural system. This involves observing the system to understand its behavior, then building a model and simulation to replicate it. Realistic traffic data is used to test the model, followed by validation to ensure accuracy.

In our simulation study, we conduct a comparative analysis between the LA-AODV protocol and two conventional protocols: AODV and DSDV. This evaluation aims to shed light on the performance differences and merits of these routing protocols within the context of vehicular communication.

1. AODV

In [22] The AODV routing protocol leverages a reactive, hop-by-hop approach with distance vector routing, minimizing control overhead and adapting to network changes efficiently. Unlike proactive protocols, AODV discovers routes on demand and utilizes Route Request (RREQ), Route Reply (RREP), and Route Error (RERR) messages for route maintenance and error notification. Figure 4, illustrates the AODV routing protocol's mechanism.

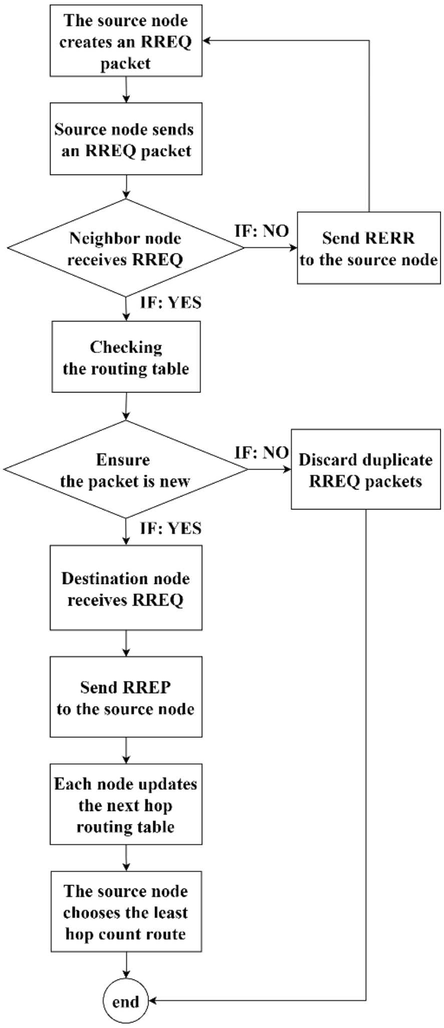

Figure 4. AODV routing mechanism.

As can be seen in Figure 4, in AODV nodes initiate route discovery with the source node creating an RREQ packet and broadcasting it when the path to the destination is not found in their route table. Then neighboring nodes receive the RREQ and ascertain the route table. RERR will be sent to the source node if the neighboring nodes do not receive the RREQ. The RREQ propagates through the network, allowing intermediate nodes to establish a return path and the destination to send the RREP back. This establishes a route for data transmission and minimizes control overhead by removing duplication.

2. DSDV

In [18] DSDV, all nodes proactively maintain and broadcast routing tables containing sequence numbers, hop counts, and destinations for efficient route discovery, with update suppression and request buffering for optimized network maintenance. Figure 5, illustrates the DSDV routing protocol's mechanism.

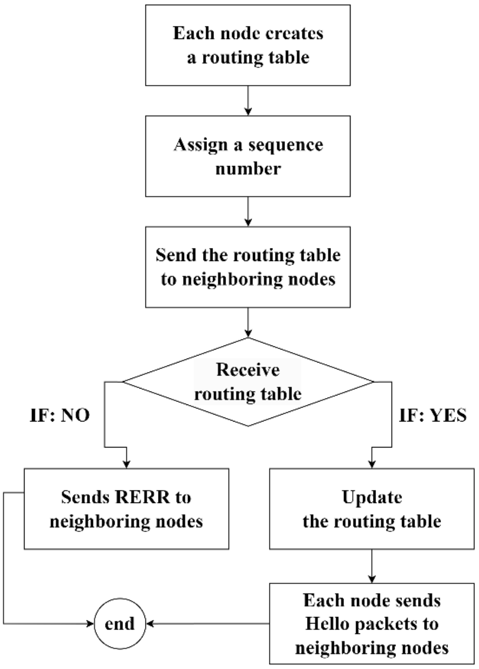

Figure 5. DSDV routing mechanism.

As can be seen in Figure 5, In DSDV, each node create a routing table with distances to all neighbors and a sequence number. This table is periodically shared with neighbors. If a node doesn't receive a table from a neighbor within a set time, it broadcasts a Route Error (RERR) to notify others of the broken link. Upon receiving an update packet, a node extracts the information and updates its table. To signal its activity, the node periodically sends Hello packets to all neighbors..

3. LA-AODV

In [3] the LA-AODV model uses input parameters to predict vehicle positions and evaluates communication stability with nearby vehicles using the Communication Quality Index (CQI). It selects relay nodes with a Total Weighted Ratio (TWR) score between 0.6 and 1, excluding nodes below 0.6. Nodes within the preferred TWR range are consistently assigned a reward value of 1, improving protocol performance and reliability. LA-AODV also boosts estimation of car parts and routing decisions in vehicular networks. It does this by predicting a vehicle's present and future positions using speed and relative positioning, while also determining real positions using velocity and acceleration parameters (as shown in Eq. 2).

$$INITpos_k = \sum_{k=1}^{k\leq R} actual_{pos_x}, actual_{pos_y}, S_k \tag{2}$$

In LA-AODV, Equation (2) is key for precise vehicle routing and positioning in the network. It uses parameters like a vehicle's initial x and y coordinates ($INITpos_k$), speed (Sk), total vehicles in transmission range (R), and a reference index (k) to identify the specific node or vehicle when determining proximity.

This study directly compares the performance of three routing protocols (AODV, DSDV, and LA-AODV) in V2V communication using QoS parameters like PDR, PLR, Average Throughput, End-to-End Delay, and Jitter.

1. PDR quantifies the proportion of packets reaching their destination within a specific timeframe[23].
2. PLR quantifies the proportion of packets failing delivery within a network[24].
3. Average Throughput quantifies successful data transfer by dividing the total received packets at the destination by the measurement interval[25].
4. End-to-end delay quantifies the average time packets require to travel from source to destination[26].
5. End-to-end jitter quantifies the variability in packet arrival times at the receiver, arising from queueing delays and packet reassembly after potential transmission errors[3].

3. RESULT

This study compared a new V2V communication routing method called LA-AODV with existing methods (AODV and DSDV) in terms of QoS using parameters such as packet delivery ratio, packet loss ratio, average throughput, end-to-end delay, and end-to-end jitter delay. Figure 6 shows the trend in Total Flood ID transmitted during a V2V communication scenario over a 300-900 second timeframe.

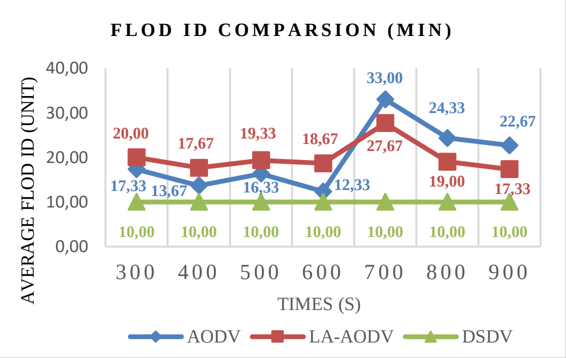

Figure 6. This study analyzes AODV, LA-AODV, and DSDV's Flood ID behavior in V2V communication (300-900 seconds).

In Figure 6, the DSDV protocol consistently demonstrated lower Flood ID values than LA-AODV and AODV at ten units. By the 300th second, LA-AODV and AODV exhibited slightly better performance, achieving Flood IDs of 20 and 17.33 units, respectively. This pattern persisted in subsequent measurements. Next, we will analyze the Packet Loss Ratio (PLR) experienced by AODV, DSDV, and LA-AODV between 300 and 900 seconds, and the results will be presented in Figure 7.

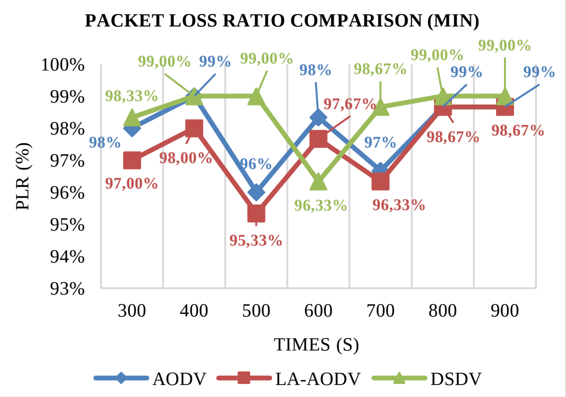

Figure 7. This study analyzes PLR in V2V communication (AODV, LA-AODV, DSDV) from 300 to 900 seconds.

The data from Figure 7 shows that DSDV consistently had a higher Packet Loss Rate (PLR) compared to LA-AODV and AODV at various time points. For instance, at 300 seconds, DSDV had a PLR of 98.33%, while LA-AODV and AODV had 97.00% and 98.00% PLR, respectively. This trend continued at 400, 500, 600, 700, 800, and 900 seconds.

Figure 8 depicts the trends observed in the PDR for the AODV, DSDV, and LA-AODV routing protocols within the V2V communication scenario. The data presented encompasses the timeframe between 300 and 900 seconds.

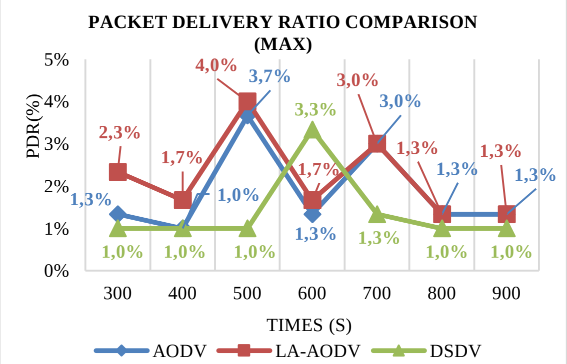

Figure 8. This research explores Packet Delivery Ratio (PDR) in V2V communication for AODV, LA-AODV, and DSDV between 300 and 900 seconds.

Based on Figure 8, LA-AODV consistently outperforms AODV and DSDV at various time intervals (300s, 400s, 500s, 600s, 700s, 800s, and 900s). The performance of LA-AODV is consistently superior to AODV and DSDV across all these time intervals. Subsequently, we proceeded to evaluate the performance metrics based on average throughput. Throughput, measured in kilobits per second (Kbps), reflects the mean rate of successful data packet transmissions. Figure 9 presents the results of average throughput across all simulated scenarios.

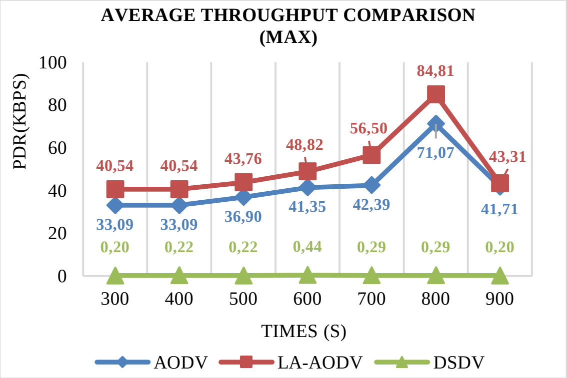

Figure 9. This study compares average throughput across all traffic conditions

LA-AODV consistently outperforms AODV and DSDV in Average Throughput, showing higher values across various time intervals, such as 300 seconds (LA-AODV: 40.54 Kbps, AODV: 33.09 Kbps, DSDV: 0.20 Kbps) and 900 seconds (LA-AODV: 43.31 Kbps, AODV: 41.71 Kbps, DSDV: 0.20 Kbps). Next, A meticulous analysis of End-to-End Delay, as illustrated in Figure 10, provides valuable contributions to our understanding of AODV, DSDV, and LA-AODV performance within the context of V2V communication.

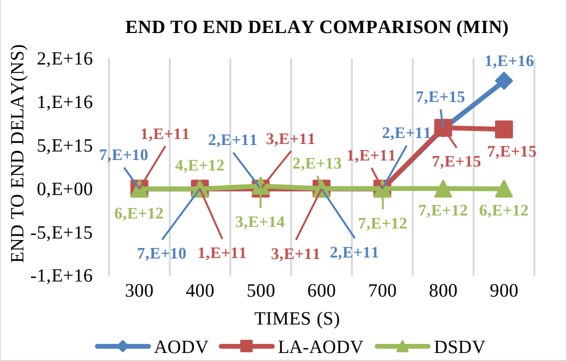

Figure 10. This study investigates how end-to-end delay varies across different traffic scenarios

In Figure 10, AODV consistently has lower End-to-End Delay values compared to LA-AODV and DSDV, with a stable delay at 7.40E+10 ns from 300 to 400 seconds, increasing to 2.49E+11 ns at 600 seconds and peaking at 1.24E+16 ns at 900 seconds. LA-AODV exhibits higher delays, ranging from 1.25E+11 ns to 2.79E+11 ns, with substantial increases and decreases at different intervals.

In contrast to the other two protocols, DSDV presents a different performance profile with high End-to-End Delay values. It starts with a delay of 5.92E+12 ns at 300 seconds, 3.64E+12 ns at 400 seconds, and 3.38E+14 ns at 500 seconds. The delay decreases to 1.76E+13 ns at 600 seconds, remains consistent at 6.81E+12 ns during the 700 and 800-second intervals, and returns to 5.92E+12 ns at 900 seconds Figure. 11 provides a comparison of end-to-end jitter across the network.

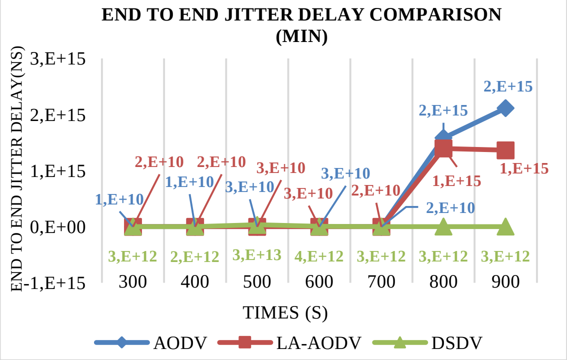

Figure 11. This study probes end-to-end jitter in V2V communication (300-900 seconds) across traffic conditions.

The data in Figure 11 indicates that AODV consistently has lower End-to-End Jitter Delay values than LA-AODV and DSDV across time intervals from 300 to 700 seconds. At 300 and 400 seconds, AODV maintains stable values around 1.36E+10 ns, with a slight increase at 500 seconds to 2.58E+10 ns and a gradual rise to 2.88E+10 ns at 600 seconds. However, there is a decrease at 700 seconds (2.26E+10 ns), followed by a significant spike at 800 seconds (1.58E+15 ns) and a recorded value of 2.11E+15 ns at 900 seconds.

4. DISCUSSION

This work presents a comparative analysis of LA-AODV, AODV, and DSDV routing protocols focusing on their QoS performance. Packet delivery ratio, packet loss ratio, average throughput, end-to-end delay, and end-to-end jitter delay were employed as QoS evaluation metrics.

4.1. Flod ID

Data presented in Figure 3 suggests DSDV exhibits lower routing control overhead compared to LA-AODV and AODV. This is evidenced by the consistently lower number of data packets transmitted by DSDV. LA-AODV, due to its dynamic route selection based on real-time traffic conditions, generates slightly more control messages than DSDV. Interestingly, AODV shows a significant increase in data packet transmission at the 700-second mark, potentially indicating a rise in routing overhead.

4.2. PLR

Figure 4 illustrates the PLR for the DSDV, LA-AODV, and AODV routing protocols during the V2V communication simulation (300-900 seconds). At 300, 500, and 700 seconds, DSDV consistently exhibited a higher PLR than LA-AODV and AODV. LA-AODV demonstrated a slight advantage in preserving packet integrity throughout the simulation compared to DSDV and AODV. LA-AODV has a consistently lower Packet Loss Ratio (PLR) than AODV and DSDV in the 300-900 second timeframe, making it a favorable choice for reliable packet delivery in V2V communication. There is an anomaly at 600 seconds where the resulting packet loss ratio is lower than the other times. This is because in the steady flow scenario with probability 0.33, there is a significant decrease of 91%. This decrease in PLR illustrates that dsdv managed to send more packets when communicating at 600 seconds. However, AODV and DSDV may have advantages in reduced routing overhead or adaptability in specific contexts. Therefore, selecting AODV, DSDV, and LA-AODV for V2V communication should consider the specific application's priorities and requirements.

4.3. PDR

The findings in Figure 5, there is also an anomaly in the packet delivery ratio at 600 seconds which results in a higher packet delivery ratio compared to other times. This is because in the stedy flow scenario with a probability of 0.33 there is a significant increase of 8%. This increase in PDR illustrates that dsdv successfully sends more packets when communicating at 600 seconds.

In the other hand, figure 5 demonstrate that LA-AODV consistently outperforms AODV and DSDV in terms of PDR in V2V communication. This suggests LA-AODV's superior efficiency and reliability in transmitting data packets. LA-AODV consistently achieves a higher success rate in delivering data packets compared to AODV and DSDV. This indicates potential challenges in reliably delivering data packets with AODV and DSDV, suggesting a trade-off between successful packet delivery and other performance considerations in V2V communication environments.

4.4. Average Throughput

A comprehensive analysis of Figure 6 reveals the LA-AODV protocol consistently exhibits stable performance in terms of Average Throughput across most of the examined time intervals. LA-AODV outperforms AODV, which demonstrates fluctuating Average Throughput values at different time points. Meanwhile, the DSDV protocol consistently provides Average Throughput values ranging from 0.20 Kbps to 0.44 Kbps. However, it’s important to note that the overall performance of DSDV remains relatively low.

4.5. End-to-End Delay

Figure 7 illustrates the End-to-End Delay Analysis, revealing AODV’s consistent superiority over both LA-AODV and DSDV across nearly all evaluated time intervals. AODV exhibits significantly lower delay values, indicating its efficient ability to facilitate rapid transmission of data packets from source to destination within V2V communication networks. This advantage becomes particularly pronounced in real-time V2V communication applications, where minimizing communication latency is of utmost importance. In contrast, LA-AODV and DSDV consistently exhibit higher and more variable End-to-End Delay values, rendering them less favorable choices for latency-sensitive applications.

4.6. End-to-End Jitter

Based on Figure 8, LA-AODV consistently shows higher End-to-End Jitter Delay values. AODV outperforms LA-AODV and DSDV in delivering data packets with consistent and predictable transmission times within V2V communication networks. AODV's ability to maintain lower jitter values is crucial for precisely delivering data packets. LA-AODV and DSDV exhibit higher and less predictable End-to-End Jitter Delay values, requiring careful consideration of specific jitter tolerance requirements in V2V communication.

4.7. Overall Result

The results show that LA-AODV has the best performance in terms of PDR (up to 4% 500 sec), PLR (95.33% 500 sec), and Throughput (84.81 kbps 800 sec), this indicates LA-AODV excels in scenarios that prioritize high data delivery and reliable data transfer. AODV exhibits the lowest latency (7.40E+10 ns 300 seconds) and jitter (1E+10 ns 400 seconds), indicating AODV is ideal for real-time V2V communication. DSDV shows flod id (10 units) at every time interval, which indicates DSDV is suitable for security-sensitive applications where minimizing traffic control is critical.

In addition to the research conducted by [3], where the research also examines the implementation of LA-AODV and AODV in changing traffic. In [3] research AODV excels in terms of flod id, delay, and jitter. Meanwhile, LA-AODV excels in terms of PLR, PDR, and thrput. In addition, there are differences in research results, namely in this study the flod id parameter is outperformed by the dsdv protocol.

5. CONCLUSION

In conclusion, LA-AODV achieved the highest packet delivery ratio (up to 4.0%), packet loss ratio (95.33%) and average throughput (reaching 84.81 Kbps), making it suitable for scenarios demanding high data reliability and transfer rates. However, AODV emerged as the best choice for minimizing communication latency and jitter (as low as 1.36E+10 ns and 2.11E+15 ns, respectively), crucial for real-time V2V communication. In contrast, DSDV minimized control message overhead but exhibited lower performance in other metrics. These findings suggest that AODV is ideal for real-time V2V communication with minimal latency and jitter requirements, LA-AODV is suitable for scenarios prioritizing high data delivery ratio and throughput, and DSDV is best for security-sensitive applications where minimizing control message traffic is essential.

Future research can explore the behavior of these protocols in large-scale V2V network simulations, validate the findings in real-world testing, and investigate the development of hybrid protocols to cater to a wider range of V2V communication needs. By understanding these trade-offs, V2V communication systems can be optimized for reliable and timely data transmission, ultimately enhancing transportation safety and efficiency.

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