Research on Innovative Application of Vehicle Road Collaboration Technology in Intelligent Transportation Engineering

Chuan Xue
Chongqing Tongnan District Transportation Affairs Center, Chongqing, China

Abstract: Smart transportation engineering is an important means to address urban transportation issues, and the continuous development and application of vehicle road collaboration technology provide new opportunities and possibilities for innovation in smart transportation. This article aims to explore the innovative application of vehicle road collaboration technology in smart transportation engineering, with a focus on analyzing its core value in real-time data communication and transportation system integration. At the same time, in-depth analysis will be conducted on the application challenges faced by vehicle road collaboration technology in smart transportation, and its innovative applications in autonomous vehicle communication, public transportation scheduling, emergency response systems, and traffic infrastructure monitoring will be demonstrated through specific cases. With the continuous acceleration of urbanization and the increasingly prominent traffic problems, smart transportation as an intelligent means of traffic management has received widespread attention. The rapid development of vehicle road collaboration technology provides technical support and innovative impetus for the implementation of smart transportation engineering. The research will start from the basic concepts of smart transportation and vehicle road collaboration technology, analyze the core value of vehicle road collaboration technology in real-time data communication and transportation system integration, and explore its application challenges and innovative application cases in smart transportation engineering, providing theoretical guidance and practical reference for the development of smart transportation systems.

Keywords: Smart Transportation; Vehicle Road Collaboration Technology; Innovative Applications

1. Introduction to Vehicle Road Collaboration

Vehicle road collaboration refers to the use of LTE-V2X short-range communication technology, which can provide low latency, high reliability, high speed, and safe communication capabilities in high-speed mobile environments, to achieve driving assistance. It expands the perception range to areas beyond the reach of onboard sensors, realizes all-round information connection and intelligence between vehicles, people, vehicles, roads, and platforms, builds a new business ecosystem for automotive life, improves traffic efficiency, and provides users with intelligent, comfortable, safe, energy-saving, and efficient comprehensive services.[1]As shown in Figure 1 and Figure 2:

Figure 1. Traffic Site Diagram

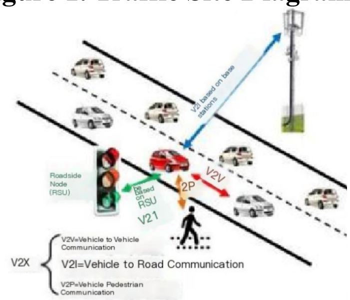

Figure 2. Schematic Diagram of Traffic Working Principle

Collaboration and Single Vehicle Intelligence

Due to the lack of interaction with the outside world, each bicycle in the intelligent control mode is an information island. Lack of traffic data support beyond the detection range of the vehicle's sensors. The intelligence of bicycles can usually only solve about 60% of traffic accidents, and cannot solve a series of complex scene problems such as complex road conditions, mixed vehicles, fast speeds, obstructions and blind spots, as well as extreme weather and distance.[2] The intelligence of bicycles is also difficult to perceive and make real-time decisions in complex road environments. Through V2X technology, which combines the intelligence of bicycles with related technologies for vehicle road coordination, over 96% of traffic accidents can be avoided.[3]As shown in Figures 3:

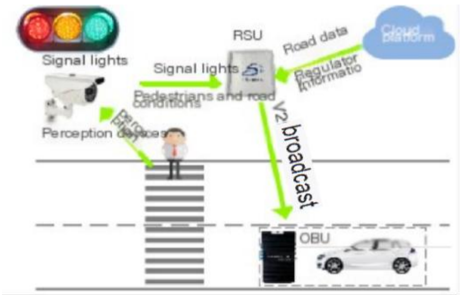

Figure 3. Schematic Diagram of Working Principle

2. Introduction to the Module Functions of Vehicle Road Collaboration

2.1 RTK Reference Station Function in Vehicle Road Coordination

After the RSU is in a fixed position and the precise coordinates are known, it can automatically calculate the RTCM data and send it to the vehicle end through PC5 or upload it to the cloud, which distributes it to other RSUs within the effective range and then sends it to the vehicle end.[4]As shown in Figure 4:

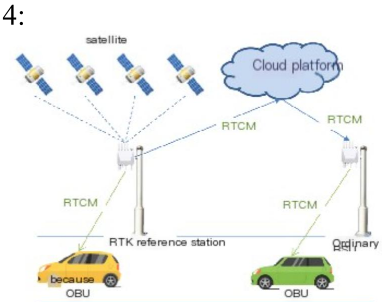

Figure 4. RTK reference station

<>Effective range: 20KM plain

<>Calibration time of 10-30 minutes is required

2.2 NTP Time Service Function in Vehicle Road Collaboration

After the RSU obtains the accurate time through satellite, it provides time service for adjacent edge computing units, sensing devices and other detection devices through NTP service. The precision is greatly improved compared with WAN time service. As shown in Figure 5:

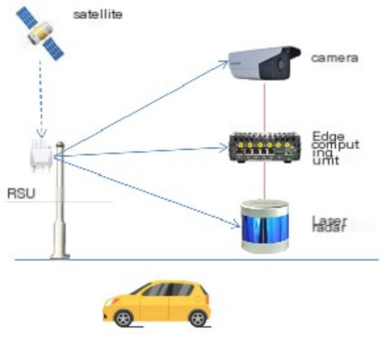

Figure 5. NTPtiming Service Function

<>Timing accuracy:<2ms

2.3 Message Relay Function in Vehicle Road Collaboration

In urban areas such as bends and intersections, PC5 signals are often obstructed by obstacles such as buildings, elevated structures, or light rail bridge piers. RSUs can relay OBU or other RSU messages to expand V2X information coverage and ensure traffic safety.[5]As shown in Figure 6:

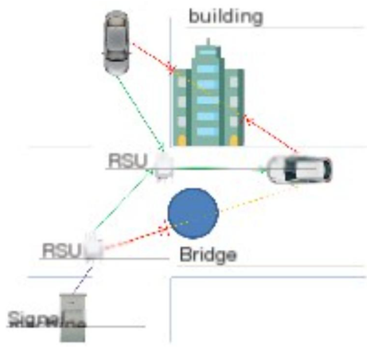

Figure 6. Message Relay Function

Common relays:

BSM→RSM/SSM

RSM/SSM →RSM/SSM

SPAT→SPAT

2.4 Broadcast Simulation Data Function in Vehicle Road Collaboration

RSU can send data such as virtual targets, road

conditions, and traffic lights through interfaces or WEB configuration interfaces for testing, simulation, and other purposes. RSU has built-in virtual signal lights.As shown in Figure 7:
Support simulation:

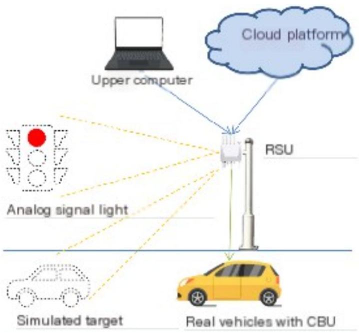

Figure 7. Broadcast Simulation Data Function

<>RSM/SSM
<> SPAT
<>RSI

3. The Benefits of Vehicle Road Collaborative Deployment

3.1 Rapid Deployment of Vehicle Road Collaborative Emergency Response System

The low latency and high reliability characteristics of vehicle road collaboration technology enable emergency services to receive detailed information about accident scenes in real time, including high-definition videos and large amounts of sensor data, enabling decision-makers to make accurate judgments and deploy necessary rescue resources more quickly. For example, in a multi vehicle collision accident, the video of the accident scene is immediately transmitted to the nearest traffic management center and relevant rescue departments through the vehicle road coordination network. These videos not only show the severity of the accident in real time, but also help rescue teams assess the specific needs of the scene, such as the number and specific deployment locations of ambulances and fire trucks. In addition, machine learning algorithms supported by vehicle road collaboration technology can perform real-time analysis of data at the accident scene, predict changes in traffic flow, quickly develop detour routes, and reduce the impact of accidents on surrounding traffic. The method not only improves rescue efficiency, but also protects the safety of more people's lives.[6]

3.2. Intelligent Monitoring and Maintenance of Transportation Infrastructure

The high-speed data transmission and low latency communication capabilities achieved through the vehicle road collaborative network enable city managers to receive real-time data from widely distributed sensors and monitoring devices. These devices are installed in key locations such as roads, bridges, tunnels, important intersections, and highways in China, constantly collecting data on traffic flow, structural health, environmental conditions, and other aspects.[7]For example, in some cities in China, especially in areas with dense traffic, the installation of intelligent sensors with vehicle road coordination technology communication functions can monitor the wear and tear of road surfaces and traffic pressure in real time. These sensors can instantly transmit data to the central control system, and through advanced data analysis technology, the system can predict the time and location of road damage, thus planning maintenance work in advance and avoiding large-scale traffic interruptions and possible accidents. Taking China's highway renovation project as an example, by deploying intelligent sensors with vehicle road collaborative communication technology on the road, real-time monitoring of road conditions including cracks, potholes, and wear levels can be achieved. These sensors can communicate in real-time with the central control system and transmit the collected data. The central control system utilizes this data, combined with advanced data analysis techniques, to predict road damage and make maintenance plans in advance. The application of this technology can not only avoid traffic congestion and accidents caused by road damage, but also reduce maintenance costs and time, improve the operational efficiency and safety of transportation infrastructure.[8] In addition, vehicle road collaboration technology also supports environmental monitoring, such as detecting air quality and noise levels. In some cities in China, environmental monitoring sensors with vehicle road collaborative communication functions can be deployed to monitor real-time environmental parameters such as pollutant concentration and noise level in the air.[9]

4. Application of Vehicle Road Collaboration Technology in Intelligent Transportation Engineering

4.1 Application of Vehicle Road Collaboration Technology in Foundation Detection and Monitoring

The high-speed data transmission capability and extremely low latency characteristics of vehicle road collaboration enable real-time transmission of data collected from ground monitoring sensors to remote monitoring centers, including real-time data on soil pressure, humidity, temperature, and other key indicators. These data are processed through high-performance analysis systems, which can promptly identify potential risk points and trends in the foundation, such as uneven settlement or abnormal increase in soil moisture. In addition, the high data throughput and network stability supported by vehicle road collaboration technology allow data from multiple monitoring points to be processed simultaneously, ensuring the comprehensiveness and meticulousness of data monitoring. Through this approach, the engineering team can respond promptly and make necessary reinforcements or adjustments, effectively preventing the occurrence of disasters and accidents. The application of vehicle road collaboration technology is not limited to traditional data collection, but also improves the accuracy of data prediction and the level of intelligent decision-making through the combination of artificial intelligence and machine learning technology. For example, by analyzing historical and real-time data through machine learning models, the system can predict possible future foundation problems, formulate response measures in advance, and optimize the risk management and resource allocation of the entire project.[10]

4.2 Application of Vehicle Road Coordination Technology in Special Section Construction

The application of vehicle road coordination technology is particularly important for construction in special areas, such as geologically unstable regions or urban areas with complex construction environments. These areas often face changes in groundwater levels, uneven soil compression, or other geological issues. The use of vehicle road coordination technology can monitor these changes in real time and adjust construction strategies in a timely manner to adapt to complex geological conditions. The vehicle road collaborative network can seamlessly connect underground sensors, drone monitoring, and mobile monitoring devices to collect data on geological subsidence, lateral movement, or other key parameters. These data are transmitted in real-time to the engineering monitoring center through the vehicle road collaborative network, and analyzed through an efficient data processing platform to present geological changes in real time, allowing engineers to make construction adjustments or take preventive measures in real time. For example, when the groundwater level rises abnormally, adjust the working parameters of the drainage system in a timely manner or strengthen the support structure of the corresponding section when geological lateral displacement is detected to prevent collapse or other safety accidents during construction. The rapid response characteristics of vehicle road collaboration technology also make it possible to make quick decisions in emergency situations, greatly improving construction safety and efficiency.

4.3 Technical Requirements for Maintenance and Operation

Maintaining the infrastructure of vehicle road collaboration, especially in widely distributed network nodes and connected environments, requires professional technical support and continuous monitoring to prevent data loss or transmission interruption, which may directly affect the real-time response capability of traffic management systems. In addition, intelligent transportation systems rely on the high-speed data communication capabilities provided by vehicle road collaboration technology. Any fluctuations or declines in network performance may lead to delays in critical services, such as emergency response systems or real-time traffic dispatch. Therefore, operating such a highly network performance dependent system requires ensuring that all network devices and related software are in optimal working condition. System maintenance also includes regular upgrades and replacements of vehicle road collaboration equipment to adapt to constantly changing technical standards and safety requirements. This requires the operations team not only to have a strong technical background, but also to understand the current network security challenges and how to effectively address them through technological means.

4.4 Network Security and Data Protection

The characteristics of the vehicle road collaborative network, such as high-speed data transmission and large-scale connected devices, greatly improve the performance of smart transportation systems, but at the same time, they also increase the security risks faced by the system. In this context, data protection not only involves personal privacy but also concerns the secure operation of the entire transportation system. For example, hacker attacks may lead to the theft or tampering of important traffic management information, which may cause traffic chaos or even accidents. Therefore, ensuring the security of data during transmission and storage is an important issue in smart transportation systems. This requires the use of advanced encryption technology to protect information security during data transmission, and strict control of data access must be implemented to ensure that only authorized users can access sensitive information. In order to prevent network attacks on smart transportation systems, it is necessary to deploy multi-layer defense mechanisms including intrusion detection systems, firewalls, and regular security audits. These measures need to be updated synchronously with technological development to combat evolving network threats.

5. Conclusion

The application of vehicle to road technology in smart transportation systems demonstrates its significant potential in improving traffic efficiency, enhancing safety, and optimizing resource management. Through practical applications such as real-time data communication, deep system integration, emergency response, and intelligent monitoring, vehicle road collaboration has become a key technology driving the development of modern transportation. The high-speed data transmission and low latency communication capability make traffic management more precise, while improving the user's travel experience and the overall reliability of the system. With the further development of vehicle road collaboration technology, it will continue to broaden the boundaries of smart transportation, bringing more innovation and improvement to urban transportation systems.

References

[1] Wang Ning Research on Innovative Application of 5G Technology in Intelligent Transportation Engineering China Equipment Engineering, 2024 (6): 26-28

[2] Zhai Lina, Lv Xin Research on the Path of 5G Intelligent Transportation Construction in Xiong'an New Area Wireless Internet Technology, 2024, 21 (2): 1-3

[3] Yang Xuan Research and application of intelligent transportation based on 5G technology Guangdong Highway Transportation, 2022,48 (3): 53-56

[4] Yang Yang Innovative Application of 5G Technology in Intelligent Transportation Engineering Transport Manager World, 2022 (1): 65-67

[5] Liu Jianhua Exploration of the Application of 5G Technology in Intelligent Transportation Information Systems Engineering, 2020 (7): 61-62

[6] Xu Chao; Wang Xiaoyan Research on the Education Model of Intelligent Audit Micro specialty in the Digital Economy Era. Software Guide, 2023 (12):38-43

[7] Kong Lingli Design of Big Data Center Construction Plan for Smart Cities. Surveying Bulletin, 2017 (10):143-147

[8] Zhang Qianhua; Zhang Jianwu Smart Government Cloud Solution Based on Cloud Security Technology. Telecommunications Science, 2017 (03):107-111

[9] Qi Yuanjun Research on the Difficulties and Strategies of Copyright Protection in Digital Publishing in the Era of Big Data. Technology and Publishing, 2014 (11):52-55

[10] Li Deren; Shao Zhenfeng; Yang Xiaomin Theory and Practice from Digital City to Smart City. Geospatial Information, 2011 (06):1-5.

