Hindawi
Wireless Communications and Mobile Computing
Volume 2022, Article ID 1498974, 8 pages
https://doi.org/10.1155/2022/1498974

Research Article

An Overall Research on Industry Ecological and Technical Solutions for 5G-V2X in Port Park Scenario

Hua Pan

Guangxi Beitou IT Innovation Technology Investment Group Co., Ltd., China

Correspondence should be addressed to Hua Pan; panh@bgigc.com

Received 20 February 2022; Revised 22 March 2022; Accepted 25 March 2022; Published 28 July 2022

Academic Editor: Kuruva Lakshmanna

Aiming at improving the user's driving safety and travel efficiency and satisfying their future needs of highly autonomous driving services and based on the features of 5G's ultralow latency, ultrahigh reliability, and ultrawide broadband, this paper proposes an overall solution for 5G-V2X, including industry ecological solutions and technical solutions. The industry ecological solutions include the analysis of the Internet of Vehicles industry chain architecture, future business models, and innovative ecosystems. The technical solutions include the overall solution for V2X, the overall blueprint of the planning function for V2X, core technology scenarios, and key technical capabilities. These solutions can integrate users, vehicles, and roads completely and effectively, which helps the government to achieve effective monitoring and management of intersection of user-vehicle-road and realizes the 5G-based V2X pan-transportation and logistics ecology. The validity and feasibility of these solutions are verified by some applications in the port park.

1. Introduction

The Minister of Industry and Information Technology ("MIIT") of China, Miao Wei, pointed out at the 2019 Boao Forum for Asia that the greatest core value in the 5G era locates on the business side, and the biggest industry application is Internet of Vehicles ("IoV")/Intelligent Connected Vehicles ("ICV")/Vehicle to Everything ("V2X"). The article "Made in China 2025" from China State Council plans to coordinate the layout and promotion of smart transportation, which also shows that smart terminal products such as smart cars continue to expand into new areas of manufacturing. The MIIT put forward "The Action Plan for the Development of the IoV (ICV) Industry" to realize the breakthrough in cross-industry integration of the IoV industry in 2020. The National Development and Reform Commission put forward the "Execution Plan for Promoting 'Internet + Convenient Transportation and Promoting the Development of Intelligent Transportation" to accelerate the construction of the Internet of Vehicles and the Internet of Ships. The Ministry of Transport proposed the "Action Plan for Promoting the Development of Smart Transportation (2017-2020)", which emphasizes the intelligent level of transportation infrastructure, the interoperability of traffic information from multiple sources, the supervision and coordination of traffic operation, the coordination of large-scale transportation hub, the application of IoV, and the intelligent level of V2X.

On June 6, 2019, the MIIT issued licenses for wireless communication based on the 5th generation communication technology to China Telecom, China Mobile, China Unicom, and China Radio and Television. As the commercial application of 5G technology becomes faster and faster, the field to which the industrial Internet can be applied becomes broader and broader, especially the fields of travel, the IoV, and V2X, which will become the most important fields for 5G applications. On May 22, 2019, at the Kunming. Tencent Digital Ecology Conference-Smart Mobility Subforum, Tencent Future Network Lab officially released the 5G-V2X open-source platform. Wuhan National Intelligent Connected Vehicle has built the first large-scale commercial 5G Internet of Vehicles, realizing remote control driving and V2X technology. The maturity of edge computing, cloud computing, artificial intelligence, image recognition, and other technologies provide technical support for the rapid development of highway intelligence.

The advancement of standards related to the IoV and the IoT continues to speed up, while the standardization in the fields of smart cities, smart transportation, and smart security continues to develop.

Since smart transportation is the most important application scenario for 5G applications, the technology of V2X will play a critical role of smart transportation and smart highways in the future. 5G network can provide V2X with supports such as competitive low latency and high reliability, ultralarge broadband wireless communication, etc. With the comprehensive connection between users, vehicles, roads, and clouds technology, also with the interactive processing of information, the Internet of Vehicles in the 5G era can provide users with personalized services such as entertainment navigation and shared travel, while can also improve the user's driving safety and travel efficiency and satisfy their future needs of highly autonomous driving services.

However, there are still remained unsolved issues in the sides of users, vehicles, roads, and networks of V2X. As to users, there is no popular software in the industry to contact with users now, which means that there has not been a V2X service provider that has clearly described how users should use it. As to vehicles, the penetration rate of in-vehicle smart terminal equipment is under 20%. As to roads, the number of operating service providers is numerous; however, the road equipment lacks effective connections, which leads to serious information fragmentation. For the network side, the 5G networks require a long time to fully stand, and they need to be adapted to the application of the platform. Moreover, the communication capabilities of the edge-to-edge equipment are weak, and the edge-to-cloud collaboration has not been opened up.

Based on the above background, this paper proposes an overall solution for 5G-V2X, including industry ecological solutions and technical solutions. The industry ecological solutions include the analysis of the Internet of Vehicles industry chain architecture, future business models, and innovative ecosystems. The technical solutions include the overall solution for V2X, the overall blueprint of the planning function for V2X, core technology scenarios, and key technical capabilities. These solutions can integrate users, vehicles, and roads completely and effectively. The validity and feasibility of these solutions are verified by some applications in the port park.

The contribution of this paper is threefold. First, the 5G-based V2X overall solution helps the government to achieve effective monitoring and management of intersection of user-vehicle-road and realizes the 5G-based V2X pan-transportation and logistics ecology, which can build an industrial chain that supports the government's plans of development. Second, this paper also makes a contribution to the literature. Guangxi Transportation Science and Technology Group integrated resources such as users, vehicles, and roads, which made up for the shortcomings of roadside research and generated a comprehensive 5G-V2X research result (standards, algorithms, models, and business models). Third, the paper offers instruction to the industry about how to build new transportation ecosystems. For example, AsiaInfo Technologies Inc. built a new transportation ecosystem based on the scenario of 5G-V2X, which formed a customer operation system and gifted ability to customers with digitalization.

Some important theoretical research would be briefly reviewed in the next section, such as the application of 5G technology and 5G-V2X. In Section 2, I show the industry ecological solutions in detail, including the analysis of the industrial chain architecture of the Internet of Vehicles, the future business model, and the discussion of innovative ecosystem. In Section 3, I show the technical solutions in detail, including the overall solution of V2X, the blueprint of V2X's overall planning function, key technology scenario, and key technical skills. Section 4 illustrates some specific applications of V2X in the port park. The conclusions of this paper would be shown in Section 5.

1.1. Theoretical Research. The literature is discussed in three major streams: (a) the system structure of the contemporary networks, (b) the communication efficiency of V2X via different communication technologies, and (c) security and credential management issues around 5G-V2X.

The system structure of contemporary networks decides their advantages and disadvantages in their application of V2X. In the aspect of the 5G network, reference [1] generally introduced the research progress of 5G network slicing and claimed that the core of network slicing is to enable multiple logical-independent networks run on single physical network. Reference [8] introduced a new software defined network ("SDN") structure SoftAir for the 5G network, which uses the new ideas of cloudified network function and virtualized network to provide flexible and elastic network structures. Reference [10] proposed the SDN programming wireless network function of the 5G network, thus providing mobile network operators ("MNO"), enterprises, and over-the-top ("OTT") third parties with network storage that supports NFV. This paper suggested using network storage as a digital distribution platform for programmable virtual network functions (VNFs), which can support 5G application use cases. Reference [11] discussed the feasibility of designing an adaptive mobile core network based on function decomposition, which enables the mobile core net to get more flexibility and supports multiple wireless access networks simultaneously. While in the aspect of the 3GPP-EPS mobile network, reference [9] introduced the development process of the 3GPP-EPS mobile network and analyzed the pivotal architecture characteristics to be released in the future. Moreover, the paper forecasted the development trend of mobile network control, management, and arrangement, also gave an in-depth introduction of future development route of 3GPP EPS and defined relevant standards. Reference [12] summarized the development process of 3GPP from the principle of network sharing, mechanisms, and architecture to the future multitenancy on-demand systems. The paper also introduced the concept of network slicing agents in 5G systems, enabling virtual network operators, top providers, and industry vertical market participants to dynamically request and lease resources from infrastructure providers by signaling.

Specifically, references [2, 13, 15] emphasized the advantages of the 5G network in the application of V2X. Reference [2] proposed a possible system design of 5G-V2X and discussed the architecture of the 5G-V2X wireless access network and the role of the 5G-V2X system in achieving efficient vehicle transportation in the future. Reference [13] discussed the design issues of the 5G-V2X wireless access system. This paper focused on the major technologies and integration of the 5G-V2X in the physical layer and introduced 5G-V2X application cases in channel modeling and designed a framework structure. Reference [15] elaborated on the technical choices and implementation concerns and challenges for the successful deployment of multitenancy vehicle 5G slices to all services and proposed the design of 5G slice(s) to customize all services for vehicles, including the exchange of data between the vehicles, the foundation facilities, and any communication entities to improve traffic mobility, safety, and road comfort.

In the realm of the communication of V2X, references [3, 7] focused on the radio resource management ("RRM") of V2X services based on D2D communication, in which vehicle-vehicle ("V2V") and vehicle-infrastructure (V2I) communications coexist. Reference [3] proposed an effective resource allocation and power control algorithm (ERAPC) for V2X communication, which maximizes the total rate of V2I users to ensure users' requirements of high reliability and low latency. Reference [7] discussed the RRM in safety-critical V2X communication based on D2D, which converted V2X requirements into computable constraints using only sluggishly changing channel state information, and proposed a heuristic algorithm cluster-based resource block sharing and power allocation (CROWN) as a solution. Reference [5] proposed a low-latency and high-reliability broadcast communication method of 5G-V2X based on NOMA, which works on a dense vehicle communication network. The paper used NOMA technology to reduce the delay and improve packet reception probability and convert the centralized scheduling and resource allocation problem to the multidimensional stable roommate matching problem, which can be solved with a new rotating matching algorithm illustrated in the paper. Reference [6, 14] analyzed the LTE (long-term evolution vehicle) as an in-vehicle communication technology. Reference [6] provided a detailed description of LTE-related work and operation-standard activities. This paper analyzed the advantages and disadvantages of LTE and pointed out the existence of critical design issues, which serve as technical guidance for future research in this hotspot field. Reference [14] overviewed the LTE-V standard, which supports the use of LTE's direct interface PC5 for side chain or V2V communication in LTE. The paper also analyzed the performance of LTE-V side chain mode 4 and improved the performance of its distributed scheduling. Reference [20] presented a V2X downlink system with a simultaneous wireless information and power transmission (SWIPT) system. The paper proposed a nonconvex optimization method to maximize the minimum captured energy power when it meets the minimum capture energy power threshold of the information vehicle receiver and the safety vehicle in the energy vehicle receiver required for communication.

In the realm of security and credential management issues around 5G-V2X, reference [4, 16–19] discussed different solutions. Reference [14] studied the security management as a sustainability principle and evaluated the compromise by the number of key updates required to maintain the authentication connection between the vehicle and the 5G terminal so that the integrity of the safety function on the backhaul is ensured. Reference [16] introduced one of the security certification management system (SCMS) for V2X communication, which was developed by the Collision Avoidance Measurement Partner Co. Ltd. (CAMP) according to a cooperation agreement with USDOT. The system design has been transitioned from research stage to proof-of-concept stage and is a major candidate to support the establishment of a nationwide public key infrastructure (PKI) for V2X security. Reference [17] discussed common V2X threats, summarized the existing V2X authentication solutions, especially the authentication entities of V2X, and presented the security problem of V2X communication in cellular networks and other potential problems and challenges. Reference [18] studied the process of certificate revocation and offered a structure with versatility and low complexity, to facilitate the distribution of the certificate revocation list ("CRL") for certification authority ("CA"). This paper proved that compressing the distribution of CRL can significantly improve the scalability of the system without increasing the complexity during the revocation process. Reference [19] discussed security issues that may create a serious threat to crowd perception in V2X networks. This paper focused on specific V2X threats in V2X networks, like interference rejection and perception data forgery. The paper also discussed how to face these threats, and what technical challenges should be solved in the process of implementing these methods.

However, there are still a lot of unsolved problems in every sides of users, vehicles, roads, and networks of V2X. As to users, there is no popular software in the industry to contact with users now, which means that there has not been a V2X service provider that has clearly described how users should use it. As to vehicles, the penetration rate of in-vehicle smart terminal equipment is under 20%. As to roads, the number of operating service providers is numerous; however, the road equipment lacks effective connections, which leads to serious information fragmentation. For the network side, the 5G networks require a long time to fully stand, and they need to be adapted to the application of the platform. Moreover, the communication capabilities of the edge-to-edge equipment are weak, and the edge-to-cloud collaboration has not been opened up.

To overcome above problems, this article proposes overall solutions, including design and technical solutions of 5G-V2X for the specific environment in port zoom.

2. Industry Ecological Solutions

2.1. Analysis of the Industry Chain Architecture of the Internet of Vehicles. The development of multidimensional technologies like 5G technology promotes the function of device-to-device services on the Internet of Vehicle. By this, users can obtain the ability to realize the strategic transformation of industrial digitalization. And more detail of analysis about the industry chain architecture of the IoV is shown in Figure 1 below.

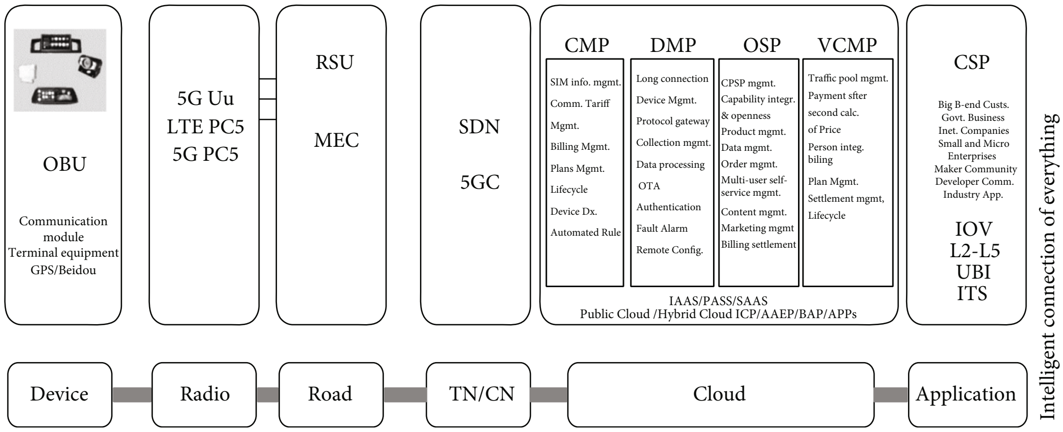

Figure 1: Industry chain architecture of the Internet of Vehicles.

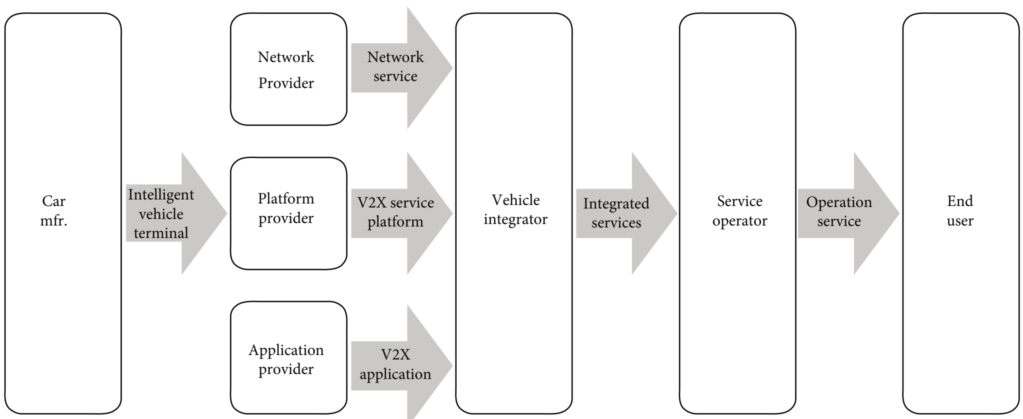

Figure 2: Future business model.

Table 1: Comparison of business models.

	Traditional model	Future model
Car machine manufacturers	Manufacturing of vehicle terminal, collection of vehicle data, bisualization of vehicle service	Platformization, operation in depth
Network suppliers	Provide communication channels, output network and connection, management capabilities	Expand network and service cooperation across the entire industry chain
Platform suppliers	Merge network data and vehicle data, rely the TSP platform to provide comprehensive management capabilities for vehicle companies	From connected services to end-to-end service
Application suppliers	OTT ecological multi-industry integration, providing various ecological applications	Focus more creating content applications, simplify product operations
Vehicle integrators	Vehicle manufacturing; integration of all modules in the industry chain	Traditional companies: get involved in platforms and content Online companies: end-to-end integration of internet thinking
Service operators	Connection operation, vehicle and machine data operation, content and service operation	Shift from connected operation to ecological operation, develop towards an intelligent dynamic service provider

2.2. Future Business Model. Today is the era of industrial interconnection. Because various business modules will extend and merge with each other, leading to more and more complex business models. The production chain mainly relates to six major business modules: car machine manufacturers, network suppliers, platform suppliers, application suppliers, vehicle integrators, and service operators. The future business model is shown in Figure 2 below.

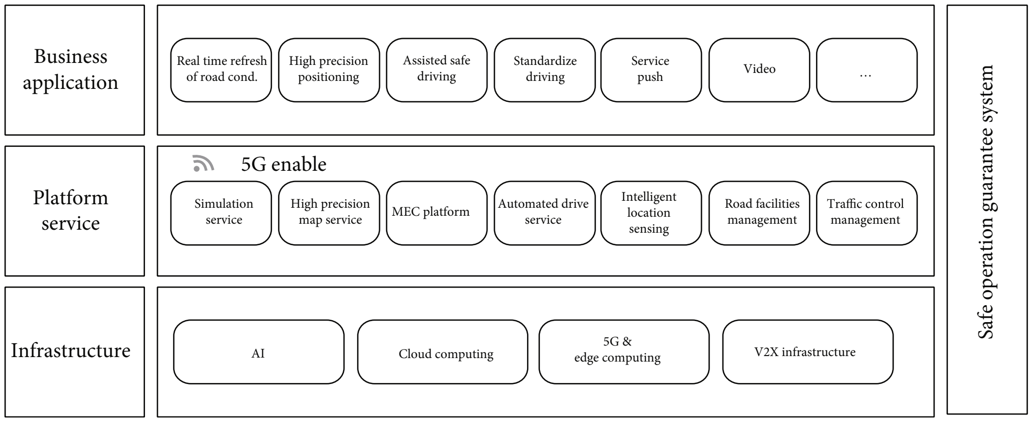

Figure 3: Innovation ecosystem.

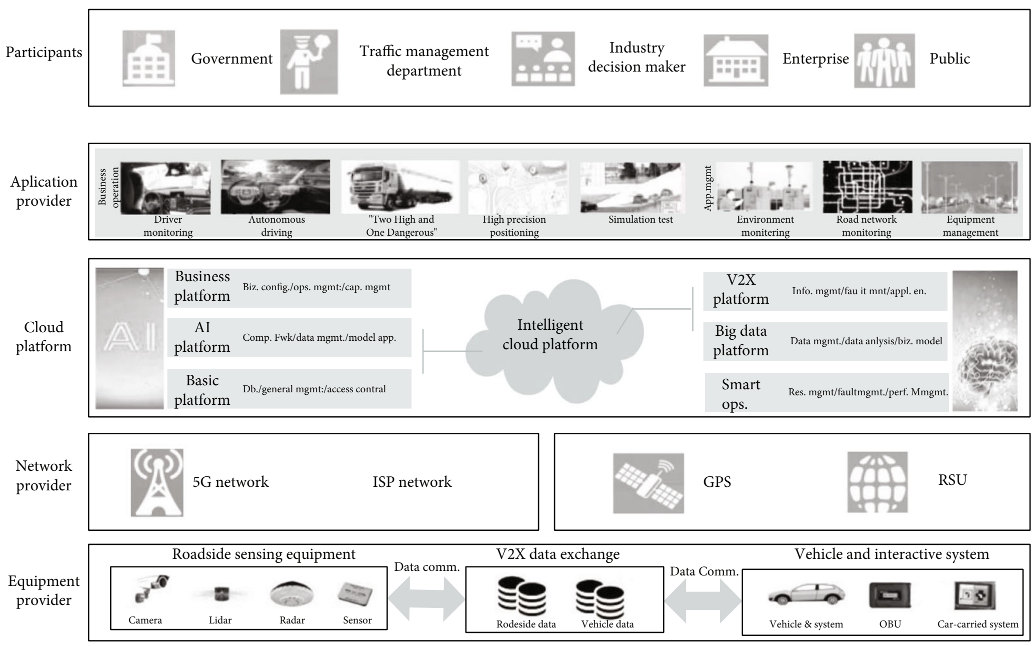

Figure 4: Overall solution of V2X.

Table 1 compares traditional business model with the future model from different aspects.

2.3. Innovative Ecosystem. The system is realized through an open layered structure; it supports the application of 5G-V2X terminal equipment and provides scene services such as driving, information notification, and precise locating by platform; it also provided a union and common business support model for provinces, cities, partners, and users, meeting the development of demand of Nanning, Guangxi's V2X business. The specific innovation ecosystem is shown in Figure 3 below.

3. Technical Solutions

3.1. Overall Solution of V2X. The overall solution of V2X is shown in Figure 4 below.

3.2. Blueprint of V2X's Overall Planning Function. The blueprint of V2X's overall planning function is shown in Figure 5 below.

3.3. Key Technology Scenario. The core technical scenario of V2X is triple play communication, as shown in Figure 6 below.

3.4. Key Technical Skills. By connecting with the vehicle 5G communication module, real-time collection of vehicle information, driving information, environmental information, etc., ensure vehicle information management and achieve vehicle status, driving, behavior, and other monitoring, early warning and effective control requirements.

The information got mainly includes vehicle information (speed, fuel consumption, status, and faults), driving information (braking, steering, and driving), and environmental information (obstacles, location, and weather).

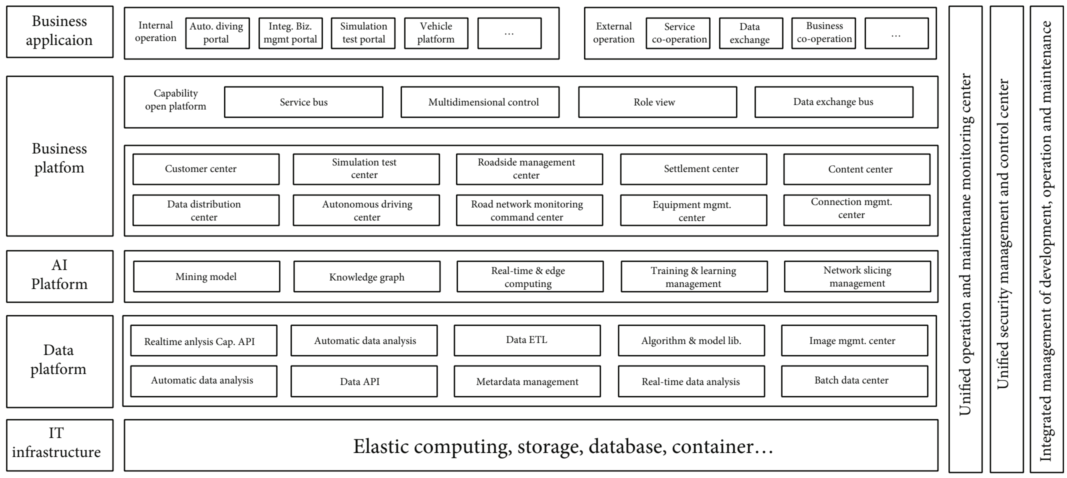

Figure 5: Blueprint of V2X's overall planning function.

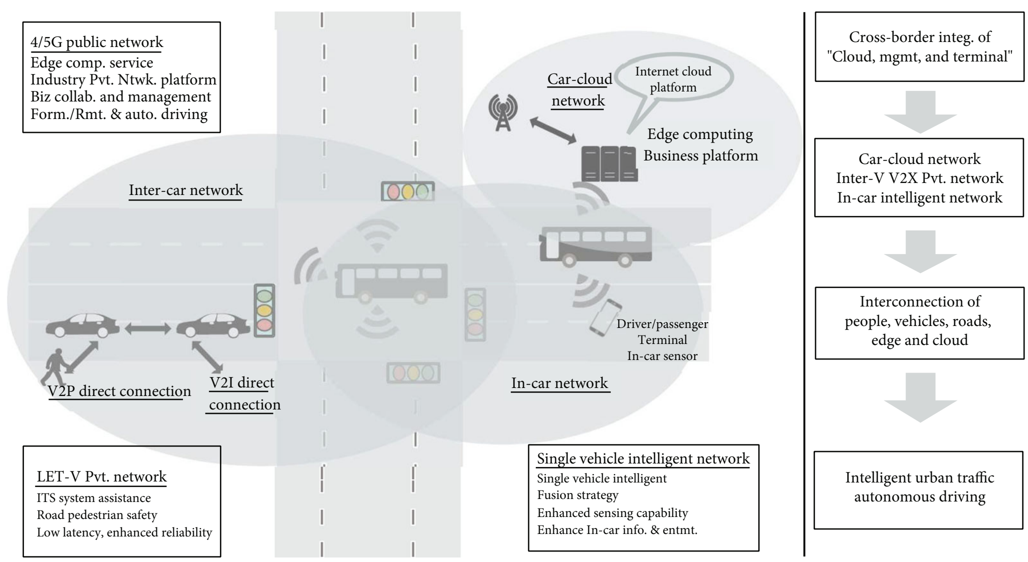

Figure 6: Key technology scenario of V2X.

The main application of the 5G network: low-latency transmission of information and fast transmission of big data.

The main application of the cloud platform: real-time monitoring of vehicle information, real-time monitoring of vehicle status, and vehicle control in time.

4. Specific Application (Port Park)

To overcome the above problems, this article proposes overall solutions, including design and technical solutions of 5G-V2X for the specific environment in the port park based on related references. It showed the comprehensive application scenario of V2X in Figure 7 below.

Two types of vehicle applications are mainly considered, trucks and park area guest cars.

(1) For trucks, besides the application of V2H, V2V, and V2R, we should also consider the subsequent intelligentization of cargo handling and transportation, and it can improve the port park efficiency

(2) For guest cars, the 5G network is mainly used to connect people, cars, and roads to improve the traffic efficiency of the port park

(3) In terms of core technology, except 5G, we need to pay attention to RSU, OBU, road sensors, edge computing, onboard computers, onboard switches, integrated navigation, autonomous driving algorithms, and so on

The V2X is mainly composed of two core systems+one platform: intelligent on-board system (vehicle-side), intelligent roadside system (road-side+cloud-side), and communication platform (car-to-vehicle and real-time information transmission of V2R).

At the intersection of port scenario, the scene is described as follows:

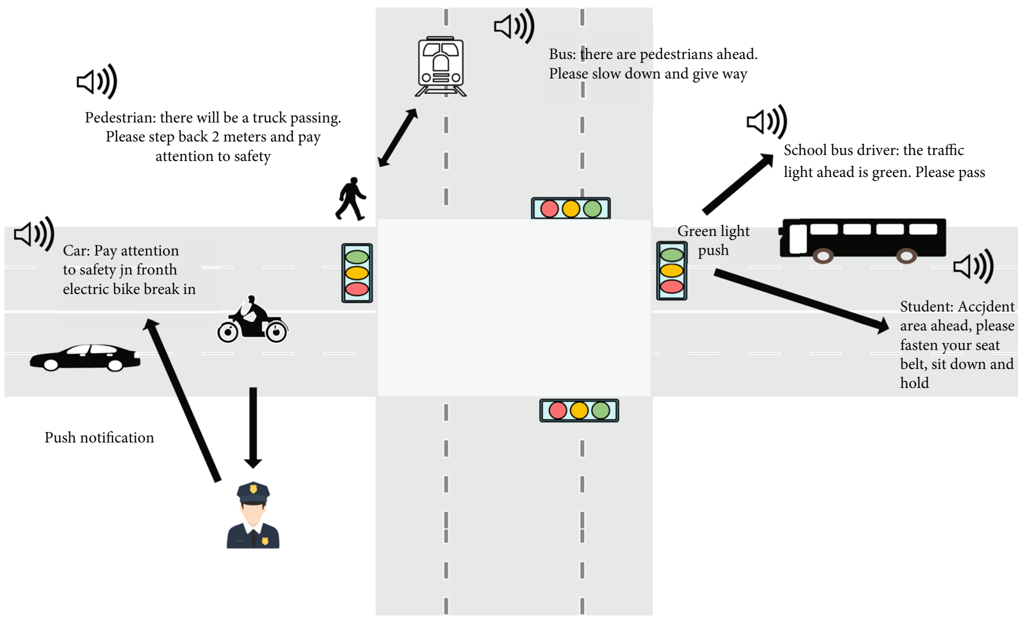

Figure 7: Specific application scenario in port park.

(1) When the vehicle passes through an intersection in the port zoom, the vehicle collects current road conditions, traffic conditions, and other information from the road

(2) The road terminal will give feedback results to the car after receiving information analysis and processing through the communication platform

(3) According to the result information, the car terminal will complete actions including normal driving, safety alarm, and early warning

(4) The above are scenes where the 5G network covers humans, vehicles, and roads at intersections in the port park

5. Conclusions

Aiming at improving the user's driving safety and travel efficiency and satisfying their future needs of highly autonomous driving services and based on the features of 5G's ultralow latency, ultrahigh reliability, and ultrawide broadband, this paper proposes an overall solution for 5G-V2X, including industry ecological solutions and technical solutions. The industry ecological solutions include the analysis of the IoV industry chain architecture, future business models, and innovative ecosystems. The technical solutions include the overall solution for V2X, the overall blueprint of the planning function for V2X, core technology scenarios, and key technical capabilities. These solutions can integrate users, vehicles, and roads completely and effectively. The validity and feasibility of these solutions are verified by some applications in the port park.

The contribution of this paper is threefold. First, the 5G-based V2X overall solution helps the government to achieve effective monitoring and management of intersection of user-vehicle-road and realizes the 5G-based V2X pan-transportation and logistics ecology, which can build an industrial chain that supports the government's plans of development. Second, this paper also makes a contribution to the literature. Guangxi Transportation Science and Technology Group integrated resources such as users, vehicles, and roads, which made up for the shortcomings of roadside research and generated a comprehensive 5G-V2X research result (standards, algorithms, models, and business models). Third, the paper offers instruction to the industry about how to build new transportation ecosystems. For example, AsiaInfo Technologies Inc. built a new transportation ecosystem based on the scenario of 5G-V2X, which formed a customer operation system and gifted ability to customers with digitalization.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author does not have any possible conflicts of interest.

References

[1] X. Foukas, G. Patounas, A. Elmokashfi, and M. K. Marina, "Network slicing in 5G: survey and challenges," *IEEE Communications Magazine*, vol. 55, no. 5, pp. 94–100, 2017.

[2] M. Boban, A. Kousaridas, K. Manolakis, J. Eichinger, and W. Xu, "Use cases, requirements, and design considerations for 5G V2X," *IEEE Vehicular Technology Magazine*, vol. 13, no. 3, 2018.

[3] A. Masmoudi, S. Feki, K. Mnif, and F. Zarai, "Efficient radio resource management for D2D-based LTE-V2X communications," in *2018 IEEE ACS 15th International Conference on Computer Systems and Applications (AICCSA)*IEEE.

[4] V. Sharma, Y. Ko, J. Kim, and I. You, "Security management for backhaul-aware 5G-V2X," in *Conference on Information Security and Cryptography-Winter (CISC-W)*, 2018.

[5] B. Di, L. Song, Y. Li et al., "NOMA-based low-latency and high-reliable broadcast communications for 5G V2X services," in *GLOBECOM 2017 - 2017 IEEE Global Communications Conference*, 2017.

[6] G. Araniti, C. Campolo, M. Condoluci, A. Iera, and A. Molinaro, "LTE for vehicular networking: a survey," *IEEE Communications Magazine*, vol. 51, no. 5, pp. 148–157, 2013.

[7] W. Sun, D. Yuan, E. Strom, and F. Brännström, "Cluster-based radio resource management for D2D-supported safety-critical V2X communications," *IEEE Transactions on Wireless Communications*, vol. 15, no. 4, pp. 2756–2769, 2015.

[8] I. F. Akyildiz, P. Wang, and S. C. Lin, "SoftAir: a software defined networking architecture for 5G wireless systems," *Computer Networks*, vol. 85, pp. 1–18, 2015.

[9] P. Rost, A. Banchs, I. Berberana et al., "Mobile network architecture evolution toward 5G," *IEEE Communications Magazine*, vol. 54, no. 5, pp. 84–91, 2016.

[10] N. Nikaein, E. Schiller, R. Favraud et al., "Network store: exploring slicing in future 5G networks," in *Proceedings of the 10th International Workshop on Mobility in the Evolving Internet Architecture*, pp. 8–13, 2015.

[11] M. R. Sama, X. An, Q. Wei, and S. Beker, "Reshaping the mobile core network via function decomposition and network slicing for the 5G era," in *IEEE wireless communications and networking conference workshop*, pp. 1–7, 2016.

[12] K. Samdanis, X. Costa-Perez, and V. Sciancalepore, "From network sharing to multi-tenancy: the 5G network slice broker," *IEEE Communications Magazine*, vol. 54, no. 7, pp. 32–39, 2016.

[13] M. Boban, K. Manolakis, M. Ibrahim, S. Bazzi, and W. Xu, "Design aspects for 5G V2X physical layer," *2016 IEEE conference on standards for communications and networking (CSCN)*, 2016.

[14] R. Molina-Masegosa and J. Gozalvez, "LTE-V for sidelink 5G V2X vehicular communications: a new 5G technology for short-range vehicle-to-everything communications," *IEEE Vehicular Technology Magazine*, vol. 12, no. 4, pp. 30–39, 2017.

[15] C. Campolo, A. Molinaro, A. Iera, and F. Menichella, "5G network slicing for vehicle-to-everything services," *IEEE Wireless Communications*, vol. 24, no. 6, pp. 38–45, 2017.

[16] B. Brecht, D. Therriault, A. Weimerskirch et al., "A security credential management system for V2X communications," *Intelligent Transportation Systems, IEEE Transactions on*, vol. 19, no. 12, pp. 3850–3871, 2018.

[17] M. Muhammad and G. A. Safdar, "Survey on existing authentication issues for cellular-assisted V2X communication," *Communications*, vol. 12, pp. 50–65, 2018.

[18] G. Rigazzi, A. Tassi, R. J. Piechocki et al., "Optimized certificate revocation list distribution for secure V2X communications," in *2017 IEEE 86th Vehicular Technology Conference (VTC-Fall)*, pp. 1–7, 2017.

[19] K. Bian, G. Zhang, and L. Song, "Toward secure crowd sensing in vehicle-to-everything networks," *IEEE Network*, vol. 32, no. 2, pp. 1–6, 2018.

[20] S. Li, C. Li, W. Tan, B. Ji, and L. Yang, "Robust beamforming design for secure V2X downlink system with wireless information and power transfer under a nonlinear energy harvesting model," *Sensors*, vol. 18, no. 10, p. 3294, 2018.