10th International Conference on Control Engineering &Information Technology (CEIT-2025)
Proceedings Book Series –PBS- Vol 23, pp.138-144

Environmental effect on V2V communications

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***Abstract*— Vehicle-to-Vehicle (V2V) communication, a key enabler of Intelligent Transportation Systems, faces performance challenges due to environmental factors like the built environment and vehicle speed. This study investigates path loss in V2V communication using the ns-3 implementation of the 3GPP 38.901 spatial channel model. The results highlight the impact of urban infrastructure and mobility dynamics on signal attenuation, offering insights for optimizing V2V systems.**

Keywords— Vehicle-to-Vehicle (V2V) communication, Intelligent Transportation Systems (ITS), ns-3, path loss ,3GPP.

I. INTRODUCTION

Vehicle-to-Vehicle (V2V) communication is a revolutionary technology that enables vehicles to exchange real-time information with each other. This communication occurs through dedicated short-range communication (DSRC) or cellular networks like 5G, allowing vehicles to "speak" to one another and create a cooperative driving environment. V2V is a critical component of Intelligent Transportation Systems (ITS), which aim to enhance road safety, optimize traffic flow, and reduce environmental impacts through advanced technologies [1]. However, the performance of V2V communication is significantly influenced by the surrounding environment, such as the weather conditions, the vegetation in the environment and the built environment, including buildings [2].

This paper studies the effect of the build environment and the speed on the path loss by the implementation of a spatial channel model using network simulator software ns-3, following the 3GPP Technical Report 38.901.

In the first section of the paper, we present the work related to this research. In the third section, we describe the methodology and tools used in this work. The fourth section presents the results obtained from the simulation of the two methods and discussion and finally the fifth section is the conclusion and a brief future work.

II. CONTEXT AND CHALLENGES

V2V communication performance is affected by environmental factors like buildings and vehicle speed, causing signal attenuation and path loss variations. These factors contribute to signal attenuation and variability in path loss, impacting the reliability and efficiency of real-time data exchange. Understanding these challenges is crucial for designing robust V2V systems.

A. *Vehicle to vehicle communication*

Vehicle-to-Vehicle (V2V) communication enables real-time wireless data exchange between automobiles to enhance road safety and traffic efficiency, forming a critical component of intelligent transportation systems (ITS). The primary technologies facilitating V2V communication are Dedicated Short-Range Communications (DSRC) and Cellular Vehicle-to-Everything (C-V2X).

ISSN: 2961-6611

DSRC, based on the IEEE 802.11p standard, operates in the 5.9 GHz band and offers ultra-low latency (~5 ms), making it ideal for direct, high-speed vehicle interactions without cellular dependency. In contrast, C-V2X leverages 4G LTE and 5G networks in sub-6 GHz bands, providing extended range, better scalability in dense environments, and future-proof integration with evolving cellular infrastructure. Key applications of V2V include collision avoidance, emergency braking, lane-change warnings, and cooperative platooning, where vehicles share speed, position, and hazard data to prevent accidents and optimize traffic flow. While DSRC excels in low-latency direct communication, C-V2X's cellular support enables broader coverage and advanced network-assisted functionalities. Together, these technologies pave the way for safer, more efficient autonomous and connected vehicle ecosystems, though challenges such as signal interference, standardization, and environmental impacts must be addressed for widespread adoption.

B. Environmental Impact on V2V Communication

Recent studies highlight the significant influence of environmental conditions on V2V communication performance. In urban areas, high building density causes severe multipath fading and non-line-of-sight (NLOS) propagation, degrading signal reliability, as demonstrated by Mir et al. [3]. Suburban environments exhibit moderate interference but face challenges from foliage and road infrastructure, with attenuation losses reaching 15-20 dB at 5.9 GHz [4]. Meanwhile, rural settings experience fewer obstructions but suffer from long-distance path loss and sporadic connectivity, particularly in hilly terrain [5]. Weather effects such as rain-induced attenuation (~0.1 dB/km at 5.9 GHz) and snow scattering further exacerbate these issues [6]. Emerging solutions like adaptive beamforming and machine learning-based channel prediction [7] aim to mitigate these environmental impacts, though real-world deployment challenges persist.

C. Path Loss Models in V2V Communication

Path loss modeling is fundamental for predicting signal attenuation in Vehicle-to-Vehicle (V2V) communication systems, with recent research focusing on environment-specific channel characterization. The 3GPP TR 38.901 standard provides widely adopted models, distinguishing between urban (UMa/UMi), suburban, and rural (RMa) scenarios with separate formulations for line-of-sight (LOS) and NLOS conditions [8]. Empirical studies by Mir et al. [9] demonstrate that urban NLOS paths exhibit 10–15 dB higher attenuation than LOS due to building blockage, while suburban environments show intermediate characteristics influenced by foliage and road infrastructure [10]. For rural areas, measurements reveal that hilly terrain induces irregular connectivity with path loss exponents ranging from 2.1 (LOS) to 3.8 (NLOS) [11].

III. METHODOLOGY

The study employs the 3GPP Technical Report 38.901 spatial channel model, implemented in the ns-3 network simulator, to analyze the impact of environmental factors on V2V communication. This model provides a standardized framework for simulating wireless channels in various scenarios, including urban environments, by accounting for key parameters such as path loss. By leveraging ns-3, the approach enables realistic simulations of V2V communication dynamics, allowing for a detailed evaluation of how the built environment and vehicle speed influence signal propagation and path loss [12].

This study used ns-3 to simulate V2V communication across urban environments with 3GPP-compliant channel models. As an open-source network simulator, ns-3 offers specialized modules like the Wave (Wireless Access in Vehicular Environments) framework, which accurately models DSRC and Cellular Vehicle to everything (C-V2X) protocols at the *5.9* GHz band. Its flexibility allows to test V2V scenarios under realistic conditions such as urban congestion, highway platooning, or adverse weather while incorporating precise path loss models, mobility patterns, and interference effects. The setup employed 28 GHz mmWave frequencies with configurable transmission power of *30* dBm and *1.5*m antenna heights. This approach enabled performance evaluation of V2V networks in diverse real-world scenarios.

Path loss modeling in V2V communication requires environment-specific approaches to accurately predict signal attenuation. The 3GPP TR 38.901 standard provides distinct models for urban, suburban, and rural scenarios, differentiating between line-of-sight (LOS) and non-line-of-sight (NLOS) conditions. For LOS scenarios, the 3GPP urban macro (UMa) model offers a log-distance path loss formula with frequency-dependent attenuation, while the rural macro model adapts for open environments with fewer obstructions.

ISSN: 2961-6611

In NLOS conditions, the urban micro (UMi) model incorporates additional losses from building density and street canyon effects, crucial for city environments. Comparative studies show that suburban areas exhibit intermediate characteristics, requiring hybrid adjustments between UMa and UMi models. These models enable precise simulation of V2V signal degradation across diverse terrains, with NLOS cases typically showing 10-15 dB higher loss than LOS at equivalent distances due to shadowing and multipath effects.

Our approach builds upon an existing 3GPP module of ns3, to analyze the results of a V2V communication simulation in urban scenario. Fig. 1 illustrates the initial scenario, featuring four buildings: two positioned along the X-axis and two along the Y-axis. illustrates the initial setup, which includes four buildings: two aligned along the X-axis and two along the Y-axis. Two vehicles are traveling along the same road—one acting as the transmitter and the other as the receiver.

In the first experiment, we try to study the effect of the obstacles on path loss over time by modifying the scenario. In fact, using ns3, we simulate the path loss three times; the first one with the initial scenario, the second we doubled the number of buildings four buildings on the X-axis and four on the Y-axis, and the last one we take six buildings on the two axes. The velocity of the transmitter vehicle was *60* km/h and the receiver was *30* km/h in the first experience.

In the second experiment, we investigate the impact of vehicle speed on path loss over time. The scenario remained unchanged as shown in Fig. 1, while the vehicle speeds were varied across four different cases, as detailed in Table 1. In the first case, the transmitting vehicle was traveling at *100* km/h, while the receiving was moving at *50* km/h. In the second case, their speeds were reduced to *20* km/h and *10* km/h, respectively. In the third case, the receiving vehicle increased its speed relative to the transmitting. Finally, in the fourth case, both vehicles maintained a constant and identical speed.

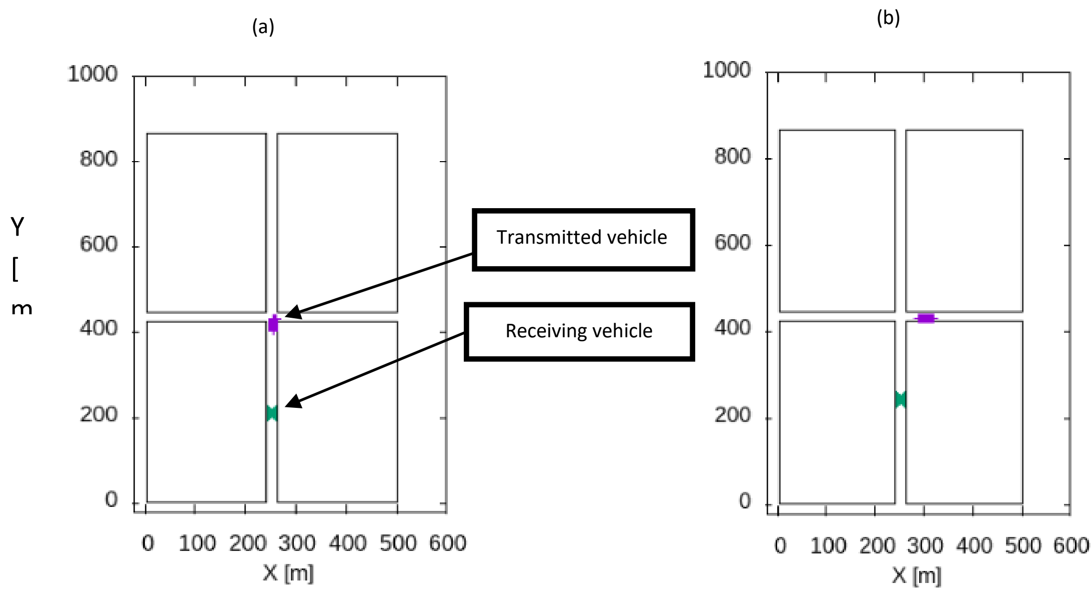

Fig1 Initial position of the transmitting and receiving vehicles for two scenarios (a) LOS, (b) NLOS

ISSN: 2961-6611

TABLE I

SIMULATION SPEED CASES

	Speed of transmitted vehicle in Km/h	**Speed of receiving vehicle in Km/h**
Case1	100	50
Case 2	20	10
Case3	60	120
Case 4	40	40

IV. SIMULATION RESULTS AND DISCUSSION

Fig. 2 shows the effect of the built environment on path loss by increasing the number of obstacles or buildings over time. It shows that the increase in the number of obstacles in a V2V communication urban scenario influences the quality and reliability of communications. The results demonstrate that the path loss escalates markedly, from *70* dB to beyond *130* dB, as the density of buildings or obstacles increases over time.

As shown in Fig. 3, speed significantly influences path loss in V2V communications. The results clearly demonstrate that variations in speed have a decisive effect on the observed path loss. If we increase the speed from *20* km/h for the transmitter vehicle and *10* km/h for the received vehicle to *100* km/h and *60* km/h respectively the number of oscillations increase over the time and the path loss rises from *75* dB to *150* dB.

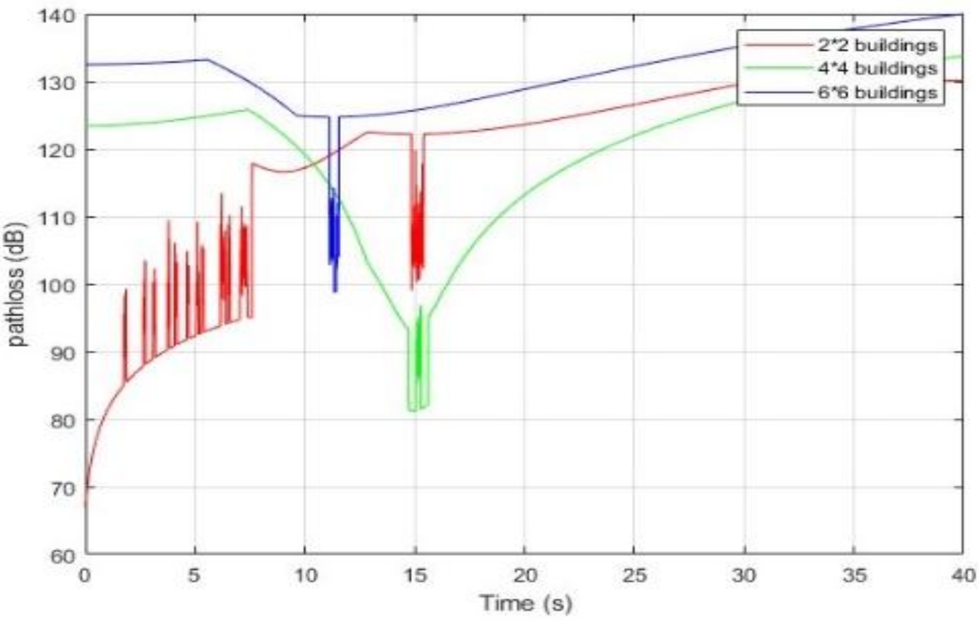

Fig. 2 Effect of build environment on path loss

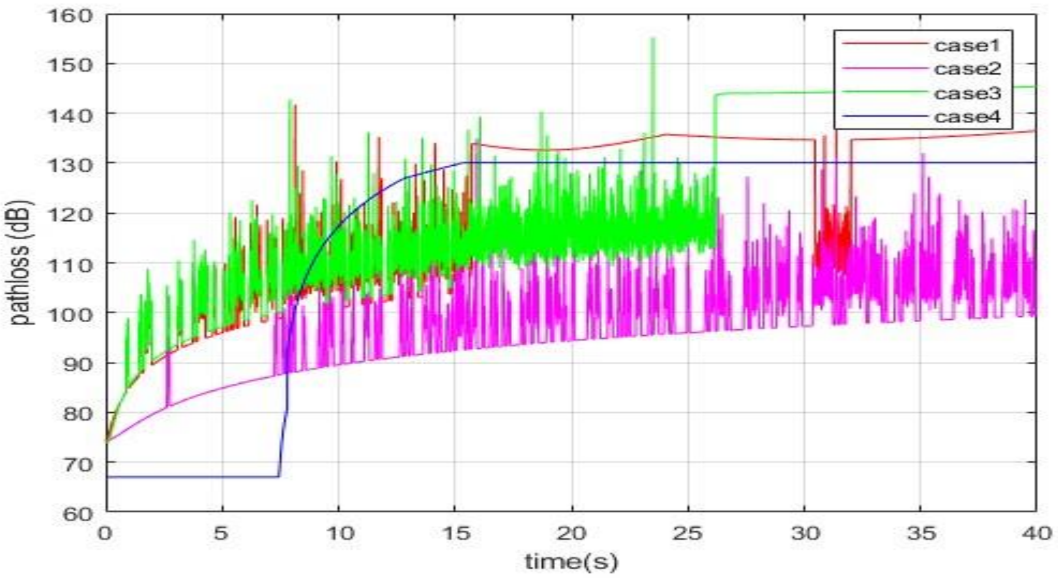

Fig. 3 Effect of the speed on the path loss

The findings reveal that increasing the number of buildings or obstacles leads to a substantial rise in path loss and for the same thing in the second simulation, the path loss increases over the time while we increase the velocity of vehicles.

V. CONCLUSION

This study investigates millimeter-wave (mmWave) communication in V2V scenarios using the 3GPP TR *38.901* channel model. The research demonstrated the significant impact of the built environment and vehicle speed on path loss in V2V communications. The findings highlight the necessity for robust communication strategies and adaptive technologies to mitigate the effects of environmental obstacles and mobility in high-frequency V2V networks. As future work, leveraging advanced techniques such as machine learning could enable more accurate and reliable predictions, thereby optimizing the performance of V2V systems across diverse traffic scenarios.

REFERENCES:

[1] He, Ruisi, Olivier Renaudin, Veli-Matti Kolmonen, Katsuyuki Haneda, Zhangdui Zhong, Bo Ai, and Claude Oestges. "A dynamic wideband directional channel model for vehicle-to-vehicle communications." *IEEE Transactions on Industrial Electronics* 62, no. 12 (2015): 7870-7882.

[2] Abd Aziz, Azlan, Azwan Mahmud, Nurul Asyiqin Mamat, Nur Asyiqin Amir Hamzah, and Hadhrami Ab Ghani. "Performance evaluation of V2V propagation channels under different link types." In *2022 IEEE International Conference on Artificial Intelligence in Engineering and Technology (IICAIET)*, pp. 1-6. IEEE, 2022.

[3] Z. Mir, F. Filali, and B. M. Lee. "Urban V2V Channel Characterization: Multipath Fading and NLOS Propagation Analysis." *IEEE Transactions on Vehicular Technology* 71, no. 3 (March 2022): 2345–2358.

[4] M. Boban et al. "Suburban Vehicle-to-Vehicle Propagation: Measurement-Based Analysis at 5.9 GHz." *IEEE Transactions on Vehicular Technology* 72, no. 4 (April 2023): 4982–4995.

[5] Heinovski, Julian, Dominik S. Buse, and Falko Dressler. "Poster: Scalable simulation of platoon formation maneuvers with PlaFoSim." In *2021 IEEE Vehicular Networking Conference (VNC)*, pp. 137-138. IEEE, 2021.

ISSN: 2961-6611

[6] S. K. Sharma and X. Wang. “Rain and Snow Attenuation Effects on 5.9 GHz V2V Communications: Measurement and Modeling.” *IEEE Communications Letters* 27, no. 2 (February 2023): 492–496.

[7] Liu, Chenguang, Yunfei Chen, Jianjun Chen, Ryan Payton, Michael Riley, and Shuang-Hua Yang. "Cooperative perception with learning-based V2V communications." *IEEE Wireless Communications Letters* 12, no. 11 (2023): 1831-1835.

[8] Z. Cui et al. “V2V Path Loss in Urban Canyons.” *IEEE Transactions on Intelligent Transportation Systems* 23, no. 5 (2022): 4123–4136.

[9] Z. Mir et al. “Urban V2V Channel Characterization.” *IEEE Transactions on Vehicular Technology* 71, no. 3 (2022): 2345–2358.

[10] A. Goldsmith et al. “Suburban V2V at 5.9 GHz.” *IEEE Access* 11 (2023): 14567–14579.

[11] R. He et al. “Rural V2V in Hilly Terrain.” In *Proceedings of the IEEE Vehicular Networking Conference (VNC)*, 1–4, 2021.

[12] M. Mezzavilla et al. “End-to-End Simulation of 5G Millimeter-Wave Networks.” *IEEE Communications Surveys & Tutorials* 20, no. 3 (third quarter 2018): 2237–2263.

ISSN: 2961-6611