International Journal of Automobile Engineering

**E-ISSN:** 2707-8213
**P-ISSN:** 2707-8205
IJAE 2024; 5(2): 36-39
www.mechanicaljournals.com/ijae
Received: 09-06-2024
Accepted: 16-07-2024

**Faridah Ismail**
Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

**Nur Aisyah Mahmud**
Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

**Corresponding Author:**
**Faridah Ismail**
Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

# Vehicle-to-everything (V2X) communication: The future of connected cars

**Faridah Ismail and Nur Aisyah Mahmud**

**Abstract**
Vehicle-to-Everything (V2X) communication represents a transformative technology in the automotive industry, aimed at connecting vehicles with the surrounding environment, infrastructure, and other vehicles to improve road safety, efficiency, and driving experience. V2X encompasses several subcategories, including Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Pedestrian (V2P), and Vehicle-to-Network (V2N). This review study explores the key components, benefits, and challenges associated with V2X communication, drawing on previous research and studies. We analyze the advancements in V2X technology, its integration with autonomous driving, and the role of 5G in enhancing connectivity. Future directions and potential roadblocks to widespread adoption are also discussed.

**Keywords:** Vehicle-to-everything (V2X), vehicle-to-vehicle (V2V), autonomous driving, 5G, connected cars, road safety, smart cities

## Introduction
The advent of Vehicle-to-Everything (V2X) communication marks a significant shift toward the future of connected and autonomous vehicles. By allowing vehicles to communicate with each other and their surroundings, V2X technology is poised to enhance road safety, reduce traffic congestion, and increase energy efficiency. V2X consists of several communication technologies, including Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Pedestrian (V2P), and Vehicle-to-Network (V2N) communication. Each of these components enables real-time data exchange, supporting functions such as collision avoidance, traffic signal coordination, and dynamic routing.
According to studies by Zhang *et al*. (2020) and Fang *et al*. (2019), V2X communication can reduce road accidents by providing real-time alerts and predictive analytics, allowing vehicles to adjust to dynamic road conditions before human drivers can react. This paper aims to present a comprehensive review of V2X communication based on existing research, focusing on its technological advancements, benefits, integration with autonomous driving, and future prospects in the context of smart cities and 5G networks.

## Objective of the paper
The objective of this paper is to review the advancements, benefits, and challenges of Vehicle-to-Everything (V2X) communication technology, exploring its role in enhancing road safety, reducing traffic congestion, and supporting the development of autonomous vehicles.

## Components of V2X Communication
Vehicle-to-Everything (V2X) communication encompasses several key components, each of which plays a crucial role in enabling vehicles to interact with their environment and other road users. These components include Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Pedestrian (V2P), and Vehicle-to-Network (V2N) communication. Together, they form a comprehensive network that facilitates real-time information exchange to enhance safety, improve traffic flow, and enable smart mobility solutions.
Vehicle-to-Vehicle (V2V) communication enables direct communication between vehicles. V2V technology allows vehicles to share essential data such as speed, location, and direction, which can be used to predict potential collisions and warn drivers in real-time. For instance, if one vehicle detects a sudden obstacle and decelerates, it can immediately transmit this information to surrounding vehicles, allowing them to take preventive action.

V2V communication relies on short-range communication protocols, including Dedicated Short-Range Communication (DSRC) and Cellular V2X (C-V2X), both of which offer low-latency data transmission. By enhancing awareness and reaction times, V2V significantly improves road safety, especially in high-density traffic and dangerous road conditions.

Vehicle-to-Infrastructure (V2I) communication connects vehicles with the surrounding infrastructure, such as traffic lights, road signs, and toll booths. Through V2I, vehicles can receive real-time information about traffic signals, road conditions, and construction zones, allowing them to adjust their speed and route to optimize fuel efficiency and reduce congestion. For example, a V2I-equipped vehicle can communicate with traffic signals to determine the timing of lights, reducing the likelihood of unnecessary stopping and starting, which contributes to fuel wastage. In a broader sense, V2I plays a critical role in enabling smart cities, where infrastructure is interconnected with vehicles to enhance overall traffic management and urban mobility.

Vehicle-to-Pedestrian (V2P) communication focuses on enhancing the safety of vulnerable road users, such as pedestrians and cyclists. V2P allows vehicles to detect the presence of pedestrians, even if they are out of direct view, such as behind large vehicles or in low-visibility conditions. Pedestrians with mobile devices or wearables that are equipped with V2P technology can send signals to nearby vehicles, alerting drivers of their presence. This can prevent accidents in urban environments where pedestrian traffic is dense. V2P also provides safety warnings to pedestrians, such as alerts for oncoming vehicles while crossing streets or at intersections. In areas where pedestrian-vehicle interactions are frequent, V2P is an essential component in minimizing accidents.

Vehicle-to-Network (V2N) communication connects vehicles to external data sources via cloud networks, enabling access to dynamic information such as weather updates, traffic conditions, and navigation services. V2N enhances the decision-making capabilities of vehicles by providing a constant flow of updated information. For instance, V2N can allow vehicles to reroute in real-time based on current traffic data or road closures, improving travel efficiency. In the context of autonomous vehicles, V2N plays a crucial role in supporting the collection and processing of data needed for safe navigation. V2N also facilitates over-the-air software updates for vehicles, ensuring that they remain updated with the latest safety protocols and features.

Each of these components works together to create a highly connected environment where vehicles, infrastructure, pedestrians, and networks exchange critical information. The combination of V2V, V2I, V2P, and V2N enables a holistic approach to road safety and efficiency, helping to reduce accidents, ease congestion, and promote sustainable mobility. As V2X communication evolves, the integration of these components will become more seamless, particularly with advancements in 5G technology, which will offer faster, more reliable connectivity across all aspects of V2X communication. However, challenges such as infrastructure development, data security, and privacy concerns must be addressed for these technologies to reach their full potential and be widely adopted across different regions.

**Advancements in V2X Technology**

Significant advancements in Vehicle-to-Everything (V2X) technology have positioned it as a cornerstone for the future of connected and autonomous vehicles. The evolution of communication protocols, improvements in network infrastructure, and the integration of V2X with next-generation technologies like 5G have all contributed to its growing effectiveness and adoption.

Initially, V2X communication relied heavily on Dedicated Short-Range Communication (DSRC), a wireless protocol designed for low-latency, high-reliability communication between vehicles and their surroundings. DSRC has proven to be effective in various safety applications, such as collision avoidance and emergency braking alerts. Its ability to function in real-time, without the need for external network infrastructure, made it ideal for early V2X applications. However, its limitations in terms of range, bandwidth, and scalability prompted the need for more advanced solutions as the demands of connected vehicles grew.

The development of Cellular V2X (C-V2X) has marked a key advancement in V2X technology. C-V2X utilizes existing cellular networks for communication, enabling broader coverage and greater scalability compared to DSRC. C-V2X operates in two modes: direct communication between vehicles and infrastructure (V2V, V2I, and V2P) and network-based communication through cellular networks (V2N). This dual approach allows for real-time data exchange and broad network integration, making C-V2X a more versatile and future-proof solution. Studies have shown that C-V2X offers improved reliability and latency, particularly in high-traffic or complex environments, making it well-suited for the demands of smart cities and autonomous vehicle ecosystems.

The most transformative advancement in V2X technology is the integration of 5G networks. 5G offers ultra-low latency, high bandwidth, and increased capacity, all of which are essential for supporting the large volumes of data that V2X systems generate. The high-speed data transmission capabilities of 5G enable vehicles to process and respond to information faster and more accurately, reducing the risk of accidents and improving the overall safety of connected cars. With 5G, V2X can support more complex applications, such as real-time video streaming for autonomous driving, enhanced situational awareness, and multi-vehicle coordination. The increased reliability and connectivity provided by 5G also allow vehicles to maintain constant communication with cloud services, enabling seamless updates and continuous improvement of vehicle functions.

Another advancement is the growing integration of artificial intelligence (AI) and machine learning (ML) with V2X technology. AI and ML enable vehicles to process vast amounts of data more efficiently, allowing them to learn from real-time road conditions, driving behaviors, and environmental factors. This continuous learning process enhances decision-making and predictive capabilities, enabling vehicles to anticipate potential hazards and optimize their driving strategies. AI-powered V2X systems can dynamically adjust to changes in traffic flow, weather, or infrastructure, further improving the safety and efficiency of connected vehicles.

As V2X technology continues to evolve, advancements in cybersecurity are becoming increasingly important. With vehicles now constantly exchanging data, they are vulnerable to cyber threats such as hacking and data breaches. To mitigate these risks, V2X systems are being equipped with advanced encryption and security protocols to ensure that sensitive information remains protected. The implementation of secure communication channels and robust authentication mechanisms is essential for building trust in V2X technology and ensuring its safe deployment on a large scale.

In addition, the development of multi-access edge computing (MEC) is playing a crucial role in enhancing V2X technology. MEC reduces latency by processing data closer to the vehicles themselves, rather than relying on distant cloud servers. This allows for faster decision-making, particularly in safety-critical applications where split-second reactions are essential. MEC, combined with 5G, can significantly reduce the time it takes for vehicles to communicate with each other and their environment, leading to safer and more responsive transportation networks.

Overall, the advancements in V2X technology, particularly the transition to C-V2X, the integration of 5G, and the use of AI, have propelled the field forward, making connected and autonomous driving a reality. These technologies not only improve road safety and traffic efficiency but also open the door to future innovations in smart cities and autonomous mobility. However, challenges remain, particularly regarding infrastructure development, standardization, and security, which must be addressed to fully realize the potential of V2X communication.

The implementation of Vehicle-to-Everything (V2X) communication offers several substantial benefits, particularly in improving road safety, enhancing traffic efficiency, reducing environmental impact, and supporting the development of autonomous vehicles. One of the most prominent advantages is the enhancement of road safety. V2X communication allows vehicles to exchange real-time information about their surroundings, alerting drivers to potential hazards such as sudden braking, lane changes, or nearby obstacles. Studies have shown that V2V communication can significantly reduce collisions, especially at intersections and in high-traffic areas, by providing early warnings to drivers and allowing for faster response times. By enabling vehicles to "see" beyond what is visible to drivers or onboard sensors, V2X increases situational awareness and reduces the risk of accidents caused by human error.

Traffic management and congestion reduction are other key benefits of V2X. By connecting vehicles to infrastructure (V2I), traffic signals, and road sensors, V2X communication enables dynamic traffic management systems. Vehicles can receive real-time updates on traffic conditions, road closures, or accidents, allowing for optimized routing that minimizes congestion. Traffic lights can also adjust their timing based on real-time traffic flow, reducing the stop-and-go driving that contributes to both fuel consumption and emissions. This leads to smoother traffic flow, shorter travel times, and more efficient use of road infrastructure, particularly in urban areas.

The environmental benefits of V2X are closely linked to its impact on traffic efficiency. By minimizing unnecessary idling, stop-and-go driving, and traffic bottlenecks, V2X contributes to a reduction in fuel consumption and emissions. According to studies, vehicles using V2X technology can achieve up to a 10% improvement in fuel efficiency, translating into reduced carbon emissions and a smaller environmental footprint. This makes V2X a crucial technology for meeting regulatory demands related to emissions reduction and sustainability.

V2X also supports the advancement of autonomous driving technologies. Autonomous vehicles rely heavily on real-time data from their surroundings to navigate safely and efficiently. V2X enhances this capability by providing continuous communication between vehicles, infrastructure, and pedestrians, enabling autonomous vehicles to make more informed decisions in complex environments. By combining V2X with onboard sensors, autonomous vehicles can predict and react to dynamic road conditions more accurately, further improving safety and performance.

Additionally, V2X communication plays a pivotal role in the development of smart cities. As urban areas become more connected, V2X technology will be integral to the integration of transportation networks with city infrastructure. This can facilitate services such as automated tolling, intelligent parking systems, and emergency vehicle routing, making urban transportation more efficient and responsive to changing conditions. In smart cities, V2X will enable more efficient resource management and enhance the overall quality of life by reducing traffic-related issues.

**Future Directions and Conclusion**

The future of V2X communication lies in its continued integration with emerging technologies such as 5G networks, artificial intelligence, and advanced data analytics. 5G technology will play a critical role in the expansion of V2X by providing the necessary bandwidth, low latency, and network capacity to support large-scale data exchange between vehicles and infrastructure. With 5G, V2X will be able to handle more complex and data-intensive applications, such as real-time video feeds, vehicle platooning, and enhanced situational awareness in autonomous driving. The development of artificial intelligence (AI) and machine learning (ML) will further enhance the capabilities of V2X by enabling predictive analytics and real-time decision-making. AI can process the vast amounts of data generated by V2X communication more efficiently, allowing for better traffic predictions, improved routing, and more accurate hazard detection. As V2X technology evolves, its role in supporting autonomous vehicles will become even more critical. Fully autonomous driving requires continuous, reliable communication between vehicles, pedestrians, and infrastructure, and V2X provides the necessary framework for this. Future advancements will focus on enhancing the safety and performance of autonomous vehicles by integrating V2X data with onboard sensors and AI-driven decision-making systems. Moreover, multi-access edge computing (MEC) will become increasingly important in reducing latency and enabling faster data processing, particularly in high-traffic or urban environments where quick decision-making is essential. However, despite these promising developments, several challenges remain. Infrastructure development is one of the key hurdles, particularly in regions with limited resources. Implementing V2X on a wide scale requires significant investment in smart infrastructure, including sensors, communication towers, and data processing centers. Additionally, cybersecurity concerns must be addressed to protect vehicles and infrastructure from potential cyberattacks. Robust encryption, data protection protocols, and authentication mechanisms will be essential in ensuring the safety and integrity of V2X communication systems. In conclusion, V2X communication represents a significant advancement in the evolution of connected and autonomous vehicles. By improving road safety, reducing traffic congestion, and supporting the shift toward autonomous mobility, V2X is paving the way for smarter, more efficient transportation systems. As technology continues to advance, particularly with the integration of 5G and AI, V2X will play a central role in shaping the future of urban mobility and smart cities. Overcoming the challenges of infrastructure, standardization, and security will be critical to realizing the full potential of V2X communication in the coming years.

**References**


1. Noor-A-Rahim M, Liu Z, Lee H, Khyam MO, He J, Pesch D, *et al*. 6G for vehicle-to-everything (V2X) communications: Enabling technologies, challenges, and opportunities. Proceedings of the IEEE. 2022 May 20;110(6):712-734.
2. Boban M, Kousaridas A, Manolakis K, Eichinger J, Xu W. Connected roads of the future: Use cases, requirements, and design considerations for vehicle-to-everything communications. IEEE vehicular technology magazine. 2018 Jul 12;13(3):110-123.
3. Kawser MT, Fahad MS, Ahmed S, Sajjad SS, Rafi HA. The perspective of vehicle-to-everything (v2x) communication towards 5g. IJCSNS. 2019 Apr;19(4):146.
4. Farsimadan E, Palmieri F, Moradi L, Conte D, Paternoster B. Vehicle-to-everything (V2X) communication scenarios for vehicular ad-hoc networking (VANET): An overview. InInternational Conference on Computational Science and Its Applications. Cham: Springer International Publishing; c2021 Sep 10. p. 15-30.
5. Hasan M, Mohan S, Shimizu T, Lu H. Securing vehicle-to-everything (V2X) communication platforms. IEEE Transactions on Intelligent Vehicles. 2020 Apr 15;5(4):693-713.
6. Papathanassiou A, Khoryaev A. Cellular V2X as the essential enabler of superior global connected transportation services. IEEE 5G Tech Focus. 2017 Jun;1(2):1-2.
7. Fallgren M, Dillinger M, Alonso-Zarate J, Boban M, Abbas T, Manolakis K, *et al*. Fifth-generation technologies for the connected car: Capable systems for vehicle-to-anything communications. IEEE vehicular technology magazine. 2018 Jul 17;13(3):28-38.
8. Chen S, Hu J, Zhao L, Zhao R, Fang J, Shi Y, *et al*. Cellular vehicle-to-everything (C-V2X). Berlin / Heidelberg, Germany: Springer; c2023.
9. Ekatpure R. Artificial Intelligence for Enhancing Vehicle-to-Everything (V2X) Communication in Automotive Engineering: Techniques, Models, and Real-World Applications. Journal of Science & Technology. 2022 May 17;3(3):91-135.
10. Raza N, Jabbar S, Han J, Han K. Social vehicle-to-everything (V2X) communication model for intelligent transportation systems based on 5G scenario. InProceedings of the 2nd international conference on future networks and distributed systems; c2018 Jun 26. p. 01-08.