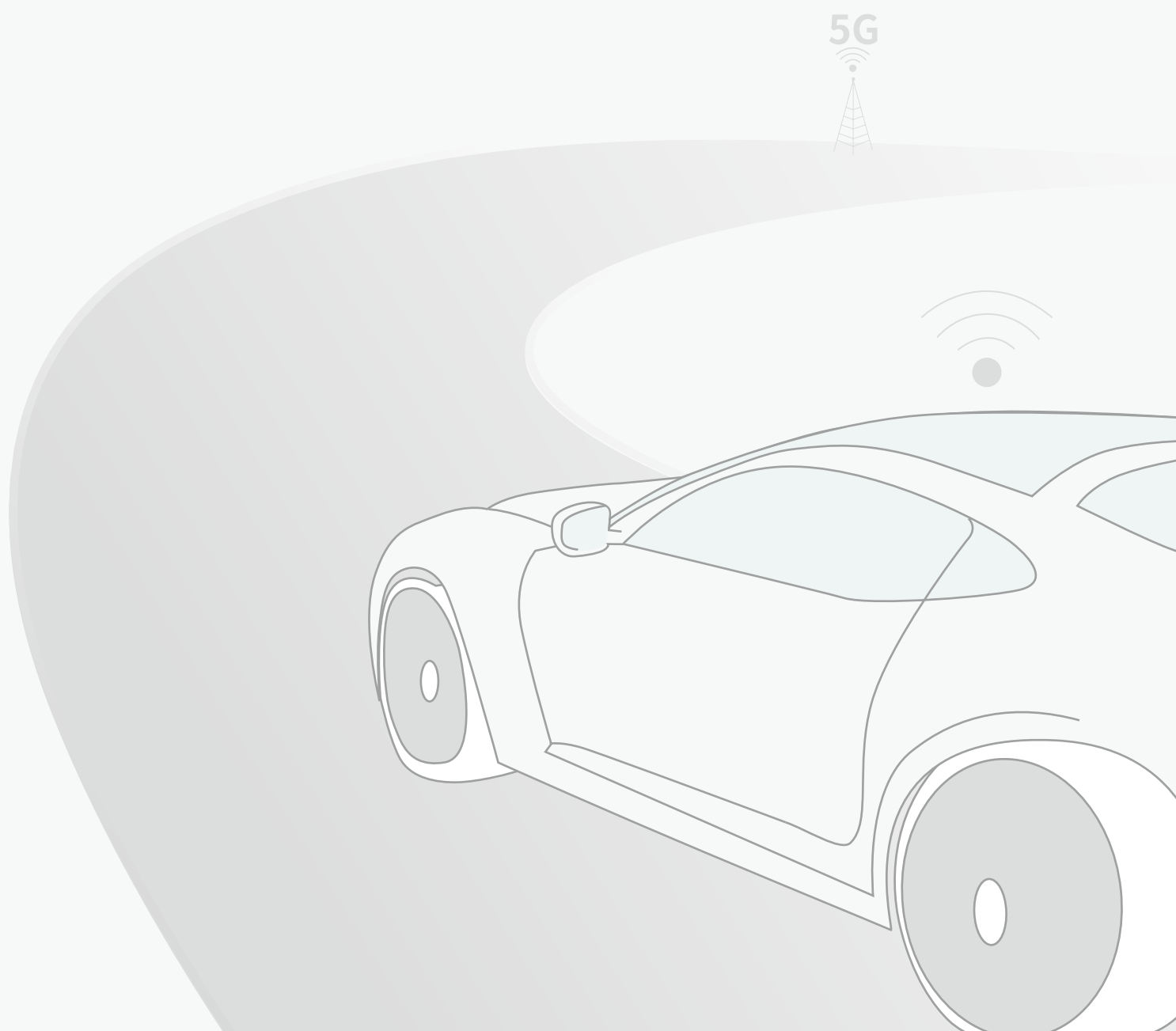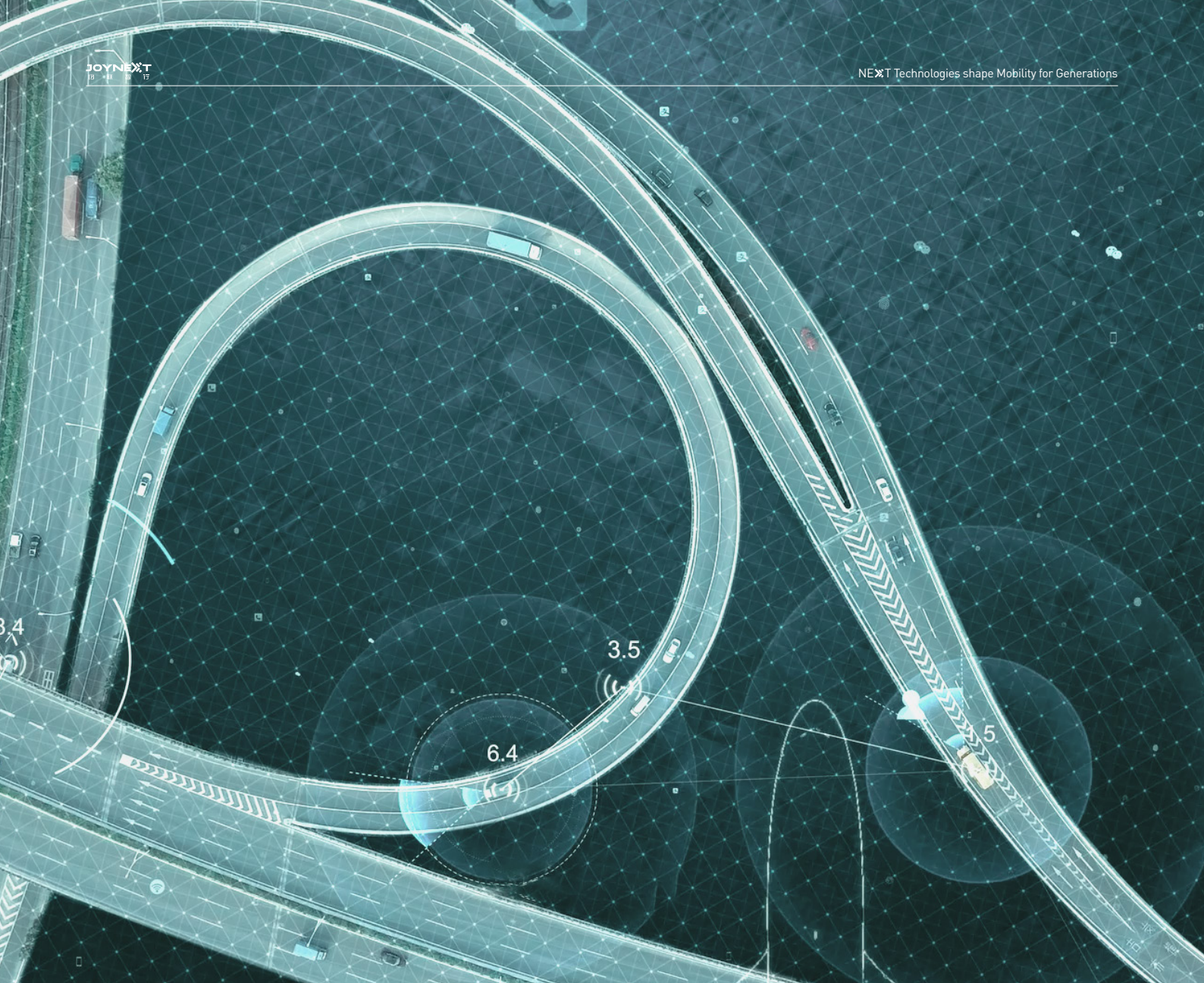Vehicle-Road Collaboration：
Empower Safer and More Efficient Autonomous Driving

——

JOYNEXT 5G+V2X Tech Paper

5G

▶ CONTENT

01 V2X Development Overview

▶ Concept of Vehicle-Road Collaboration

▶ Market Trends

▶ Application of 5G+V2X Solution in High-level Autonomous Driving

▶ Industry Landscape

▶ Typical Scenarios and Applications of C-V2X

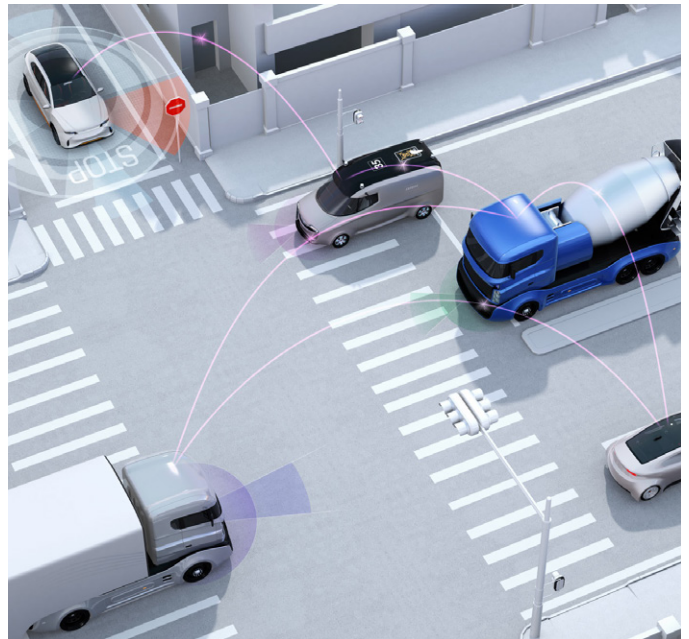JOYNEXT 5G+V2X Tech Paper | 03 ◀

▶ Concept of Vehicle-Road Collaboration

V2X (Vehicle-to-Everything) is a new generation information and communication technology that connects vehicles to other vehicles (V2V), infrastructure (V2I), pedestrians (V2P), and network (V2N). Through the organic connection between pedestrians, vehicles, infrastructure, cloud, and other traffic elements, V2X can not only capture more comprehensive information compared to single vehicle sensing technology to expedite the maturation and adoption of autonomous driving technologies, but also contribute to building an intelligent transportation system and developing new patterns of vehicle and transportation service industry.

❯ Development trends of integrated application

C-V2X (Cellular-Vehicle to Everything) based IOV (Internet of Vehicle) application will inevitably undergo different development phases, gradually **shifting the focus on traffic safety and efficiency to autonomous driving.**

- Current emphasis should be placed on improving driving safety and traffic efficiency. Based on constructing roadside infrastructure, the vehicles could support intersection collision warning, red light violation warning, traffic guiding, green wave guiding and speed limit reminding.
- The development of wireless communication technology will drive IOV applications to evolve towards collaboration and intelligence and implement more advanced and complicated autonomous driving scenarios.

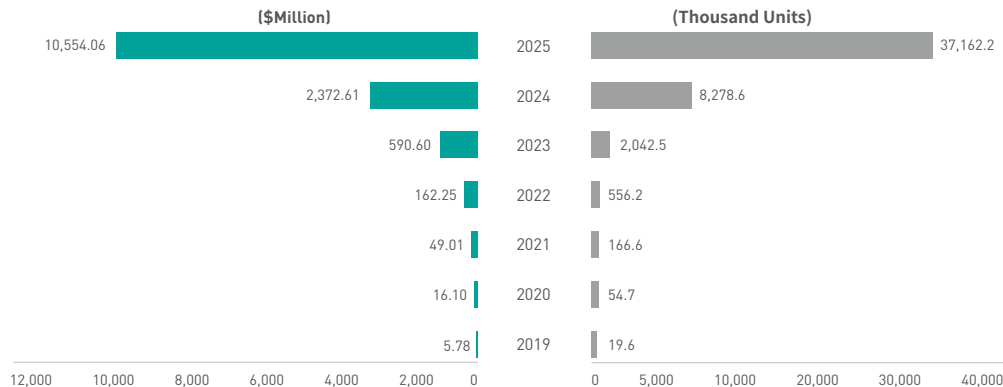### ❯ "Carbon Peak" and "Carbon Neutrality"

The "smart vehicle, intelligent infrastructure, and collaborative cloud" development pattern based on IOV can improve the traffic efficiency, alleviate road congestion, and optimize the traffic flow operation, thus reducing resource wastes and further supporting goals of achieving "carbon peak" and "carbon neutrality".

Source: White Paper of Internet of Vehicles

Market Trends

> **The C-V2X market will be fully launched in 2022. According to statistics, the global automotive V2X market size will surpass 10 billion dollars by 2025, and this technology will be deployed in over 37 million vehicles.**

Global Automotive V2X Market, $Million and Thousand Units, 2019-2025

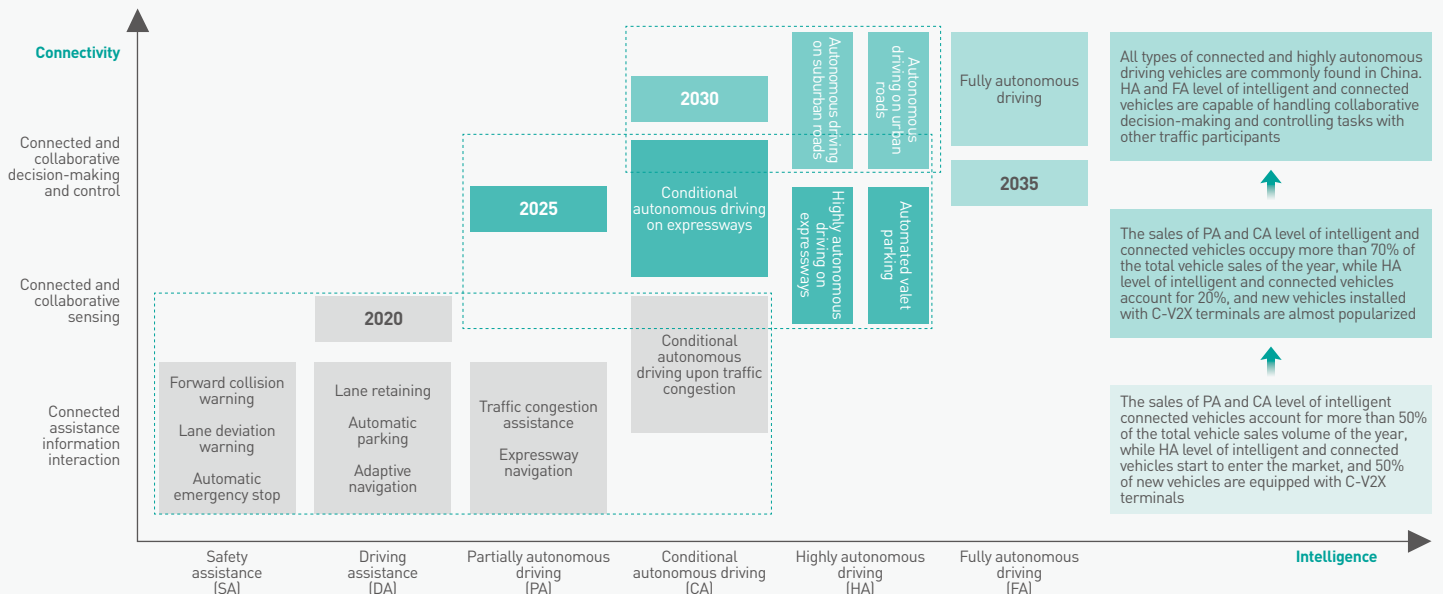| ($Million)	Year	(Thousand Units)
10,554.06	2025	37,162.2
2,372.61	2024	8,278.6
590.60	2023	2,042.5
162.25	2022	556.2
49.01	2021	166.6
16.10	2020	54.7
5.78	2019	19.6

Source: BIS Research Analysis

C-V2X technology development trends in China

Intelligent Connected Vehicle Technology Roadmap 2.0 points out that penetration of PA (partially autonomous driving), and CA (conditionally autonomous driving) vehicles will increase to 50% by 2025 and above 70% by 2030; and new vehicles installed with C-V2X terminals will account for 50% by 2025 and be almost popularized by 2030.

With the adoption of connected and collaborative sensing, collaborative decision-making, and control functions; connectivity between vehicles and other transportation infrastructure; and a more sound and integrated industry ecosystem in China, there will be substantial improvement in overall vehicle intelligence and large-scale application of connected and highly autonomous driving vehicles in the near future.


Connectivity

Connected and collaborative decision-making and control

Connected and collaborative sensing

Connected assistance information interaction

2030

2025

2020

Forward collision warning
Lane deviation warning
Automatic emergency stop

Lane retaining
Automatic parking
Adaptive navigation

Traffic congestion assistance
Expressway navigation

Conditional autonomous driving upon traffic congestion

Conditional autonomous driving on expressways

Autonomous driving on suburban roads

Autonomous driving on urban roads

Highly autonomous driving on expressways

Automated valet parking

Fully autonomous driving

2035

All types of connected and highly autonomous driving vehicles are commonly found in China. HA and FA level of intelligent and connected vehicles are capable of handling collaborative decision-making and controlling tasks with other traffic participants

The sales of PA and CA level of intelligent and connected vehicles occupy more than 70% of the total vehicle sales of the year, while HA level of intelligent and connected vehicles account for 20%, and new vehicles installed with C-V2X terminals are almost popularized

The sales of PA and CA level of intelligent connected vehicles account for more than 50% of the total vehicle sales volume of the year, while HA level of intelligent and connected vehicles start to enter the market, and 50% of new vehicles are equipped with C-V2X terminals

| Safety assistance (SA) | Driving assistance (DA) | Partially autonomous driving (PA) | Conditional autonomous driving (CA) | Highly autonomous driving (HA) | Fully autonomous driving (FA) |

Intelligence

Source: Intelligent Connected Vehicle Technology Roadmap 2.0

Application of 5G+V2X Solution in High-level Autonomous Driving

The development of autonomous driving requires the coordinated development of vehicle intelligence and connectivity, while it is difficult for individual vehicle intelligence to handle autonomous driving tasks, especially in corner case and high-cost challenges. Connectivity capabilities supported by C-V2X communication and connection technology, together with the intelligent control and management functions of individual vehicles, will pave the way for real-time information sharing and interaction, as well as collaborative sensing and control that is demanded by autonomous driving.

L0-2(1) — Alarming and partial controlling interference

FCW (Forward Collision Warning), tailgating, adjacent local traffic density calculation, left-turn assistance, blind zone detection, merging/dispersing assistance, unavoidable collision alarming, overtake assistance, forward abnormal alarming, and emergency braking warning

L0-2(2) — Capturing of partial traffic information

RSU (Road Side Unit) collision reminding, guidance of green wave speed, crossroads relevant applications, local road information delivery, regional local density and risk evaluation, block corner FCW

L3 — Partial controlling interference

Local movement strategy generation and execution, exact danger positioning and avoid strategy generation

L3-4 — Controlling interference

Individual vehicle trace and behavior prediction, regional traffic path prediction, local movement strategy correction, local information sensing and risk evaluation

L4-5 — Artificial intelligence interference

Individual vehicle trace generation and feedback, regional traveling path generation and correction, local regional information evaluation and customized sharing, vehicle platooning control

L5 — Cloud platform interference

Traffic condition prediction and information delivery, remote vehicle control and management (including platooning), global sensing and customized sharing, value-added information service
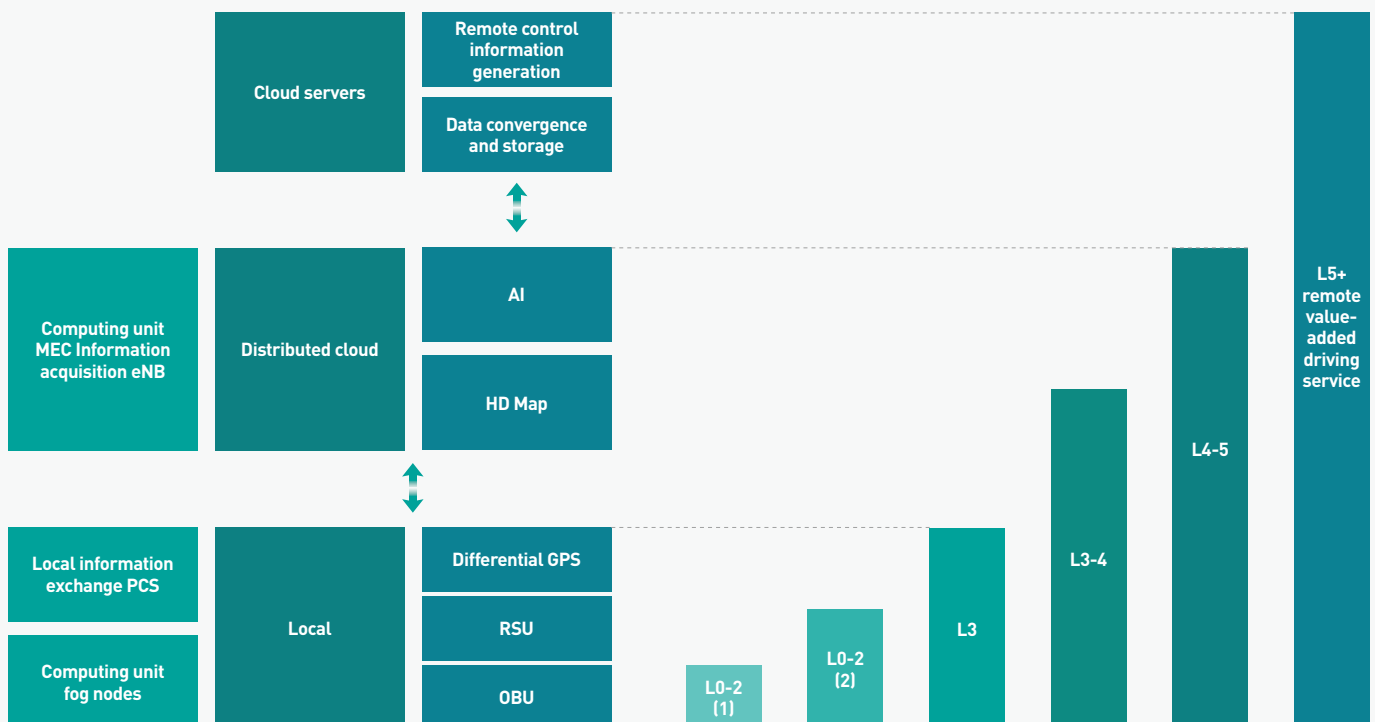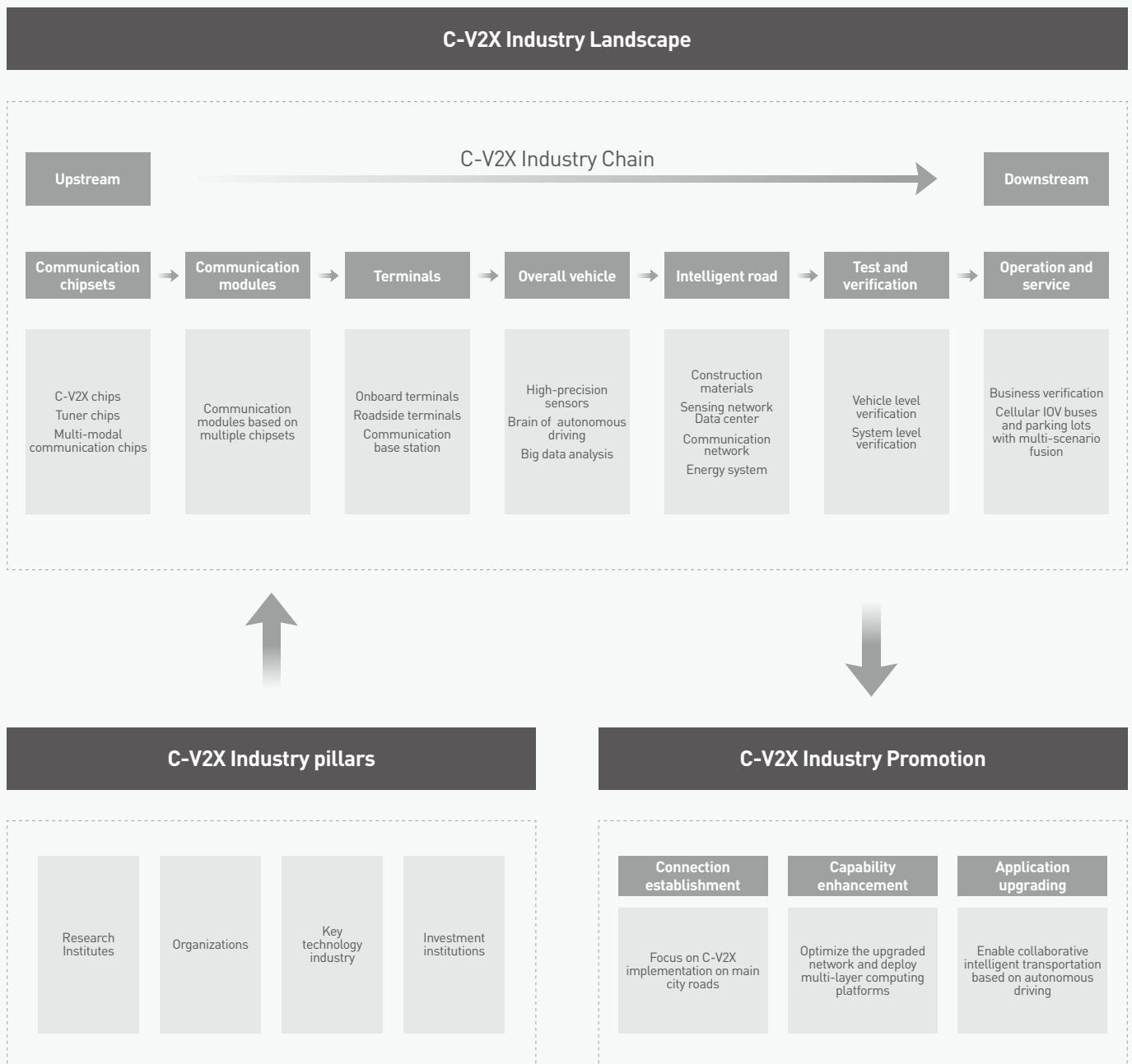

Source: BIS Research Analysis

Industry Landscape

The IOV industry chain involves a long process
Upstream: core terminal components: chipsets, communication modules, etc.
Midstream: onboard and roadside terminals
**Downstream:** test and verification, operation and services, etc.

C-V2X Industry Landscape

C-V2X Industry Chain

| Upstream | | Downstream |

Communication chipsets	Communication modules	Terminals	Overall vehicle	Intelligent road	Test and verification	Operation and service
C-V2X chips Tuner chips Multi-modal communication chips	Communication modules based on multiple chipsets	Onboard terminals Roadside terminals Communication base station	High-precision sensors Brain of autonomous driving Big data analysis	Construction materials Sensing network Data center Communication network Energy system	Vehicle level verification System level verification	Business verification Cellular IOV buses and parking lots with multi-scenario fusion

C-V2X Industry pillars

Research Institutes	Organizations	Key technology industry	Investment institutions

C-V2X Industry Promotion

Connection establishment	Capability enhancement	Application upgrading
Focus on C-V2X implementation on main city roads	Optimize the upgraded network and deploy multi-layer computing platforms	Enable collaborative intelligent transportation based on autonomous driving

Source: Computer Industry In-depth Report-IOV Vision Approaching and Industry Landscape Spreading Broadly

Typical Scenarios and Applications of C-V2X

Typical information service scenarios

Information service scenario is important for improving driving experiences, and also a key part of C-V2X applications.
Typical information service scenarios include **emergency calling business.**
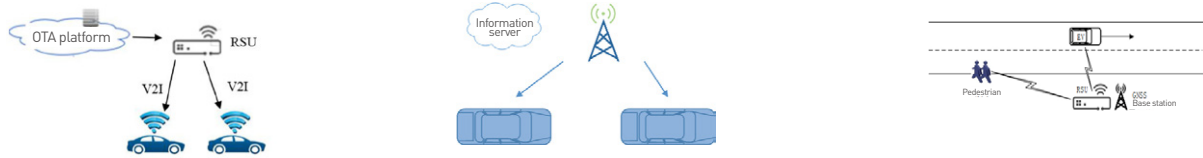
| Remote software update based on vehicle-road collaboration | In-vehicle infotainment system | Differential data service |

Typical traffic safety scenarios

Traffic safety is one of the most important scenarios of C-V2X application, which has a significant meaning for avoiding traffic accidents and reducing the life and property losses arising from them.
Typical traffic safety scenarios **include intersection collision warning.**
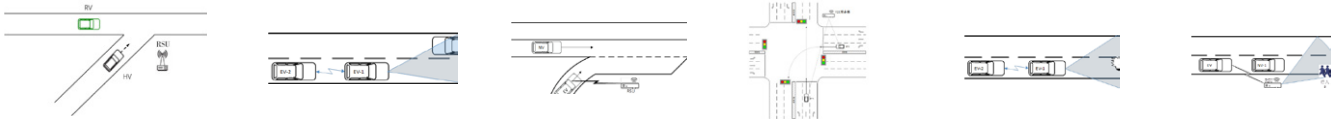
| Vehicle merging and diverging | Sharing of sensing data of traffic participants | Collaborative ramp merging | Intersection transiting based on vehicle-road collaboration | Accident alerting | Vulnerable road user recognition |

Typical traffic efficiency scenarios

Traffic efficiency is one of the most important scenarios of C-V2X application, and also a key part of intelligent transportation.
Typical traffic efficiency scenarios including **speed guidance.**
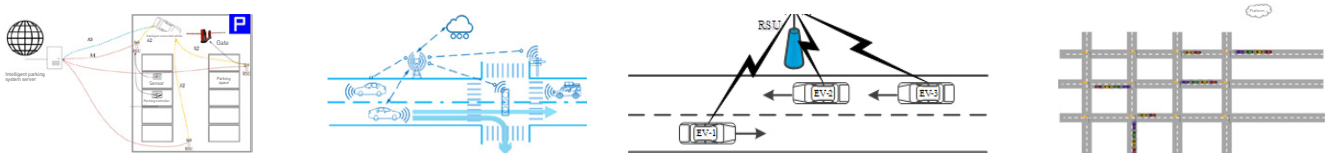
| Intelligent parking guidance | Local road guidance | Floating car data collection | Dynamic traffic signal timing optimization based on real-time network data |

Typical autonomous driving scenarios

Similar to camera, millimeter-wave radar and laser-radar identification, C-V2X is an alternative information interaction method for capturing moving conditions of nearby vehicles and pedestrians (speed, braking and lane change), which is invulnerable to weather, barrier, distance, and other external influences. Meanwhile, C-V2X can also help build an integrated service system that supports time-sharing lease and sharing along with vehicle, infrastructure, pedestrian and cloud collaboration, thus facilitating the development of autonomous driving industry.
Typical autonomous driving scenarios include **vehicle platooning** and **remote-controlled driving**.

| Vehicle platooning | Collaborative fleet management | Remote-controlled autonomous driving | Automated valet parking |

Source: White Paper on 5G IOV Demands and Technologies

V2X

02 JOYNEXT 5G+V2X Solution

▶ JOYNEXT Product Roadmap

▶ JOYNEXT 5G+C-V2X Solution

▶ JOYNEXT Integrated Digital Smart Antenna Solution

▶ Customer Cases

Kevin Liu

Chairman & CEO, JOYNEXT

> **More and more people have realized that single vehicle intelligence is not sufficient to achieve the highest level of autonomous driving, while V2X technology will be the ultimate way to reach the highest stage. That's why we attach great importance to V2X technology.**
>
> As the key technology of vehicle-road collaboration, 5G+V2X solution will bring two main benefits for users and even the whole society, that is, enhancing both traffic efficiency and safety, which will greatly advance the development of the intelligent connected vehicle industry.

As one of the leading global innovators of intelligent connected vehicle technology, JOYNEXT has established a closed-loop system of **"absorption, innovation, iteration, and payback"** based on 5G+V2X technology.

Early in 2015, our Europe team had invested much efforts in the DSRC technology roadmap. However, due to the limit of permeability of roadside infrastructure, slowness of cloud technology development and other complicated factors, considerable difficulties are still encountered when V2X technology is launched in European and North American markets.

Supported by China's policies that promote innovation, JOYNEXT China team had been fixed on C-V2X technology development and partnered with some leading enterprises to accelerate product verification and iteration, and finally pioneered the global mass production in 2021.

Meanwhile, JOYNEXT has also extended the successful mass production experience to the global market, which helps us win increasing orders from famous global OEMs and further strengthened our leading position in V2X technology.
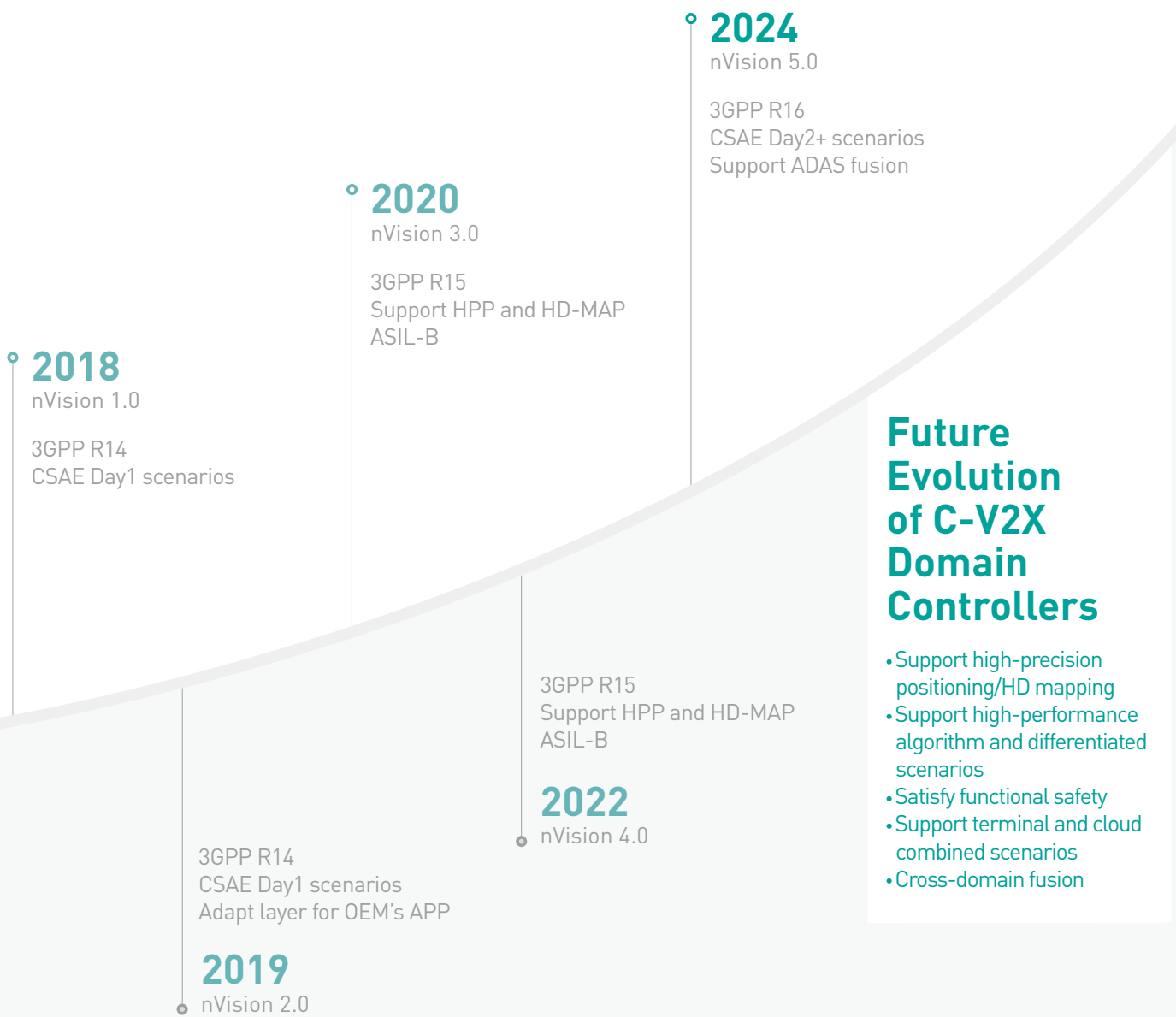
In terms of technology iteration, we have also finished the primary development of advanced functions and are able to implement more vehicle-road collaboration scenarios through OTA updates (Over-the-Air Technology).

In the future, V2X technology will play an even more important role in global IOV technology innovation, industry fostering and transportation transformation, thus greatly empowering the commercialization of autonomous driving.

▶ JOYNEXT Product Roadmap

As 3GPP continuously promotes the standardization of C-V2X, the technical evolution path of C-V2X has gradually come to the surface. This technology is generally used to support basic safety businesses, including driving assistance, and traffic safety and efficiency boosting applications. By combing with AI and big data analysis technologies, along with radars, multiple sensors and other hardware support functions, the future autonomous driving and ubiquitous networking visions will become reality.

Due to the freezing of 3GPP R17 standard, JOYNEXT 5G+C-V2X technology will be more widely used in IOV field, and gradually complete the iteration from assistance to collaborative sensing, then to collaborative planning and collaborative control.

2024
nVision 5.0

3GPP R16
CSAE Day2+ scenarios
Support ADAS fusion

2020
nVision 3.0

3GPP R15
Support HPP and HD-MAP
ASIL-B

2018
nVision 1.0

3GPP R14
CSAE Day1 scenarios

Future Evolution of C-V2X Domain Controllers

- Support high-precision positioning/HD mapping
- Support high-performance algorithm and differentiated scenarios
- Satisfy functional safety
- Support terminal and cloud combined scenarios
- Cross-domain fusion

3GPP R15
Support HPP and HD-MAP
ASIL-B

2022
nVision 4.0

3GPP R14
CSAE Day1 scenarios
Adapt layer for OEM's APP

2019
nVision 2.0

JOYNEXT 5G+C-V2X Solution

> Product overview

5G+C-V2X technology can enable information exchange and sharing between vehicles and all other traffic participants, along with complicated environment sensing, intelligent decision-making, collaborative controlling and executing capabilities by integrating modern communication and networking technologies. JOYNEXT 5G+C-V2X solution highly integrates high-precision positioning algorithms of C-V2X, camera and HD maps to achieve C-V2X standard functional scenarios.

> Technical Details

- SoC: Qualcomm, MTK
- Architecture & OS: Linux, RTOS, AUTOSAR
- External interfaces: 5G/4G, GNSS, C-V2X, DSRC, BT/BLE, Wi-Fi, UWB, etc.
- Internal interfaces: Ethernet, CAN, LIN, etc.
- Positioning: GPS and BDS, DR, RTK,IMU
- Security: HSM, PKI, TrustZone
- Safety: A/B section safety update

> Market Application

As one of the pioneers of mass-production in 5G+C-V2X, JOYNEXT solution has implemented all CSAE defined Day 1 scenarios. JOYNEXT has also finished the primary development of advanced functions and are able to implement more vehicle-road collaboration scenarios through OTA updates. Up to now, JOYNEXT 5G+C-V2X technology has been applied in many famous OEMs in the world, supplying millions vehicles.
Looking forward, C-V2X technology will develop in the direction of other domain controllers and cover differentiated terminal and cloud combined scenarios through high-performance algorithm and high precision positioning and HD mapping support on the basis of functional safety.

> Typical Scenarios
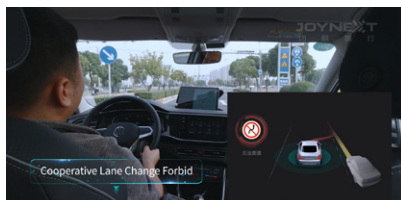
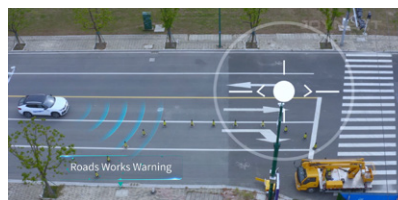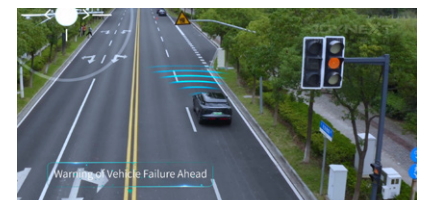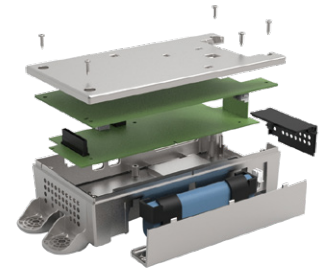| Cooperative lane change	Cooperative vehicle merge	Blind spot warning
Left turn assist	Vulnerable road user warning	Traffic jam warning
Forward collision warning	Roads works warning	Abnormal vehicle warning

JOYNEXT Integrated Digital Smart Antenna Solution

> Product Overview

With the development of 5G technology, it's the industry trend of integrating Radio Frequency (RF), antenna and digital signal processing to greatly improve communication performance and antenna efficiency.
JOYNEXT digital smart antenna possesses strong platform integration capacities, supports the integration of more than 10 kinds of vehicle services. This solution has been nominated by world famous OEMs for global markets, first SOP in 2024.

> Technical Details

- **Variants:** Shark fin type, flat box type
- **Thermal design:** Adaptive for high temperature application, support 95°C working environment
- **Innovative structure design:** Meeting the needs of flexible deployment in the car
- **Higher integration capability:**
  - 5G+C-V2X for all V2V/V2I standard scenarios and OEM customized scenarios, and high level scenario extendable (5G+C-V2X product variant)
  - TBOX function incl. connectivity, remote vehicle control, remote update, emergency assistance and roadside assistance, big data and safety function
  - Providing solution for digital key based on BLE or UWB
  - HD GNSS capabilities
  - Centimeter-level high-precision positioning for an algorithm fusion of V2X, camera, HD map, etc., and provided to L3 autonomous driving
  - Nearfield communication technologies (UWB, NFC, BLE, Wi-Fi)
  - Market specific tuner variants (AM/FM, DAB)
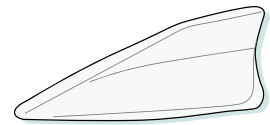
Shark Fin Digital Smart Antenna
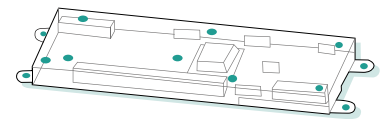
Flat Box Digital Smart Antenna

> Solution Advantages

High Scalability	One structure, multiple choices

- 5G
- 5G + V2X
- 5G + V2X + BT/UWB key
- 5G + V2X + BT/UWB key + High-precision fusion positioning
- 5G + V2X + BT/UWB key + High-precision fusion positioning + High-precision map
- 5G + V2X + BT/UWB key + High-precision fusion positioning + High-precision map + Tuner

High Adaptability	One product, multiple deployment

- NAD adaptable, SA415M/ SA515M/ SA522M/ MT2735/ SECTON/ MDM9x28/ MDM9150
- MCU adaptable, NXP/ Ti/ RENESAS
- 3GPP adaptable, R14/ R15/ R16
- V2X stack adaptable, C-V2X Day-1 & Day-2/ ITS-G5
- China/ USA/ EU certifications of adaptation

High Security & Safety	Adaptive to different integration requirements

- Support ASIL-B level function safety
- Info security (access management/ security boot/ cyber security/ storage/ security communication/ security interface)
- eCall, Passed EU certification
- Commercial Vehicle National Security Requirements
- Commercial Vehicle Environmental Testing Requirements

High Integrity	Adaptive to different integration requirements

- Shark fin integrated smart antenna design
- Flat box integrated smart antenna design
- Distributed integrated digital smart antenna design
- ECU standalone design

▶ Customer Cases—HiPhi X by Human Horizons

JOYNEXT Project Achievements

|		
One of the world's first 5G+C-V2X mass production project	**Enable Chinese new generation of vehicle manufacturers to improve the capability of vehicle-road collaboration**	**Provides high-precision positioning and HD map solution which satisfied ASIL-B**

❯ Product Solution

- Traditional TBOX functions and services, including networking, remote control and upgrade, eCall, big data service and safety service
- Centimeter level high-precision positioning that combines C-V2X, camera and HD map algorithm, which supports L3 autonomous driving
- Bluetooth-based smart key solution with 5 BLE modules and smart key algorithm
- BT, 4G/5G, GNSS and C-V2X integrated intelligent antenna
- Remote update of the latest technology via OTA updates

❯ Application Scenarios

- Support all V2V and V2I standard scenarios and partial OEM customized scenarios
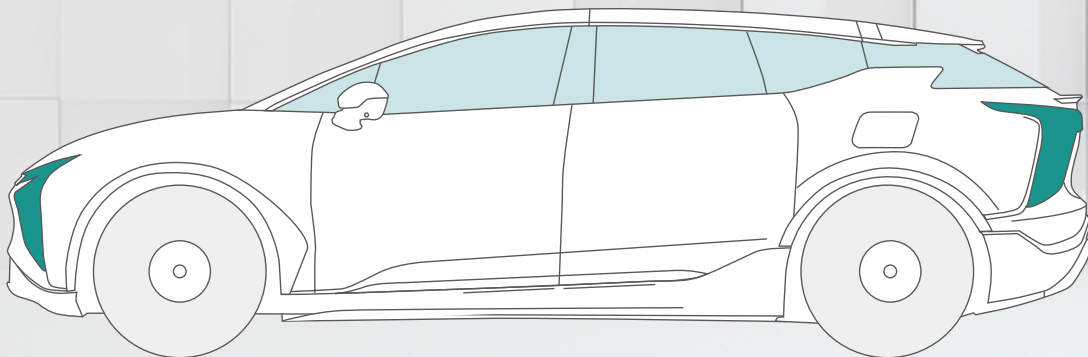
▶ Customer Cases—NIO

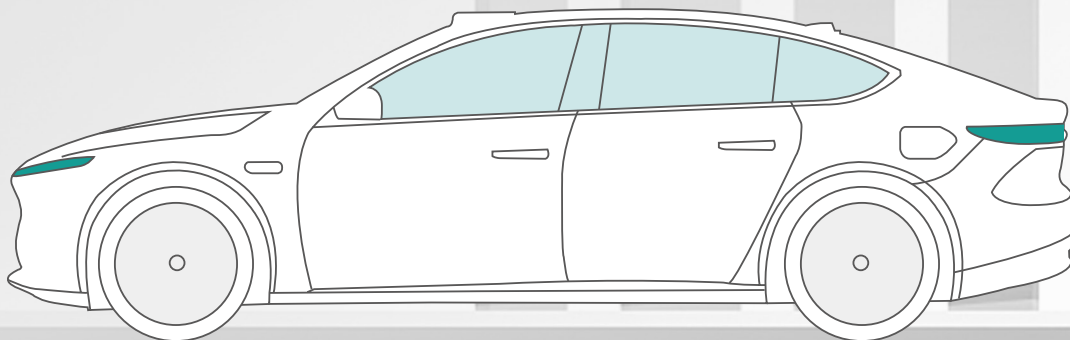| JOYNEXT Project Achievements		
Enable assisted autonomous driving by combing laser radar technology, thus improving traffic efficiency and safety	Extend Day2 capabilities through OTA upgrades, helping users implement more advanced vehicle-road collaboration scenarios	Comply with European 5G and market certification requirements, catering to vehicle export demands

❯ Product Solution

- Variants: Standalone 5G (Europe) and 5G+C-V2X
- CAN and Ethernet communication
- 5G and Wi-Fi
- BLE and charging station communication
- eCall, bCall and iCall as well as European eCall
- IMU, DR, and RTK
- High level security
- OTA updates

❯ Application Scenarios

- Support ETSI/CSAE defined V2X standard scenarios

* CSAE (China Society of Automotive Engineers)
* ETSI (European Telecommunications Sdandards Institute)

Customer Cases—a Global famous OEM

JOYNEXT Project Achievements

|	
World's first mass produced NR-C-V2X version (3GPP-R16) product, which supports more advanced urban transportation collaboration and automated driving functions, and strengthens weak group protection	Support distributed and integrated multiple digital antenna designs, flexible adaption to various vehicle types, along with C-V2X/Tuner/eCall and other diversified functional demands from global markets

> Product Solution

- Variants: shark fin type, flat box type digital smart antenna
- Configurations: Standalone 5G and 5G+C-V2X
- Qualcomm's next-generation high-performance chip, compliant with the latest 3GPP R16 standard
- High-precision positioning, RTK and IMU integration
- eCall, bCall, iCall and CAN diagnosis
- Wi-Fi, BLE and UWB
- Integration of 5G, GNSS, V2X, Wi-Fi and AM/FM/DAB
- Support security and functional safety
- Support OTA updates

> Application Scenarios

- Support ETSI/CSAE defined V2X standard scenarios
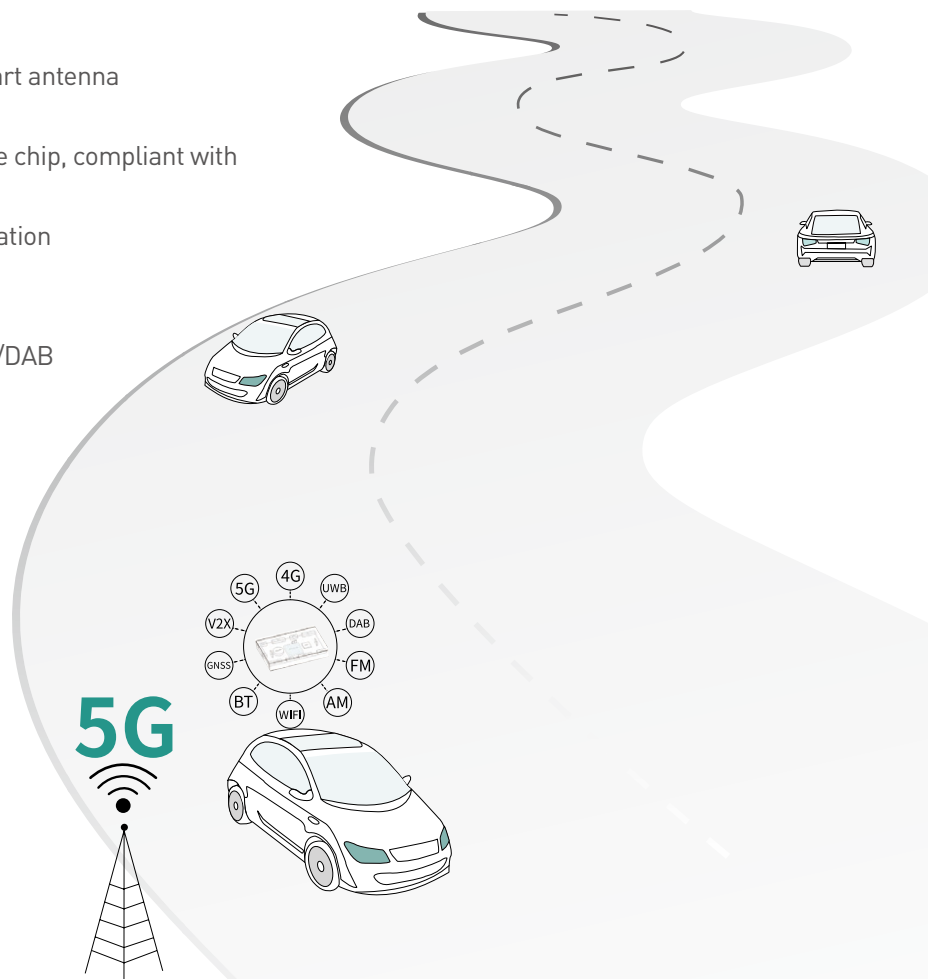
▶ Customer Cases—a Germany luxury brand

| JOYNEXT Project Achievements		
First mass production order installed with V2X product for the brand, covering multiple vehicle models from Level A to Level C	Supply millions of vehicles during the lifetime	Comply with AUTOSAR standard, improve adaptability and upgrade flexibility

❯ Product Solution

- Variant: V-box, only 115*115*20mm
- Deep fusion of the technology solution and overall vehicle to enable vehicle-road collaboration under multiple scenarios, and scale to advanced autonomous driving scenarios through OTA upgrades
- GNSS, V2X, and high-precision positioning functions are integrated to provide highly flexible adaptive solutions on customers' demands
- AUTOSAR architecture
- C-V2X protocol stack, and CSAE Day1 & Day2 scenarios
- CAN and Ethernet communication
- Support OTA updates

❯ Application Scenarios

- Support CSAE defined V2X standard scenarios
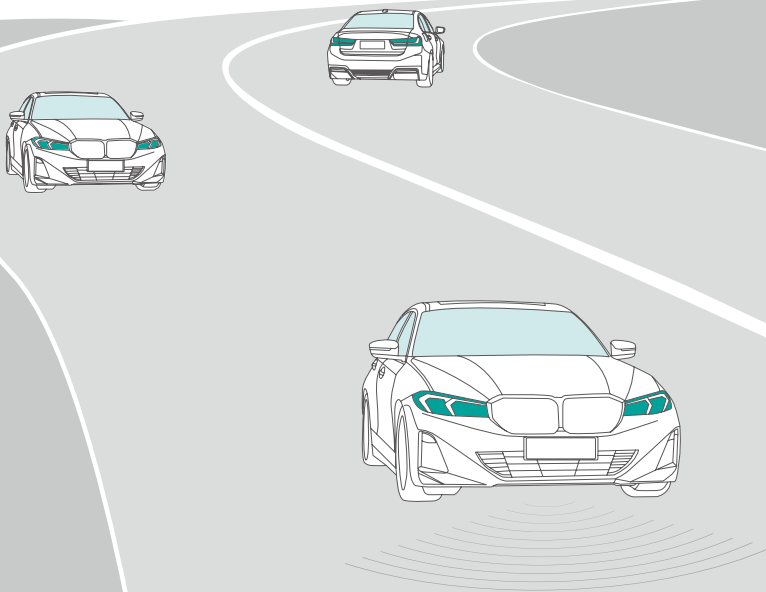
▶ Industrial Association & Alliance

Cherishing a grand vision of internet of vehicles, JOYNEXT is targeted at providing safer and more comfortable driving experiences to users and creating more intelligent and efficient transportation services for the world.

As one of the driving forces of intelligent vehicle and intelligent transportation, V2X technology plays a significant role in autonomous driving. Therefore, we actively participate and promote V2X industry development. Furthermore, we facilitate the fusion of wireless communication technology and the internet of vehicles and integrate intelligent electronics as a core brand element to empower the automotive industry.

JOYNEXT is the leading mass producers in the field of 5G+C-V2X technology around the world, and this technology has equipped with millions of vehicles around the world. In the future, JOYNEXT will provide the highest quality services to more global OEMs.

JOYNEXT has participated in CAAM, CCSA, CAICV, C-SAE and more than **a dozen of other national alliances and increasingly** expanded our influences worldwide. JOYNEXT has also involved in the IOV standardization programs in vehicle, public security, electronics, communication and transportation industries, and jointly support in the compilation of The Requirements Standard for Enhanced V2X Application Layer Data Interaction, Performance Requirements and Test Methods for Intelligent Connected Vehicle GPS System and several other **V2X related standards, including 1 national standard, 3 industrial standards and 16 group standards, of which a total of 10 standards have been published.**

Meanwhile, we have been continuously promoting the development of high-level autonomous driving assistance systems based on vehicle-road collaboration technology and contributed to the formulation of Data Exchange Standard for High Level Autonomous driving Vehicle Based on Vehicle-Road Collaboration and other many relevant standards.

We believe V2X will accelerate the transformation process of a safer, more efficient and more convenient transportation system, and the best path towards this is pursuing win-win cooperation on the basis of independent research.

❯ V2X Related Alliances that JOYNEXT has Joined in

▶ References

- White Paper on C-V2X Business Evolution, IMT-2020(5G) Promotion Group, June 2018
- White Paper of Internet of Vehicles, CAICT, December 2021
- Intelligent Connected Vehicle Technology Roadmap 2.0, November 2021
- Computer Industry In-depth Report: IOV Vision Approaching and Industry Landscape Spreading Broadly, Chuancai Securities Research Report, July 2020
- C-V2X Use Cases and Service Level Requirements Volume ll, 5GAA, December 2021
- White Paper on 5G IOV Demands and Technologies, CMCC, among others, April 2021
- BIS Research Analysis

▶ Contact us

Thank you very much for taking time to read this tech paper: Empower Safer and More Efficient Autonomous driving. For any suggestions or question, please scan the following **QR code** to contact us.

Email: contact@joynext.com

www.joynext.com

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▶ About JOYNEXT

As a world leading technology innovator in the intelligent connected vehicle industry, JOYNEXT has been a Tier-1 supplier to the world's top OEMs for over two decades. The company has established and maintained long-term partnerships with leading automotive brands, including Volkswagen, Audi, NIO and Human Horizons.

JOYNEXT has always been committed to product development of intelligent cockpit, smart connectivity, autonomous driving and SaaS/SaaP. Meanwhile, the company plays an active role in the joint exploration and innovation through partnerships with Huawei, Microsoft, Brose, ARM and other high-quality ecological partners, to provide open, safe, and highly specialized intelligent and connected vehicle solutions.

By putting users at the center and focusing on targeted analysis, we are consistently working on intelligent connected vehicle solutions of vital importance to both customers and users.
Using V2X technology, we have achieved intelligent connectivity between vehicles, pedestrians, infrastructure, and even mobile devices, such as smartphones, for advancing the uptake of autonomous driving. In addition to our diverse range of exemplary cloud-based service features, we also deliver IoV-related SaaS/SaaP services, such as NavCore and AR Core.
Over ten million cars around the world are equipped with our in-vehicle infotainment (IVI) and smart connectivity technologies. Moreover, JOYNEXT is also one of the world's first 5G+C-V2X mass producers.

Balancing innovation with sustainability, we build our success on a strong foundation of product development and innovation, industrialization, connectivity services, automotive cyber security. We are dedicated to promoting the introduction of software-defined vehicles and delivering next-generation technologies and making continuous efforts in shaping future mobility for generations.