GSMA | CAICV China Industry Innovation Alliance for the Intelligent and Connected Vehicles

Outlook on China 5G Automotive Application

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China Industry Innovation Alliance for the Intelligent and Connected Vehicles (CAICV) Established in 2017 under MIIT by CSAE and CAAM, CAICV advances the ICV sector, integrates cross-industry resources, and fosters global collaboration. Launched in Beijing on June 12, 2017, it has become a key innovation hub supporting policies and industrial growth, driving collaborative innovation across sectors, academia, and research. Through specialized working groups, it addresses policy strategies, R&D, standards, testing, industrialization, talent exchange, and international cooperation, achieving notable progress. Aligned with ICV roadmaps, CAICV established technical groups in V2X, cybersecurity, autopilot mapping, electronic architecture, data platforms, investment, SOTIF, testing, software, chassis control, sensors, and innovation applications. The alliance includes 64 council members and over 427 ordinary members spanning automotive, ICT, and transportation sectors.

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Contents

1 The 5G V2X Industry Registers Steady Growth

1.1 China's C-V2X Market is Rapidly Developing with Increasing 5G Connections

A look back at the development history of China's vehicle connectivity suggests that vehicle-to-everything (V2X) began to spread from 2008 to 2023 amidst the transition from 3G to 4G/5G. Since 2024, C-V2X has embraced a period of high-quality development thanks to the increasing demand for in-vehicle infotainment, the rapid development of autonomous driving, and the government's efforts behind the formulation of C-V2X-related regulations and standards. As the build-out and development of 5G continues, more and more car manufacturers are turning to 4G+5G dual-mode or 5G network slicing to meet the needs of high reliability and availability. According to data from the China Industry Innovation Alliance for the Intelligent and Connected Vehicles (CAICV), in 2024, the comprehensive penetration rate of C-V2X in passenger cars in China exceeded 80% and the penetration rate of 5G V2X reached 15.6% as shown in Figure 1-1. It is estimated that by 2030, the 5G module installation rate in passenger cars in China will reach 95% (based on the number of insured cars).

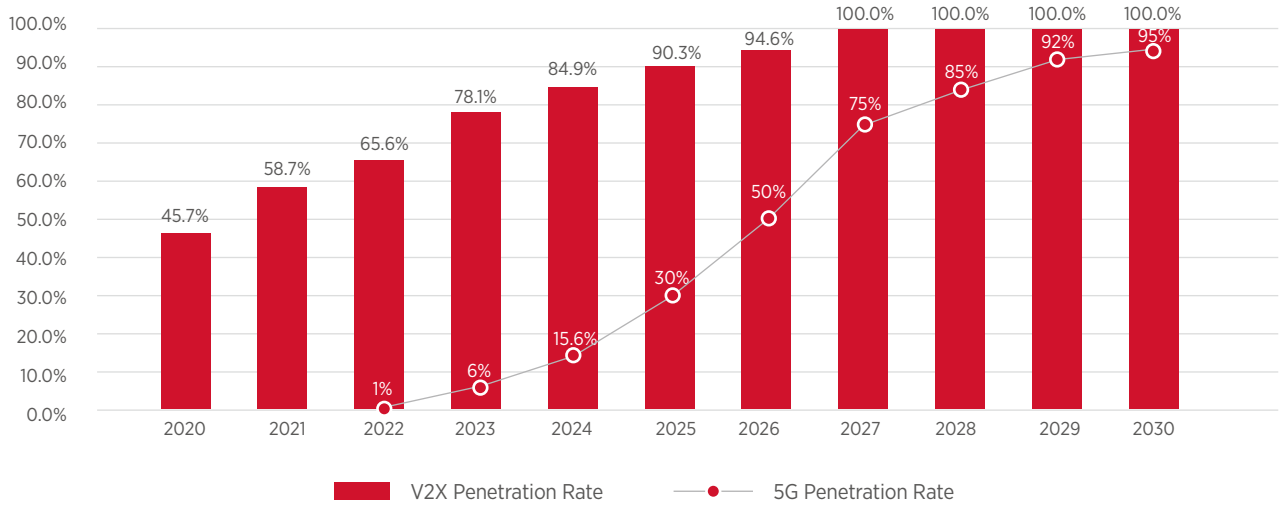


Figure 1-1. Prediction of 5G Installation Rate

Note: The mandatory national standard GB 45672-2025 "On-board Accident Emergency Call System" will be implemented starting July 1, 2027. Therefore, it is anticipated that automakers will fully implement vehicle connectivity in 2027.

1.2 5G-connected Vehicles are Gaining Mainstream Traction as Technological Maturity Advances, Fueled by the Widespread Adoption of 5G Mobile Phones

Based on the data from GSMA Intelligence, China surpassed 1 billion 5G connections in 2024, highlighting the rapid adoption of the technology since its launch five years ago. 5G adoption in China will reach 61% by the end of 2025, rising to 88% by the end of the decade.

The influence of national policy should help sustain 5G's momentum in China. The Chinese government has made 5G a national priority as part of broader goals targeting digital transformation and making the economy internationally competitive. Such goals are directly integrated into the agendas and corporate strategies of operators and network vendors, boosting the supply side of the 5G market.

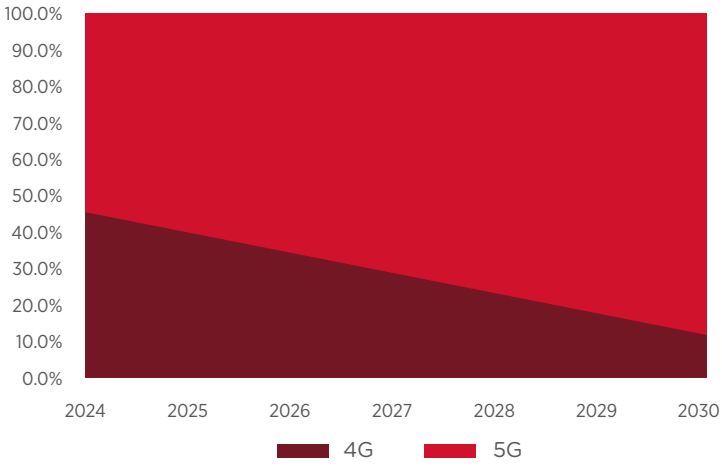


Figure 1-2 China: mobile adoption by technology

The widespread adoption of 5G mobile phones has accelerated the evolution and maturity of 5G technology, increased the coverage of 5G networks, and enabled in-vehicle 5G communication. Since December 2020, the world's first batch of production vehicle equipped with 5G communication functions officially rolled off the production line including: GAC Aion V, Rising Marvel R, BAIC Arcfox α-T, and BYD Han; factory-installed 5G modules have become the mainstream choice for smart vehicles to build brand image. The 5G installation rate in new energy vehicle brands is significantly higher, brands such as Denza, IM Motors, Li Auto, NIO, Voyah, Xiaomi, Zeekr have all installed 5G modules by default.

In terms of price distribution, 5G-connected vehicles are generally priced above 200,000 yuan. In particular, more than 50% of 5G-connected vehicles were between 200,000-300,000 yuan in 2024, which indicates that 5G technology is penetrating into ordinary family cars. Since 2025, the integration of 5G technology into vehicles has further accelerated. BYD models priced around 70,000 yuan come by default with 5G, becoming the lowest-price series equipped with 5G modules. In addition, foreign car companies like Audi, BMW, and Mercedes-Benz have also installed 5G in new China-made and China-sold models launched in 2025.

1.3 Booming 5G Automotive Applications Help the C-V2X Market Grow

In terms of vehicle installation rate, 4G technology lays the foundation for the rapid development of C-V2X in China, 5G technology holds the key to C-V2X development with its high speed and low latency, and C-V2X technology empowers direct communication between vehicles. The three together drive the continuous development of the V2X market.

With the 5G or LTE-V2X technology, the mass-produced models have realized features such as emergency braking warning, abnormal vehicle warning, vehicle out-of-control warning, advance signal warning (countdown), non-line-of-sight (non-LOS) intersection countdown timer, Green Wave Speed advisory, green light reminder, and non-LOS intersection danger recognition. In addition, reminders about rainy and slippery roads, road construction, and road signs are also available. Cockpit networking features realized through 5G technology include real-time audio and video, in-vehicle games, and multi-modal AI assistants.

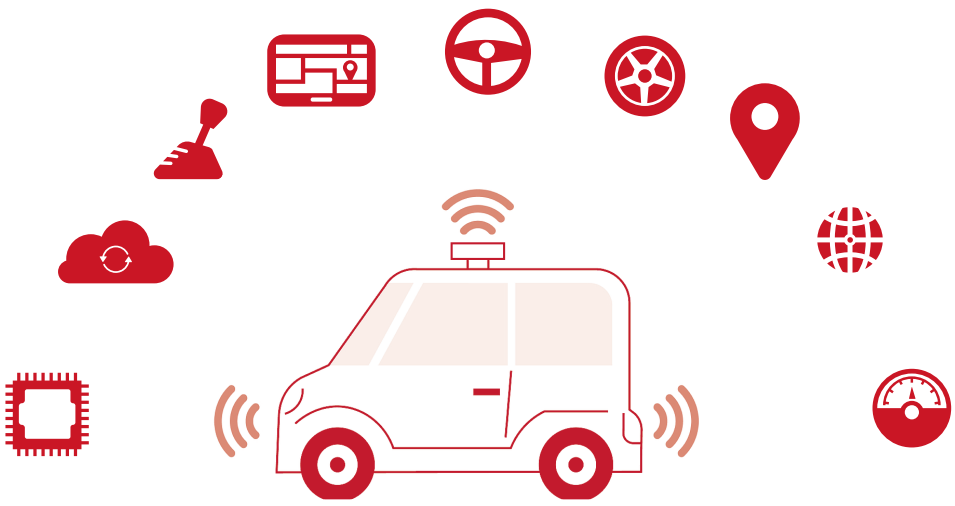
2 5G Empowers Intelligent Transformation of Vehicles

2.1 5G Installation Has Become an Inevitable Choice for Intelligent Automotive Upgrades

With characteristics of high speed, low latency, large bandwidth, and large connection, 5G is technologically advanced in autonomous driving, intelligent transportation, and in-vehicle information services. It can further expand customer touchpoints and provide users with a differentiated intelligent driving experience. The booming 5G industry has entered a critical period of evolution. The automotive industry must seize the opportunity to accelerate the application of 5G technology and realize intelligent and high-quality development.

2.2 5G Empowers Intelligent Cockpits and Intelligent Driving

5G can provide better data traffic services than 4G. With large bandwidth, high capacity, low latency, and low packet loss rate, 5G can support in-vehicle information and entertainment services (IVI) such as multi-modal AI assistants, high-definition video, AR navigation, in-vehicle games, and OTA upgrades, creating an immersive intelligent cockpit experience for users. In addition, 5G technology can deeply empower driving assistance. Thanks to the characteristics of low latency and high reliability, 5G can support C-V2X, autonomous driving assistance, remote driving, and edge computing. The 5G cellular network can help vehicles with roadside perception and support non-LOS perception to improve driving efficiency and driving safety.



3 Research on 5G Automotive Applications

3.1 Analysis of 5G-enabled Intelligent Cockpit Scenarios

(1) Real-time audio and video

The real-time audio and video function refers to the real-time transmission and playback of audio and video through in-vehicle equipment during driving. Compared with 4G networks, 5G networks can meet the real-time transmission needs of in-vehicle high-definition video and high-quality audio given a high bandwidth. The low-latency 5G networks can ensure the rapid transmission of audio and video data, while reducing lag and delay and improving user experience.

(2) In-vehicle cloud game

The in-vehicle game function refers to the game experience provided to passengers through the in-vehicle entertainment system and passengers usually use the in-vehicle display screen, touch control, or external gamepads for interaction. 5G networks support cloud gaming platforms, allowing players can connect to digital game stores anywhere and enabling content like virtual reality (VR) and augmented reality (AR) in the in-vehicle environment. Ultimately, players can enjoy high-quality and diverse gaming experiences.

(3) Multi-modal AI assistant

The multi-modal AI assistant combines information from multiple modalities such as speech recognition, visual perception, and gesture interaction, and inputs it into the multi-modal large model in the vehicle. This enables diversified understanding and response to driver and passenger instructions, supporting functions such as driver fatigue detection, emotion perception, music play, information query, and equipment control. 5G networks can realize low-latency, high-bandwidth data transmission for multi-modal AI assistants to ensure real-time integration and response of multi-sensor data and support rapid iteration of cloud AI models, thereby improving personalized interactive experience.

(4) Remote control

The vehicle remote control function refers to the rapid interaction of data inside and outside the vehicle through the integration of in-vehicle Ethernet and mobile communication networks. Users can remotely change the vehicle status, such as air conditioning control, window control, and charging management, with

mobile phones or other remote control devices. The 4G&5G dual-mode maximizes the coverage of the in-vehicle communication network. The vehicle can dynamically select the optimal network to ensure continuous transmission of control instructions and vehicle status information in complex environments (such as tunnels and remote areas), significantly improving the availability and security of remote control functions.

3.2 Analysis of 5G-enabled Vehicle-cloud Interaction Scenarios

(1) Intelligent driving data training

Intelligent driving data training means using 5G networks to transmit the intelligent driving data collected and processed by the vehicle to the cloud, where the intelligent driving large model is trained by using cloud resources to continuously optimize the intelligent driving algorithms. The optimized intelligent driving algorithms are then transmitted to the vehicle through the 5G network to enhance the vehicle's intelligent driving performance. 5G-enabled intelligent driving data training greatly reduces the cost of expanding the intelligent driving scenarios, reduces the cost and time of developing the autonomous driving system, and significantly improves R&D efficiency.

(2) Vehicle-Cloud Digital Twin

Vehicle-Cloud Digital Twin refers to running the functions of the in-vehicle control operating system on the edge cloud through the cloud-based digital twin. The life cycle of the cloud-based digital twin corresponds to a driving journey of the vehicle within the cloud service range. Thanks to the same system software, function software, and applications in the vehicle and on the edge cloud, the digital twin can perform collaborative computing with the physical vehicle through real-time communication. Personalized intelligent driving functions serving a single vehicle can be realized according to each vehicle's environmental model, vehicle information, and driving goals.

(3) OTA upgrade

OTA (over-the-air) upgrade download refers to the process of transmitting the update package of the vehicle software system to the vehicle through a wireless network connection, and installing and upgrading it on the vehicle. 5G networks provide faster download speeds and more stable connections for OTA upgrades. Especially for large software update packages, such as the upgrade of the vehicle operating system, 5G networks can greatly shorten the waiting time for consumers and significantly enhance the user experience.

(4) eCall

eCall (emergency call), also known as the automotive emergency call system or in-vehicle accident emergency call system, sends the vehicle's location and vehicle-related status information to the emergency call service platform and establishes a voice call when it automatically detects the occurrence of an accident through internal vehicle strategies or is manually triggered by occupants. 5G can solve the problems of excessive response time and unstable communication signals of the eCall function, provide clear voice call services, and significantly improve the communication efficiency, accuracy, and high availability of the eCall system. 4G&5G dual-mode communication can further safeguard the eCall function in a life cycle of 10-15 years. The dual-mode dynamic switching mechanism can adapt to different network environments. Even if a single network is interrupted, it can still maintain communication through redundant links, providing double insurance for the safety of passengers throughout the life cycle.

(5) Remote viewing

The remote viewing refers to the real-time collection of vehicle driving behavior data such as audio and video data, vehicle status, location information, and sensor data, and uploading them to the management cloud platform to achieve comprehensive video viewing, driving records, remote diagnosis, and other purposes. The high bandwidth and low latency characteristics of 5G support high-speed data transmission. Users can remotely view real-time videos inside and outside the car through a mobile app, and the cloud platform can timely understand the vehicle status and intervene when necessary to reduce the risk of accidents.

3.3 Analysis of 5G-Enabled Intelligent Driving Scenarios

(1) Collaborative early warning

Collaborative early warning refers to the use of connected traffic system information or perception data processed through multi-sensor integration to alert and warn drivers via human-machine interfaces (HMIs), compensating for the perception limitations of human drivers and single-vehicle intelligence. Specific function definitions are shown in Table 3-1.

Table 3-1. Typical Function Definitions for Collaborative Safety Warnings

Typical Function	Definition
Traffic Light Information	When a vehicle approaches an intersection, it may be unable to accurately detect the traffic light type, status, phase, duration, or countdown information due to obstructions from the vehicle ahead, weather conditions such as rain or fog, strong backlight, or unusual traffic lights. By sending traffic light status information from the cloud, the vehicle can promptly perceive real-time changes in the traffic light.
Red Light Running early Warning	When a vehicle approaches a signal-controlled intersection, it calculates (predicts) the traffic light status at the moment the front of the vehicle crosses the stop line based on its position and speed, and alerts the driver accordingly. The real-time traffic light status for the corresponding lane, along with the vehicle's position and speed, is displayed through the HMI. Based on the light status and vehicle speed, it assesses whether the vehicle in that lane is at risk of running a red light (if the traffic light is red or about to turn red when the front of the vehicle crosses the stop line) and issues a warning if there is a risk of running the red light.
Green Wave Speed Advisory	When a vehicle approaches a signal-controlled intersection, the vehicle receives the speed range for passing through the intersection calculated by the cloud control platform based on traffic light status and queue dissipation predictions. The intelligent driving system integrates the data perceived by the vehicle to determine the most suitable speed range for current traffic conditions and outputs control signals, allowing the vehicle to pass through the intersection efficiently.
Abnormal Vehicle Alert	In case of low visibility or obstructions caused by weather conditions, vehicles within a certain range can receive warnings about abnormally slow-moving/stationary vehicles ahead. This enables drivers to reduce speed or change lanes in advance to avoid collision risks, thereby ensuring driving safety.
Intersection Collision Early Warning	When a vehicle approaches an intersection with obstructions or poor visibility due to weather conditions, the cloud system can send messages about the position and posture of the approaching vehicles to the trailing vehicles and generate a collision warning, alerting drivers to slow down and give way.
Out-of-Sight Vulnerable Road Users (VRUs) Alert	When vulnerable road users (pedestrians or non-motorized vehicles) are obstructed, located in a vehicle's blind spot, or beyond the perception range, the roadside perception system detects them and sends this information to vehicles within a specific range via the cloud system to generate a collision warning, alerting drivers to slow down, give way, or change lanes.

Typical Function	Definition
Non-LOS Traffic Event Alert	When a traffic accident or road work affecting traffic safety takes place ahead, or when abnormal weather prevents the vehicle from perceiving environmental information, the cloud system can proactively send alerts about road hazards, visibility warnings, and dynamic speed limit reminders to the vehicle. This helps prevent secondary accidents and ensures safe driving.
Traffic Congestion Alert	The cloud control platform detects and assesses road congestion based on roadside perception and the reported position and speed of vehicles. If the traffic flow or congestion exceeds a certain threshold, the platform sends congestion alerts to vehicles passing through or near the congested area.
Lane Advisory	When a vehicle receives lane planning suggestions from the cloud control platform based on such dynamic information as the vehicle's position, and perceived roadside events and objects, the system integrates the vehicle's perception data to determine the most suitable route for the current traffic conditions and outputs control signals for smooth driving.

(2) Collaborative driving assistance

Collaborative driving assistance means that the vehicle receives connected information meeting specific performance (such as communication latency, message reliability, and perception accuracy) and safety (such as information security and functional safety) requirements in a connected traffic system, thereby better realizing assisted driving. Once the coverage of road infrastructure and onboard communication units reach a certain level, collaborative driving assistance will be widely applied. Specific function definitions are shown in Table 3-2.

Table 3-2. Typical Function Definition for Collaborative Driving Assistance

Typical Function	Definition
Cooperative Automated Emergency Braking (CAEB)	When a vehicle (equipped with an L2 or higher driving automation system) is traveling on the road and encounters obstructed scenes, it may not be able to timely identify potential hazards (such as occluded vehicles or pedestrians). By utilizing roadside perception and communication devices, vehicles can obtain the location and posture of these hazards in advance. If a collision risk is detected, an emergency braking is triggered.
Cooperative Adaptive Cruise Control (CACC)	Based on traditional ACC features, CACC anticipates non-LOS targets and road traffic information. This enables adaptive cruise control across all road sections, especially at intersections, improving overall response speed and stability, and reducing following distances.
Cooperative Navigate on Autopilot (CNOA)	When the NOA feature is activated for the vehicle, the system can autonomously change lanes, cut in, navigate on and off ramps, avoid obstacles, and manage passage through protected or unprotected intersections by utilizing connected perception information and decision reference data.
Connected Intersection Program (CIP)	As the vehicle approaches an intersection, it combines the vehicle's intended action (going straight or turning left) with connected perception data, decision reference information, and a local dynamic map to ensure that vehicles going straight and turning left can efficiently and orderly pass through the intersection.
Highway Differential Speed Limit (HDSL)	While the vehicle is driving on the highway, the cloud platform dynamically adjusts speed limits based on traffic flow monitoring, environmental assessments, and accident risk identification as well as the vehicle's motion and intent. It then provides reference information for driving decisions to the intelligent driving system. This enables smooth speed changes, facilitates early obstacle avoidance, and ensures that the vehicle travels on the appropriate lane.

(3) Collaborative autonomous driving

Collaborative autonomous driving refers to the support of vehicle automation with connected information meeting higher performance (such as communication latency, message reliability, and perception accuracy) and safety (such as information security and functional safety) requirements in a connected traffic system. Once the coverage of road infrastructure and onboard communication units reach a certain level, the integrated vehicle-road-cloud autonomous driving systems will be widely adopted, especially in urban and highway environments. Specific function definitions are shown in Table 3-3.

Table 3-3. Typical Function Definitions for Collaborative Autonomous Driving

Typical Function	Definition
Collaborative Automated Valet Parking	Users exit the vehicle at a designated drop-off point and issue a parking command via a mobile app. The vehicle can automatically drive to a parking space without user control or monitoring. Users can also issue a command to retrieve the vehicle, which will automatically drive from the parking space to the designated pick-up point. If multiple vehicles receive parking commands simultaneously, they can dynamically wait to enter parking spaces. The vehicle can adhere to road traffic rules or the operator-developed parking lot rules during this process.
Remote Takeover	When the cloud control platform detects anomalies in the vehicle or driver, or upon request from the vehicle, it can receive driving control instructions from a remote control cockpit to navigate out of extreme situations.

4 Development Roadmap of 5G Automotive Application

As more and more network channels shift to 5G, the integration of 5G communication technology into vehicles is accelerating. The advantages of 5G—high speed, large bandwidth, low latency, and high reliability—can expedite the mass production of high-value V2X functions, creating differentiated and immersive human-machine interaction experiences while fostering the innovative development of business models. Moreover, with the large-scale application of warning and alert features, the impact of connected scenarios on traffic safety and efficiency becomes increasingly evident. With the support of 5G technology, the advantages of integrated vehicle-road-cloud systems will be further realized, empowering roadside collaborative perception and cloud computing resources to enhance intelligent driving.

This report outlines a list of 5G in-vehicle application scenarios based on high consumer experience perception, comprehensive standard systems, and scalable mass production principles. After industry research and validation, it predicts the timeline for the large-scale deployment of these scenarios and presents a development roadmap as illustrated in Figure 4-1.

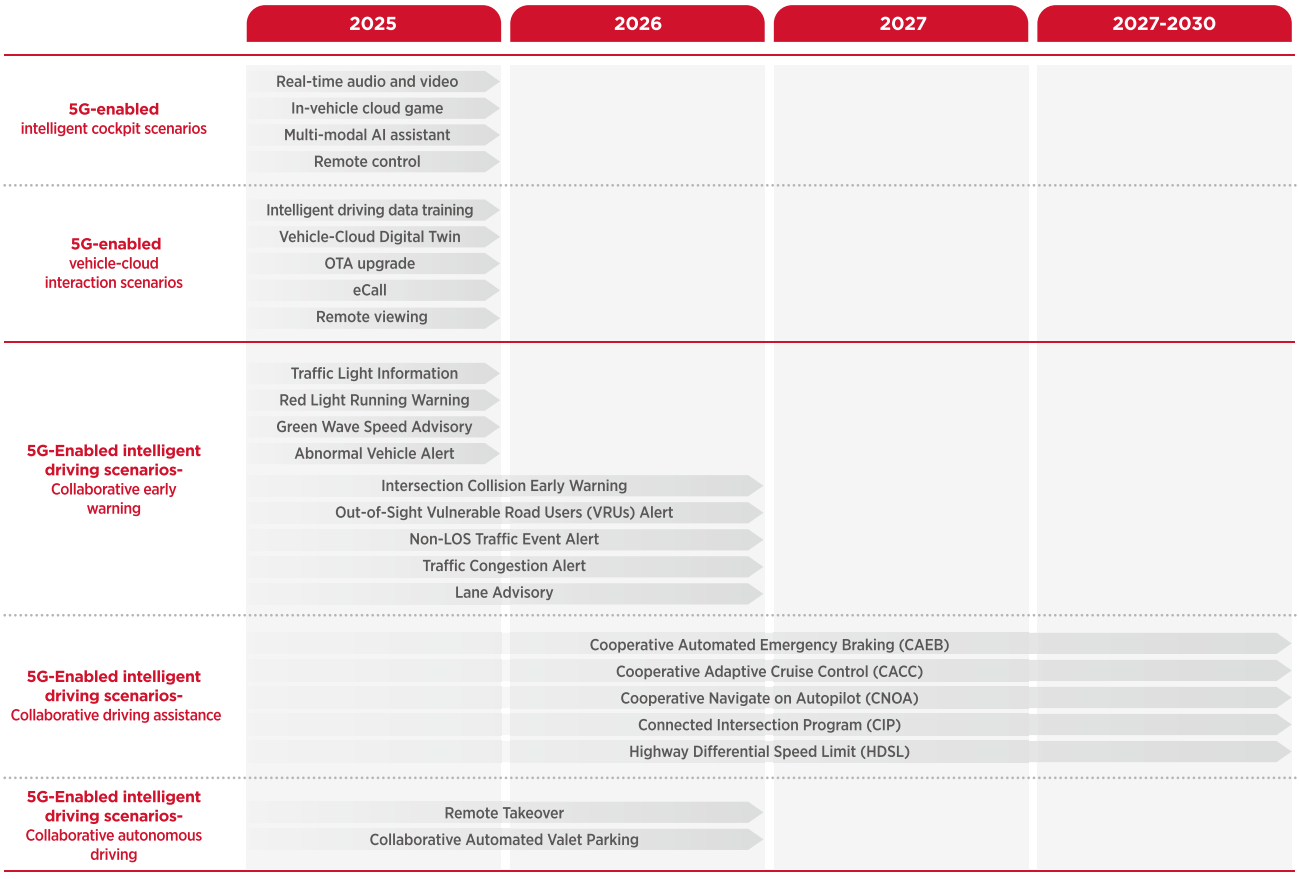


Figure 4-1. Development Prospect for 5G Automotive Application in China

In the future, 5G technology is expected to bring significant value to the V2X market, delivering a new level of driving and entertainment experience while promoting the safety of connected cars through Collaborative early warnings and driving assistance. This report argues that further advancement of 5G in-vehicle applications requires:

4.1 Strengthening Regulatory Framework & Technical Specification and Accelerating Core Technology Innovation

Strengthen regulatory framework & technical specification for 5G in-vehicle applications. Enhance 5G vehicle networking standards and innovative practices based on pilot projects like intelligent and connected vehicle (ICV) access and road operation trials and integrated vehicle-road-cloud system trials. Improve standards and systems in 5G in-vehicle application and accelerate the establishment of necessary 5G V2X standards to support comprehensive innovations.

Strengthen the development of core technologies for in-vehicle 5G hardware. Promote innovation in key hardware such as 5G communication chips and automotive modules. Encourage companies to adopt advanced manufacturing processes, improve product cost-effectiveness through technological iteration, and reduce overall hardware costs. Promote the large-scale application of new technologies like lightweight 5G (i.e.,5G RedCap) to enhance the 5G ecosystem. Unify industry standards for in-vehicle 5G hardware. Standardized design helps effectively simplify the hardware development process, reduce compatibility issues between different manufacturers, and lower the complexity of production and integration.

4.2 Exploring More Scenarios for 5G Automotive Application

Ensure communication security for high-level vehicle networking applications by utilizing 5G technology with high bandwidth and low latency. Explore how to commercialize 5G in-vehicle applications, focusing on integrated applications in such key areas as collaborative driving assistance, remote driving, and onboard AI. Accelerate the integration of 5G and AI to enhance the user experience in ICVs. Leverage integration advantages to develop smoother in-vehicle infotainment systems, providing a rich and diverse interactive experience. Further unlock the potential of 5G in areas such as OTA upgrades, vehicle health monitoring, eCall, cloud computing deployment, and intelligent driving data lifecycle management.

Explore scenarios for 5G automotive applications by identifying application features that can be commercially deployed on vehicles in the short term. Define a development roadmap for 5G automotive applications, clarify the pace for large-scale application of 5G in vehicles, enrich automotive application scenarios, and prioritize applications that enhance consumer perceived value.

4.3 Building Industry Consensus and Creating an Integrated Ecosystem

Strengthen industry communication and collaboration to build consensus on 5G integration. Jointly develop common technologies for 5G V2X and foster innovation in applications and business models across industries. Encourage collaboration among partners in the V2X ecosystem and explore mechanisms for joint development, sharing, and mutual benefits across different fields. Promote extensive cooperation among all parties in areas such as product development, standard formulation, technological innovation, market expansion, and marketing promotion. Strengthen collaboration across the supply chain, break down industry barriers, and jointly foster an open, integrated, and vibrant innovation ecosystem.

4.4 Exploring New Business Models for Win-Win Results in the Industry

Explore new business models (e.g., subscription-based or tiered service models based on functionality and service scope) to meet diverse user needs. Explore data-driven business models that meet relevant rules and regulatory requirements based on the vast data generated by 5G in-vehicle applications and offer customized insurance and traffic optimization services. Create an ecosystem platform involving vehicle manufacturers, telecom operators, software developers, and data service providers to drive the application and innovation of 5G technology in the automotive sector via data sharing, interconnectivity, and resource integration. While enriching services, it can allow relevant parties to share operational costs and expand market scale.

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