C-V2X Pilot and Demonstration Areas in China

5GAA Automotive Association
Technical Report

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Contents

Foreword

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(1) This numbering system has six logical elements:

(a) x: a single letter corresponding to the working group:

where x =

T (Use cases and Technical Requirements)

A (System Architecture and Solution Development)

P (Evaluation, Testbed and Pilots)

S (Standards and Spectrum)

B (Business Models and Go-To-Market Strategies)

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1 Scope

This TR outlines progress in existing key C-V2X testing zones in China. Firstly, the National C-V2X Pilot Areas and Demonstration Areas in China are briefly summarised. Then the latest series of Cross-Layer tests and verifications are introduced. Lastly, the implementation of C-V2X in Beijing 2022 Olympic Winter Games is presented.

2 References

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3 Abbreviations

For the purposes of the present document, the following symbols apply:

CAICT	China Academy of Information and Communications Technology
CAICV	China Industry Innovation Alliance for the Intelligent and Connected Vehicles
CV	Connected Vehicles
C-V2X	Cellular Vehicle to Everything
CVIS	Cooperative Vehicle Infrastructure System
HD	High Definition
ICV	Intelligent Connected Vehicle
ITS	Intelligent Transportation System
LTE	Long-Term Evolution
MEC	Multi-access Edge Computing
MIIT	Ministry of Industry and Information Technology
MOT	Ministry of Transport
MoHURD	Ministry of Housing and Urban-Rural Development
MPS	Ministry of Public Security
OBU	On-Board Unit
OEM	Original Equipment Maker
RSU	Road-Side Unit
VRU	Vulnerable Road User

4 Overview

In China, central governments and local governments are actively promoting the development of Cellular Vehicle-to-Everything (C-V2X) technology and industry.

China has made remarkable progress in the practice of the Connected Vehicles (CV) industry. Focusing on the construction of test Pilot and Demonstration Areas, provinces and cities across the country have carried out large-scale and multiple-scenario CV applications and built a number of Cooperative Vehicle Infrastructure System (CVIS) application/demonstration zones with integrated regional advantages and characteristics.

In order to promote Intelligent Connected Vehicle (ICV), the C-V2X industry, and Smart City Infrastructures and ICV, China has approved three types of Pilot and Demonstration Areas:

(1) China has built **four National Pilot Areas** for CV, including Wuxi City in Jiangsu Province, Xiqing District in Tianjin Municipality, Changsha City in Hunan Province and Liangjiang District in Chongqing Municipality.

(2) Ministry of Industry and Information Technology (MIIT), Ministry of Transport (MOT), and Ministry of Public Security (MPS) have actively promoted and cooperated with local governments to support the construction of **18 ICV Demonstration Areas** in Shanghai, Beijing, etc. Different climatic conditions and geomorphic characteristics are considered in order to carry out tests under diverse conditions.

(3) The Ministry of Housing and Urban-Rural Development (MoHURD) and MIIT approved two batches of **16 Pilot Cities** – including Beijing, Shanghai and Guangzhou – for the coordinated development of Smart City Infrastructures and ICV.

The geographical distribution of part of the Four National Pilot Areas and 18 CV Demonstration areas are shown in the Fig. 1, while the geographical distribution of 16 Pilot Cities of Smart City infrastructures and ICV are shown in Fig. 2.

Fig. 1 Geographical distribution of part of ICV Demonstration Areas in China

Fig. 2 Geographical distribution of Pilot Cities of Smart City Infrastructures and ICV

5 National Pilot Areas and Demonstration Areas of CV

5.1 Introduction

The MIIT, MOT, and Ministry of Public Security (MPS) and other departments in China have carried out strategic layout and development planning for the CV National Pilot Areas and Demonstration Areas. Meanwhile, local governments have actively promoted the constructions.

China has thus built four National Pilot Areas for CV, including Wuxi City in Jiangsu Province, Xiqing District in Tianjin Municipality, Changsha City in Hunan Province and Liangjiang District in Chongqing Municipality.

The various ministries have actively promoted and cooperated with local governments to further support the construction of 18 ICV Demonstration Areas in Shanghai, Beijing, etc.

The MoHURD and the MIIT approved two batches of 16 Pilot Cities for the coordinated development of Smart City Infrastructures and ICV.

Different climatic conditions and geomorphic characteristics enable ICV testing and verification to be carried out under diverse conditions. Another selection criteria is how well developed the automobile industry is in the ICV Demonstration Area being considered. Typical scenarios, such as urban versus rural roads and other features, are covered in the Demonstration Areas with installed C-V2X devices, transportation facilities, cellular networks and other infrastructure. The related constructions and the supported use cases and scenarios are gradually promoted. National Demonstration Areas in Shanghai, Beijing and Hebei, Chongqing, Changchun are ongoing, while earlier test sites in Changsha, Jiangsu Taixing, Shanghai Lingang have already been put into operation. Other test Pilot and Demonstration Areas are in active planning or construction phase. Cross-regional architecture has been established to further promote data-sharing and business collaboration.

The construction of Four National Pilot Areas, 18 Demonstration Areas, and 16 Pilot Cities of CV in China are summarised in Table 1.

Table 1 Summary of 4 National Pilot Areas, 18 Demonstration Areas, and 16 Pilot Cities of CV in China

City	National Pilot Areas	Test and Demonstration Areas	Pilot Cities of Smart City infrastructures and ICV
Beijing Municipality		●	●
Shanghai Municipality		●	●
Tianjin Municipality	●		
Chongqing Municipality	●	●	●
Baoding City, Hebei Province		●	
Hangzhou City, Zhejiang Province		●	
Tongxiang City, Zhejiang Province		●	
Changchun City, Jilin Province		●	●
Wuhan City, Hubei Province		●	●
Guangzhou City, Guangdong Province		●	●
Wuxi City, Jiangsu Province	●	●	●
Chengdu City, Sichuan Province		●	●
Changsha City, Hunan Province	●	●	
Xian City, Shaanxi Province		●	

Taixing City, Jiangsu Province		●	
Xiangyang City, Hubei Province		●	
Shenzhen City, Guangdong Province			●
Xiamen City, Fujian Province			●
Changde City, Hunan Province			●
Foshan City, Guangdong Province			●
Guiyang City, Guizhou Province			●
Jinan City, Shandong Province			●
Hefei City, Anhui Province			●
Cangzhou City, Hebei Province			●
Wuhu City, Anhui Province			●
Zibo City, Shandong Province			●

5.2 National Pilot Areas of CV

During the construction of National Pilot Areas of CV, a strong collaborative ecosystem was formed which brought together actors from the Intelligent Transportation Systems (ITS) and ICV fields with the local industrial chain.

For example, the Wuxi National ITS is a comprehensive test base jointly built by MIIT, MPS and Jiangsu Province, which is today recognised as the world's first urban LTE-V2X application project. Tianjin has established the ICV quality supervision and inspection centre, which has noteworthy expertise in research and development, standard formulation and revision, as well as test and verification services for various key technologies. Changsha has issued several plans to vigorously promote the transformation of ICV on urban roads and in public and specialised vehicles. Chongqing focuses on the full-scenario tests and large-scale commercial use of complex road traffic characteristics and special road conditions. Altogether, the National Pilot Areas have made good progress and are considered relatively mature. Meanwhile, the ICV and Smart City Pilot is still under construction and needs more tracking data to report on its progress.

(1) Jiangsu (Wuxi) National Pilot Area 江苏（无锡）国家级车联网先导区

In May 2019, MIIT officially approved and supported Wuxi to create China's first national-level CV pilot area. By the end of 2021, the deployment scale of the Internet of Vehicles in Wuxi was predicted to reach 400 square kilometres and cover 800 road segments, including the deployments of 595 dual-mode Road-Side Units (RSU) (Uu+PC5), deployments of 201 single-mode RSUs, upgrades of 656 traffic signal controllers, and deployments of 6 4.9G-dedicated 5G base stations, 620 video detectors, 203 millimetre-wave radars, 21 LIDARs and 100 MEC units. It basically covers Liangxi District, the whole area of Jingkai District, and the core areas of Xishan, Binhu and Xinwu Districts. The specific road scenarios covered in the pilot area include urban roads, expressways, viaducts, intersections, etc. The current supported applications in the pilot area include:

1. **Assisted driving applications based on LTE-V2X**
V2I applications: traffic light information display, traffic light optimal speed advisory, traffic accident warning, variable lane warning, traffic jam warning, intersection video on demand, speed limit warning, emergency vehicle passing warning
V2N applications: reporting of illegal driving actions, reporting of vehicle dynamic information
V2V applications: collision avoidance warning at intersections, emergency braking warning, abnormal vehicle warning, lane change warning, blind spot monitoring, left turn assist, forward collision warning, ramp merge warning
V2P applications: vulnerable road user collision warning, e-bike collision warning
2. **Applications for 5G-V2X testing and verification**
5G-V2X test verification for specific applications such as collision warning, speed advisory, and platooning
3. **Industry-oriented applications**
Focusing on the actual development needs of the industry, the Wuxi government supported key enterprises in deploying 'last mile' applications such as autonomous driving shuttles, autonomous trucks for logistics services, and unmanned delivery services, which have achieved normal operations.

(2) Tianjin (Xiqing) National Pilot Area 天津（西青）国家级车联网先导区

Tianjin (Xiqing) Internet of Vehicles Forerunner Pilot Zone was approved by MIIT in December 2019. The main tasks and objectives of the Pilot Zone are as follows:

1. Explore new models of cross-industry standardisation, strengthen the construction of testing and evaluation systems, and promote the improvement of related policies and regulations.
2. Deploy V2X infrastructures and upgrade the transportation facilities and systems in key areas, promote deployment of V2X terminals, establish cloud service platforms for V2X security management, authentication, and information openness and interconnection.
3. Explore and enrich the application scenarios of V2X, build an open and innovative industrial ecology, and explore feasible operation modes for V2X testing.

The Pilot Zone is being constructed in two phases: Phase I has been completed, and 67 intersections with full-range perception and V2X communication have been upgraded, deploying more than 200 road infrastructures, including MECs, RSUs, LiDARs, radars and cameras, covering 48 kilometres of road open area. Phase II is under preparation and will continue to expand the scope of development, covering the Xiqing District core area and main roads, 408 open road intersections, and more than 100 scenarios. The platform could also provide V2X service for up to 100,000 connected cars.

Fig. 3 Phase II of Tianjin (Xiqing) Internet of Vehicles Forerunner Pilot Zone

Tianjin (Xiqing) Pilot Zone has built a vehicle-road collaborative platform with a V2X application service system, data analysis system, and operating system providing services in different scenarios for governments, enterprises and individuals. More than 100 use cases have been carried out for traffic safety, traffic efficiency and information services, including typical Day-1 use cases, vehicle/VRU warnings based on infrastructure perception, and others. Various kinds of user terminals are supported via both PC5 and 4G/5G Uu to increase user penetration, such as OEM front-loading OBUs, aftermarket OBUs and smart phone apps/WeChat mini apps.

The test and verification system has been established in Tianjin for intelligent connected vehicle R&D and testing, including virtual test fields, closed test fields and open roads. Verifying V2X security capability and application is one of the key tasks for Tianjin pilot zone. The C-V2X security verification activities are held in Tianjin in April, 2022. 20 security related scenarios are set along 7.6 km open road for enterprises to verify C-V2X security mechanisms such as secure communication protocols, security certificate applications, and security certificate management. 5

(3) Hunan (Changsha) National Pilot Area 湖南（长沙）国家级车联网先导区

In the area of 300 square kilometres, network infrastructure has been built along 113 kilometres of highways and 135 kilometres of urban roads in order to achieve LTE-V2X PC5 and NR Uu coverage. A first batch of Baidu Robotaxis is being tested with passengers on the public road of Changsha. Network infrastructure and other intelligent devices are being deployed in Changsha step by step. In the first phase, LTE-V2X RSU and 5G base stations were deployed in some sections to support basic ITS applications, such as smart buses and intelligent traffic management, followed by communication devices in a second phase.

Additional roadside equipment combining a MEC platform and sensing devices, such as cameras and LIDARs, will be deployed. Some other ITS applications, such as VRU detection and HD map distribution, will be achieved with these devices.

(4) Chongqing (Liangjiang New Area) National Pilot Area 重庆（两江新区）国家级车联网先导区

Chongqing (Liangjiang New Area) National Pilot Area was approved by MIIT in January 2021. This Pilot Area is simultaneously promoting the construction of **three zones, one line and two points** with accompanying road infrastructures, scenarios and platforms. Meanwhile, the three types of application scenarios are supported by a programme of industrial upgrades and digital transformation. The three zones, namely Lijia, Yuelai and Longsheng, are constructed for Cooperative Vehicle Infrastructure System (CVIS) test scenarios. The ‘one line’ is Liyue Road, which connects the Yuelai and Lijia zones and provides a CVIS demonstration experience integrated with ITS, Smart City and life and leisure components. The ‘two points’ – the Comprehensive Airport Functional Area and Orchard Port – are supported by a collaborative application scenario of intelligent logistics vehicles and roads.

Fig. 4 Chongqing (Liangjiang New Area) National Pilot Area

The Chongqing (Liangjiang New Area) National Pilot Area is being completed in two stages: the first part in August 2021 and the second in December 2022. The reconstruction work and infrastructure for this Pilot Area will be built in eight streets of Liangjiang New Area, Yuelai International Convention and Exhibition City, Longxing Yufu Area, Collaborative Innovation Zone, etc., and cover a total of 319 kilometres and 470 intersections. The Big Data cloud service platform of CV will be built, more than 100 CV and automated driving scenarios will be realized, more than 10000 vehicle terminals will be mounted, and finally realise the full coverage of CV in Chongqing (Liangjiang New Area) National Pilot Area.

At the time of writing, the Pilot Area has been extended to cover nearly 100 kilometres of urban (demonstration) roads including intelligent network test roads, an i-VISTA intelligent vehicle integration test area, intelligent logistics, and 5G automated driving test phase at Airport Industrial Park. The pilot demonstration zones, such as Lijia Smart Park and Liangjiang Collaborative Innovation Zone, will also be included in the large-scale application of CV.

6 Series of Cross-Layer Tests

In order to further verify the C-V2X application of multiple vendors operating in the real road environment in China, the C-V2X Working Group of the IMT-2020 (5G) Promotion Group and the China Industry Innovation Alliance for the Intelligent and Connected Vehicles (CAICV) organised a series of large-scale C-V2X interoperability test activities from 2018 to 2022.

This series of Cross-Layer Tests Activities included:

(1) [2018] 'Three-Layer' Chipset, Terminals, OEM Interoperability V2X Application Demonstration

Fig. 5 2018 Three-Layer Field Demonstration

This event was the first worldwide Three-Layer interoperability testing of LTE-V2X. It illustrated the maturity of the C-V2X industry and promoted C-V2X deployment in China.

(2) [2019] 'Four-Layer' Interoperability Application Demonstration

Fig. 6 2019 Four-Layer Field Demonstration

Based on 2018 Three-layer Test Activities, LTE-V2X security mechanisms were also included in 2019 Four-layer Test Activities. LTE-V2X direct communication security solutions were also provided; the related LTE-V2X standards were verified and improved, thus laying the foundation for commercialisation of V2X.

(3) [2020] 'New Four Layers' and Large-Scale Pilot Demonstration

This event focused on verifying the large-scale operation capability of C-V2X, and fully verified the communication performance of C-V2X technology in a real environment. New digital certificate format is adopted and high-precision maps and high-precision positioning applications are supported. Test activities included the following aspects:

a) Provide a large-scale test environment, 180 background LTE-V2X PC5 modules

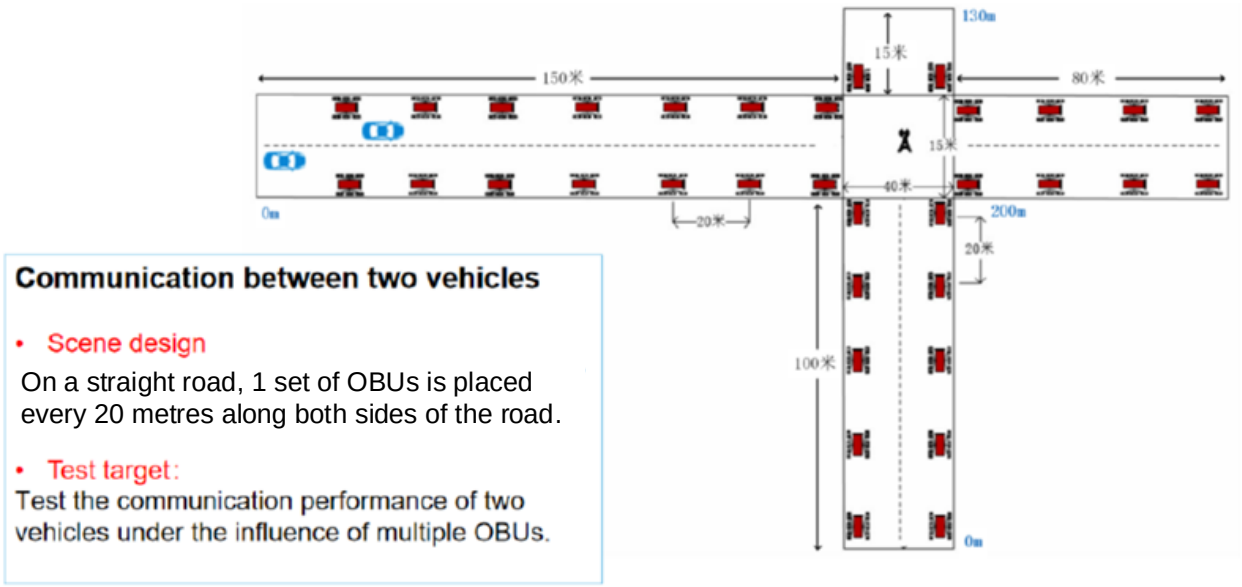


Fig. 7 Example of 2020 Large-scale LTE-V2X communication performance test

b) Support LTE-V2X test:
   i. Communication performance test: packet loss, throughput, transmission delay
   ii. Application function test: time to collision, braking distance

(4) [2020] 'New Four Layers' Pilot Demonstration

The demonstration was held on the same road as the 2019 test – Shanghai International Automobile City Intelligent Network Open Road Test Area – with a total length of 11.4 kilometres. It involved V2V/V2I/V2P scenarios, attack scenarios, and MEC-enabled scenarios were showcased for the public.

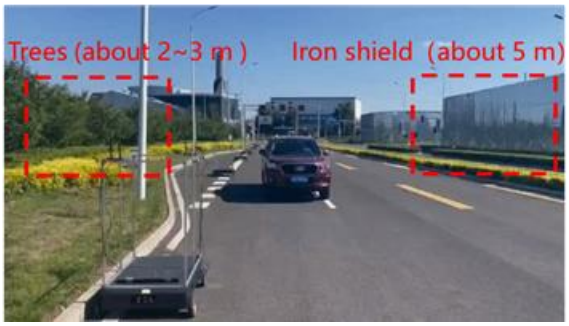
Fig. 8 2020 'New Four Layers' Pilot Demonstration

(5) [2021] Series of C-V2X Pilot Demonstrations

1) 2021 Large-scale testing:

The CAICT collaborated with the Beijing Intelligent and Connected Vehicles Industry Innovation Centre to set up a test environment in the closed test area of the National Intelligent Vehicle and Intelligent Transportation Demonstration Area in Daxing District, Beijing.

- 100 OBUs were placed on trollies evenly distributed along the roadsides and at intersections
- Supported by additional 100 LTE-V2X OBUs and one online RSU



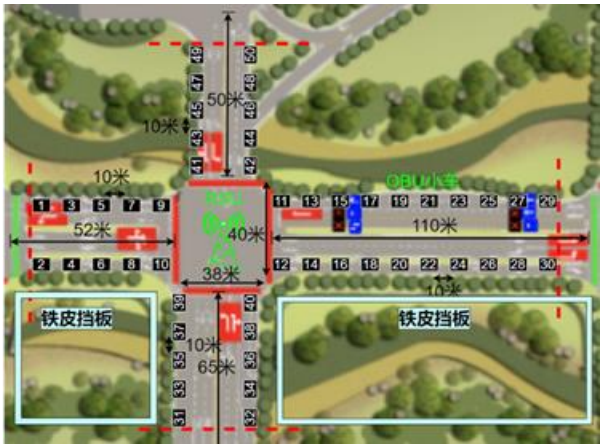


Fig. 9 2021 Large-scale testing

a) Provide a large-scale test environment, 100 background LTE-V2X PC5 modules
b) Support LTE-V2X communication performance test: packet loss, throughput, transmission delay

2) 2021 C-V2X Cross-industry (Shanghai, Suzhou and WuXi) Pilot Demonstration:

Relying on the built intelligent infrastructure and the vehicle-road-cloud collaborative platform environment in the Yangtze River Delta, new elements such as roadside perception and intelligent driving have been innovatively added, for the first time, the Yangtze River Delta cross-provincial C-V2X interconnection practice activity was held.

Suzhou: C-V2X Day-1+Day-2 Scenario Demonstration

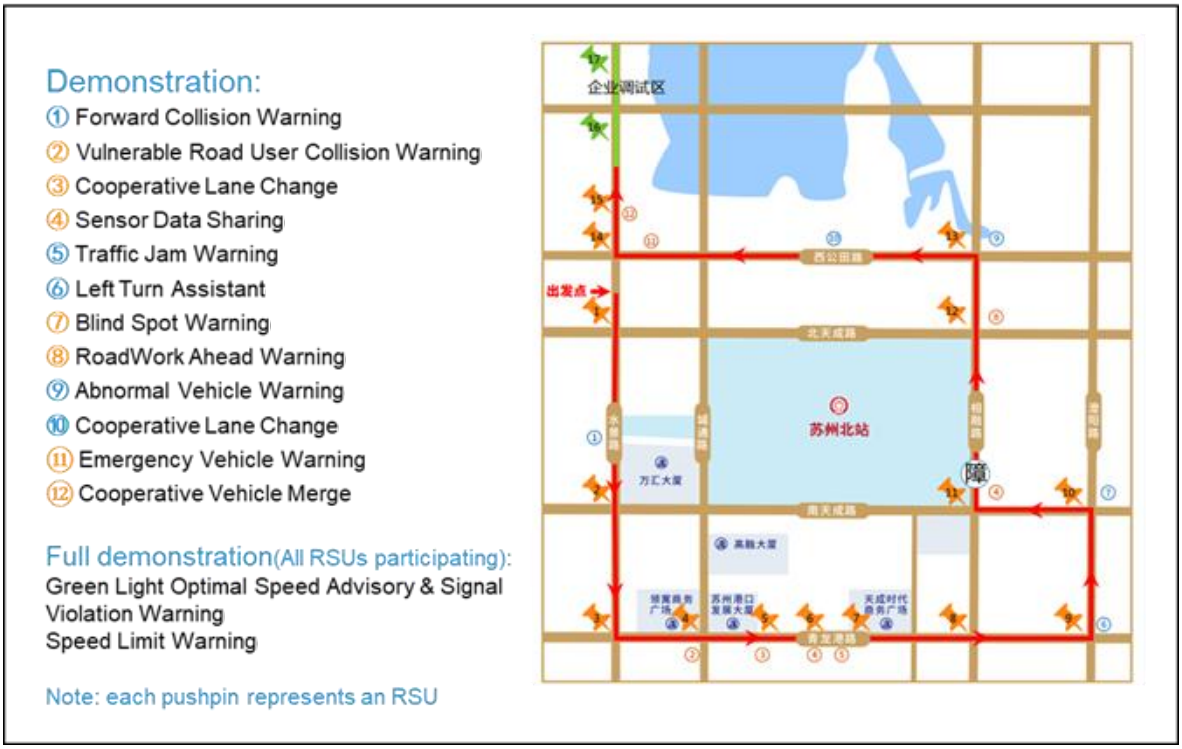


Fig. 10 2021 Suzhou Pilot Demonstration

Shanghai: Mass Production Vehicle Demonstration

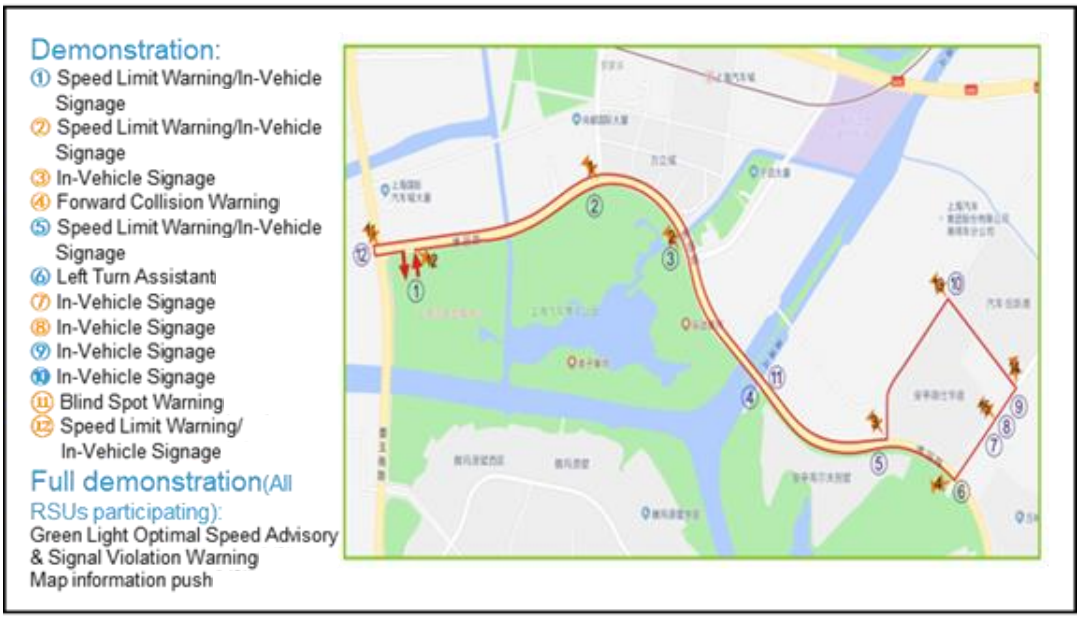


Fig. 11 2021 Shanghai Pilot Demonstration

Wuxi: C-V2X+ Vehicle Control Demonstration

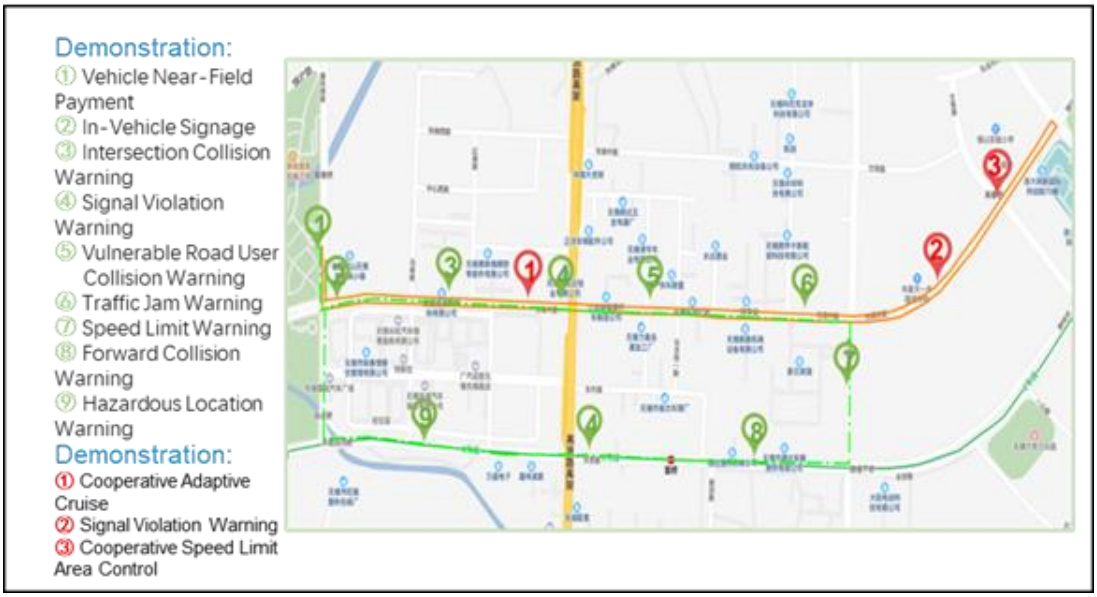


Fig. 12 2021 Wuxi Pilot Demonstration

(6) [2022] Series of C-V2X Pilot Demonstrations

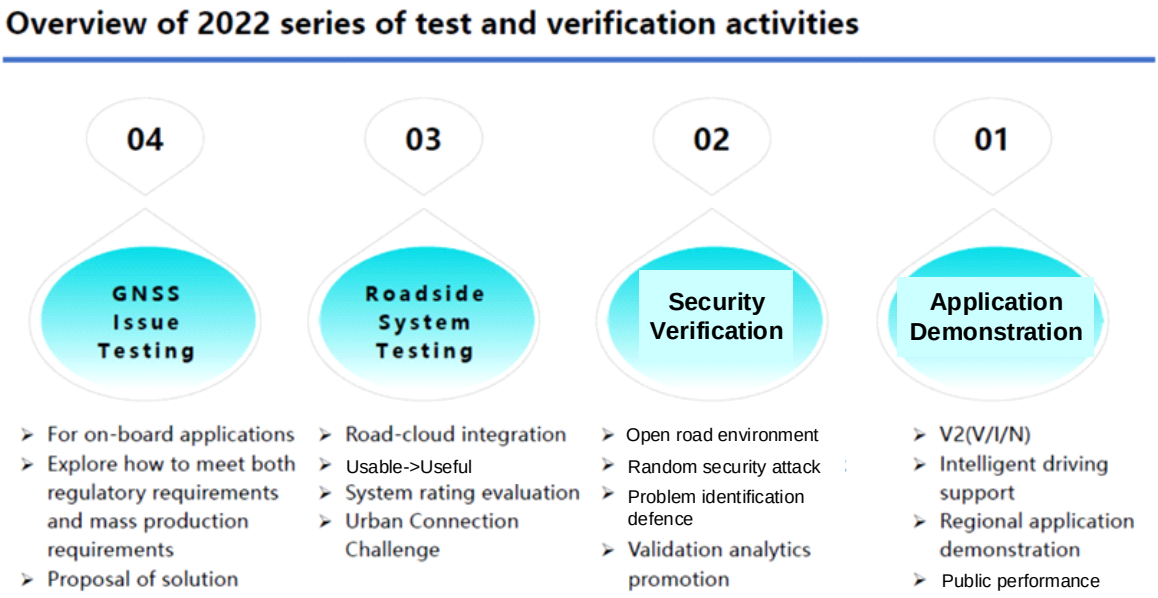


Fig. 13 Overview of the 2022 series of C-V2X test and verification activities

2022 C-V2X Security Verification Activity

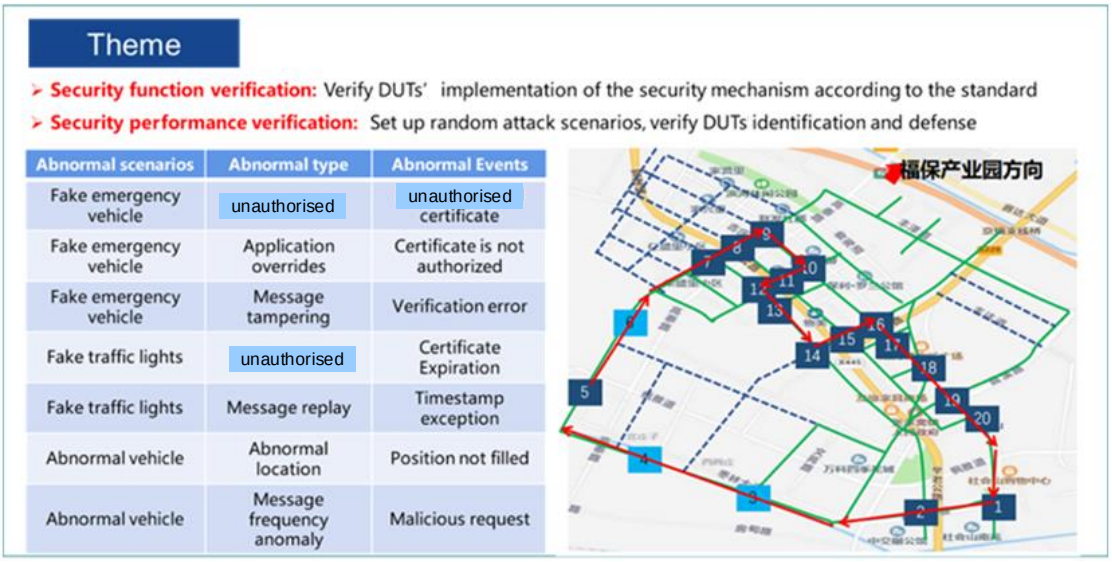


Fig. 14 2022 C-V2X security verification in Tianjin

7 Implementation of C-V2X in Beijing 2022 Olympic Winter Games

During the 2022 Beijing Winter Olympic Games, China Unicom carried out the first-ever torch relay using unmanned vehicles based on 5G CV in Shougang Park, as well as other innovative demonstrations, such as unmanned sweeper and retail/delivery vehicles. The intelligent vehicle scenarios demonstrated during the Winter Olympics were mainly thanks to some key technologies, including 5G+C-V2X integrated networks and Beidou high-precision positioning and traffic situation perception.

7.1 Deployment and Functionalities

In Shougang Park, China Unicom cooperated with CATT, Tsinghua University, and Beijing Automotive Industry Corp. (BAIC) to deploy 17 5G base stations, 20 RSUs, 55 roadside MEC units, and dozens of roadside sensing devices such as radar and cameras, covering an area of more than 1 million square metres. Various types of vehicles in the park were also equipped with OBU and 5G terminals. C-V2X direct communication enabled real-time CVIS using sensing devices and roadside MEC units providing 'integrated 'perception' around the main roads of park. The 'information interaction' between the vehicle, road and service platform was achieved thanks to a 5G+C-V2X high-performance network to ensure safe and stable automated driving.

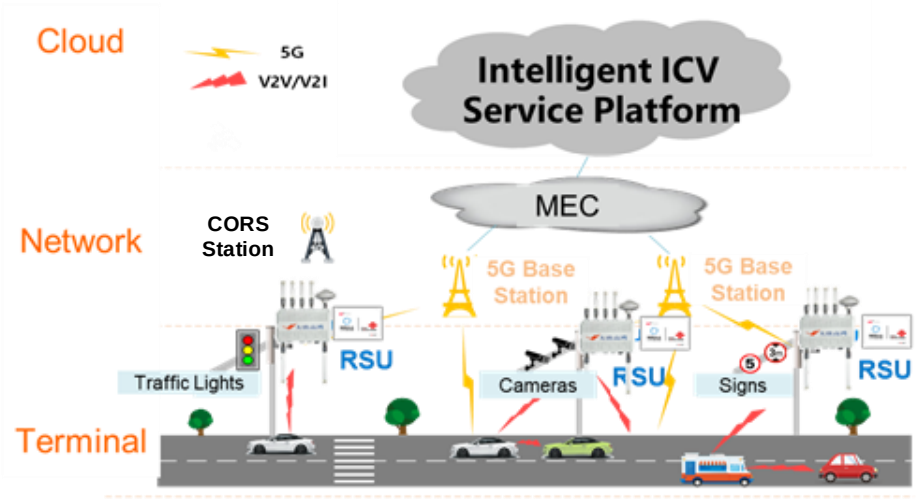


Fig. 15 ICV system based on 5G and C-V2X integrated network

7.2 Typical Application Demonstrations

(1) Winter Olympics Torch Relay with Unmanned Vehicles

During the torch relay on 2 February 2022, the unmanned car smoothly completed the handover according to the established route in Shougang Park, a world first for the Olympic Games. In this demo, the unmanned vehicles completed the real-time collection, fusion perception, and analysis of the traffic environment through C-V2X. In addition, relying on the 5G high-bandwidth and low-latency network, real-time data interaction between the vehicle and the service platform was achieved.

Fig. 16 Torch Relay Activity with Unmanned Vehicles

(2) Unmanned Platooning Buses

Unmanned platooning of buses and shuttle vans was possible using real-time traffic data assembled through V2V and V2I communication, and connected to an intelligent service based on 'vehicle-road-cloud' collaboration using C-V2X

technology, 5G and the CV service platform. This led to a stable, safe and efficient travel experience meeting the on-time travel requirements of participants.

Fig. 17 Unmanned Platooning Buses Demonstration

8 Summary and Proposal

This TR provides a solid introduction and overview of the latest C-V2X tests and verification activities in China, including valuable insights and guidance for related R&D in the area and for further consideration by 5GAA in its C-V2X activities covering the whole industrial chain in different sectors, countries and regions.

Thanks to the support of central governments and local governments in recent years, China's C-V2X Pilot Areas and Demonstration Areas have made notable progress. Four National C-V2X Pilot Areas and a number of National Demonstration Areas have been approved by MIIT, MOT, MPS, MoHURD and other departments. A series of Cross-Layer tests and verifications running between 2018 and 2022 have been conducted, as summarised in this report. The implementation of C-V2X functions, including examples of deployment and typical applications, during the Beijing 2022 Winter Olympic Games has presented a unique opportunity to highlight the latest developments in this area and state of play in China, in particular.