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Evaluating the Performance of ETSI-ITS Multi-Stack Protocols for V2V Communication in VANETs: A Simulation Study

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Abstract – The research evaluates various multi-stack protocols for Vehicular Ad-hoc Networks (VANETs), focusing on Vehicle-to-Vehicle (V2V) communication scenarios with Emergency Vehicle (EV) simulations. The study uses the ns-3 network and SUMO (Simulation of Urban MObility) traffic simulators to test these protocols in diverse scenarios, including fluctuating data rates and dense network conditions. By implementing the IEEE 802.11p protocol alongside vehicular message dissemination stacks compliant with ETSI (European Telecommunications Standards Institute) ITS (Intelligent Transport Systems) standards, the study performs simulation experiments with varying vehicle counts, ranging from 20 to 35. It employs two distinct data rate configurations while maintaining a constant transmission power of 23 dBm. The results indicate a decline in the average Packet Reception Ratio (PRR) as vehicle density increases, indicating heightened contention and interference. At the same time, there is an observed increase in average latency, contributing to increased message transmission and reception delays. The quantitative analysis demonstrates an inverse relationship between the average PRR and the total vehicle count when the SEND_CAM message is enabled. On the other hand, disabling SEND_CAM maintains a relatively consistent average PRR across scenarios. Additionally, a positive correlation between vehicle count and average latency underlines the impact of network congestion and interference on communication efficacy within VANETs. Despite suboptimal PRR values falling between 41% and 47%, latency performance remains satisfactory, with average latency durations ranging from 0.154 s to 0.187 s. Notably, the SEND_CAM parameter status shows negligible impact on protocol performance, suggesting that network density plays a more pivotal role. Finally, this study offers valuable insights into the trade-offs and challenges of multi-stack protocols in V2V communication within VANETs. Further optimization efforts are recommended to improve packet reception ratios, especially in high-vehicle-density environments, while maintaining acceptable latency levels. These findings contribute to the ongoing efforts to enhance the reliability and efficiency of communication protocols in VANETs, thus advancing the development of intelligent transportation systems. The study's quantitative protocol performance analysis under varying network conditions provides valuable guidance for optimizing V2V communication deployments in VANETs.

Keywords – *V2V communication, VANETs, Multi-stack protocols, ETSI-ITS, NS-3 simulator*

I. INTRODUCTION

The increasing demand for Intelligent Transportation Systems (ITS) applications has led to the development of Vehicular Ad-hoc Networks (VANETs), which enable Vehicle-to-Vehicle (V2V) communication between vehicles[1][2]. VANETs provide a flexible and dynamic communication infrastructure for ITS applications. Still, they also present complex and challenging communication requirements, such as high-speed communication, real-time support, and security and privacy[3], [4]. Various communication protocols have been proposed for VANETs, including single-stack and multi-stack protocols[5]. Multi-stack protocols offer advanced features and can handle a broader range of communication requirements, but they can also be more complex and challenging to manage. As such, the simulation of multi-stack protocols for V2V communication in VANETs is a crucial step in evaluating their performance and identifying areas for improvement and future research[6].

A multi stack protocol survey[7] found that Communication among vehicular nodes, which enable drivers to make appropriate decision needs high reliability; therefore the design of a routing protocol that ensures a certain level of QoS represents one of the most critical challenges of the vehicular networks. Related to the QoS performances, a new approach is proposed to improve the V2V communication in VANET[8]. Albattah [9] Analyzed the current vehicular communication research flow and their deployments and found that the emerging technologies in the upcoming markets will enable the development of high-featured VC technologies for a wide range of applications in the future. While Khan[10], Identifying multi-layer issues and possible solution in Wireless Access in Vehicular Environment (WAVE), a suite of communication and security standards in the Vehicular Area Networks (VANETs). Another study reports the evaluation performance of various VANET communication standards related to the connected vehicles problem [11]. In addition, to connect the vehicles through V2V communication in order to anticipate dynamic traffic, a Non-IP multi-stack protocol like WAVE and ETSI ITS G5 is essential to provide safety [12].

However, it is still the need for more knowledge and understanding of the performance of multi-stack protocols for Vehicle-to-Vehicle (V2V) communication in Vehicular Ad-hoc Networks (VANETs) in various scenarios such as various data rate communication, and dense networks. Despite the increasing demand for Intelligent Transportation Systems (ITS) applications and the development of VANETs to enable V2V communication, there need to be more comprehensive studies evaluating the performance of multi-stack protocols in these scenarios[13]. The study evaluates the performance of multi-stack protocols for Vehicle-to-Vehicle (V2V) communication in VANETs, specifically in the context of Emergency Vehicle (EV) simulations under various scenarios and provide valuable insights into the trade-offs and limitations of multi-stack protocols and inform the development of future VANET communication solutions.

The contribution of this study is significant to the field of VANET communication. The research provides an in-depth evaluation of the performance of multi-stack protocols for Vehicle-to-Vehicle (V2V) communication in Vehicular Ad-hoc Networks (VANETs) through Emergency Vehicle (EV) simulation. The study analyzes the performance of the protocols under various challenging scenarios, including various data rate communication and dense networks. It presents valuable insights into the trade-offs and limitations of multi-stack protocols. The simulation framework used in this study, which combines the ns-3 simulator and the SUMO (Simulation of Urban MObility) simulator, provides an open-source solution for V2V communication in VANETs. This study's findings will benefit researchers and practitioners interested in optimizing V2V communication in VANETs and inform future research and development in this field.

II. RESEARCH METHODOLOGY

A. The Simulation Environment

Simulation of Urban MObility (SUMO) GUI [14] *v.12*: SUMO allows users to model traffic systems that include road vehicles and public transport; even pedestrians can be modeled into the traffic systems, providing the GUI to visualize the mobility and improve the interaction with the user using the TraCI to make the simulation easier than standard SUMO simulation. TraCI interface has been used to couple the SUMO functionalities with NS-3

Network Simulator 3 (NS3) [15] *v3.35*: NS3 is a discrete-event simulator that allows users to model all the aspects of communication among the various entities, including the involved network stacks. It is an open-source application that can be combined with the other simulation, such as SUMO, to provide interactive and user-friendly network simulation.

NetAnim *v.1.18* [16] : NetAnim is an offline animator based on the Qt toolkit. We are animating the simulation using XML trace files collected during the simulation. In this study, NetAnim is used to visualize the connectivity between vehicle nodes based on the XML trace file generated from the NS3 simulation. If SUMO represents the movement mobility of the vehicle nodes, then NetAnim simulates the connectivity of the vehicle mobility, which is simulated on SUMO. Linux Ubuntu 20.02 was utilized as the operating system for the simulation environment.

B. V2V Communication Standard Model

The V2V communication model is based on the ITS standard defined by ETSI (European Telecommunications Standards Institute). The message exchange model for V2V communication on the ETSI-ITS[17] standard uses the Cooperative Awareness Message (CAM) and Decentralized Environmental Notification Message (DENM) schemes. CAM is a broadcast message periodically broadcast by vehicles containing information about the actual position, speed, and direction of movement of the vehicle at a frequency of 10 Hz. Meanwhile, DENM is an event-based message sent if there is an event, such as a collision warning, road hazard, *E.tc* [18].

The communication standard is based on IEEE 802.11p -WAVE, WAVE (Wireless Access Vehicular Environments), an NS3 module that is a refinement of the IEEE 802.11 model. The WAVE module with the IEEE 802.11p standard is designed to support ITS[19]. WAVE operates in the 5.9 GHz band using an OFDM (Orthogonal Frequency Division Multiplexing) multiplexing system and can achieve data transmission speeds of between 6 – 27 Mbps[20]. WAVE consists of seven channels at a frequency of 10 MHz, one control channel, and six service channels at 5.9 GHz bandwidth. The service channel is used for public safety and private services, while the control channel is used as a reference channel to build a communication link between RSU (Road - Side Unit) and OBU (On - Board Unit). Figure 1 Describe the V2V Communication based on 802.11p-WAVE.

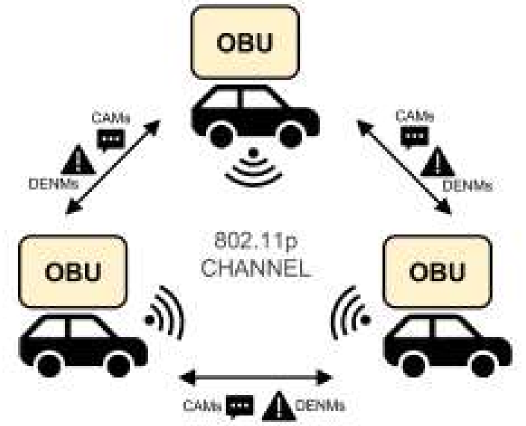

Fig 1. V2V Communication 802.11p WAVE-based Model[6]

Figure 1 shows that the OBU use the control channel for broadcast application services, warning messages, and safety status messages[21]. So, the main application of IEEE 802.11p is communication systems between vehicles, with the communication system used as DSRC (Dedicated Short Range Communication). In this study, we tested the performance of this WAVE on the ETSI-ITS standard.

C. The ETSI Facilities Layer

Through ETSI TS 102 894-2 regarding the ITS facilities layer, ETSI has determined the standard facilities layer, which aims to support the distribution and processing of messages from an application within the ITS structure[22]. These Facilities, called CA and DEN Basic Services, manage the transmission and reception of CAM and DENM messages and are implemented in our framework following the ETSI standards on ITS messages[6].

ASN.1, which encodes CAM and DENM messages, allows the representation of complex data structures that any platform can read[23]. This notation is completely programming language-agnostic, allowing different platforms with different architectures to exchange information. We used ASN.1 inside the ETSI-ITS module to encode and decode the message to extract the relevant information and provide the V2V communication for ITS applications[24]. CAM and DENM modules are in charge of receiving a piece of relevant information for the ITS application. The process of encoding and decoding messages via CAM and DENM is one of the core functions implemented in this simulation[25]. This study does not use all of ETSI's core functions, such as security, Geo-Networking, and others. Figure 2 depicts the logical implementation of CA and DEN basic service to support ITS Station (ITS-S) define by ETSI facilities layer.

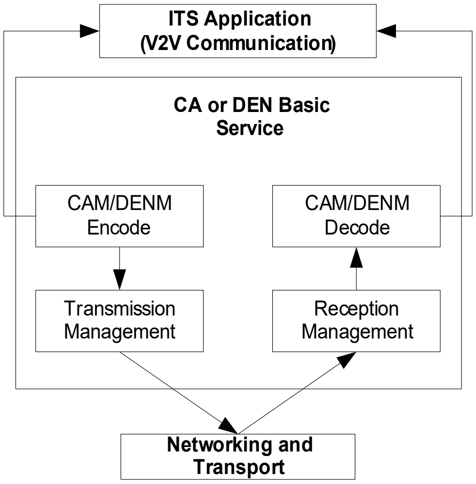

Fig 2. CA and DEN basic service to support ITS-S in ETSI facilities layer

In Figure 2, The CA Basic Service is responsible for encoding CAM (Cooperative Awareness Message) messages for ITS-S (Intelligent Transportation Systems-Services) applications and handling the dissemination process through the CAM Transmission Management. The service delivers the CAM message to the lower layers of the communication stack when it is ready to be sent. On the receiving side, the CA Basic Service manages the reception of the CAM message from the underlying layers. It decodes the message, encoded using ASN.1. Then the information included in CAM will be forwarded to the ITS-S application. The DEN Basic Service offers similar capabilities to the ITS-S applications for transmitting and receiving DENM messages.

D. The Simulation Scenario

The simulation demonstrates the V2V communication models through a scenario involving an Emergency Vehicle (EV) and passenger car, using IEEE 802.11p as the vehicle connectivity to transmit CAM and DENM messages. The simulation has two scenarios: first, communication between passenger vehicles such as buses and cars, and second, communication between passenger cars when an EV is present on the road. Following the standard, all vehicles exchange CAM messages to inform nearby vehicles about their status. The presence of EVs, however, requires a system in which they can move without being impeded by other vehicles. A vehicle performing emergency duties, such as an ambulance, police motorcycle, or fire truck, is referred to as an EV in this scenario. The simulation showcases the communication between three periodically transmitting EVs and nearby vehicles through DENM messages.

Upon receiving a meaningful message (DENM from an approaching EV), a typical vehicle will try to reduce its interference with the EV. If the passenger vehicle is in the same lane as the EV, it will speed up and change lanes as soon as possible. If on a different lane, it will slow down, allowing the EV to pass without being forced to reduce its speed. In this study, a modification was made to a previous research's network map to make it suitable for the SUMO simulation. The network map includes two intersections, highways, and typical urban roads, and its details can be viewed in Figure 3.

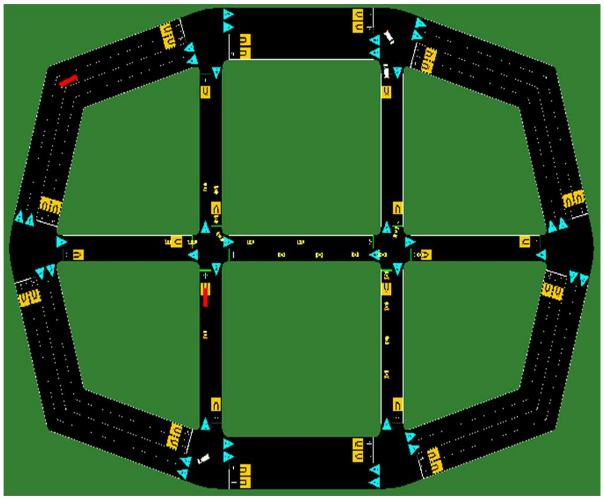

Fig 3. A Modification Offline Network Map in SUMO

In Figure 3, we simulated an urban environment, with passenger vehicles having a maximum speed ranging from 30 km/h to 60 km/h, while EVs can travel at a speed of up to 75 km/h. The simulation includes a circular road with two lanes for each direction of travel. In the simulation scenario, the red vehicle is an Emergency Vehicle (EV) broadcasting Distributed Emergency Network Management (DENM) messages, while the orange vehicles are nodes that have successfully received and processed the DENM message from the EV, causing them to slow down to allow for a safe overtake. The green vehicle is located on the same lane as the EV and thus attempts to speed up and change lanes as soon as possible to make way for the EV. The yellow vehicles are cars that do not need to respond to the approaching EV, as they may be traveling in the opposite direction, not directly affected by the EV's trajectory, or still too far away, and its details can be viewed in Figure 4.

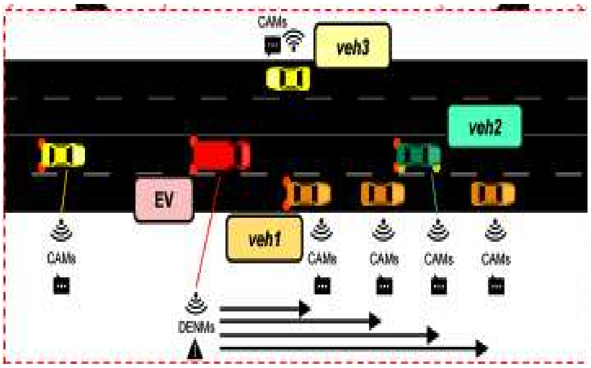

Fig 4. Implementation of V2V communication on SUMO

In Figure 4, every vehicle entering the scenario will send CAMs with a frequency between *1 Hz* and *10 Hz* (according to the ETSI standards). The vehicles are divided into "passenger" vehicles and emergency vehicles. When an emergency vehicle generates a CAM message, it sets the "*StationType*" Data Element to "special vehicles." Upon receiving a CAM message from an emergency vehicle, passenger vehicles evaluate their heading and distance from the emergency vehicle. If the heading is similar and the distance is close, the emergency vehicle is approaching. In response, the passenger vehicles either slow down on a different lane or try to change lanes as quickly as possible by accelerating for a short period if they are in the same lane as the emergency vehicle.

In Table 1, The simulation setting was based on the ETSI standard and involved a car-only network with a left-hand traffic representative of Indonesia. The simulation was run 100 times with a default road type and the total number of vehicles varying from 20 to 40. The node speed was set according to the 75 km/hour in highway area and 25 km/h in urban area and there were two traffic light junctions in the simulation. The vehicles' mobility was determined at the beginning of the simulation, with their travel routes set, and the data rate was also set in 4.5.

Table 1. Simulation Setting

Simulation Setting	Value
Traffic map name	ETSI Standard example with modification
Type of vehicles	Car-Only Network
Type of traffic	Left-hand Traffic, Indonesia
simulation time	100 second
Road type	Default
Total Vehicles Number	20, 25, 30, 35
Node speed	75 km/hour in highway area, 25 km/h in urban area
Traffic Light Junctions	2 area
Vehicles mobility	The vehicle travel route is determined at the beginning of the simulation
Data Rate	4.5 Mbit/s
Simulation speed	0.01 simulation step
Transmission power (Tx power)	23dBm

In Table 1, the evaluation is based on comparing the scenario in which the alert is enabled and the case in which it is not. We considered different vehicle densities and data rates to properly evaluate the proposed application, ranging from 5 vehicles/km up to more than 18 vehicles/km. For each density, we ran five simulations, each lasting 100 seconds, always using different mobility traces, including three EVs, one per travel direction. The result and evaluation criteria define in Table 2.

Table 2. The result and evaluation criteria[22]

Result Parameter	Result Indicator
Average PRR (Packet Reception Ratio); Packet Loss	0-2,9% (Ideal), 3 – 14.9 (Good), 15-24.9 (average), >=25% (bad)
Average Latency (ms)	<150 ms (Ideal), 150 ms-299 ms (good), 300 ms-449 ms (average), >450 ms (bad).

Table 2 summarizes the results and evaluation criteria for two performance parameters: the average packet reception ratio (PRR) and the average latency. The PRR is a measure of the percentage of successfully received packets, and it is categorized as ideal, good, average, or bad based on a range of values from 0 to 2.9%, 3 to 14.9%, 15 to 24.9%, and greater than 25%, respectively. The average latency, on the other hand, is a measure of the delay in message transmission and reception, and it is evaluated as ideal, good, average, or bad based on the time intervals of less than 150 ms, 150 to 299 ms, 300 to 449 ms, and more than 450 ms, respectively. These two parameters comprehensively evaluate the performance of the multi-stack protocols for V2V communication in VANETs.

III. RESULTS AND DISCUSSION

The experiments was conducted by varying the total number of vehicles from 20 to 35 and using two different data rate configurations while keeping the transmission power constant at 23 dBm. The Packet Reception Ratio (PRR) and latency were evaluated for each configuration. The results show in Table 3.

Table 3. Simulation Result of The V2V Communication

Vehicles (unit)	**Data Rate (Mbit/s)**	**SEND_CAM status**	**Average PRR (Loss)(%)**	**Average PRR Criteria**	**Average Latency (s)**	**Average Latency criteria**
20	12	TRUE	47%	Bad	1.86E-01	Good
25	12	TRUE	45%	Bad	1.86E-01	Good
30	12	TRUE	44%	Bad	1.87E-01	Good

35	12	TRUE	41%	Bad	1.86E-01	Good
20	12	FALSE	47%	Bad	1.54E-01	Good
25	12	FALSE	47%	Bad	1.54E-01	Good
30	12	FALSE	45%	Bad	1.54E-01	Good
35	12	FALSE	44%	Bad	1.54E-01	Good

Table 3 analyses the relationship between changes in the number of vehicles and the average SEND_CAM and average latency in V2V communication using the multi-stack protocol compliant with ETSI-ITS standards. Under the scenario where the SEND_CAM message was enabled, the average PRR (Packet Reception Ratio) or packet loss decreased as the total number of vehicles increased, indicating that the performance of the multi-stack protocol improved in denser networks. Further explanation is in Figure 5(a) Figure 6, and Figure 7. In Figure 5 and (b), the average latency increased slightly with the increasing number of vehicles, indicating that the delay in transmitting messages increased in denser networks.

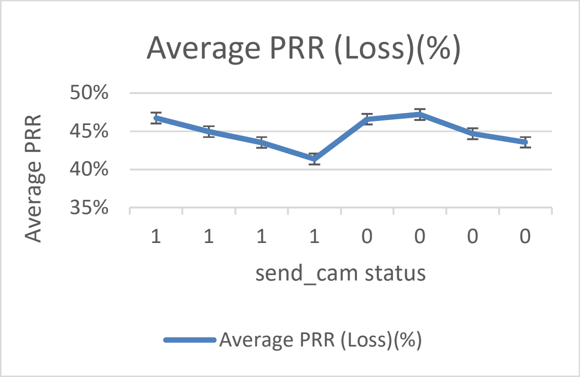

Fig 5. Average PRR Result

When the SEND_CAM message was disabled, the average PRR remained relatively constant across different scenarios, with a slightly higher average PRR for 25 vehicles.

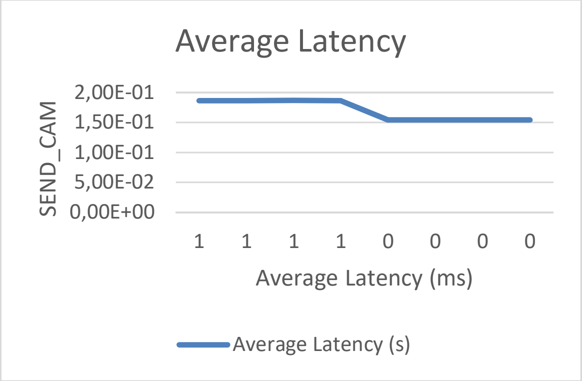

Fig 6. the average latency decreased slightly as the number of vehicles increased

However, in Figure 6, the average latency decreased slightly as the number of vehicles increased, indicating that the delay in transmitting messages improved in denser networks. A detailed correlation analysis between the total number of vehicles and the average PRR provided in Figure 7.

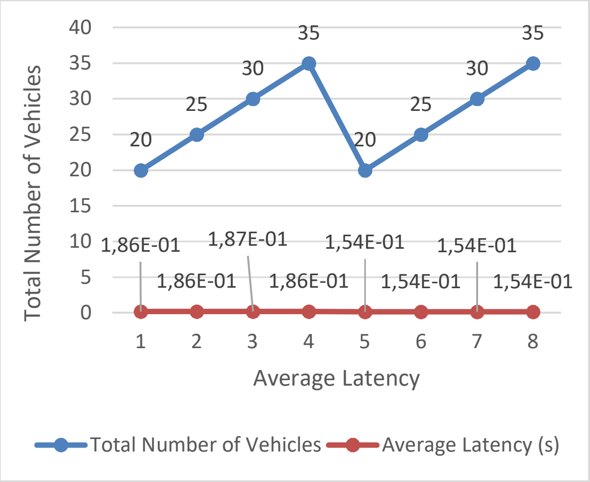

Fig 7. positive correlation between the number of vehicles and the average latency

Figure 7 illustrates a positive correlation between the number of vehicles and the average latency. For example, for a data rate of 12 Mbit/s and a transmission power level of 23dBm, the average latency increases from 154.17ms to 187.02ms when the number of vehicles increases from 20 to 30. Similarly, with the same data rate and transmission power level, the average latency increases from 154.17ms to 186.4ms when vehicles increase from 20 to 35. The findings suggest that the rise in the number of vehicles in the network can cause increased interferences and contention for the communication medium, leading to higher delays in message transmission and reception.

Table 3 summarizes the simulation results of a study on the performance of multi-stack protocols for V2V communication in VANETs. The simulations were conducted with different numbers of vehicles, data rates, and transmission powers, and the evaluation criteria were the average packet reception ratio (PRR) and the average latency. The protocols must be improved to achieve higher packet reception rates. For all simulations, the average PRR values were below the ideal range, indicating that the protocols struggled to maintain reliable communication under the given conditions. Specifically, the PRR values were all categorized as bad, ranging from 41% to 47%. The protocols are capable of providing satisfactory latency performance under the given conditions. On the other hand, the average latency values were all within the good range, indicating that the protocols could provide relatively low transmission delays. The average latency values ranged from 0.154 s to 0.187 s, corresponding to a good range of less than 150 ms.

Interestingly, the simulation results indicate that the status of the SEND_CAM parameter did not significantly affect the performance of the protocols, as the PRR and latency values were similar for both true and false states. However, the number of vehicles in the network affected the latency, as the average values increased as the number of vehicles increased. Overall, the simulation results suggest that the performance of multi-stack protocols for V2V communication in VANETs can be improved in terms of packet reception ratio while maintaining satisfactory latency performance.

IV. CONCLUSION

Our study delved into the performance of multi-stack protocols for V2V communication in VANETs. We discovered that when the SEND_CAM message was enabled, the Packet Reception Ratio (PRR) decreased as the total number of vehicles increased. This finding suggests that the protocol's performance is enhanced in denser networks. Conversely, when the SEND_CAM message was disabled, the PRR remained relatively stable across different scenarios, indicating that the protocol was less responsive to changes in network density. These insights have significant implications for the design and implementation of multi-stack protocols in real-world V2V communication scenarios.

The study also found a direct correlation between the number of vehicles and the average latency. This implies that higher vehicle densities lead to increased delays in message transmission and reception, underlining the impact of network congestion and interference on communication performance in VANETs.

Furthermore, the analysis of simulation results indicates that the protocols showed suboptimal PRR values below the ideal range. However, they demonstrated satisfactory latency performance within acceptable thresholds. Suggests an opportunity for improvement in achieving higher packet reception rates while maintaining low transmission delays.

Interestingly, the status of the SEND_CAM parameter did not notably influence protocol performance. The situation implies that other factors, such as network density, play a more significant role in determining communication effectiveness.

In summary, our study reveals that multi-stack protocols in V2V communication within VANETs face challenges and trade-offs. Notably, the SEND_CAM parameter did not significantly impact protocol performance, suggesting that other factors, such as network density, are more influential. We also found that the protocols demonstrated suboptimal PRR values but satisfactory latency performance, indicating room for improvement in achieving higher packet reception rates while maintaining low transmission delays. These insights contribute to the ongoing efforts to enhance the reliability and efficiency of communication protocols in VANETs, thereby advancing the development of intelligent transportation systems.

REFERENCES

[1] K. Ashok *et al.*, "Review on Energy Efficient V2V Communication Techniques for a Dynamic and Congested Traffic Environment," *2022 Int. Conf. Comput. Commun. Informatics, ICCCI 2022*, pp. 0–5, 2022, doi: 10.1109/ICCCI54379.2022.9740853. DOI:10.1109/ICCCI54379.2022.9740853

[2] S. Hakak *et al.*, "Autonomous Vehicles in 5G and Beyond: A Survey," *Veh. Commun.*, vol. 39, p. 100551, 2022, doi: 10.1016/j.vehcom.2022.100551. DOI:10.1016/j.vehcom.2022.100551 http://arxiv.org/abs/2207.10510

[3] T. K. Priyambodo, D. Wijayanto, and M. S. Gitakarma, "Performance optimization of MANET networks through routing protocol analysis," *Computers*, vol. 10, no. 1, pp. 1–13, 2021, doi: 10.3390/computers10010002. DOI:10.3390/computers10010002

[4] P. K. Singh, S. K. Nandi, and S. Nandi, "A tutorial survey on vehicular communication state of the art, and future research directions," *Veh. Commun.*, vol. 18, p. 100164, 2019, doi: 10.1016/j.vehcom.2019.100164. DOI:10.1016/j.vehcom.2019.100164 https://doi.org/10.1016/j.vehcom.2019.100164

[5] M. Malinverno, F. Raviglione, C. Casetti, C. F. Chiasserini, J. Mangues-Bafalluy, and M. Requena-Esteso, "A Multi-stack Simulation Framework for Vehicular Applications Testing," *DIVANet 2020 - Proc. 10th ACM Symp. Des. Anal. Intell. Veh. Networks Appl.*, pp. 17–24, 2020, doi: 10.1145/3416014.3424603. DOI:10.1145/3416014.3424603

[6] F. Belamri, S. Boulfekhar, and D. Aissani, "A survey on QoS routing protocols in Vehicular Ad Hoc Network (VANET)," *Telecommun. Syst.*, vol. 78, no. 1, pp. 117–153, 2021, doi: 10.1007/s11235-021-00797-8. DOI:10.1007/s11235-021-00797-8 https://doi.org/10.1007/s11235-021-00797-8

[7] C. R. Guerber, E. L. Gomes, M. S. Pereira Fonseca, A. Munaretto, and T. H. Silva, "Transmission Opportunities: A New Approach to Improve Quality in V2V Networks," *Wirel. Commun. Mob. Comput.*, vol. 2019, 2019, doi: 10.1155/2019/1708437. DOI:10.1155/2019/1708437

[8] W. Albattah, S. Habib, M. F. Alsharekh, M. Islam, S. Albahli, and D. A. Dewi, "An Overview of the Current Challenges, Trends, and Protocols in the Field of Vehicular Communication," *Electron.*, vol. 11, no. 21, 2022, doi: 10.3390/electronics11213581. DOI:10.3390/electronics11213581

[9] U. A. Khan and S. S. Lee, "Multi-layer problems and solutions in VANETs: A review," *Electron.*, vol. 8, no. 2, 2019, doi: 10.3390/electronics8020204. DOI:10.3390/electronics8020204

[10] M. N. Tahir and M. Katz, "Performance evaluation of IEEE 802.11p, LTE and 5G in connected vehicles for cooperative awareness," *Eng. Reports*, vol. 4, no. 4, pp. 1–14, 2022, doi: 10.1002/eng2.12467. DOI:10.1002/eng2.12467

[11] P. Sousa, M. Alam, J. Ferreira, and J. ao P. Barraca, "Non-IP Multi-protocol Stack for Vehicular Communications," *Mob. Networks Appl.*, vol. 23, no. 5, pp. 1179–1193, 2018, doi: 10.1007/s11036-

016-0781-x. DOI:10.1007/s11036-016-0781-x

[12] T. K. Bhatia, R. K. Ramachandran, R. Doss, and L. Pan, "A Comprehensive Review on the Vehicular Ad-hoc Networks," *ICRITO 2020 - IEEE 8th Int. Conf. Reliab. Infocom Technol. Optim. (Trends Futur. Dir.*, pp. 515–520, 2020, doi: 10.1109/ICRITO48877.2020.9197778. DOI:10.1109/ICRITO48877.2020.9197778

[13] K. G. Lim, C. H. Lee, R. K. Y. Chin, K. Beng Yeo, and K. T. K. Teo, "SUMO enhancement for vehicular ad hoc network (VANET) simulation," *Proc. - 2017 IEEE 2nd Int. Conf. Autom. Control Intell. Syst. I2CACIS 2017*, vol. 2017-Decem, no. October, pp. 86–91, 2017, doi: 10.1109/I2CACIS.2017.8239038. DOI:10.1109/I2CACIS.2017.8239038

[14] W. Liu, X. Wang, W. Zhang, L. Yang, and C. Peng, *Coordinative simulation with SUMO and NS3 for Vehicular Ad Hoc Networks*. IEEE, 2016. doi: 10.1109/APCC.2016.7581471. DOI:10.1109/APCC.2016.7581471

[15] M. R. Hasan, Y. Zhao, Y. Luo, G. Wang, and R. M. Winter, "An Effective AODV-based Flooding Detection and Prevention for Smart Meter Network," *Procedia Comput. Sci.*, vol. 129, pp. 454–460, 2018, doi: 10.1016/j.procs.2018.03.024. DOI:10.1016/j.procs.2018.03.024 https://doi.org/10.1016/j.procs.2018.03.024

[16] S. Laux *et al.*, "Demo: OpenC2X - An open source experimental and prototyping platform supporting ETSI ITS-G5," *IEEE Veh. Netw. Conf. VNC*, vol. 0, pp. 10–11, 2016, doi: 10.1109/VNC.2016.7835955. DOI:10.1109/VNC.2016.7835955

[17] D. Grewe, A. Tan, M. Wagner, S. Schildt, and H. Frey, "A Real World Information-Centric Connected Vehicle Testbed Supporting ETSI ITS-G5," *2018 Eur. Conf. Networks Commun. EuCNC 2018*, pp. 219–223, 2018, doi: 10.1109/EuCNC.2018.8442818. DOI:10.1109/EuCNC.2018.8442818

[18] I. A. Rahardjo, R. Anggoro, and F. X. Arunanto, "Studi Kinerja 802.11P pada Protokol Ad Hoc On-Demand Distance Vector (AODV) di Lingkungan Vehicular Ad Hoc Network (VANET) Menggunakan Network Simulator 2 (NS-2)," *J. Tek. ITS*, vol. 6, no. 1, pp. 1–6, 2017, doi: 10.12962/j23373539.v6i1.21994. DOI:10.12962/j23373539.v6i1.21994

[19] J. Joo, O. S. Eyobu, J. H. Kim, H.-J. Jeong, and D. S. Han, "Analysis of Radio Propagation Characteristics for V2V Scenarios in WAVE Standard Based Vehicular Communication System," *The Journal of Korean Institute of Communications and Information Sciences*, vol. 42, no. 6. Korea Information and Communications Society, pp. 1175–1184, 2017. doi: 10.7840/kics.2017.42.6.1175. DOI:10.7840/kics.2017.42.6.1175 http://dx.doi.org/10.7840/kics.2017.42.6.1175

[20] Y. H. Kim, S. Peeta, and X. He, "Modeling the information flow propagation wave under vehicle-to-vehicle communications," *Transp. Res. Part C Emerg. Technol.*, vol. 85, no. October, pp. 377–395, 2017, doi: 10.1016/j.trc.2017.09.023. DOI:10.1016/j.trc.2017.09.023 http://dx.doi.org/10.1016/j.trc.2017.09.023

[21] ETSI EN 302 890-1, "Intelligent Transport Systems (ITS); Facilities layer function; Part 1: Services Announcement (SA) specification," *Etsi*, vol. 1, pp. 1–19, 2019.

[22] S. Eckelmann, T. Trautmann, H. Ußler, B. Reichelt, and O. Michler, "V2V-Communication, LiDAR System and Positioning Sensors for Future Fusion Algorithms in Connected Vehicles," *Transp. Res. Procedia*, vol. 27, pp. 69–76, 2017, doi: 10.1016/j.trpro.2017.12.032. DOI:10.1016/j.trpro.2017.12.032 https://doi.org/10.1016/j.trpro.2017.12.032

[23] D. Eckhoff, N. Sofra, and R. German, "A Performance Study of Cooperative Awareness in ETSI ITS G5 and IEEE WAVE".

[24] B. Fernandes, M. Alam, and J. Ferreira, "Implementation and Analysis of IEEE and ETSI Security Standards," 2018.