V2V Communication in Smart Traffic Systems: Current Status, Challenges and Future Perspectives

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Abstrak−Penerapan komunikasi V2V dalam sistem lalu lintas cerdas telah menjadi topik yang semakin menarik karena potensinya untuk meningkatkan keselamatan jalan raya dan arus lalu lintas. Namun, penerapan komunikasi V2V secara luas dalam sistem lalu lintas cerdas dapat disebabkan oleh berbagai tantangan, seperti biaya infrastruktur, keamanan, dan interoperabilitas. Tantangan-tantangan ini harus diatasi untuk meningkatkan potensi manfaat komunikasi V2V. Rumusan masalah dari penelitian ini adalah untuk menguji potensi manfaat dan tantangan komunikasi V2V dalam sistem lalu lintas cerdas dan memberikan wawasan tentang keadaan terkini dalam penelitian komunikasi V2V. Pendekatan yang diusulkan adalah melakukan tinjauan literatur terhadap penelitian terbaru tentang komunikasi V2V dalam sistem lalu lintas cerdas untuk mengidentifikasi potensi manfaat dan tantangan komunikasi V2V dan keadaan terkini dalam penelitian komunikasi V2V. Studi ini bertujuan untuk berkontribusi di lapangan dengan memahami secara komprehensif penerapan komunikasi V2V dalam sistem lalu lintas cerdas dan menginformasikan potensi penelitian masa depan di bidang ini. Komunikasi V2V dapat meningkatkan keselamatan jalan dan arus lalu lintas dalam sistem lalu lintas cerdas. Namun, diperlukan lebih banyak penelitian untuk mengatasi tantangan ini dan mengembangkan sistem komunikasi V2V yang canggih dan hemat biaya.

Kata Kunci: Komunikasi V2V; Sistem Lalu Lintas Cerdas; Manfaat dan Tantangan V2V; Adopsi V2V; ITS.

Abstract−Implementing V2V communication in intelligent traffic systems has been a topic of growing interest due to its potential to improve road safety and traffic flow. However, the widespread adoption of V2V communication in intelligent traffic systems could be enhanced by various challenges, such as infrastructure cost, security, and interoperability. These challenges must be addressed to improve the potential benefits of V2V communication. The problem statement of this study is to examine the potential benefits and challenges of V2V communication in intelligent traffic systems and provide insights into the current state of the art in V2V communication research. The proposed approach is to conduct a literature review of recent research on V2V communication in intelligent traffic systems to identify the potential benefits and challenges of V2V communication and the current state of the art in V2V communication research. The study aims to contribute to the field by comprehensively understanding the implementation of V2V communication in intelligent traffic systems and informing potential future research in this area. V2V communication can improve road safety and traffic flow in intelligent traffic systems. However, more research is needed to address the challenges and develop advanced and cost-effective V2V communication systems.

Keywords: V2V Communication; Smart Traffic System; V2V Benefit and challenges; V2V adoption; ITS.

1. INTRODUCTION

V2V (vehicle-to-vehicle) communication in smart traffic systems has gained significant attention in recent years as a way to improve the efficiency and safety of transportation[1], [2]. V2V communication enables vehicles to communicate with each other and share real-time data about traffic, weather, and other conditions, which can be used to optimize routes, reduce congestion[3], and improve safety on the road[4], [5]. Several studies have examined the potential benefits of V2V communication in smart traffic systems. The survey study about V2V communication, For example, a survey study[6], found that V2V communication can improve traffic flow efficiency by allowing vehicles to coordinate their movements and optimize routes. Another study [7] demonstrated the feasibility of discrete event simulation of a road intersection that integrates V2V and V2I (vehicle-to-infrastructure) features to improve traffic flow. V2V communication can occur between OBUs (on-board units) or through intermediaries such as RSUs (roadside units) [8].

However, despite the potential benefits of V2V communication in smart traffic systems, several challenges must be addressed before widespread adoption. One of the main challenges is the high infrastructure cost associated with implementing V2V communication systems and the need to establish security protocols to protect against cyberattacks and data breaches [9]. In addition, there is a need to ensure interoperability between different V2V communication systems, which can be a challenge given the diverse range of vehicle

manufacturers and technology providers [10]. There are still significant gaps in understanding how V2V communication systems can be effectively integrated into smart traffic systems to deliver desired outcomes and a need for further research to address the challenges and fully realize the potential benefits of this technology.

To support the widespread adoption of V2V communication in the smart traffic system, various organizations such as the IEEE (Institute of Electrical and Electronics Engineers) [11], the US Department of Transportation, and the European Telecommunications Standards Institute (ETSI) [12] have developed standards for V2V communication, including IEEE 802.11p, WAVE (Wireless Access in Vehicular Environments)[13], and DSRC (Dedicated Short-Range Communications) [14], respectively define the communications protocols, services, and message formats needed to support V2V communication. They also provide security measures to protect communication from unauthorized access and tampering. One major challenge is related to development cost [15], [16]. Some challenge is security [17], [18], as it is important to ensure that V2V communication systems are secure and cannot be easily hacked or compromised[19]. Next, Interoperability [20] between V2V communication systems from different manufacturers, as it is important to ensure that these systems can work seamlessly together and support a wide range of applications [21]. Additionally, another challenge is the cost of infrastructure[22], as the implementation of V2V communication systems in smart traffic systems requires the deployment of communication equipment and infrastructure, which can be expensive.

The literature highlights several challenges that need to be addressed for the widespread adoption of V2V communication in smart traffic systems. Despite the challenges, it is clear that V2V communication has the potential to be a valuable tool for improving road safety and traffic flow in intelligent traffic systems. Further research is needed to address the challenges and to develop more advanced and cost-effective V2V communication systems.This research paper provides an overview of the current state of V2V communication in smart traffic systems and its potential benefits, such as improved safety and efficiency on the road. It also acknowledges the challenges that need to be addressed for the widespread adoption of V2V communication, including infrastructure cost, security, and interoperability. The study aims to contribute to the field by highlighting the benefits and challenges of V2V communication and providing a comprehensive understanding of the current state of V2V communication research. This information can inform future research and help guide the development and implementation of V2V communication in smart traffic systems.

2. RESEARCH METHOD

The study highlights the current research, the importance of addressing the challenges, and considering the future perspectives of the technology to ensure its successful deployment and use. The proposed method in the V2V communication study on smart traffic systems can be in Figure 1.

Figure 1. The proposed method

In Fig 1, The method involves the following steps, first, the Current status assessment reviews the current state of V2V communication in smart traffic systems, including the technologies, protocols, and applications currently in use. Second, the identification of challenges, An analysis of the difficulties facing implementing V2V communication in smart traffic systems, including privacy and security concerns, scalability, reliability, cost-benefit ratio, and human factors. Next, Future perspectives discuss the trends and developments in V2V communication in smart traffic systems, including the potential benefits and applications of the technology and the challenges that need to be addressed. And Solution development is the development of solutions to address the challenges and improve the performance of V2V communication in smart traffic systems, including adopting interoperable protocols, developing security measures, and deploying advanced technologies such as machine learning and artificial intelligence.

A systematic literature review identifies relevant studies on "V2V communication in smart traffic systems". The search was performed in 2022. The following databases were searched: Scopus, Web of Science, and IEEE

Xplore Digital Library. The search terms used were ("V2V communication" OR "vehicle-to-vehicle communication" OR "V2V" OR "vehicle-to-vehicle") AND ("smart traffic" OR "intelligent transport systems" OR "ITS" OR VANET) included peer-reviewed journal articles were included in the review. The search was limited to the paper published between 2017 and 2022. A total of 203 articles were identified through the investigation, and after applying the inclusion and exclusion criteria, the report included a final sample of 80 pieces of paper in the review.

3. RESULT AND DISCCUSSION

In the category of Benefits and Challenges of V2V communication in smart traffic, studies have reported that V2V communication can improve road safety and traffic flow by providing timely and accurate information about the surrounding vehicles and the road environment[23], [24], allowing for more efficient and coordinated driving[22], [25]. Table 1 summarizes the benefits and challenges of V2V Communication in smart traffic systems.

Table 1. Benefit and Challenges

No	Benefit	Challenges
1	Safety improvement	infrastructure cost
2	Efficiency improvement	Privacy issue
3	Traffic management improvement	limited ability to detect and respond to attacks
4	Enhanced public transportation	lack of standardization in the security measures used
5	Real-time data enhancement	

Based on the literacy studies summarized in Table 1, this study identifies the benefit of implementing V2V communication on intelligent traffic systems and challenges that need to be considered when preparing, implementing, and supporting the sustainability of V2V communication-based smart transportation systems. Table 1 also contains information on potential further research opportunities in developing V2V communication on smart traffic systems. Especially, to overcome several challenges that need to be solved or optimized from various perspectives, such as technical, economic, social, and so on.

3.1. The Benefit of Using V2V Communication in Smart Traffic System

Regarding Table 1, we identify Several benefits of using V2V communication in smart traffic systems such as Safety improvement[26] to prevent accidents and improve safety on the road, Efficiency improvement reduce congestion and improve efficiency on the road[25] where V2V communication can support the development of smart traffic systems, leading to improved efficiency and sustainability for transportation networks[27]. Traffic management improvement to improve safety on the road by alerting drivers to potential hazards and helping them to avoid accidents where V2V communication can allow vehicles to communicate with each other to coordinate merging and lane-changing activities, reducing the potential for accidents and improving traffic flow[28]. Enhanced public transportation[29] to improve the efficiency of public transportation systems by allowing buses and trains to communicate with each other and with a central control center[30]. By integrating V2V communication with public transportation systems, transit agencies can provide better and more efficient customer services. And Real-time data enhancement[31] to improve the accuracy and effectiveness of traffic management systems by gathering and share real-time data about traffic, weather, and other conditions. It can improve traffic flow, reduce congestion, and increase road safety[32].

3.1.1. Safety Improvement

One of the main benefits of V2V communication is that it allows vehicles to "see" beyond their line of sight and detect potential hazards that may not be visible to the driver. V2V Communication can help to prevent accidents and improve safety on the road. V2V communication can improve traffic flow by allowing vehicles to coordinate their movements and avoid congestion[33]. It can provide a more comprehensive view of the surrounding environment than traditional sensors, such as cameras and radar[34]. V2V communication allows vehicles to exchange information about their location, speed, and direction of travel with each other, which can help to create a more accurate and complete picture of the surrounding environment[35].

The second is lane change assistance; V2V communication can detect when it is safe to change lanes and alert drivers to potential hazards in their blind spots. This can help to reduce the risk of accidents caused by lane changes[36]. The third is an Intersection collision warning; V2V communication can alert drivers to potential collisions at intersections and help them to avoid accidents [37]. Next, Emergency warning systems, the V2V communication alerts drivers to potential hazards, such as accidents, road closures, and other emergencies [38].

3.1.2. Efficiency Improvement

V2V communication can help improve the transportation system's efficiency by reducing congestion, improving traffic flow, and making travel more predictable. The efficiency improvement is achieved through V2V communication in several ways, such as Coordinated traffic lights that allow vehicles to communicate with traffic lights, providing information about their location, speed, and direction of travel. It will enable traffic lights to adjust their timing based on the actual traffic flow, reducing wait times for vehicles and improving the overall flow of traffic.[39]. The second is a **cooperative cruise control** which allows vehicles to communicate with each other using V2V communication to optimize their speed and distance, reducing fuel consumption and emissions. [40]. The Vehicles can share information about their speed and location, which allows them to coordinate their speed and distance to reduce the need for sudden braking and acceleration[41]. The third is to provide a Better routing which can help other vehicles to avoid these areas and find the quickest route to their destination[42].

Next is Emergency vehicle prioritization. Emergency vehicles like ambulances and fire trucks can use V2V communication to notify other vehicles of their presence, allowing them to move through traffic more quickly and safely. V2V communication has the potential to enhance emergency vehicle prioritization in smart traffic systems. V2V communication can help emergency vehicles avoid traffic congestion, find the quickest route to their destination, and reduce response times by exchanging real-time information on vehicle speed, location, and road conditions and allowing a faster and more effective response in emergencies, improving public safety and reducing the risk of accidents. The Platoon formation based on V2V communication will enable vehicles to drive in close shape, known as platooning, which can help to reduce wind resistance, improve fuel efficiency, and save time for drivers[43], [44]. The last one is the Greenlight optimal speed advisory. By providing information about the speed at which a vehicle should be traveling to hit a green light, V2V communication can help drivers to travel at a more consistent rate, reducing the need for sudden braking and acceleration, which can help to reduce congestion and improve traffic flow[45].

3.1.3. Traffic Management Improvement

V2V communication can improve traffic management by providing real-time information about the location and speed of vehicles on the road. Traffic managers can use this information to make more informed decisions about traffic flow, incident management, and traffic signal timings. V2V communication can achieve Traffic Management Improvement through V2V communication in several ways, such as real-time traffic monitoring to inform the vehicles of any information about traffic congestion, accidents, and other road hazards, which can help traffic managers to identify problem areas and make adjustments to traffic flow as needed[46]. Related to real-time traffic monitoring is incident management. In the event of an accident or other incident, V2V-equipped vehicles can share information about the location, severity, and impact of the incident[47]. This can help traffic managers to respond more quickly and effectively, reducing the impact of the incident on traffic flow[48]. The third is an adaptive traffic signal control that allows multiple vehicles to communicate with traffic lights. It will enable traffic lights to adjust their timing based on the actual traffic flow, reducing wait times for cars and improving the overall flow of traffic.[49]. Emergency vehicle prioritization to notify other vehicles of the ambulance's presence, allowing them to move through traffic more quickly and safely. It can help to reduce delays and ensure that emergency vehicles reach their destinations as soon as possible[50].

3.1.4. Enhanced Public Transportation

V2V communication can enhance public transportation by providing real-time information about the location and status of public transportation vehicles, which can help to improve the overall efficiency and reliability of the public transportation system[51]. Enhanced public transportation services, V2V communication, can improve the overall efficiency and reliability of the public transportation system, attracting more riders and reducing the number of cars on the road, leading to a reduction in traffic congestion and air pollution[52]. V2V communication can enhance public transportation by providing several improvements, such as real-time vehicle

tracking[53], which can help to provide real-time tracking information to passengers and traffic managers and improve the overall efficiency of the public transportation system by reducing wait times and improving the reliability of vehicle arrival times. Third, V2V communication can enhance dispatching and route planning[54]; V2V-equipped public vehicles can share information about traffic congestion, accidents, and other road hazards, which can help dispatchers to make more informed decisions about route planning and vehicle scheduling.

Fourth, cooperative traffic signal control allows traffic lights to adjust their timing based on the actual traffic flow of public vehicles, reducing wait times and improving the overall flow of traffic. Improved emergency response, In an emergency, V2V-equipped general cars can share information about the location, severity, and impact of the incident, which can help emergency responders respond more quickly and effectively[55]. Overall, V2V communication can enhance public transportation by providing real-time information about the location and status of public transport, which can improve the overall efficiency and reliability of the public transportation system.

3.1.5. Real-time Data Enhancement

Real-time data enhancement is a critical component of V2V communication. It enables vehicles to make informed decisions and respond quickly to changing road conditions, thereby improving road safety, efficiency, and mobility [56]. Real-time data enhancement is essential for V2V communication because it allows vehicles to make real-time decisions based on the information they receive from other cars. This real-time data exchange can significantly improve road safety by reducing the number of accidents and incidents caused by human error or limited visibility. It can also increase efficiency by reducing traffic congestion and improving traffic flow on the road. Additionally, real-time data enhancement can enhance mobility by providing drivers with real-time information about road conditions, traffic patterns, and alternative routes.

3.2. Challenges of Using V2V Communication in Smart Traffic System

However, based on the Table 1, the studies also highlighted the challenges such as security improvement[6], privacy issue[57], and infrastructure cost[58], [59]. Hardware costs, One of the most considerable costs associated with V2V communication is the cost of the hardware required to support the communication[60]. The software required for V2V communication is also costly. The software includes the cost of developing and maintaining the communication protocols, services, and message formats, the cost of integrating the V2V communication system with other systems, such as the vehicle's onboard computer and navigation system while the other price is certification, development anad maintenance to ensure they continue functioning correctly and securely[61].

Second is the Privacy issue. V2V communication systems collect and transmit important data about vehicles and their occupants. This data can include location, speed, and other sensitive information. If this data is not adequately protected, it can be accessed and used by unauthorized parties, raising serious privacy concerns[62]. There is also a need for more standardization in the security measures used; it is challenging to ensure communication security. Another issue is a limited ability to detect and respond to attacks; V2V communication systems cannot currently see and respond to cyber attacks in real-time. Good standardization makes it challenging to stop an attack once it has been launched[63], [64]. It is essential to develop and implement robust security measures for V2V communication systems that can protect against cyberattacks and ensure the privacy of the data transmitted.[65], [66]. In the category of Technical Issues, studies have reported that there is a lack of standardization and regulations for V2V communication, which is an obstacle to the implementation of the technology[67].

Several technical issues need to be addressed when implementing V2V communication in a smart traffic system, such as Network infrastructure to support the high-bandwidth and low-latency communication between vehicles that can be challenging to deploy, particularly in areas with poor network coverage or where the existing infrastructure is inadequate[68]. The Hardware compatibility, V2V communication requires that all vehicles on the road be equipped with the same hardware and communication protocols for the system to work effectively. Ensuring compatibility between different car makes and models can be challenging.[57]. Interoperability to ensure that all vehicles can communicate with one another effectively, energy consumption can be a problem for electric cars with limited resources or battery capacity [69]. And scalability scale to handle the increasing volume of data and the number of connected cars, particularly in areas with high traffic density, where the system will need to be able to handle a large number of vehicles communicating with one another simultaneously[70].

3.3. Future perspectives of V2V Communication for Smart Traffic System

V2V communication has the potential to significantly improve the safety, efficiency, and mobility of intelligent traffic systems in the future. V2V communication could be used in the future for the support system of autonomous vehicles; as autonomous vehicles become more prevalent, V2V communication will become increasingly important for these vehicles to share information with traffic infrastructure. It can lead to better traffic flow, safety improvement, and reduced congestion[71]. Supporting Intelligent Transportation Systems to provide a more comprehensive view of traffic conditions and help to improve traffic flow [70]. It is an essential component of ITS as it enables vehicles to share real-time information, such as speed, location, and road conditions.[72]. V2V communication can be used to support the development of smart cities as part of innovative city initiatives to improve the overall efficiency of transportation within urban areas. V2V communication enables traffic management systems to control and manage traffic flow, reduce congestion, and enhance the driving experience. It allows vehicles to share real-time information such as location, speed, and traffic conditions with other vehicles and road infrastructure, thus providing a comprehensive view of the city's traffic system.[73], [74].

Next, V2V communication will significantly boost the development of connected electric vehicles to optimize the use of the electric grid and reduce the overall cost of electric vehicle ownership [74]. By allowing electric vehicles to communicate with each other and the surrounding infrastructure, V2V communication can provide important information such as charging station availability, battery status, and driving range, which can help drivers make informed decisions about their driving behavior and route planning[75]. Advanced driver-assistance systems (ADAS) enhancement, the V2V communication, is applied to enhance the functionality of ADAS, such as adaptive cruise control, lane departure warning, and automatic emergency braking, which can help to improve safety and make driving more comfortable.[76], [77]. And The Smart Parking System, V2V communication, is applied to communicate the availability of parking spots, which can help other vehicles to find parking spots more efficiently, reducing the congestion and air pollution caused by circling looking for a parking spot [78]. V2V communication can also provide information on parking fees, operating hours, and parking restrictions, which can help drivers make informed decisions when parking their vehicles[78].

Overall, the future of V2V communication for smart traffic systems is bright, as the technology will continue to evolve and be integrated with other technologies to improve the efficiency, safety, and overall experience of transportation. The integration of V2V communication with other technologies such as V2I, V2N, and V2X and the use of AI[79], ML[12], Cloud[80], and 5G technologies[81], [82], [83] are considered as an opportunity for the improvement of V2V systems for smart traffic systems.

3.4. Discussion

The literature review conducted in this study revealed several important insights into the implementation of V2V communication in smart traffic systems. The findings indicated that V2V communication has the potential to improve road safety and traffic flow. However, several technical challenges must be addressed to facilitate the widespread adoption of V2V communication technology in an intelligent traffic system. The literature also showed a growing trend towards integrating V2V communication with other technologies, such as V2I and V2N, to create a comprehensive V2X communication system. Furthermore, integrating V2V communication with 5G networks is an exciting area for future research. While the benefits of V2V communication in smart traffic systems are clear, challenges must be addressed. Strategies are needed to reduce the costs of V2V communication technology and to improve data security to increase public trust and ensure the privacy and security of the data. Strict security regulations and guidelines must be implemented to protect V2V communication from potential threats such as hacking and data breaches.[84].

Promoting interoperability between V2V communication systems from different manufacturers is another strategy. Promoting interoperability can be done by developing standards and protocols allowing these systems to work seamlessly together and support a wide range of applications. Developing and enforcing regulations for V2V communication is another crucial strategy. Governments and regulatory bodies must establish standards and guidelines for V2V communication to ensure its safe and effective deployment, which lies in several factors; first, it helps to ensure that drivers are aware of the capabilities and limitations of the technology and how it impacts their driving experience. Secondly, regulations provide a clear framework for the deployment and use of the technology Third; rules can ensure the privacy and security of drivers and their data and give the fair and responsible use of the technology by all parties involved. Finally, another crucial strategy is to educate the public about the benefits and safety of V2V communication technology. Education can help to build trust and

acceptance of this technology among the general public[85]. The public must know its benefits and how it works, including understanding the technology behind V2V, its uses, and how it can improve road safety. Furthermore, educating the public on the potential privacy and security concerns associated with V2V and how these concerns can be addressed is also important.

4. CONCLUSION

The literature review of V2V communication in smart traffic systems has shown that it has the potential to enhance road safety and traffic flow by providing real-time information about surrounding vehicles and the road environment. However, challenges such as security, privacy, cost, and a lack of standardization and regulations must be addressed for widespread adoption. The literature review highlights the need to address the challenges of cost, security, and standardization and the opportunities provided by integrating other technologies and AI, ML, Edge, Cloud, and 5G to improve the current V2V systems in smart traffic systems. One important finding is the trend toward integrating V2V communication with other technologies like V2I, V2N, and V2X to create a more comprehensive communication system. Additionally, integrating AI, ML, Edge computing, Cloud computing, and 5G networks with V2V communication systems is a chance to enhance the current V2V systems in intelligent traffic systems. Despite the challenges, the literature review confirms that V2V communication has the potential to improve safety and efficiency on the road. However, more research is needed to overcome the challenges and develop more advanced and cost-effective V2V communication systems.

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