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# Comparison and Optimization of DSRC and C-V2X Technologies: Current Status, Challenges, and Future Prospects

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**Abstract:** DSRC (Dedicated Short-Range Communication) and C-V2X (Cellular Vehicle-to-Everything) have emerged as two key communication technologies for vehicular networks. However, both technologies face challenges in terms of communication performance and integration. This paper presents a detailed comparison and optimization study of DSRC and C-V2X, focusing on their status, technical challenges, and future development trends. The study reviews recent advancements in enhancing the throughput, communication range, and resource allocation of both technologies. Moreover, we explore the potential of AI and 5G technologies in addressing the limitations of DSRC and C-V2X, offering insights into their integration in next-generation vehicular communication systems. Finally, this paper discusses the technical challenges and possible future directions for the convergence of these two technologies, aiming to enhance vehicular network efficiency and support advanced V2X applications.

**Keywords:** DSRC; C-V2X; Autonomous driving; AI optimization; Resource allocation.

## 1. Introduction

With the rapid development of global Intelligent Transportation Systems (ITS), Vehicle-to-Everything (V2X) communication technologies have emerged as crucial components in improving road safety, optimizing traffic flow, and advancing autonomous driving [1,2]. V2X enables seamless information exchange between vehicles, infrastructure, pedestrians, and networks, providing vital support for traffic management in future smart cities. As urbanization accelerates worldwide, the demand for V2X technologies has become increasingly pressing, particularly in the context of strained traffic infrastructure due to population concentration [3].

Road safety concerns have also become more prominent. According to the World Health Organization (WHO), over 1.3 million people lose their lives in traffic accidents annually [4]. Cooperative Intelligent Transportation Systems (C-ITS) are becoming essential tools in reducing accidents and alleviating traffic congestion through enhanced communication and data transmission [4]. Additionally, the rapid growth of the global connected vehicle market has fueled the advancement of V2X technologies, with the market expected to reach USD 225 billion by 2025[5].

This paper provides a comprehensive review of the status, advantages, and challenges of DSRC and C-V2X, discusses existing optimization strategies, and explores the future development of V2X communication, driven by 6G and AI technologies.

## 2. Current Status and Comparison of DSRC and C-V2X Technologies

### 2.1. Current Status and Challenges of DSRC

#### 2.1.1. Introduction to DSRC Technology:

DSRC (Dedicated Short-Range Communication) is based on the IEEE 802.11p standard and supports vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication. Its layered structure includes a physical layer, a media access control (MAC) layer, and an application layer, each with different communication functions. The physical layer is responsible for radio signal transmission, the MAC layer manages channel access and conflict avoidance, and the application layer provides users with a variety of V2X applications, such as collision warning and traffic management [6,7]. DSRC performs particularly well in low-latency scenarios and remote areas because it does not require a dedicated communication infrastructure [8].

#### 2.1.2. Current status of DSRC research:

Currently, the DSRC standard has been adopted in many countries around the world, but it has not yet formed a unified international standard. For example, the U.S., Europe and Japan have adopted the technology in different frequency bands respectively, and the specific allocations are shown in the literature [9]. China, on the other hand, has allocated the 5.8 GHz band to DSRC since 1998, providing a clear direction for the domestic standardization process [7].

#### 2.1.3. Challenges of DSRC and existing solutions:

Although DSRC technology has demonstrated reliable low latency benefits in V2X communications, it still faces significant challenges at the physical and MAC layers. Firstly, frequency selective fading due to high-speed vehicle movement, especially when using the IEEE 802.11p standard, becomes a key factor limiting its performance. It has been indicated that the accuracy of channel estimation can be effectively improved by introducing Turbo receivers and decision feedback receivers, significantly enhancing the robustness of communication, as demonstrated in prior research [10]. Second, in high-density traffic environments, the CSMA/CA mechanism of DSRC is prone to triggering channel congestion, which leads to a decrease in data transmission efficiency. To address this issue, a time slot synchronization system has been proposed, which helps alleviate congestion and improve the packet reception rate, particularly in high-density user environments [10]. Although these optimization schemes address the challenges of DSRC in high-speed and complex environments to a certain extent, DSRC still suffers from deficiencies in scalability and resource scheduling compared to C-V2X. Therefore, it remains a key research direction to further enhance the adaptability of DSRC, maintain its low latency advantage, and improve its performance in high-density networks in the future.

## 2.2. State of the art and development of C-V2X:

Similar to DSRC, C-V2X, another V2X communication technology, also shows great potential in responding to the need for efficient and secure communication

### 2.2.1. Introduction to C-V2X technology and standard evolution:

Cellular Vehicle-to-Everything (C-V2X, Cellular Vehicle-to-Everything) technology, relying on the strong coverage capability and long communication distance of cellular networks, has been an important development direction in the field of Vehicle-to-Everything (V2X) in recent years. Since the introduction of the LTE-V2X standard (Rel. 14), C-V2X has gradually evolved to 5G NR-V2X (Rel. 16 and its subsequent versions), which provides more efficient communication performance and expands more complex application scenarios. Figure 1 gives the standard evolution

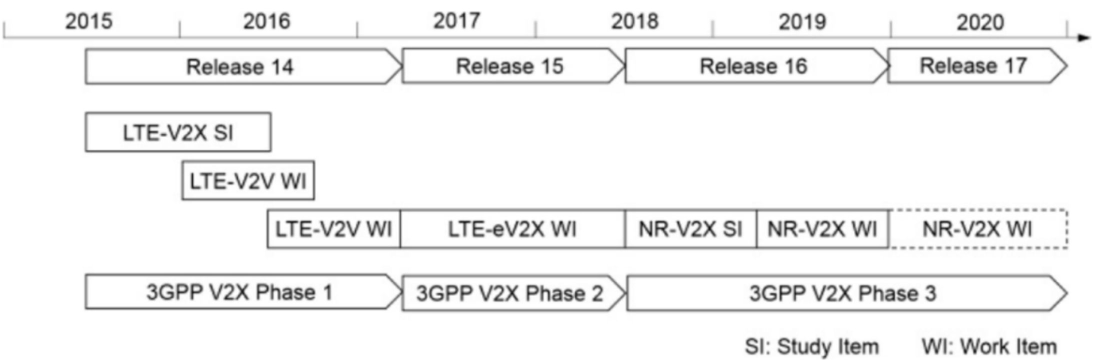


**Figure 1.** Timeline of C-V2X standardization [11,12]

### 2.2.2. The current status of C-V2X research [13]:

Since 2017, China has vigorously promoted the development of C-V2X through policy support and industrial layout. The government issued the Action Plan for the Promotion of Intelligent Connected Vehicle Industry, which specifies the spectrum planning for LTE-V2X and promotes cross-industry integration. China has formed a complete C-V2X ecosystem in terms of standardization, technology development and commercialization application, covering key areas such as communication modules, chipsets, on-board units (OBUs) and roadside units (RSUs).

Internationally, the development of C-V2X is also rapid. The U.S. was the first to promote DSRC legislation, but in recent years has shifted to support C-V2X. Europe has adopted a dual-track parallel strategy to support IEEE 802.11p and cellular V2X technologies, while Japan has accelerated the standardization and testing process of LTE-V2X. Companies in various countries have also demonstrated C-V2X-based Telematics applications.

### 2.2.3. C-V2X application phase:

The application development of C-V2X technology can be divided into several stages, from improving traffic efficiency and road safety through V2V and V2I communication to gradually realizing the autonomous driving function of commercial vehicles and passenger cars. In the initial stage, C-V2X has been shown to effectively improve traffic management efficiency and reduce accident risks through the collaborative sensing of V2V and V2I, as highlighted in previous research [13].In the field of commercial vehicles, C-V2X, working in concert with edge computing (MEC), has already realized the application of autonomous driving in closed areas such as ports and industrial parks. In the future, as C-V2X technology is deployed in a wider range of scenarios, automated driving for passenger cars will also gradually mature and expand to more complex open transportation environments. Figure 2 shows:

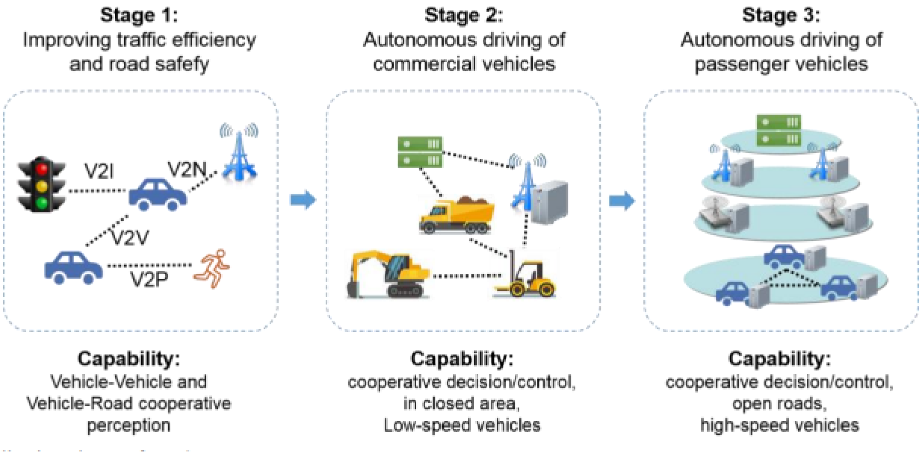


**Figure 2.** C-V2X three phases [13]

In addition to the existing application phase, C-V2X will play a more important role in the future of intelligent fleet management and logistics. With the wide-area coverage and low-latency communication of C-V2X technology, logistics fleets will achieve highly intelligent management, including fleet dispatch optimization, real-time route planning, vehicle health monitoring and other functions. Logistics companies can realize multi-vehicle cooperative transportation through C-V2X, significantly reducing operating costs and improving overall transportation efficiency. As self-driving technology continues to mature in the commercial vehicle sector, C-V2X is expected to drive the full automation of long-haul logistics fleets. Through real-time communication and dynamic decision optimization, the fleet management system will further reduce fuel consumption, avoid congestion, and improve overall operational efficiency.

In summary, C-V2X is especially suitable for high-density and long-distance transportation application scenarios with its advantage of relying on cellular networks. In the future, with the continuous optimization and expansion of the technology, C-V2X will play an increasingly important role in autonomous driving, fleet management and intelligent transportation systems. However, it is worth noting that although C-V2X performs well in high-density traffic scenarios, DSRC still has advantages in specific application scenarios. Therefore, a detailed comparative analysis of DSRC and C-V2X application scenarios will be presented in the next section.

## 2.3. DSRC vs. C-V2X:

With the rapid development of C-V2X, comparative analysis with DSRC becomes crucial to help decision makers and technicians choose the most suitable application scenarios, which will be compared in the following through two dimensions: progress and technical indicators.

### 2.3.1. Comparison of Progress:

Progress in DSRC and C-V2X has varied in different regions. China has actively promoted C-V2X technology through policy and has launched pilot programs in several cities. The U.S., while supporting DSRC in the early days, has been gradually transitioning to C-V2X technology in recent years. Europe supports both DSRC and C-V2X standards, and countries such as Germany and the Netherlands have launched large-scale testing programs. Japan, on the other hand, continues to promote the development of C-V2X, especially in the management of smart cities and logistics fleets, showing a wide range of applications. Table 1 gives a detailed comparison.

**Table 1.** Comparison of progress among countries

| Aspect | China | United States | Europe | Japan |
|---|---|---|---|---|
| Policy Support | Strong support for C-V2X, with the *Action Plan for Promoting Intelligent Connected Vehicles* in 2017. Actively promotes spectrum allocation and industry development. | Initially supported DSRC, now shifting to C-V2X. The FCC reallocated spectrum for C-V2X. | Dual-track approach supports both DSRC and C-V2X. | Focuses on C-V2X but retains DSRC for drones and logistics fleets. |
| Technical Progress | Rapid C-V2X growth with large-scale tests in major cities, especially for smart vehicles. | C-V2X testing in some states, mainly for autonomous driving and highways. DSRC still in legacy use. | Parallel trials of DSRC and C-V2X in countries like Germany and the Netherlands. | C-V2X is widely used in smart cities and autonomous driving; DSRC continues in logistics and drones. |
| Applications | Smart buses, autonomous taxis, and intelligent road systems in cities like Shanghai and Wuhan. | Focuses on autonomous driving and highway coordination, with trials in California and Michigan. | Applied in smart cities and logistics, e.g., Germany's digital highways and the Netherlands' smart cities. | Smart city projects, autonomous taxis, and logistics fleets in Tokyo. |
| Standards Progress | C-V2X standards have developed rapidly, covering access, network, and security layers. | Transitioning from DSRC (IEEE 802.11p) to C-V2X. Standardization is gaining momentum. | Advancing both DSRC and C-V2X standards (LTE-V2X, 5G-V2X). | Steady progress in LTE-V2X, with DSRC standards retained for specific use cases. |

The current status of C-V2X research [13]:

DSRC and C-V2X have their own advantages in terms of technical specifications, and the following is a key comparison between the two.

### 2.3.2. DSRC's Decentralization and Low-Density Application Advantages:

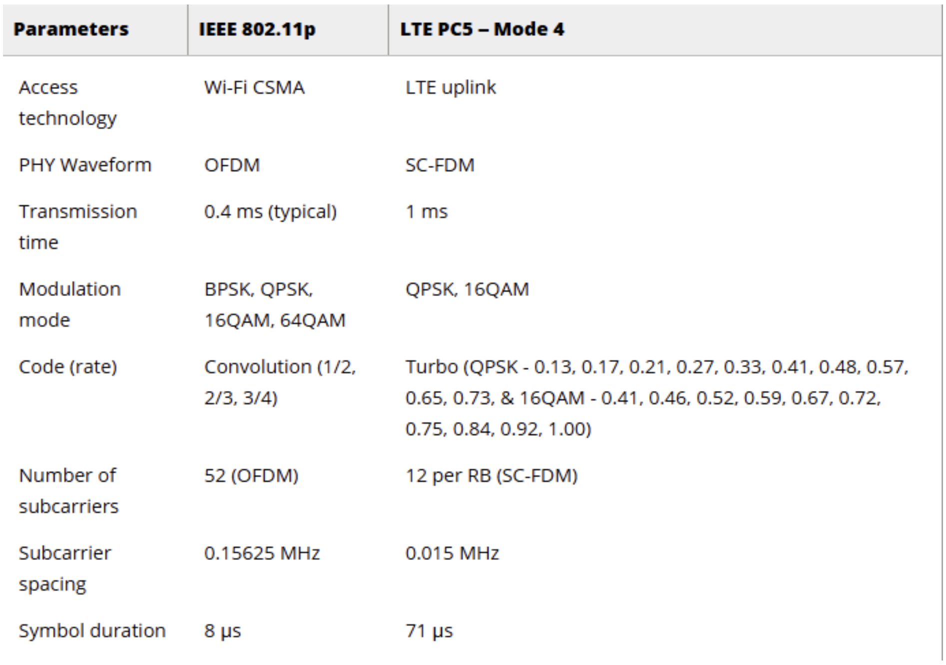
DSRC relies on the CSMA/CA mechanism and has significant advantages in low-density environments. Its autonomous channel access mechanism effectively reduces communication conflicts and delays, making it excellent in short-range, decentralized Telematics scenarios, such as collision avoidance systems with low latency requirements [13]. However, as the network density increases, DSRC suffers from channel congestion in high-density scenarios, and the transmission efficiency decreases rapidly, especially when the competition at the MAC layer increases [14]. In low-density environments, DSRC can maintain a relatively stable packet reception rate (PDR), but as user density increases, the PDR is significantly reduced by channel congestion [9].

### 2.3.3. C-V2X's high-density and long-range communication benefits:

C-V2X relies on cellular network architecture and shows excellent performance in high-density and long-distance application scenarios. Its SPS (semi-persistent scheduling) mechanism and Turbo coding technology effectively enhance the communication efficiency in high-load environments [13]. In complex traffic scenarios, such as ramp merging and queue braking, C-V2X dramatically reduces communication latency through fast scheduling and optimized spectrum utilization [15].C-V2X performs particularly well in long-distance communication, maintaining high-quality packet reception rates (PDRs) even at distances of over 200 meters [14]. Despite the high resource consumption in extremely high-density environments, the scheduling flexibility and interference immunity of C-V2X significantly improves its scalability and reliability.

### 2.3.4. Applicability analysis of application scenarios:

Combined with existing research, DSRC has better applicability in low-density, decentralized short-range communication scenarios, especially in applications requiring low latency and high real-time performance, such as collision avoidance systems and other in-vehicle safety communications [15,16]. In contrast, C-V2X is suitable for high-density, centralized scenarios, such as information transmission needs and frequent data exchanges in complex urban traffic, by virtue of its high bandwidth and long-distance communication advantages [17].C-V2X is able to better cope with dynamic traffic environments and large-scale data transmission needs through more flexible resource allocation and strong link maintenance capabilities. C-V2X is more advantageous when dealing with large-scale Vehicular Networking communications in complex urban traffic or high-speed road sections.



| **Parameters** | **IEEE 802.11p** | **LTE PC5 – Mode 4** |
|---|---|---|
| Access technology | Wi-Fi CSMA | LTE uplink |
| PHY Waveform | OFDM | SC-FDM |
| Transmission time | 0.4 ms (typical) | 1 ms |
| Modulation mode | BPSK, QPSK, 16QAM, 64QAM | QPSK, 16QAM |
| Code (rate) | Convolution (1/2, 2/3, 3/4) | Turbo (QPSK - 0.13, 0.17, 0.21, 0.27, 0.33, 0.41, 0.48, 0.57, 0.65, 0.73, & 16QAM - 0.41, 0.46, 0.52, 0.59, 0.67, 0.72, 0.75, 0.84, 0.92, 1.00) |
| Number of subcarriers | 52 (OFDM) | 12 per RB (SC-FDM) |
| Subcarrier spacing | 0.15625 MHz | 0.015 MHz |
| Symbol duration | 8 μs | 71 μs |

**Figure 3.** Demonstrates the comparison of the technical characteristics of IEEE 802.11p and LTE PC5 [9]

To summarize, DSRC performs stably in low-load environments, but its scalability is limited in high-density networks, while C-V2X performs better in large-scale data transmission and complex traffic scenarios. The two complement each other's strengths, and future synergistic applications of the technologies are expected to provide more efficient and reliable communication solutions for ITS. Next, we will discuss the research progress of DSRC and C-V2X in the optimization direction and propose potential improvement strategies and future development paths in combination with existing models.

## 3. Existing Optimization Models and Innovation Research Directions (EOMIRD)

The growing demand for V2X communications in high-density traffic scenarios has led to serious challenges in transmission efficiency and resource management for DSRC and C-V2X technologies. To address these issues, researchers have proposed a variety of optimization models aimed at improving the performance and reliability of these two technologies. Existing optimization schemes and future innovative directions are discussed in detail below.

### 3.1. Existing optimization models for DSRC:

In high-density traffic environments, the transmission efficiency of DSRC decreases significantly, so improving its performance is a research priority. Several studies have proposed the following main optimization schemes [18,19]:

(1) Semi-Persistent Contention Density Control (SpCDC) scheme: This scheme improves the communication performance in high-density environments by optimizing the broadcast mechanism of DSRC. Simulation results show that the packet transmission rate is improved by more than 10% and the delay is reduced by 50%. However, the practical application of SpCDC is still limited by the physical layer and network architecture, especially in the case of tight frequency resources, and the effectiveness of its deployment still needs to be verified [18].

**Table 2.** Comparison of DSRC and C-V2X by performance

| Parameter | DSRC (IEEE 802.11p) | C-V2X (4G LTE / 5G) |
|---|---|---|
| ISO | IEEE 802.11p | 3GPP (Release 14 for LTE-V2XRelease 16 for 5G-V2X) |
| spectral range | 5.9 GHz (ITS band) | 5.9 GHz (ITS band) |
| communication mode | Decentralized, self-organizing networks (Ad-hoc) | Coexistence of centralization and decentralization, support for direct and cellular communication< |
| Transmission Range | 300-500 meters | More than 500 meters |
| Latency | <10ms | 20-30ms(LTE-V2X),<10ms(5G-V2X) |
| Data Throughput | Lower (27 Mbps per channel) | High (LTE and 5G offer greater bandwidth) |
| Application Scenarios | Low-density, short-range vehicle-to-vehicle (V2V) communications | High-density, long-range V2V, V2IV2P communications |
| Congestion Control Mechanism | CSMA/CA based, vulnerable to high density networks< | SPS (Semi-Persistent Scheduling), which can effectively reduce congestion |
| anti-interference capability | Weak, especially poor in high density traffic environments | Stronger, especially in 5G-V2Xthrough frequency multiplexing and beamforming optimization |
| Communication Reliability | Higher (over short distances) | Higher (superior long range communication performance especially in complex traffic scenarios) |
| Future Development | Evolution to IEEE 802.11bd for improved throughput and interference immunity | Fusion of AI technology, network slicing, and edge computing to support autonomous driving scenarios |

(2) Adaptive Transmission Frequency Scheme: an adaptive scheme that can dynamically adjust the broadcast frequency according to real-time network conditions has been proposed in previous research [19]. Despite its excellent performance in dynamic traffic environments, this scheme may increase computational overhead and complexity under frequent adjustments. Future research should find a balance between frequency tuning flexibility and cost control to ensure efficient applications.

While these optimizations have improved DSRC performance, there is still a need to develop more forward-looking solutions, especially in terms of cross-technology synergies and resource management, in the face of autonomous driving and more complex future requirements.

## 3.2. Existing Optimization Models for C-V2X:

C-V2X shows greater potential for long range and high-density communications, and several key optimization models are shown below:

(1) Centralized Resource Allocation Framework: The framework optimizes the resource allocation for both cellular and non-cellular links through a low-complexity algorithm, improving the transmission rate by 6% in simulation tests [20]. However, in practical applications, centralized management may face challenges in terms of real-time processing and management overhead, especially in high-speed vehicle scenarios, where centralized resource allocation might struggle to meet the dynamic network demands.

(2) Enhanced MAC protocol: to address the limitations of the SPS protocol in high-density environments, the study proposes a scheme to reduce conflicts by adjusting the transmit power and resource reservation [21]. Despite the enhanced communication stability, the protocol still has room for improvement in the flexibility of resource management, especially how to cope with the unbalanced network load.

(3) Optimization scheme for multi-hop broadcasting of emergency messages: in C-V2X Mode 4, multi-hop broadcasting of emergency messages often conflicts with beacon messages. The study proposes a method to optimize message transmission through independent resource authorization and by reducing the number of forwarding nodes [22]. Despite improving the system efficiency, it is still a key research direction to further improve the reliability of messages in complex urban transportation environments.

Although C-V2X has made significant progress in resource optimization, future developments require more resilient and efficient solutions to meet the challenges of variable communication demands and large-scale vehicular networks. Cross-level cooperative optimization, intelligent scheduling algorithms, and AI-driven adaptive resource allocation may be the next research focus.

## 3.3. Optimization Direction and Outlook for DSRC and C-V2X:

With the rapid advancement of autonomous driving and intelligent transportation, DSRC and C-V2X, as core technologies, still face the need for further optimization. To this end, researchers have proposed several optimizations:

### 3.3.1. Optimization directions and outlook for DSRC:

Although DSRC performs well in low-density, short-range communication, further enhancement of its performance becomes critical with the increasing demand for Telematics. Several optimization directions for DSRC have been proposed, as outlined in previous studies [10]: a) Improvement of channel interleaving and channel coding b) Migration to modern PHY technologies c) Enhancement of channel flexibility d) Optimization of MAC layer congestion control protocols. Even though these optimization directions proposed in previous studies [10] provide a clear path to improve DSRC performance, these schemes still face certain challenges in practical applications. For example, although the schemes for improving channel interleaving and channel coding can enhance the anti-jamming capability, how to realize efficient coding under limited spectrum resources still needs further research. In addition, although the 802.11n standard can improve the performance of the PHY layer, how to maintain its backward compatibility is still a major challenge in the implementation process.

In terms of optimization of congestion control at the MAC layer, time-slot synchronous systems can indeed reduce channel contention, but AI-driven prediction models may be more effective than existing time-slot-based schemes in highly dynamic in-vehicle networks. Therefore, future research should focus more on intelligent congestion control mechanisms to improve the adaptability of DSRC in autonomous driving scenarios.

### 3.3.2. Optimization directions and outlook for C-V2X:

Although C-V2X performs well in high-density and long-distance communication, performance optimization is still crucial to cope with the complex demands of autonomous driving and intelligent transportation systems. Several optimization directions, such as adaptive power control, interference suppression, frequency hopping, AI prediction, and beamforming, have been proposed in previous studies [8].Although they can effectively reduce interference and improve stability, the balance between power control and interference management is still a challenge in dense urban environments or high-speed scenarios, especially the high demand of computational resources for AI algorithms that may affect real-time performance. Therefore, future research should focus on how to improve the efficiency of AI algorithms with limited resources. The accuracy of channel estimation is crucial for high-speed scenarios. While existing frequency guiding and channel tracking methods improve the adaptability, their bandwidth consumption affects the efficiency, and the development of lightweight algorithms will be key. Network slicing techniques, on the other hand, can dynamically allocate resources to cope with the high priority demands of autonomous driving, but the dynamic slicing strategy still needs to be improved under the bursty, and large bandwidth demands of Telematics. The combination of federated learning and edge computing can reduce latency and enhance privacy protection, but its communication overhead has not yet been solved, and future research should focus on how to enhance system flexibility while reducing the communication burden.

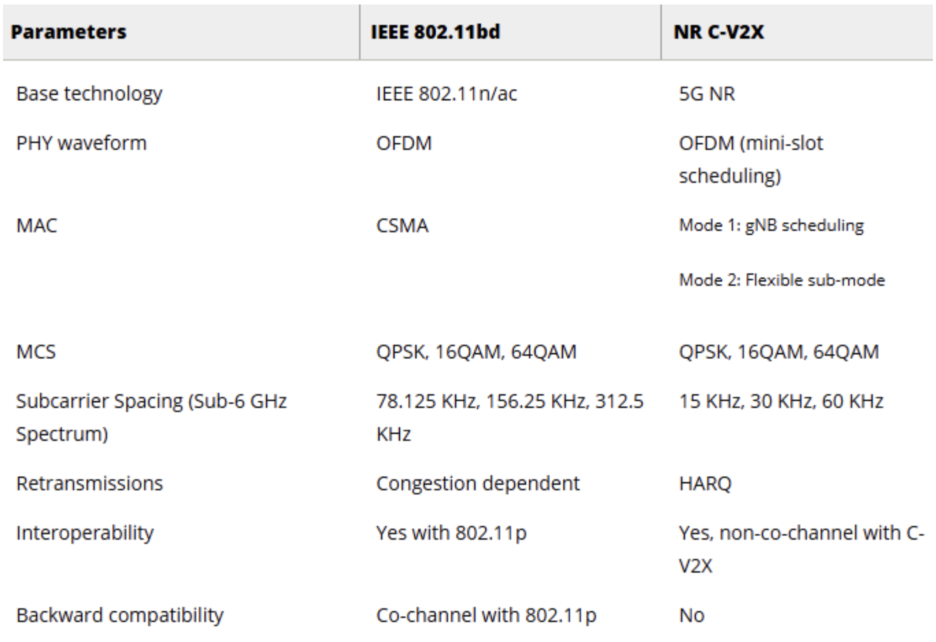
# 4. Future Optimization Directions and Prospects (FODP)

## 4.1. Evolution of Next Generation DSRC with C-V2X:

The IEEE 802.11bd Task Force was established in 2019 in order to narrow the performance gap between DSRC and C-V2X and to further improve the throughput and communication range of both. By introducing advanced technologies such as Orthogonal Frequency Division Multiplexing (OFDM) and 256-QAM (Quadrature Amplitude Modulation), DSRC's coding efficiency and interference immunity have been significantly improved. In addition, improvements at the media access control (MAC) level, especially in link establishment and error correction mechanisms, have led to significant enhancements in the overall communication performance of DSRC.

Meanwhile, the next-generation C-V2X based on 5G technology demonstrates higher data transmission capabilities, supports up to 99.999% packet transmission success rate, and optimizes resource allocation and scheduling mechanisms. These technological improvements address the needs of advanced V2X applications in autonomous driving, such as collaborative navigation and cognitive radio. In particular, C-V2X performs particularly well in complex high-density communication scenarios, greatly improving spectrum utilization and data transmission performance.

*The above is adapted from the literature [9].*



| Parameters | IEEE 802.11bd | NR C-V2X |
|---|---|---|
| Base technology | IEEE 802.11n/ac | 5G NR |
| PHY waveform | OFDM | OFDM (mini-slot scheduling) |
| MAC | CSMA | Mode 1: gNB scheduling<br>Mode 2: Flexible sub-mode |
| MCS | QPSK, 16QAM, 64QAM | QPSK, 16QAM, 64QAM |
| Subcarrier Spacing (Sub-6 GHz Spectrum) | 78.125 KHz, 156.25 KHz, 312.5 KHz | 15 KHz, 30 KHz, 60 KHz |
| Retransmissions | Congestion dependent | HARQ |
| Interoperability | Yes with 802.11p | Yes, non-co-channel with C-V2X |
| Backward compatibility | Co-channel with 802.11p | No |

**Figure 4.** Comparison parameters of DSRC and C-V2X

## 4.2. Outlook for DSRC and C-V2X Convergence:

A single V2X technology is gradually showing its limitations in coping with efficient and reliable communications. For this reason, a hybrid scheme that combines DSRC and C-V2X technologies to fully utilize their respective advantages has been proposed in previous studies [23,24]. The cellular network can be used as an alternate path in case of V2V multi-hop connection interruption to ensure the continuity of data transmission and provide stable Internet access and control message transmission to the vehicle [23]. In contrast, DSRC's Ad-hoc routing protocol may fail in GPS signal-scarce environments, while cellular networks can provide more reliable connectivity and information services in widely deployed base station environments [24].

However, the widespread use of cellular networks faces the problem of dynamic topology changes and management complexity due to high-speed vehicle movements. With the increase of small base stations, vertical switching and intelligent network selection techniques become particularly important to ensure stable connectivity [24]. The hybrid architecture proposed in the literature achieves optimal allocation of resources and smooth switching across networks through a distributed management system and adaptive algorithms, effectively improving communication efficiency and network stability. Future research should further explore how to balance the advantages and disadvantages of the two technologies and optimize the switching strategy and network management in practical deployments to cope with the increasingly complex demands of intelligent transportation.

# 5. Application and Future Potential of AI in V2X

In recent years, the application of AI technology in V2X communication has demonstrated great potential, but the existing research is still insufficient in some key areas. Deep reinforcement learning-based spectrum management and resource co-optimization schemes have been proposed in previous studies [25,26], which effectively improve communication efficiency and resource utilization by optimizing spectrum subband selection and transmission power. However, these schemes mainly target a single communication system and fail to solve the cross-technology switching and resource scheduling problems in multi-mode communication. The distributed congestion control (DCC) algorithm has been shown to perform well in single-side-link communication but underperforms in dynamic switching in high-density traffic environments and multi-mode fusion [27]. Additionally, previous studies have highlighted the potential of deep learning in optimizing C-V2X channel utilization and transmission rate [28]. Although it addresses part of the congestion issue, it remains inadequate in handling resource coordination and switching requirements between C-V2X and DSRC.

Therefore, AI technology can play a key role in bridging these deficiencies. First, through the real-time monitoring function of AI, it can dynamically adjust the communication mode according to the changes in QoS demand, channel status and vehicle density, achieve seamless switching between C-V2X and DSRC, and optimize the resource allocation in multi-mode communication. Secondly, the cross-layer optimization capability of AI technology breaks through the traditional limitation of being limited to the physical layer or link layer, and is able to flexibly adjust the parameters of each layer to ensure that the system still maintains efficient communication in complex traffic environments. Finally, AI's advantages in intelligent congestion control and QoS management are particularly prominent, especially in the dynamic adjustment of transmission rate and broadcast frequency. Through real-time adjustments, the throughput and packet reception rate (PDR) of the system are significantly improved, further optimizing the overall performance and ensuring that the system can still operate stably and efficiently in highly dynamic scenarios such as autonomous driving.

# 6. Existing Literature-Based Future Outlook for 6G in V2V Communication: A Literature-Based Future Outlook

## 6.1. Prospects of 6G technology in V2X communication:

With the rapid development of 6G technology, V2X communication will see significant breakthroughs, especially in terms of data transmission efficiency, responsiveness, and safety. The core technologies of 6G, such as Intelligent Reflective Surfaces (IRS), Machine Learning (ML), Terahertz (THz) communication, and Quantum Computing, will significantly enhance the overall performance of the V2X system. Studies have shown that the combination of these technologies will significantly enhance the efficiency of information exchange between the vehicle and the environment, especially in complex traffic environments, where the ultra-high-frequency (UHF) band provided by THz communication supports a larger bandwidth and very low latency, providing strong support for real-time decision-making in self-driving vehicles [29,30].In addition, quantum computing will further enhance the computational power for resource allocation and decision making, especially in high-density traffic scenarios to effectively reduce latency.

6G also shows significant potential for applications in V2V communications. Research suggests that 6G is expected to provide ultra-high-speed data transfer rates of up to 1 Tbps, which will greatly enhance the real-time performance and accuracy of V2V communications. This is particularly beneficial in high-density traffic areas, where critical data such as speed, position, and obstacle information can be shared more quickly among vehicles, thus reducing traffic accidents and improving driving safety [29-31].6G-supported large-scale device connectivity will ensure stable communication in high-density traffic environments [32], which is especially important for future highly automated transportation networks. Meanwhile, 6G's enhancements in security and privacy protection can effectively prevent data leakage and malicious attacks in self-driving vehicles [33].

From a general point of view, 6G technology can not only provide an ultra-high-speed, low-latency network environment for V2V communications, but will also play an important role in the fields of intelligent collaborative perception, high-precision localization and large-scale device access. In the future, 6G-driven V2V communication will enable self-driving vehicles to perceive their surroundings in real time and share information with other vehicles, forming an intelligent and dynamic traffic network and truly realizing intelligent collaborative driving.

## 6.2. Outlook of future application scenarios for V2V communication:

V2X communications have already demonstrated significant application potential in the areas of fleet management, smart infrastructure, and emergency services, particularly in enhancing traffic management efficiency, reducing congestion, and improving public safety [34,35]. With the introduction of 6G technology, these application scenarios will further expand and gain deeper optimization.

In terms of fleet management and logistics, 6G-enabled C-V2X communications will drive a high degree of automation and intelligent collaboration for commercial vehicle fleets. With 6G's ultra-low latency and wide-area coverage, fleets will be able to perform dynamic path planning based on real-time data, quickly respond to changes in road conditions, and optimize transportation efficiency. Seamless communication between self-driving vehicles will further reduce energy consumption and operating costs, and ensure safety and flexibility during transportation.

In the construction of smart infrastructure and smart cities, the technological advantages of 6G will make V2V communication an important support for urban traffic management. Vehicles, as nodes in the intelligent transportation network, can interact with traffic signals, parking facilities and other public systems in real time. 6G's large-scale connectivity and high-speed processing capabilities will enable city managers to effectively control traffic flow, reduce congestion, and optimize resource allocation through data-driven optimization. This will not only dramatically improve citizens' traveling experience, but also provide a solid data foundation for future smart city planning and operations.

In terms of emergency services and public safety, the ultra-low latency of 6G will allow for faster information delivery after an accident. Emergency service vehicles will be able to coordinate in real time with the surrounding transportation system and other vehicles to ensure priority access and rapid avoidance, greatly reducing response time. At the same time, emergency service fleets can utilize shared real-time data for efficient collaboration, enhancing rescue efficiency and the ability to handle emergencies, further safeguarding public safety.

# Acknowledgment

Through in-depth analysis of DSRC and C-V2X technologies, this paper reveals their respective advantages and challenges in V2X communications. DSRC shows excellent performance in low-density, short-range scenarios, while C-V2X performs more excellently in high-density, long-range applications. In the future, with the introduction of cutting-edge technologies such as 6G and AI, V2X communication will usher in further optimization and breakthroughs. the convergence of DSRC and C-V2X is expected to provide a more efficient and reliable communication foundation for intelligent transportation and autonomous driving systems, and to promote the comprehensive development of intelligent transportation.

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