Version 2024

# Intelligent Automotive Solution 2030

Building a Fully Connected,
Intelligent World

# Foreword

## ICT enables an intelligent automotive industry and helps carmakers build better vehicles

The beginning of the 2020s has marked a rapid shift towards more intelligent electric vehicles within the automotive industry. A new era for the automotive industry is just on the horizon, and we will soon see these profound changes affect our daily lives.

**There is an industry-wide consensus that vehicles will be more electric and intelligent.**

Carmakers are embracing this trend by actively adjusting their business strategies and ramping up R&D investment. Many have made transformation a core part of their future development strategy and have already begun to take concrete steps in this area.

**Technology and user experience are driving rapid growth in the new energy vehicle (NEV) market.**

In 2023, China's passenger vehicle market continued to recover thanks to the introduction of next-generation intelligent NEVs. In China, sales of NEVs reached 7.94 million vehicles. This increase of 35% massively exceeded the 5% average growth rate seen across the automotive market. As a result, the market share of NEVs increased from 27.6% to 35.5%. This can be attributed to two key drivers – technology and user experience – that NEV companies have been able to leverage through heavy investment into R&D and closer analyses of user requirements.

**Data and software are turning traditional vehicles into intelligent and software-defined vehicles.**
Data and software support faster iteration of vehicle functions, helping vehicles deliver experiences beyond consumer expectations. New, ever-evolving functions and services are also providing stable revenue streams for carmakers, pushing the industry to move away from product-centered operations towards user-centered operations.

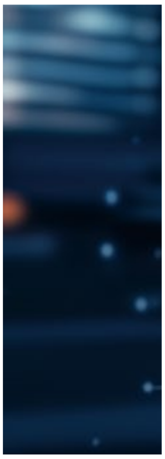
**What it means to "build better vehicles" is changing dramatically for carmakers.**
Users are increasingly focused on intelligent and electric features, rather than the traditional mechanical aspects of a vehicle. To make great intelligent electric vehicles, carmakers need to use digital platforms to achieve faster vehicle development and improve efficiency at lower costs. They also need to enable fast software iteration, ensure vehicle safety and trustworthiness, and address other challenges that consumers might face. These are what it means to "build a better vehicle" in the era of intelligent electric vehicles.

In the future, the market for new intelligent connected vehicle components will be worth trillions of dollars. Huawei hopes to bring its decades of ICT expertise to the automotive industry **as a provider of new components for intelligent connected vehicles.** As vehicles become more electric and intelligent, Huawei wants to **help carmakers build better vehicles.**

# Contents

03

## Technology projection: New components will drive sustained innovation in intelligent vehicles 18



01

# Macro trends: Cross-sector collaboration for shared success

The automotive industry is changing rapidly, and so are its products and industry landscape. As ICT is integrated into the automotive industry at an increasing speed, cross-industry collaboration becomes increasingly important. Huawei is committed to researching basic ICT technologies and bringing its ICT expertise to the automotive industry through partnerships with carmakers.

## 1.1 Faster industry upgrade brings a bright future for electric and intelligent vehicles

### 1.1.1 Favorable policies create new opportunities for electric and intelligent vehicles

Carbon neutrality has become a globally recognized mission. Many countries are racing to become carbon neutral. The transportation industry plays a key role in this process as it presents huge opportunities to conserve energy and cut emissions. This in turn makes the NEV industry very promising.

The EU has tightened carbon emissions standards and increased penalties, significantly driving up compliance costs for traditional fossil fuel vehicles. As part of its broader efforts to stimulate the NEV market, the EU also now offers purchasing incentives and tax benefits for those who buy electric vehicles. Similarly, the US has released a 2030 plan for electric vehicles, and is currently accelerating the deployment of charging infrastructure.

In China, low-carbon vehicles are playing a key role in the government's carbon peak and carbon neutrality ambitions. The transportation industry – the automotive industry in particular – is setting out a roadmap for reaching its carbon peak and carbon neutrality goals. The Chinese government has also tightened its dual-credit policy, which assesses carmakers according to their efforts to cut fuel consumption and produce NEVs. This policy has yielded positive results and stimulated significant investment into NEVs. China's big push for the electrification of public transportation is also driving NEV sales.

Many governments are fostering positive policies and regulatory environments for their intelligent automotive industry through independent research and policy guidelines. China, for example, has introduced many policies on intelligent connected vehicles in recent years, including specifications for vehicle quality and safety, functional safety, cyber security, data security, and road tests, which has facilitated the construction of demonstration zones for new products. Looking ahead, standards and regulation for intelligent vehicles will continue to develop in line with new technological advances. This kind of regulatory environment is critical to commercializing mature technologies and promoting sustainable growth in the intelligent automotive industry.

China's New Infrastructure Plan has laid out the requirements for enhancing the top-level designs for information, convergence, and innovation infrastructure, while improving underlying infrastructure like 5G, big data centers, artificial intelligence (AI), charging infrastructure, and integrated vehicle-road-cloud for NEVs. China is also promoting a new development model – the dual circulation model – which aims to create a powerful domestic market while promoting consumption and creating more space for investment. This new model will allow Chinese carmakers to compete globally while also increasing internal circulation by stimulating domestic demand.

### 1.1.2 ICT accelerates upgrades in the intelligent automotive industry

The new vehicle lifecycle sees core functions continuously upgraded. This means vehicles need more sophisticated electrical/electronic (E/E) architecture, system on chip (SoC) computing power, software and data use, and cyber security. This is changing the automotive industry at a fundamental level, as it embraces more advanced ICT technologies and solutions.

Moore's law has long been the golden rule for the semiconductor industry, profoundly influencing the development of PCs, digitalization, Internet, and more for over 50 years. The next 10 years will continue to see Moore's law governing the development of computing power required for intelligent vehicles. Huawei predicts that that a vehicle will require more than 5,000 trillion operations per second (TOPS) of computing power by 2030 to enable the further advancement of telematics applications like intelligent driving, intelligent cockpits, and extended reality (e.g., augmented reality [AR] and virtual reality [VR]).

5G (including 5G-A) promises high bandwidth, low latency, and ultra reliability, making it possible to meet the essential connectivity requirements of intelligent vehicles. By 2030, intelligent digital platforms, powered by emerging technologies like 5G, cloud, big data, Internet of things (IoT), and optical technologies, will connect the physical and digital worlds for vehicles. This will greatly drive innovation and upgrade in the automotive industry.

### 1.1.3 Changes in supply: Vehicle sales will surpass those of fossil fuel vehicles by 2030

Huawei predicts that NEVs will account for 82% of China's total new vehicle sales in 2030. Electric vehicles will become much cheaper than fossil-fuel-powered vehicles. As charging and battery-swapping become more efficient, electric vehicles will be able to drive for one kilometer after just one second of charging. In addition, as more people switch to electric vehicles and China's New Infrastructure initiative is implemented, the number of charging and battery-swapping stations will continue to increase. This will make it easier for electric-vehicle drivers to travel longer distances without worrying about running out of power.

Carmakers both in and outside China are accelerating the deployment of NEVs. By 2030, Volvo, Bentley, Jaguar, BYD, and Geely will be exclusively manufacturing NEVs. Volkswagen and BMW have committed to making at least 50% of their new vehicles NEVs by 2030.

### 1.1.4 Changes in demand: Stimulating the intelligent electric vehicle market

User demand for intelligent electric vehicles is on the rise. As electric vehicles will soon cost much less and become more convenient, China is set to benefit greatly from its large consumer market. This gives the nation a base from which it can further develop intelligent electric vehicles. The Chinese market has long been less saturated than more developed markets, and Chinese consumers are also proving to be more receptive to new developments like electric vehicles and intelligent driving.

Due to China's constantly changing demographics, income structure, and consumer purchasing behavior, its consumption structure is also changing at a rapid pace. China will soon become a middle- or high-income economy, and consumption is expected to continue to grow as per capita GDP and household disposable income increases. Consumer distribution is also changing, which means demand is becoming more diversified. China's Post-2000 generation, a Gen Z analogue of true Internet natives, are big fans of new technology and individual expression. They represent a huge engine for growth in domestic consumption. A sliver economy – all economic activities linked to China's older age groups – is also emerging. The two- and three- child policy is also reshaping consumer demand.

Such changes in consumption structure will also affect car consumption, both directly and indirectly pushing China's vehicle market from relying on traditional models to digital models, from commodity-oriented to experience-driven, and from valuing commonality to valuing individuality.

## 1.2 Changes in product attributes: Reshaping the automotive value chain

### 1.2.1 Key vehicle differentiators: From powertrain and chassis systems to intelligence

As vehicles' power systems become electric, their powertrain and chassis systems will gradually become more standardized. This makes intelligent cockpits, intelligent driving, and other intelligent functions the key differentiators of vehicles. The intelligence level of vehicle cockpits and driving systems will become key factors in users' purchasing decisions. Over-the-air (OTA) updates will be used to deliver superior user experiences and further increase users' uptake of intelligent functions.

Such shifts also present an opportunity for carmakers to expand their hold on the vehicle market. As the laws, regulations, and policies on intelligent vehicles continue to improve and intelligent driving technologies become mature, autonomous driving will enter large-scale commercial use via robotaxis and closed or semi-closed low-speed driving scenarios by 2030 before gradually being implemented in passenger vehicles. In addition, human-machine interaction technologies will continue to advance and the intelligent cockpit application ecosystem will continue to improve, making vehicles an intelligent mobile "third space" outside of home and workplace.

### 1.2.2 A wider industry: From automotive products to all-scenario mobility services

5G (including 5G-A), IoT, AI, edge computing, and low-carbon technologies are still rapidly developing, converging, and iterating. They are accelerating the automotive industry's CASE transition. How carmakers will commercialize intelligent vehicles in specific scenarios is becoming increasingly clear.

As intelligent driving technologies continue to improve in different market segments, scenario-specific autonomous driving applications will be become more widely adopted. New forms of autonomous vehicles will emerge for specific scenarios, and the connection between transportation tools across different scenarios will become more seamless. Autonomous mobility services will appear in every link of people's travel. This will fundamentally change how people travel, how people interact with transportation tools, and how transportation tools interact with each other, greatly improving "mobility-as-a-service".

People's basic mobility needs have gradually changed from owning different transportation tools for different scenarios to using integrated mobility solutions for complex mobility scenarios. Many third-party application developers are mobilizing industry resources to develop new service applications for different scenarios, with the purpose of seamlessly connecting different transportation tools and providing end-to-end intelligent mobility services for users. These mobility solutions and services are providing new revenue streams for the automotive industry.

### 1.2.3 New profit models: From hardware to software and services

As key differentiators for vehicles change and the automotive industry's reach expands, individual intelligent vehicles will become platforms for continuous value creation. This will reshape the automotive industry's standard business model and value distribution pattern.

Carmakers have long profited from one-off deals – multiplying the unit price by the total number of vehicles or hardware units they sell. Software-defined vehicles will turn software and services into new revenue streams for carmakers, and their profits will be determined by software fees and car parc. Moving forward, data and software will support ongoing, OTA iteration of vehicle functions by allowing carmakers to remotely repair and upgrade products, and improve user experience. This will give users more flexible and operable service models, driving a shift in the industry from product-centered operations to user-centered operations. These revenue streams will also be more stable for carmakers.

The automotive industry as a whole will focus on the new operation and charging model created by intelligent driving as it greatly expands profits for carmakers. In addition, software-defined vehicles will reshape the value chain, and creating more opportunities to unlock value. This will attract more third-party developers and innovators to invest in the intelligent automotive industry, which will help improve the intelligent connected vehicle ecosystem and build a positive cycle of value creation.

## 1.3 Cross-sector collaboration will define the new industry landscape

### 1.3.1 Carmakers and tech companies work together to maximize their strengths

Intelligent vehicles are the product of multiple industries, built on the integration of core digital technologies (e.g., ICT, software, big data, and AI) and traditional mechanical technologies. Emerging carmakers are the frontrunners in the first phase of CASE journey. However, other carmakers are also joining the trend and beginning to improve their core competencies in software, electronics, and big data.

Auto underbody solutions are slowly standardized, becoming a shared platform on which other industries can grow. Tech companies, from consumer electronics manufacturers to Internet companies, are taking advantage of this trend and expanding into the automotive industry either on their own or through alliances. These companies have large amounts of capital, strong experience in ICT, significant technological innovation capabilities, and huge brand recognition. Their entry into the industry is driving rapid development in intelligent connected vehicles and pushing the automotive industry towards CASE 2.0.

The automotive industry has been around for over 100 years, and carmakers have emerged as leaders in manufacturing, quality control, safety, and reliability capabilities. Tech companies, on the other hand, have amassed extensive experience and advantages in intelligent technology applications, such as AI algorithms and big data. Software-defined vehicles will significantly change how companies capture value, serve their customers, and build their talent mix. To meet increasing user requirements, all companies along the value chain should become more agile and adapt to this new environment.

Software and hardware will decouple and general platformization and standardization will continue.

This means the only way forward will be to foster a more open supply chain system and adopt more flexible vehicle models. Carmakers and tech companies will need to maximize their respective strengths, while also relying on cross-industry partnerships to find new and innovative ways to achieve business and social value.

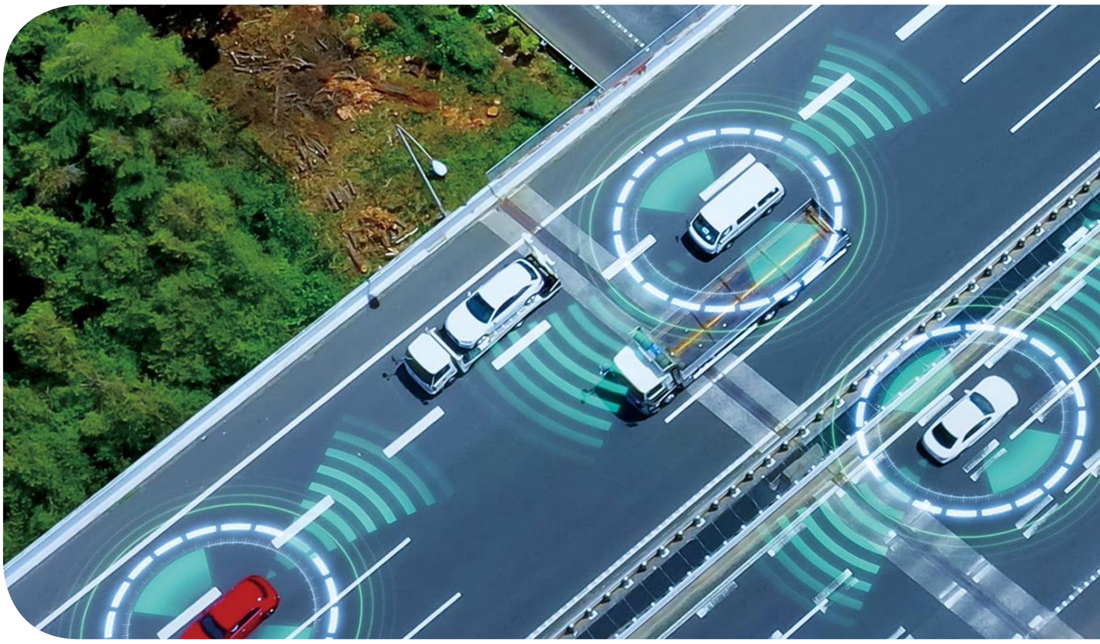
### 1.3.2 ICT is key to better travel experiences in the growing mobility sector

As the automotive industry's reach expands, demand for transportation and mobility services in new market segments will continue to increase. This will drive exponential growth in the forms and quantity of vehicles, as well as their related infrastructure. More and more traditional vendors are announcing transition plans to become "mobility solution providers", intending to tap into this huge new market. Different players will have different roles to play.

Mobility solution providers provide end-to-end solutions to meet user requirements across different mobility scenarios and control user traffic. Operators in closed scenarios understand operation requirements, customize the form factors of vehicles, and deploy infrastructure in closed scenarios. Carmakers use their existing manufacturing platforms and supply chains to manufacture these vehicles. Tech companies provide solutions like intelligent software and hardware, intelligent driving, and cockpit connectivity and control. Third-party ecosystem developers provide massive numbers of apps and deliver seamless travel experiences to users.

As the forms and quantity of vehicles continue to grow alongside their related infrastructure, we need to connect the vehicles and infrastructure in specific scenarios. Scheduling and connection across different scenarios, data sharing between different vehicles, and scenario-based smart service applications will need to be hosted on a cloud-based "brain". ICT will play a key role in connecting these disparate points and enabling scenario-based digital service sharing.

02



# New scenarios: Bringing intelligence to every vehicle

As digital technologies are widely adopted and carbon neutrality has become a globally recognized mission, it is becoming an obvious trend that vehicles will become more electric and intelligent. Bringing intelligence to every vehicle will empower intelligent driving, intelligent spaces, intelligent services, and intelligent operations. This will allow for safer and more efficient transportation, greener and more convenient travel, more fun and intelligent lifestyles, and more efficient and lower-carbon operations.

## 2.1 Intelligent driving: Safer, smoother, and more efficient travel experiences

Intelligent driving can be categorized into six levels by automation, ranging from 0 to 5. Level 0 (L0) refers to traditional human driving with no automation. L1 offers AI-assisted driving with low automation, meaning that continuous driver assistance is required; L2 offers a moderate level of driving automation; L3 provides conditional driving automation; L4 delivers a high level of driving automation; and L5 represents full driving automation, which means that the vehicle can

be entirely controlled by the AI system with no human operation needed. Intelligent driving can be applied to almost any kind of road or area that meets the necessary level of automation. L2 intelligent driving is already available in passenger cars, providing consumers with a safer and smarter driving experience. L3 and higher levels of intelligent driving are still undergoing testing. L4 and L5 intelligent driving will first be seen on highways, campuses, and other closed roads, and will gradually expand to public roads such as streets in urban areas. We believe that advanced intelligent driving will revolutionize mobility and our entire society.

In 2030, robotaxi services provided by self-driving fleets are expected to cut labor costs and provide 24/7 mobility services that are more flexible and affordable.

Intelligent driving technologies will be integrated into existing modes of transport to provide safe, efficient, and affordable mobility service solutions that meet different travel needs and deliver the best possible experience. Mobility resources will be centrally managed and data will be shared in real time, making it possible to build an end-to-end, point-to-point, and door-to-door mobility network. This will in turn help maximize the use of all available mobility resources.

When a user plans a trip, a cloud-based brain weighs up all the possibilities and, based on real-time awareness of the traffic situation, offers the optimal route and mode of transport. Diverse mobility resources will allow users to enjoy efficient, green, and safe travel while maintaining a dynamic balance in urban transportation capacity, contributing to sustainable urban development.

## 2.2 Intelligent spaces: From a flexible mobile space to an intelligent living space that integrates the virtual and physical worlds

Vehicles are no longer just a tool for transport. Their relationships with people and with their surroundings are changing dramatically.

Advanced intelligent driving technology will free commuters to enjoy work, study, entertainment, and much more within their vehicles. When vehicles serve as mobile offices – or even mobile living rooms – it will change how people think about their daily commute.

Powered by human-machine interaction, in-vehicle optical technologies, and immersive AR/VR technologies, intelligent cockpits will become multi-functional units. People will find themselves spending more time in their vehicles even when they do not want to go anywhere. For example, it will not be uncommon to see people sitting in parked vehicles watching movies.

The way we interact with our vehicles is about to experience three major changes. First, a cockpit will no longer be a combination of a steering wheel, an instrument panel, and a screen; it will integrate the virtual and physical worlds. Features such as voice control, facial recognition, and gesture interaction will make interactions simpler, more natural, and more efficient. What's more, it will not be long until brain-computer interfaces start seeing commercial application. Second, our vehicles will no longer passively await our instructions; they will intelligently anticipate our needs. Technologies such as AI, biometric recognition, emotion perception, and vital sign monitoring will allow vehicles to better understand drivers' behavior, habits, and thinking, and become close partners that truly understand drivers' needs. Third, in-vehicle optical technologies will offer a richer spatial optical experience, and AR/VR technologies will further transcend the barriers of time and space. Such an immersive experience will drive broader and richer vehicle applications in both mobile and static scenarios.

An intelligent vehicle will become a truly intelligent space that integrates the physical and virtual worlds.

(1) Driving: The combination of in-vehicle sensors and wearable devices can accurately monitor drivers' health indicators, recognize fatigue, and send timely reminders to ensure safe driving.

(2) Entertainment: Passengers will be able to have true-to-life experiences of concerts and sports events without having to be there in person. A cinema will no longer be the best place to watch movies. AR technology will make gaming more immersive. Vehicles can become a personal entertainment space, a private cinema, an outdoor cinema, and a preferred place to play games with friends.

(3) Mobile office: Seats can be adjusted and rotated and windows can be used as large projection screens. A conferencing stream on a smartphone can be easily transferred to the vehicle, and the shielding function of the vehicle's sound zone ensures the privacy of the conference. Vehicles will become mobile offices, allowing professionals to get work done on the way to the airport, a restaurant, or their homes.

(4) Social networking: Drivers will not miss the beautiful scenery outside the window. Cameras mounted on the outside of the vehicle can be used to record, edit, and share beautiful moments. Getting stuck in a traffic jam no longer has to be boring. You can watch movies, play games, and make friends with nearby drivers using the head unit. AR/VR brings your friends within easy reach. With separate sound zones created within your vehicle, you will even be able to keep conversations private from other people in the vehicle.

## 2.3 Intelligent services: More intelligent scenario-based services

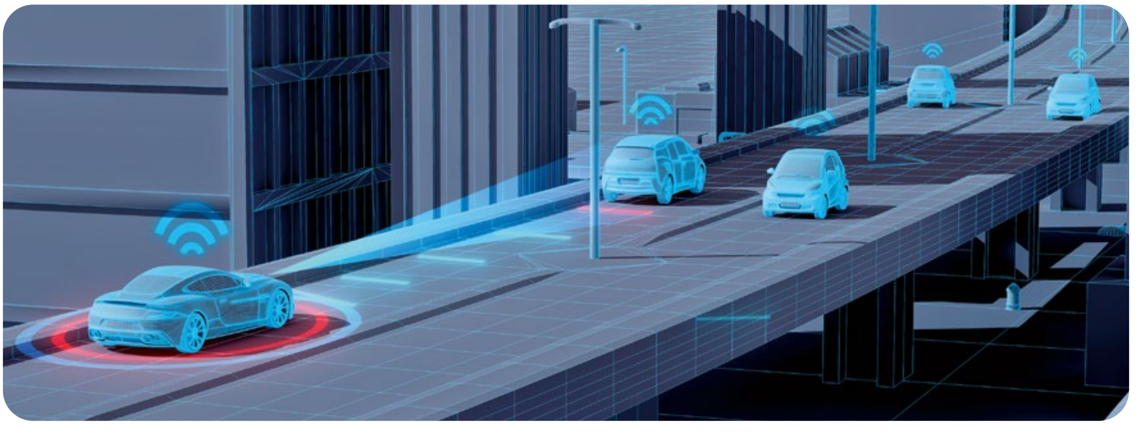
Digitalization is reshaping the world, and as a result, consumption patterns will change dramatically over the next decade. Services in all kinds of industries will be available online and become more customized, personalized, responsive, and scenario-based. As digital technologies are deeply integrated with vehicles, services will be intelligently and rapidly pushed to users based on the scenario they are in. This will be achieved in three ways.

First, as vehicles become more intelligent, interactions between users and vehicles will inform the services to be provided. Intelligent algorithms can identify, analyze, and understand users' interactions, predict their behavior based on their basic information and historical preferences, and provide the right services. Intelligent vehicles will continuously improve their understanding of users, in order to deliver better services.

Second, intelligent vehicles will make it possible to efficiently and accurately identify user needs in real time. By identifying and analyzing vehicle data, location information, and surrounding environments, intelligent systems can determine what scenarios users are in, proactively predict user needs, and provide the right services.

Third, brand-new, interconnected operating systems (OSs) can create more service scenarios, giving rise to an application ecosystem that is based on new modes of interaction. As the intelligent world approaches and the digital economy develops, a richer digital ecosystem is emerging to support all scenarios. In the connected world, more services will be provided by intelligent vehicles. The scenario-driven functions and services offered by connected vehicles will become increasingly intelligent, efficient, and convenient.

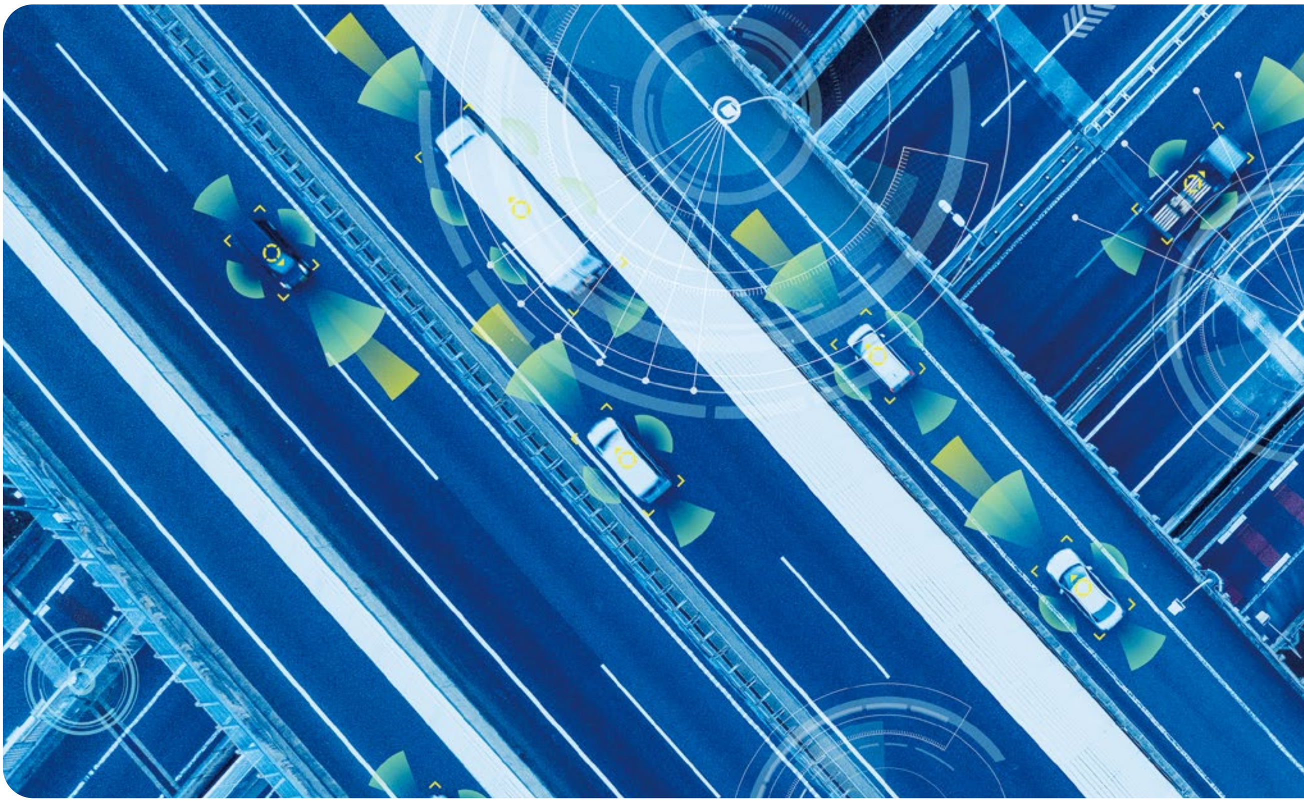
We can even imagine a situation in which a group of people would want a pizza while driving across town. Mobility-as-a-service providers will provide a shared vehicle that perfectly matches the passengers' preferences, select a high-rated pizzeria located along the planned route, and order the pizza in advance. The restaurant will then prepare the food, which will be collected by a drone. When the vehicle arrives at the designated handover location, its sunroof will automatically open and the drone will lower the food inside. This is a level of service that can only be achieved when every part of the process is seamlessly connected.



## 2.4 Intelligent operations: Autonomous driving is expected to be applied in commercial vehicles first, boosting the productivity of intelligent operations

Commercial vehicles are important tools for transport and the functioning of modern society. Their evolution into intelligent autonomous vehicles can help achieve the goal of carbon neutrality and boost work and operation efficiency while contributing to a more mature intelligent vehicle ecosystem. By 2030, commercial autonomous vehicles will be used on trunk lines and public roads in addition to closed areas and dedicated roads. This will make intelligent operations a reality and greatly increase productivity.

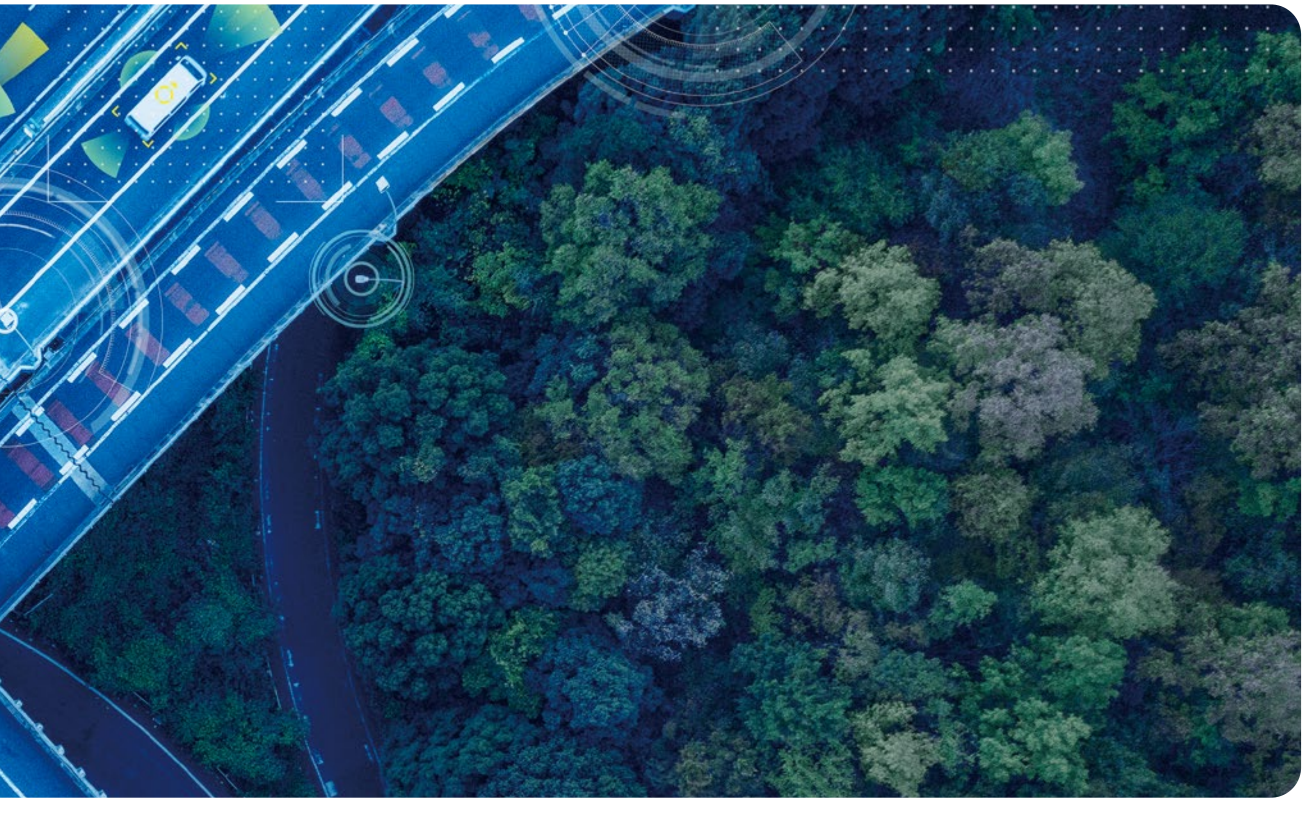
When autonomous vehicles are operated in a closed area, it is possible to enumerate all the scenarios in which a vehicle might find itself and foresee potential emergencies. For this reason, commercial autonomous vehicles will find their first large-scale commercial applications to be in closed areas like ports, mines, farms, campuses, airports, and closed scenic spots. In these areas, intelligent commercial vehicle technologies will not only be applied to transport vehicles; they will also be integrated with operations management systems to build unmanned manufacturing systems where autonomous driving applications have been integrated into the core production systems that support transportation and distribution. This means intelligent vehicle technologies will be commercially used on a large scale.

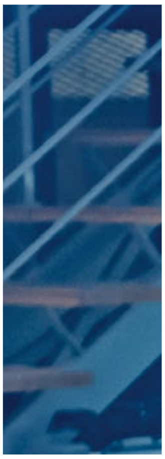


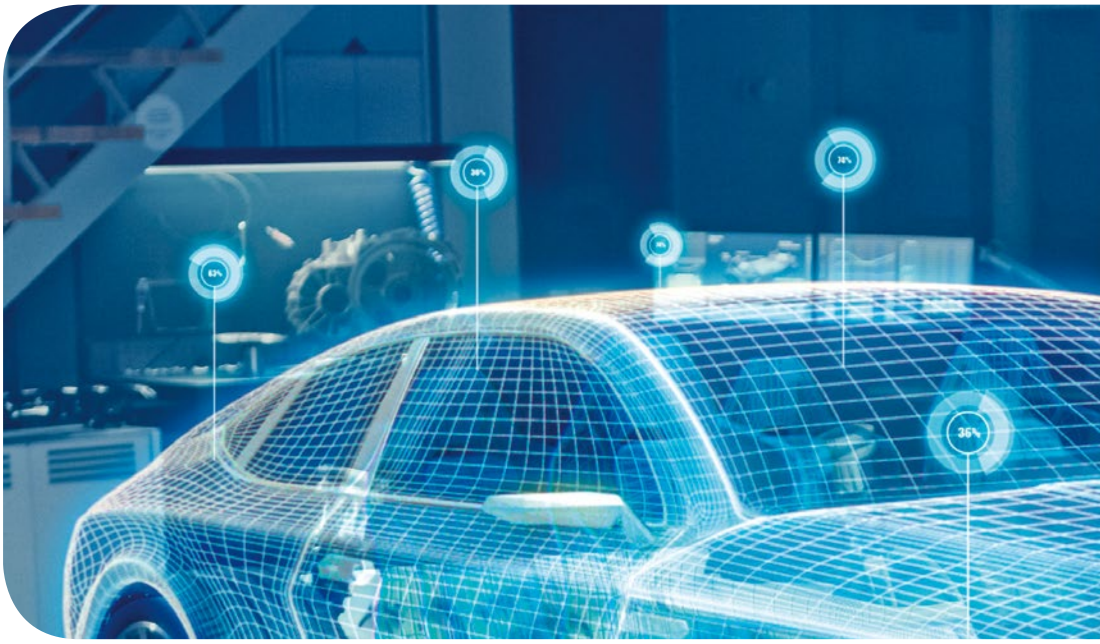
By 2030, vehicle-road-cloud collaboration solutions will make it possible for multiple autonomous vehicles to collaborate in closed areas, which means autonomous driving has the potential to be commercialized in vertical industries. Service capabilities, like comprehensive environment perception, global resource scheduling, dynamic service mapping, multi-vehicle cooperative driving, lane-level route planning, coordinated signal control, and service simulation testing, will further streamline service processes, make the collaboration between multiple autonomous vehicles a reality, and increase scenario-based operation and transportation efficiency. All of these will help cut costs and boost productivity.

Cloud scheduling will be critical to the service management and scheduling of autonomous vehicles. When intelligent commercial vehicles are used in closed areas, operation managers will use the vehicle cloud control management system to schedule and monitor those vehicles, and support service and safety management using end-to-end large models. In a port, for example, the operation control platform of an intelligent horizontal transport system will be connected to the terminal operating system (TOS), which means the scheduling of autonomous container trucks will be fully integrated into the automatic port scheduling system. This level of integration will help fully automate port operations.

As road infrastructure is upgraded over the next decade, on trunk lines, commercial vehicles will gradually shift from assisted driving systems to fully autonomous driving. As electric vehicles are widely used in urban short-distance transportation, and roadside network infrastructure becomes more intelligent, the penetration rate of intelligent commercial vehicles is expected to rise sharply on more complex public roads, including urban roads. Building on the basic capabilities of autonomous vehicles and their potential commercial application, carmakers can work with ecosystem partners to build more viable intelligent driving applications to overcome the challenging scenarios faced by commercial vehicles.







03

# Technology projection: New components will drive sustained innovation in intelligent vehicles

## 3.1 Evolving to a central computing and communications architecture for software-defined vehicles

Today, most vehicles still use a decentralized E/E architecture. Under this architecture, each separate function has an independent controller, so a vehicle has almost 100 controllers and over three kilometers of wiring. This makes vehicles costly and heavy, and difficult to automate vehicle assembly. In addition, electronic control units (ECUs) are often developed by different vendors, meaning they have inconsistent standards which carmakers struggle to develop new functions or perform OTA updates. In the future, intelligent connected vehicles will be even more complex. The volume of data collected by vehicle-mounted sensors will dramatically increase. This will raise the bar for real-time data transfer and data processing. These trends mean that vehicles' E/E architecture must evolve.

With the rapid development of digital and intelligent technologies, vehicle functions are becoming more integrated and centralized. There is a widespread understanding in the automotive industry that a decentralized architecture is no longer viable, and that it must evolve first into cross-domain architecture, and eventually into a single central computing platform. Vehicle functions will become applications loaded onto a central processor so that they can share a single set of sensors and actuators. Components will gradually become more standardized. This will help reduce the cost and complexity of new function development in the long run. Meanwhile, domain controllers will evolve through the addition of new software features. By 2030, the

E/E architecture of vehicles will be a computing and communications architecture that consists of a central computing platform, zonal control, and high-bandwidth in-vehicle communications.

### 3.1.1 High-performance central computing platforms power software-defined vehicles

Central computing plus zonal control, either in a hub-and-spokes or ring model, offers architecture stability and functional scalability. Within this architecture, new external components can easily be added from the gateway of the nearest zone, and with pluggable hardware, computing capacity can be upgraded as necessary, enabling simple iteration and upgrades of application software on the central computing platform.

The mobility scenarios are complex and subject to frequent change. New functions such as intelligent cockpits, intelligent driving, and vehicle control are constantly being developed. A high-performance central computing platform is required to support them. This platform can perform several thousand TOPS. It must be based on a powerful SoC with a vehicle-specific operating system, middleware, toolchain, and a centralized architecture. Such platforms will offer a stable architecture for software-defined vehicles, while still allowing room for smooth evolution. The chassis, powertrain, cockpit, and intelligent driving system will each place different demands on the central computing platform in terms of security, latency, dynamic response, and the supporting software ecosystem. A high-performance in-vehicle central computing platform will use hardware virtualization and a central functional safety framework, as well as AI algorithms to deliver the necessary levels of security and ensure that hardware resources are available as required for each domain. The technologies required include:

- **High capacity processors:** SoC will deliver the thousands of TOPS of computing power required by the vehicle, including the chassis, powertrain, cockpit, and intelligent driving system. Key technologies needed to build SoCs include computing in memory and trustworthiness and functional safety islands.

- **High-speed concurrent processing for guaranteed low latency:** High bandwidth is only part of low latency; an even more crucial factor is the capacity to process data in real time. High-speed concurrent processing enables central systems to simultaneously receive data from multiple sources. It prevents data surges, and will enable the vehicle to handle the data generated by an ever-growing number of apps and the ever-increasing demands on the system.

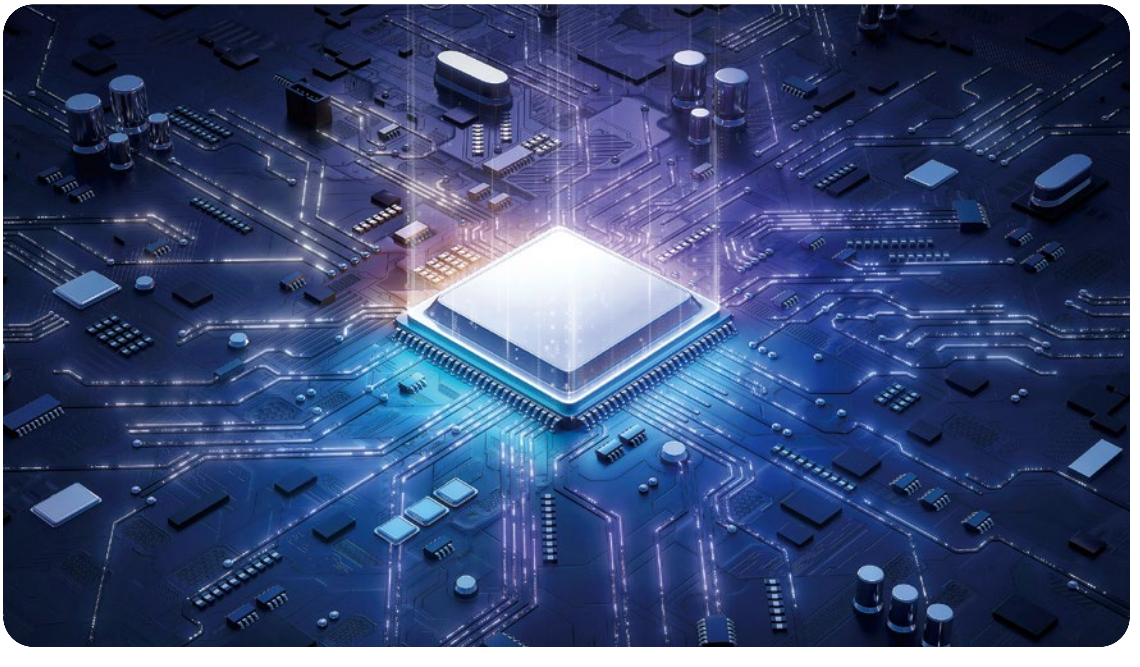
- **Hypervisor secure partitioning of hardware:** The Hypervisor allows one physical server to function as multiple virtual servers and delivers customized functional safety for the different domains of a vehicle. AI engines monitor and forecast the workloads for different virtual partitions and dynamically schedule hardware resources, thereby achieving secure partitioning and load balancing.

- **Inter-app freedom from interference (FFI):** The Hypervisor partitioning function delivers a secure silo of resources for the applications, communications mechanisms, OS, and hardware accelerators. Within the processors, a dedicated safety island provides a safety system that reaches the standards of 3-Level Safety Monitoring. The safety island's intelligent fail safe and fail operational functions enable coordination of the safety responses with other vehicle functions.

Building on a powerful central computing platform, the software-defined vehicle sector will concentrate efforts on agile development and real-time release of new functions to deliver the diverse experiences that users will demand of mobility.

### 3.1.2 In-vehicle, high-bandwidth, and multi-protocol networks for software-defined vehicles

The centralization of vehicle functions will drive substantial changes in the access approach and method used for communications. Vehicles will be divided into a number of zones, each with its own gateway. Zones will be defined by function, physical position, criticality, and safety. Sensors and



actuators will be connected to the nearest access points to transfer data to the backbone network and then to the central computing platform. This approach will reduce the total amount of wiring required, and support the development of new functions. Sensors will no longer be limited to a single function, and actuators will not be bound to a directly connected controller.

By 2030, multiple access protocols will be in concurrent use. Local Interconnect Network (LIN), Single Edge Nibble Transmission (SENT), and Peripheral Sensor Interface (PSI5), though slow, will still be used because of their cost advantages. But ultra-high-definition (UHD) cameras, 4D imaging radars, and high-resolution lidars will require much more bandwidth. According to Huawei, in-vehicle network transmission speed per link will exceed 100 Gbps by 2030. Vehicle Ethernet will become standard, and optical technologies will be widely deployed in vehicles because of their high bandwidth, light weight, insensitivity to electromagnetic interference, and low cost.

Conventional communications technologies are predominantly signal-oriented, using protocols such as Controller Area Network (CAN) and LIN. This approach deeply integrates communications with vehicle component deployment and routing, creating a problem: A change of the transmit/receive nodes will lead to changes of all nodes along the route.

Ethernet communications are service-oriented and can effectively address this problem. When the transmit/receive nodes are changed, no other nodes on the route will be changed. This will:

Decouple communications from vehicle component deployment and routing, making it easier to scale up.

- Make interfaces standardized and contractual.
- Achieve interconnectivity of in-vehicle services.

Once these technologies are realized, a point-to-point backbone network for software-defined vehicles can be created. The technologies that would be required for this include:

- **High bandwidth copper communications:** Signal attenuation is significant in copper cable over even short distances. Enhanced coding and algorithms will be required for intelligent power distribution and high-speed, high-bandwidth Ethernet transmission (10 Gbps to 25 Gbps). This will provide the high bandwidth required by in-vehicle applications for backbone networks.

- **In-vehicle fiber communications:** For bandwidths over 25 Gbps, copper is no longer an option, because of cost, engineering, and electromagnetic compatibility (EMC) challenges. This makes fiber an excellent solution. Fiber is cost-effective, light-weight, and is not affected by EMC issues. If solutions can be found for vehicle-related problems around temperature, vibration, and service life, optical fiber communications will be widely used in in-vehicle applications and support the evolution to higher-bandwidth communications.

- **Deterministic latency:** Real-time communications protocol stacks as well as time-sensitive network (TSN) protocol suites at the transport layer will need to ensure end-to-end deterministic latency at the microsecond level for vehicles. Transmission policies can be designed for specific service scenarios to meet the needs of different communications functions.

### 3.1.3 New wireless communication technologies for high-quality in-vehicle connectivity

By 2030, in-vehicle wireless communications will remove all barriers to connection within the vehicle. Any component will be able to connect using sliced wireless capabilities, so that new vehicle applications can call on them as needed. A new air interface will be required to deliver extremely low latencies of less than 20 microseconds for unidirectional transmission, five nines reliability, synchronization accuracy within one microsecond, up to hundreds of connections


and concurrent service provisioning, plus end-to-end cyber security. This is the level of quality required for vehicle connectivity. Service-specific resource management mechanisms will support in-vehicle wireless connections. Wireless slicing will make many things possible, like lossless audio streaming, UHD video apps, and ultra-low-latency interactive games. By taking the collaboration of multiple information domains to the next level, the interior of a vehicle will become an infotainment center offering immersive sound, video, images, and even light applications and sensations.

In-vehicle wireless communications technologies will transform the in-vehicle networking and enable simple upgrades of various vehicle modules. The use of wireless in place of wired connections will address design, production, assembly, and maintenance challenges created by vehicle wiring, and put an end to the highly-coupled architecture that wired connections create. In its place will be a platform + modular communications architecture, which can be replicated across many different models of vehicle. The flexibility of wireless communications allows for a range of different architectures, providing standardized wireless access interfaces. When vehicle-mounted devices become modular, standardized, and plug-and-play, the costs of vehicle development will fall, and smooth and ongoing evolution of the foundational platform will be supported.

With its extensive experience in wireless communications, Huawei will develop the next-generation wireless short-range communication solution to further improve the in-vehicle communications architecture and create greater value for customers.

### 3.1.4 Decoupled, service-oriented architectures for software-defined vehicles

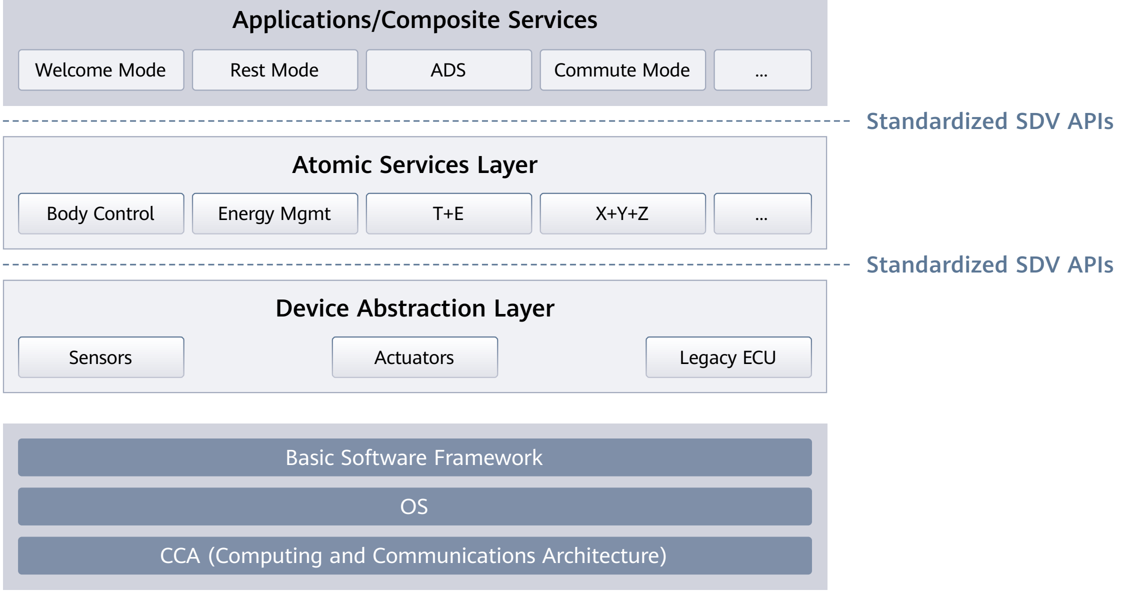
Vehicles are now digital, intelligent products. User values, preferences, and needs no longer require vehicles to be a tool for transport; now, as with the phone, users want personalized experiences. Smart technologies, personalized features, and user experience are now the key factors guiding consumers' vehicle choices. At the same time, hardware and the associated technologies that go into vehicles are becoming less easily distinguishable, and carmakers are looking to software and algorithms to create competitive advantages and deliver more value. All industry players are now pursuing software-defined vehicles.

Being software-defined means that software is a key feature in a vehicle's concept, development, testing, sales, and after-sales services. It also means that the entire process will be constantly refined, with refreshed experiences and continuous value creation. A key feature of these vehicles is the decoupling of the software from the hardware. In terms of physical delivery, that means that the hardware and software are delivered separately. In essence, vehicle functionality can be expanded, software can be replicable and upgraded, and hardware can be swapped out or scaled up.

OTA updates can keep software at peak performance; plug-and-play components can be freely added to expand functionality. Flexible, scalable software-defined vehicle platforms will be used to help intelligent vehicles meet the challenges of complex use cases and growing demands on functionality. A service-oriented architecture (SOA), with decoupled layers of software, has also been recognized as the best option for general software architecture. To realize this architecture, the system will need to add a device abstraction layer and a layer of atomic services.

Atomic services provide basic service capabilities, enabling upper-level applications to be replicable and portable across different vehicle models. The device abstraction layer normalizes the capabilities of underlying hardware, so that software can be decoupled from the hardware, enabling plug-and-play replacement and upgrades of hardware modules.

Services will be decoupled from system design to create basic service units. Each separate hardware component will be abstracted into a standardized service component, and each service component will provide one atomized function. These can be called on recursively and combined to produce complex functions, thus reusing the software as much as possible. Ecosystem partners can develop vehicle applications using platform components and standardized APIs that will then be managed by the vehicle platform. The platform will carry out app authentication, granting of access privileges, API call, security checks, and emergency management. Users will be able to choose vehicle apps the same way they do for their mobile phones. This will give users access to new vehicle experiences at very low cost: same vehicle, but a new journey every day! Developers, in turn, will benefit from consumers downloading their apps.



## 3.2 Intelligent driving: Making autonomous driving a commercial reality faster

Huawei uses sensor fusion technology to deliver superior safety in intelligent driving. Different types of sensors, including lidars, mmWave radars, ultrasonic radars, and cameras, are used to support the fusion and reconstruction of multi-dimensional environmental information. By continuously improving the sensing network, Huawei has eliminated the need for high-definition (HD) maps in vehicles. Intelligent driving, powered by autonomous sensing and navigation maps, is being widely adopted, and it enables vehicles to drive on any road with ease. The rapid development of AI is speeding up the deployment of end-to-end intelligent driving networks, which will soon be widely used in commercial settings. The continual and rapid iteration of these networks will ultimately enable a human-like driving experience even on roads with complex conditions. Looking ahead, Huawei's Global Industry Vision (GIV) predicts that by 2030, a staggering 90% of passenger vehicles in China will be equipped with L2 intelligent driving systems and 30% will be capable of L3 intelligent driving.

### 3.2.1 Continuous algorithm upgrades and digital materials for better user experience and autonomous driving

There are still many technical challenges that need to be overcome if we want to make autonomous driving a commercial reality. Given the complexity of corner cases in real-road conditions and how difficult it is to collect long-tail data, perception algorithms, planning and control algorithms, and simulation and training algorithms will be crucial for autonomous driving experience.

If we look at sensor fusion algorithms, there are many technologies that determine a vehicle's ability to perceive and understand its surroundings. These technologies include a vision-based perception framework, lidar point cloud generation and enhancement, lane-level traffic light processing in complex light environments, flashing and fuzzy light source processing, color processing, light source luminance differences, overlapping object recognition, and vehicle interaction prediction. Huawei's GIV predicts that by 2030, the algorithms will achieve a general object detection accuracy of over 99% which further enhances the vehicle's perception, and this goes hand in hand with their human-like understanding capabilities that enable them to understand complex traffic flows.

As perception and prediction both involve an element of uncertainty, the industry needs to further develop core planning and control algorithms that involve multi-object and multi-stage game-theory decision making, motion planning, human-like decision making and planning models focused on risky and complex interactions, and the identification and automatic labeling of key scenarios based on massive amounts of data. According to Huawei's GIV, these algorithms are expected to have an end-to-end response time of 400 milliseconds or less by 2030, which is twice as fast as that of humans.

Intelligent driving algorithms will evolve towards an end-to-end large-scale model which will enable the creation of a lossless information transmission channel that connects the sensing system to the planning and control system. By utilizing NN-based collaborative sensing, fusion, prediction, decision-making, and planning, intelligent vehicles will be able to drive just as well as humans, and ten times more safely. Huawei's GIV predicts that by 2030, this will increase the miles per intervention (MPI) to 621 miles (equivalent to 1000 km), reflecting the improved safety, comfort, and efficiency of intelligent driving.

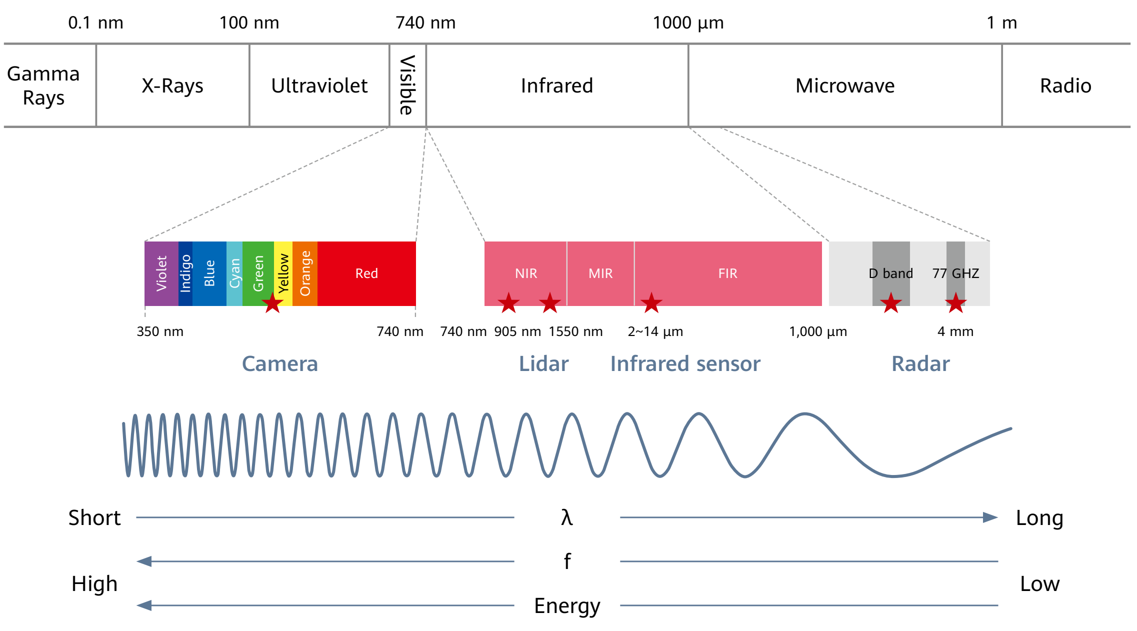
Data is essential for rapid algorithm iteration, and virtual simulation systems offer a cost-effective and efficient way to obtain it. A comprehensive, high-fidelity simulation system can provide a constant supply of digital materials to facilitate the iteration of intelligent driving algorithms. Huawei's GIV predicts that by 2030, such a system will be capable of simulating a daily driving distance of 6.21 billion miles (equivalent to 10 billion km), and this requires a model for the various interactions between different traffic participants in many different large-scale simulation scenarios. With this simulation system, the end-to-end large-model algorithms can be continually improved, and this will ultimately improve autonomous driving capabilities.

### 3.2.2 Developing full-spectrum perception capabilities to make everything sense

As the automotive industry becomes more intelligent, perception systems become increasingly important. One day, they will be a cornerstone of intelligent driving. Ideally, the sensors that enable these systems will reach full coverage and cover all objects, all scenarios, and all weather conditions.

- **All objects:** People, vehicles, obstacles, road facilities, structures, etc.
- **Full coverage:** 360-degree coverage without dead zones.
- **All scenarios:** Highways, urban areas, traffic jams, accident scenes, and construction zones.
- **All weather conditions:** Day, night, rain, snow, fog, strong light, low light, and other harsh environments.

However, the industry still has a long way to go before it can make ideal sensors a reality. To make this happen, perception capabilities need to be built based on all sections of the spectrum.




**1. Radars: The shift from the 77 GHz band to D band (110 GHz to 170 GHz) will significantly improve resolution.**

Radar sensors can perform consistently in all weather conditions because they work on super-long wavelengths. These systems excel in measuring velocity, so they can create unique value in dynamic and static separation and simultaneous localization and mapping (SLAM). However, currently, their poor resolution is limiting their use scenarios.

Radar resolution can be improved by utilizing either ultra-high bandwidth or large-scale antenna arrays.

According to existing international standards, the 76 GHz–81 GHz frequency bands are already allocated to automotive radars. This means high-range resolution can be achieved through the higher 4 to 5 GHz spectral band. Angular resolution is determined by antenna arrays, which means the more antennas allocated for transmission and reception, the higher the angular resolution. Current radar systems still use three transmitting antennas and four receiving antennas (a 3T4R antenna array). Huawei recently improved on this by launching a 12T24R antenna array radar. However, the antenna arrays used in wireless communications have already reached 128T128R configurations.

Automotive radar sensors need to be physically small, which means the antennas used in wireless communications systems are unsuitable for automotive applications. These size restrictions and the 77 GHz wavelength mean that antenna arrays for radar sensors would be 48T48R to 64T64R, at maximum. The shift towards higher frequency bands will continue. The D band (110 GHz to 170 GHz) provides ultra-high bandwidth and has generally not yet been allocated or used for other services. The 140 GHz band is still being researched, but has a relatively suitable atmospheric window, so its propagation is less attenuated. What's more, wavelengths in this band are reduced by half. That means imaging radars that use an ultra-large 128T128R antenna array can be used in a limited space while still delivering high resolutions.

**2. Lidar systems are moving from the 905 nm wavelength with time of flight (ToF) to the 1550 nm wavelength with frequency-modulated continuous waves (FMCW). Lidars are being integrated with chips, and high-performance 4D lidars will be widely adopted.**

Thanks to their relatively mature components, 905 nm lidars have already been widely adopted and are ready for mass production. From a technical perspective, as the industry moves from analog to digital and from discrete to integrated, the transmitting and receiving components are being arranged in arrays, and core modules will be integrated directly into chips.

These trends mean high-performance, low-cost, highly integrated, and highly reliable lidars may be the way forward:

- Transmitters will go from discrete edge emitting laser (EEL) components to EEL arrays, and finally to large vertical-cavity surface emitting laser (VCSEL) arrays.
- Receivers will shift from avalanche photodiodes (APDs) to single-photon avalanche diodes (SPADs), and finally to SPAD arrays. This will help improve receiver sensitivity and support long-range and high-precision depth measurements.
- Scanners will move from mechanical scanning to micro rotating mirrors and finally to being made up exclusively of solid-state components.

It is worth mentioning that the transition from APDs to SPADs is not just about performance improvement; more importantly, it marks the shift from analog to digital. SPAD is a pixel structure, so SPAD chips using complementary metal-oxide-semiconductor (CMOS) technology can evolve into photosensitive chips like the ones used in cameras. According to Moore's law, pixel size will continue to increase, possibly even to tens of millions of pixels, to support higher-resolution lidars.

Most light at 1550 nm, a near-infrared band, is blocked by human cornea before it reaches the human retina, which means it does not cause much damage to human eyes. Because of this, the 1550 nm band allows lidars to transmit at higher powers, which can greatly increase coverage. In terms of modulation, FMCW's use for radars can also be applied to lidars. FMCW lidars deliver better performance through high-performance 4D imaging (which can be used to measure velocity), strong anti-jamming capabilities, and higher sensitivity and dynamic range. In addition, FMCW lidars can be mass produced at lower costs, when combined with silicon photonic and optical phased array (OPA) technologies.

However, FMCW technology at the 1550 nm wavelength is far from ready for commercial use and will require concerted efforts from across the entire value chain to develop further. Further exploration of silicon photonic technology in line with Moore's law is one way that can help support FMCW. More complex and discrete optical functions can also be integrated into silicon-based chips, making lidar sensors more integrated, more affordable, and smaller.

**3. Cameras will integrate visible light and infrared thermal imaging technologies to work in all weather conditions.**

Cameras are a type of passive sensors and are most similar to the human eye. They can sense surrounding objects through catoptric imaging. As one of the three major types of sensors used in vehicles, cameras are the most critical for identifying elements in a static environment, like traffic lights and road signs.

However, cameras also have drawbacks. The performance and confidence of catoptric imaging suffers at night and in low-light conditions, and heavy rain and snow can impede a camera's line of sight, greatly reducing its visibility. Cameras cannot independently overcome these harsh weather conditions.

However, in the infrared spectrum (in the 2–14 μm band) right next to the visible spectrum, a thermal emission imaging system can be used. Sensors that work on this band have effective night vision, and can detect objects through rain, snow, sand storms, and fog. They even have certain perspectives to further meet the requirements of all weather conditions. Vehicles are now starting to come equipped with infrared thermal imagers that have night vision, but this application still needs a low-cost solution for mass production.

### 3.2.3 Full convergence: Accelerating innovation in sensor form factors for simplified deployment

As vehicles become more intelligent, the number of sensors per vehicle is increasing dramatically. Vehicles come equipped with many sensors, from 1V and 1R1V to 5R5V and 6R13V3L configurations, and more will be deployed in the future. Here, R refers to radar, V means vision (i.e., camera), and L means lidar.

However, a vehicle's body is limited in size, and the installation and deployment of sensors raise even high requirements for body design, such as strict requirements on fascia, thickness, installation intervals, and flatness. This makes the entire style and design process much more difficult, because designers must balance vehicle appearance and sensor performance.

To make sensors easier to deploy in vehicles, innovation in form factors is a must. Miniaturization of sensors will be the way forward. In addition, sensors will need to be designed to better fit vehicle styles. Integrated designs that consider both sensors and vehicle style can greatly reduce the constraints on the vehicle body. This requires joint efforts from multiple sectors including materials, processes, and engineering.

**1. Distributed antennas and central computing**

Radars generally come in an integrated design that encapsulates front-end antennas and back-end signal and perception processing units into one box, to support point cloud generation, object detection, and perception processing. As central computing becomes more common, radar signals can be segmented and extended using the techniques already utilized in Huawei's distributed base stations. Conventional monolithic radars can be used only to generate point clouds, while perception processing units can be integrated with domain controllers. Radars that use distributed antennas and central computing deliver better performance, consume less power, and occupy less space than current radars. Solid-state lidars can also be deployed in a similarly distributed manner.

**2. Integration into the vehicle body**

An alternative solution for separate deployment is integrating sensors with existing components into vehicle bodies. Shark fin antennas already support GPS, 4G/5G, and frequency modulation. Surround-view cameras are also already integrated into rearview mirrors. Similar solutions can be implemented in the future, such as installing lidars into front-view headlights, integrating distributed antennas into glass components and doors, and combining far-infrared sensors with existing cameras. Such combinations can make sensors more adaptable and easier to deploy, but they also raise the bar for sensors. More effort is needed to address heat dissipation, interference, EMC, and other related issues that may arise from such convergence.

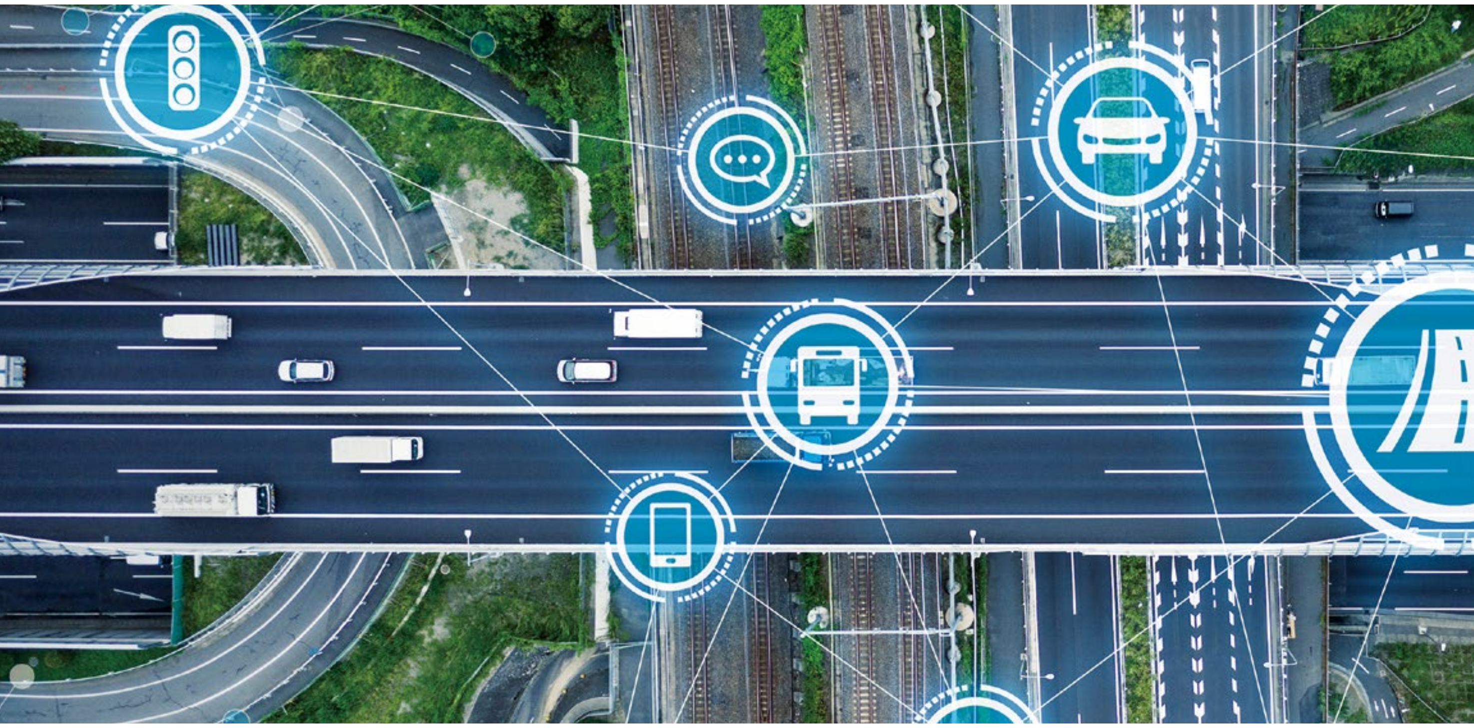
Sensors can also be integrated with each other. Low-cost distributed inertial measurement units (IMUs) can be physically integrated with sensors, which can help change sensors' motion compensation from inter-frame compensation into intra-frame (signal-level) compensation and improve the accuracy of sensor attitude perception. This model can help further improve sensors' overall performance and safety in scenarios like vibration, dead reckoning, and slopes.

### 3. Surface-mount sensors will reshape sensor deployment.

Surface-mount sensors are the ultimate vision for future sensor deployments. Such sensors would need to be smaller and flatter, and eventually plug-and-play. Highly integrated chips would be necessary for this solution, as well as:

- **Microlens array technology:** An assembly of precision-manufactured microlens, just a few millimeters deep and high, used to project a tightly-focused beam. This can massively reduce the focal length between light sources and lenses, making flat designs possible. Though this technology is now mainly used in projectors, it also provides a new possible path for miniaturized lidars and surface-mount sensors.

- **Smart Skin (conformal antenna) technology:** An antenna array designed to conform to the shape of the carrier. This allows an antenna array to be directly attached to the surface of a carrier like a Band-Aid, so that the antenna array can be integrated with the platform structure. This makes sensors more adaptable,



and adds more flexibility in vehicle style design.

In the future, sensors will be like a layer of skin attached to the outer surface of intelligent vehicles. To make this vision a reality, all players along the value chain need to work together to advance in multiple fields, including materials, processes, and engineering.

### 3.2.4 Central computing platforms: Providing large computing power to support intelligent driving

Powerful computing platforms will provide the fundamental computing power needed for intelligent driving. More sensors, both in type and number (over 50), will be deployed in a single vehicle to enable intelligent driving in all scenarios in complex road conditions. This includes 100-million-pixel cameras, event cameras, 4D imaging radars, high-resolution lidars, ultrasonic radars, infrared detectors, and sound detectors. In addition, all of these sensors will be increasingly accurate. These sensors will generate massive amounts of data that needs to be analyzed and processed in real time.

Huawei's GIV predicts that by 2030, a vehicle will come equipped with a computing power of over 5,000 TOPS and 3 million DMIPS with less than 150 W of power thanks to improved chip processes. When these advancements are combined with improvements in memory technology, they will further boost energy efficiency ratio of new vehicles. These central computing platforms will provide the computing power needed to enable intelligent driving.

### 3.2.5 V2X cloud brain for multi-vehicle collaboration and intelligent driving

Connected infrastructure is continuing to improve, and intelligent driving is already being adopted in more scenarios. The challenge we face is no longer just making single vehicles intelligent. Now, we want to make vehicles that cooperate with each other. This will push commercial intelligent driving and intelligent transportation to the next level.

Ubiquitous (vehicle-to-everything) V2X connections need to be built to intertwine people, vehicles, and road infrastructure. A vehicle-road intelligent cooperative driving platform needs to be established on the cloud to streamline end-to-end application scenarios. Thankfully, multi-vehicle cooperative intelligent driving will quickly become a commercial reality, thanks to services like comprehensive environment perception, global resource scheduling, dynamic service mapping, multi-vehicle cooperative driving, lane-level route planning, coordinated signal control, and service simulation testing.

---

A cloud-based brain can integrate all the necessary information elements of people, vehicles, roads, and environments, improving vehicles' ability to perceive dynamic traffic environments. A cloud-based brain can also share driving strategies between different vehicles, allowing vehicles and traffic infrastructure (e.g., traffic lights and signs) to work in synergy. This allows us to optimize overall (not partial) driving strategies and further promote the development of intelligent transportation systems.

---

## 3.3 Intelligent cockpits: AI speeds up software and hardware upgrade

### 3.3.1 Open cockpit OSs for an ever-evolving application ecosystem with brand-new experiences

Compared with smartphones and other consumer devices, an intelligent cockpit has more peripherals and supports multiple users, multiple concurrent operations, and multiple modes of interaction. The design and development process of OSs for intelligent cockpits must consider these factors. In addition, an ever-evolving application ecosystem is vital for cockpits to bring brand-new experiences to users. This raises the bar for the consistency and stability of a cockpit OS application interfaces.

At present, the cockpit OS market is plagued by the fragmentation and customization of solutions across the industry. For example, when a carmaker is developing a function that needs to work with a camera or microphone, they have to create unique versions of the function for different vehicle models because each hardware platform is different. This fragile approach to software development prevents different hardware components from effectively connecting with each other or sharing software capabilities.

There is yet another challenge for carmakers in software development. The work is outsourced to multiple vendors, with each being responsible for different functions, and redundant copies of the same function may co-exist. This creates chaos in version management, leads to a lot of extra development work, and complicates software upgrade and maintenance.

In the future, there could be three primary OSs in the intelligent cockpit field with unified APIs to support a thriving and ever-evolving application ecosystem. Developers will be able to quickly develop applications to improve the cockpit ecosystem by utilizing the basic platform-based capabilities that APIs provide.

### 3.3.2 Platform-based interaction algorithms, quickly improving cockpit application development efficiency

Integrating the fundamental algorithms for human-machine interactions in cockpits into a single OS can help ecosystem partners improve development efficiency. In future intelligent cockpits, technologies that support primary interaction capabilities — such as voice, visual, and audio — will remain essential for human-machine interactions. Specifically:

**Voice:** When it comes to experience, voice will be the most important interaction capability of intelligent cockpits. As foundation models and computing power continue to improve, voice capabilities will advance to allow for more human-like interactions , intelligent services, and personalized experiences.

(1) Human-like voice interactions: With voice technology, cockpits can recognize emotions and engage in emotional interactions. The system can utilize visual and voiceprint recognition technologies to quickly detect users' emotional state and provide emotional support through human-like tone of voice, emotional responses, and interactive UI images. In this way, voice interaction truly transforms from human-machine interaction to human-human interaction.

(2) Intelligent services: Generalization is the key for voice technology to understand more. As foundation models become widely implemented, developing voice technology that understands more and provides more services requires the integration of a variety of ecosystem applications. Cockpits need extensive ecosystem applications and accessible interfaces that can handle vague or complex commands like "navigate to the nearest fast-charging station" or "play the most recently watched episode of Peppa Pig."

These capabilities are essential for cockpits to provide intelligent services.

(3) Personalized experience: In the future, in-vehicle voice technology will increasingly rely on multimodal fusion. Integration of visual and voiceprint recognition capabilities allows the voice assistant to accurately identify each occupant and their preferences, providing personalized services.

**Visual:** The second key way that vehicles interact with users will be through vision. Currently, in-vehicle visual recognition technology is mainly used for the driver monitoring system, cockpit monitoring system, and detection and recognition of human-machine interactions (e.g., through gestures). In the future, more advanced visual recognition technologies will emerge to deliver functions such as detecting living beings in the vehicle, monitoring users' health, and enabling secure payment, entertainment, and integrated audio-video services.

Users will be able to interact with their vehicles in new ways, with vehicles providing more precise and convenient services. For instance, eye tracking technology and AR-HUD will work together to identify objects within eyesight in real time, and then project information about the objects, such as their details and relevant ads. When vision-based gesture recognition technology is used in conjunction with mmWave radars, the accuracy of gesture recognition will be improved and users will be able to smoothly interact with their devices. When there is a lot of background noise, integrated visual-audio technology will read the user's lips and translate lip movements into commands, supporting speech recognition and vehicle control across all scenarios.

**Audio:** Cockpits of the future will possess more advanced audio capabilities in terms of smart sound effect, smart sound field, and active noise cancelation.

(1) Smart sound effect: Software algorithms automatically separate sound elements and add angles and trajectories to create a 3D surround sound effect, even for 2D audio sources.

(2) Smart sound field: Intelligent processing of audio signals allows occupants to listen to personalized content thanks to independent sound zones while experiencing immersive multi-channel surround sound.

(3) Active noise cancelation: This will continue to be a major area of focus for in-vehicle audio technology over the next ten years. More advanced hardware and algorithms will be needed to thoroughly cancel out the noise generated by the vehicle engine, road traffic, and wind, so as to continuously improve the ride comfort.

In the next 10 years, breakthroughs in components, algorithms, and architecture, along with improvements in high-performance computing chips and digital signal processors (DSPs), will take in-vehicle audio to new levels, transforming vehicles into mobile entertainment hubs.

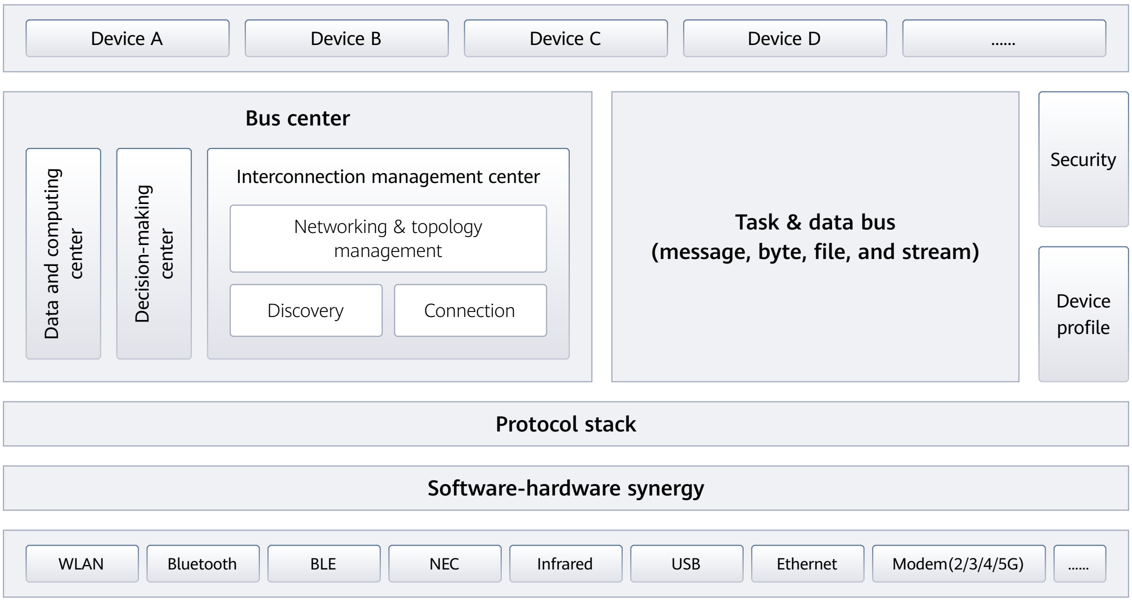
### 3.3.3 Multi-device collaboration through distributed technology for seamless intelligent experiences

Intelligent vehicles are integrated systems, and how they interact with users will involve the broader surroundings. Connection and interaction of devices depends on both general-purpose cloud technology and a distributed software bus. Huawei's HarmonyOS for Automotive provides a distributed software bus to create a seamless experience across nearby devices, making it easier and more comfortable for users to interact with their devices.

Imperceptible sensing and zero-wait transmission are the deciding factors for realizing seamless experience across nearby devices. If we are to meet these preconditions, we must first devote efforts to answering the questions of how different devices should discover and connect with each other, how connected devices should come together to form a network, and how transmission between devices that use different protocols can be realized. The key technologies here include automated device discovery, connection, networking (e.g., multi-hop automated networking and multi-protocol hybrid networking), and transmission (e.g., diverse protocols and algorithms, and intelligent perception and decision making).

A distributed software bus (DSoftBus) connects different types of devices by using a "protocol shelf" and a software-hardware collaboration layer, despite the different protocols used by the devices. The hub module of the bus analyzes commands to discover and connect devices. The task bus and data bus provide other functions, such as transferring files and messages between devices.

The following figure shows the HarmonyOS DSoftBus architecture.




Several preconditions have to be met before an intelligent vehicle and IoT devices can work synchronously to offer an interactive experience. In terms of design logic, it is important that interactive experience of the intelligent cockpit be consistent with that of mobile phones or other such devices. Regarding operating logic, intelligent cockpit applications must provide the unified functions of smartphone applications, and may be designed based on the hardware capabilities of cockpit peripherals. In addition, users want a seamless experience when they switch between cockpit and smartphone applications, especially when it comes to their calendar, navigation, music, video, and conferencing applications.

### 3.3.4 Standardized interfaces keep user experiences fresh throughout hardware lifecycles

Consumer devices like smartphones usually last two to three years, and their software and hardware integration packages are small. Vehicles have a longer lifespan, including a sales window of 5 to 10 years and a useful life of 10 to 15 years. Carmakers tend to research and develop multiple vehicle models at the same time, so they have no choice but to simultaneously maintain a whole range of software and hardware versions.

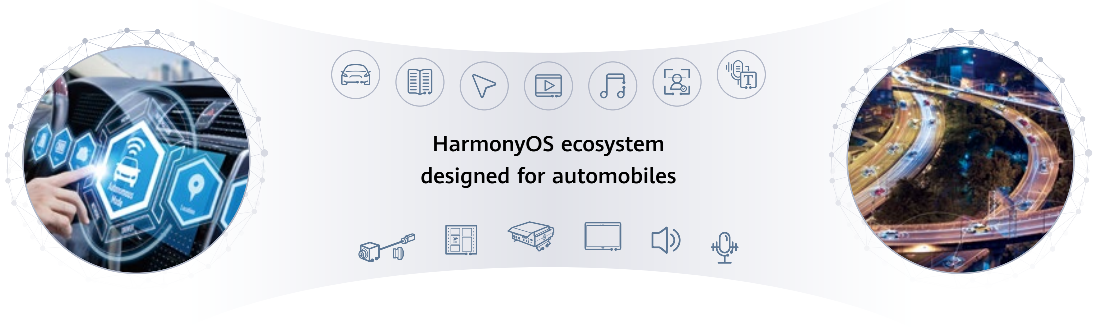
As novel applications appear, hardware performance needs to keep up. For example, chips and other key components like cameras and displays will have to stay up-to-date throughout a vehicle's lifecycle. Cockpit hardware upgrading will lead to new business models in the post-sales stage.

**Open and Specialized Hardware and Software Streamline New Functions in Vehicles**

**Up-to-date apps**
Supports immediate app upgrade through a neutral, open ecosystem

**Quick development**
Enables developers to design better services and apps using HMS-A service kits

**All-scenario collaboration**
Achieves seamless people-vehicle-home connection




**Plug and play**
Efficiently integrates chips and peripherals

**Continuous upgrade**
Collaborates with partners to continuously improve solution capabilities

**Standardization**
Cooperates with industry partners to develop wired and wireless standards for vehicular communications to promote rapid industry development

Inside a vehicle, chips or chip modules must be able to meet the computing needs of software and hardware for the next three to five years. The chip module itself needs to be designed for backward and forward compatibility, so as to ensure easy upgrade (e.g., through pluggable components) and strike a balance between hardware lifetime and computing demand. Hardware plug-and-play is essential for this type of chip module.

When a key peripheral is replaced by a new one, it is necessary to install a new driver to support the new peripheral. Carmakers should aim to make this process as simple as installing a new driver on a Windows operating system. Also, it should allow OTA updates for certain parts of the cockpit OS. To make this possible, unified standards should be established for the interfaces of cockpit hardware, in order to eliminate issues caused by customized interfaces of head units, cameras, displays, HUDs, intelligent seats, intelligent steering wheels, in-vehicle robots, intelligent windows, holographic projection hardware, etc. To standardize cockpit hardware, the automotive industry needs to double down on standardizing communications interfaces, including those for short-distance wireless communications, wired communications, video, and audio. Standardization is key to driving down component costs and cultivating a hardware ecosystem.

### 3.3.5 Up-to-date OS and diverse ecosystems enable a sophisticated and engaging cockpit experience

Intelligent cockpits are driving the need for diverse user experiences, requiring collaboration from various ecosystem partners. However, adapting applications for each OS proves costly due to the relatively small number of vehicles compared to smartphones. This is why mainstream car models often have a limited selection of applications, leading to usability difficulties and low adoption rates. To address these challenges, cockpit vendors require an integrated OS platform and ecosystem that is supported by multiple carmakers and models, empowering application developers to create value and attract more users. Additionally, cockpit vendors should provide ecosystem partners with a streamlined development platform that requires minimal input while delivering substantial output, ultimately offering users more sophisticated experiences.

A unified OS is essential for cockpits, as it can foster a cohesive user experience while enabling seamless cross-model upgrades that guarantee access to cutting-edge system capabilities. In addition, open APIs are integral for empowering application developers to create applications that can be deployed across multiple devices with minimal additional effort. By minimizing the complexities associated with diverse hardware configurations, transmission protocols, OSs, and functional modules, a unified OS enables exceptional experiences to be swiftly replicated across various vehicles.

Today, HarmonyOS and its ecosystem applications have been deployed for 23 vehicle models, providing over 300,000 users with diverse experiences through nearly 150 apps across 12 categories. Huawei works closely with content providers to enhance user experience and explore new business opportunities in navigation, music, video, gaming, themes, and charging. Notably, the company partners with game content providers to design "steering wheel racing games," audio-visual content providers to create "cockpit concerts," and theme content providers to develop "customizable themes." All of these help to deliver unique experiences to users. These innovative applications can be developed for a single vehicle and upgraded on many, receiving iterative updates every quarter on the HarmonyOS platform. This approach fosters an ongoing cycle of innovation and improvement, providing users with a fresh and up-to-date experience.

## 3.4 In-vehicle optical applications: Lighting up a new vision for drivers and passengers

### 3.4.1 Viewing: Panoramic, immersive holograms for eye-opening experiences

Humanity's desire for superior visual experiences knows no limits. As vehicles become more intelligent, their front windshields, side windows, and panoramic sunroofs are quickly becoming displays that can show information through lifelike holograms. As intelligent laser and pixel technologies continue to evolve, they are expanding the roles of headlights, from being mere sources of lighting to projecting 3D information in all directions around the vehicle.

In-vehicle optical applications are designed to create superior visual experiences as they support information display, interaction, and entertainment. In terms of navigation, the windshield can be used to enhance driving safety by displaying essential information and safety warnings like road directions and obstacles. The windshield and even rear side windows can be used for entertainment, serving as holographic screens that offer the kind of immersive 2K/4K viewing experiences that you get at the cinema. Curved panoramic sunroofs can project customized light patterns, to mimic everything from meteor showers and constellations to deep-sea coral reefs. Going forward, intelligent vehicles will also be equipped with headlights capable of wide-gamut, high-pixel projection that will allow users to project and watch movies outdoors.

Vehicles are quickly becoming the third living space for people after their home and workplace. This is why user demand for visual experiences on the go has been increasing. Users expect immersive experiences that deliver images and video with higher resolution and broader view. Users are also looking for new eye-friendly technologies that can help with carsickness. This means interactive functions not only have to create truly immersive experiences, but also help users avoid getting carsick while making long video calls or watching movies. In addition, rear-seat passengers expect optical display technologies to deliver a wide array of entertainment functions without fatiguing their eyes.

Looking to the future, spatial optical technologies – in tandem with human-focused experiences – will reproduce the real world with extremely high-resolution images that are sharper than even the human eye can process. This will require:

- **Wide-view, immersive technology:** Spatial optical technologies like freeform mirrors, diffractive optical waveguides, and polarization beam splitting can be used to project images up to 100 inches in size from a 10-inch display. With directed light field technology, users can watch 3D movies on in-vehicle displays without 3D glasses. Also, directed sound field technology offers amazing acoustics that would previously have been available only to best seats in the cinema.

- **True-color UHD displays:** Displays will soon come fitted with optical engines for 2K, 4K, and 8K video, and diffuser film displays based on a micro-nano structure. These UHD displays will significantly enhance pixels and brightness, making the text and images they display so crisp that the pixels will not be visible to the naked eye. With RGB lasers, UHD displays will support DCI-P3 color space or even BT.2020 color space for 8K video, perfectly showcasing the true colors of objects being displayed.

- **Visual health:** Virtual imaging systems can display images at a 3-meter distance from the viewer's eyes, thus eliminating the risk of myopia. Passive cool tint technologies also make it possible for displays to emit zero radiation and reduce the amount of blue light that reaches the eye.

- **Human-focused experiences:** Carsickness is caused by conflicting information the human body receives from eyes and ears when a vehicle is in motion. Staring at an on-board screen in a moving vehicle often exacerbates this problem. When engineering technologies that focus on dynamic human factors are incorporated into on-board screens, this problem can be minimized or avoided completely. Eye fatigue occurs when the eyes' ciliary muscles contract too tightly. The technologies that enable eye tracking and diffuser film displays that automatically adjust the distance between your eyes and the images being projected can all help relax ciliary muscles.

### 3.4.2 Connecting: New interaction methods ensure better driving safety and stronger emotional bonds

In-vehicle optical applications provide new ways for vehicles to interact with their users and the world around them. These applications are also crucial for driving safety. Inside vehicles, augmented-reality head-up displays (AR-HUDs) are an intuitive tool for vehicle-driver interaction. They can directly display information on the windshield, enabling the driver to more easily view information, instead of having to look down at various instruments. The AR-HUDs can display real-time information, such as AR navigation directions, alerts for obstacles, vision augmentation in rain, fog, and darkness, as well as information about nearby gas stations and other services.

Intelligent lighting systems also provide a new way for vehicles to interact with the outside world beyond just their horn and signal lights. When a vehicle is in motion, intelligent lighting can project interactive information onto the road, such as vehicle width, alerts for rain and fog, and night vision, to help drivers make more informed decisions and enhance safety. In addition, intelligent lights can project useful information for pedestrians, such as turn and right-of-way signals. Intelligent lights are also capable of projecting emotions, showing customized information such as patterns, emojis, texts, and weather data, and can even enable other forms of interaction through light shows and concerts.

In the future, a variety of in-vehicle optical applications will create even more ways for intelligent vehicles to interact with people. This can happen through:

- **HUDs:** Currently, AR-HUDs use megapixel-level optical modulation engines and spatial optical technology, but future adoption of dual-focal plane technologies will pave the way for even more advanced multi-layer AR-HUDs that will be able to project dashboard information two to three meters in front of the driver, and navigation and other useful information seven to ten meters in front of the driver. Future naked-eye 3D technology will also further improve the interactivity and experience of HUDs.

- **Lights:** With megapixel-level modules and optical lens, automotive lights will be transformed into projectors, displaying information such as vehicle-to-vehicle distance alerts and animated greetings. Vehicles that use precision laser lighting and sensing technologies will be able to interact with the environment through methods like dynamic ground projection (dubbed "dynamic light carpets"), to illuminate the surrounding area outside the vehicle and provide centimeter-level precision lighting. This will undoubtedly make driving safer and more fun. In the future, current/voltage modulation will also make it possible to display information in beams, and visible light communications technology will be able to support vehicle-to-vehicle communications.

- **Windows as displays:** Ultraviolet light projectors and fluorescent film glass will turn vehicle windows into colorful, full-size displays where notifications of the driver's intent, ads, and other types of information can be shown to pedestrians.

## 3.5 Intelligent vehicle cloud services: Providing ultimate experiences and attentive services throughout the lifecycle of intelligent vehicles

As vehicles become increasingly intelligent and connected, data has transformed from a mere utility into a vital asset and key differentiator in the automotive industry. In response to this shift, carmakers must adapt to meet the growing demand for diverse intelligent applications, foundational models, efficient intelligent vehicle services spanning the entire product lifecycle, and algorithm training for advanced driving systems and cockpits. This has paved the way for data-driven intelligent applications and comprehensive lifecycle services to emerge as the lifeblood of the automotive sector, guiding the development of intelligent connected vehicle cloud platforms.

The intelligent connected vehicle cloud platform is a comprehensive service platform that seamlessly integrates cloud computing, big data, Internet of Things (IoT), and AI technologies. It provides efficient, secure, and intelligent data and application services for intelligent connected vehicles, delivering an unparalleled experience of interconnectivity between the vehicle, cloud, and mobile device. Furthermore, by offering efficient and attentive services throughout the entire lifecycle of the vehicle, it caters to diverse user needs and preferences.

As the automotive sector undergoes rapid transformation, traditional carmakers' Telematics Service Platform (TSP) is being completely transformed, evolving into a sophisticated, intelligent, and all-encompassing cloud service platform tailored to next-generation connected vehicles. Early TSP platforms offered basic functionalities like vehicle access management, location tracking, and emergency response systems. But these platforms were hampered by


technological limitations, restricting their scope and capabilities. And with the widespread adoption of cutting-edge technologies such as cloud computing, big data, and AI, coupled with the integration of intelligent components into vehicles, carmakers are compelled to proactively explore innovative ways to craft more intuitive and personalized service experiences. As a result, traditional TSP platforms are being replaced with modern intelligent connected vehicle cloud platforms, which not only elevate user satisfaction but also significantly enhance carmakers' offerings in terms of intelligent services. This has helped to inject fresh dynamism into the entire automotive industry.

### 3.5.1 Proactive services for vehicles throughout their entire lifecycle with innovative big data and intelligent applications

The advent of intelligent connected vehicles has ushered in a new era of unprecedented challenges and opportunities for the automotive industry. While traditional component failures can be readily identified by using specific fault codes together with local diagnostic equipment, and then resolved through replacement or repair, the complexities inherent in intelligent vehicle components present a daunting task.

With a high degree of hardware concentration and a substantial software proportion, these advanced components exhibit significantly increased functional complexity. This makes pinpointing and diagnosing intelligent component faults an arduous process, which is made worse by the increasing number of experience-related problems that arise from the growing variety and complexity of automotive applications. This creates significant challenges for after-sales service of intelligent vehicles.

Nevertheless, the deep integration of ICT technology and the automotive industry has yielded substantial benefits through provisioning efficient services for intelligent connected vehicles. By establishing a comprehensive vehicle data application service system in the cloud, carmakers can consolidate data from various vehicle components to enable functionalities such as real-time vehicle status monitoring, alarm management, fault warning, remote diagnosis, and predictive maintenance. This not only enhances service quality and operational efficiency but also gives their services a competitive edge, ultimately contributing to increased market share and improved brand reputation.

To fully integrate intelligent components with cloud-based technologies like big data and AI, several key considerations must be taken into account within the cloud environment. These include collecting more maintainable data from intelligent components and collecting and aggregating signals from automotive components more efficiently. Furthermore, incorporating service logic, industry expertise, and industry practices is essential for driving innovation in intelligent applications. In particular, the following specific areas require attention:

#### (1) Efficient collection and aggregation of vehicle data and signals

By leveraging open and standardized V2X technology, it is possible to access a massive number of vehicles and provide concurrent services to millions of users through the cloud. A data pipeline should be built to support efficient collection and aggregation of vehicle data, signals, and other relevant information from various automotive components, such as the advanced driving system, cockpit, vehicle control module, T-Box, powertrain, and body.

#### (2) Vehicle data analysis and processing

It is necessary to leverage vehicle data to develop various services, including vehicle status inquiry, data dashboard, fault management, alarm management, problem management, signal analysis, log management, data analysis, and more. These features will facilitate user-centric services, risk mitigation, fault location, remote diagnosis, predictive maintenance, and other critical operations.

#### (3) Efficient remote fault diagnosis and warning model

A cross-domain diagnostic and analytical model should be constructed for fault scenarios, utilizing vehicle signals and data in conjunction with industry knowledge and experience. In this way, a fault diagnosis model can be built, facilitating rapid identification and resolution of complex problems and faults across domains, ultimately benefiting both carmakers and consumers.

#### (4) Specialized large model

Proactively exploring the potential application of large models within the automotive sector is a worthwhile endeavor. Currently, Huawei's intelligent vehicle cloud service stands at the forefront of intelligent diagnostics, underpinning the Yunque model — an L2 large model tailored specifically for the automotive industry. Built on top of a foundational large model with 10 billion parameters, the Yunque model integrates cumulative fault diagnosis data and expertise alongside an industry-specific knowledge base to facilitate automated fault diagnosis. Through question-and-answer interactions, the Yunque model can identify faults or problem descriptions, perform intelligent triage, and formulate diagnostic solutions. At the end of the automated diagnosis process, it generates conclusive findings and comprehensive diagnosis reports. This not only enhances the efficiency of remote vehicle problem diagnosis but also paves the way for more sophisticated services and applications in the future, ultimately elevating user experience.

### 3.5.2 Accelerating application and business model innovation for an ultimate device-cloud connection experience

In today's interconnected world, the device-vehicle-cloud synergy has given rise to an array of innovative experiences, such as digital keyless entry, smartphone-based car finding, scheduled charging, one-touch vehicle preparation, and remote parking. And as the automotive industry continues to evolve, we can expect to see even more sophisticated applications to emerge. Such applications will leverage the power of intelligent vehicles to create new possibilities for on-board video conferencing, social networking, real-time environmental awareness, live streaming of scenic views, smart route planning, smart home automation, e-commerce and logistics management, seamless multimedia entertainment, and personal health monitoring.

The intelligent vehicle cloud plays a pivotal role in enabling carmakers and developers to create superior device-cloud interconnectivity experiences from the following three aspects:

### (1) Ensuring a seamless service experience of V2X applications

Underlying IoT communication technologies and optimized algorithms enhance Quality of Service (QoS), reduce end-to-end latency, and ensure the reliability and efficiency of operations, enabling seamless interactions among mobile devices, IoT terminals, vehicles, and the cloud.

### (2) Optimizing service experiences with data-driven closed-loop capability

Carmakers can analyze user feedback on service experience using cloud service data. By delving into the service logic segment by segment, they can identify areas for improvement and implement targeted optimizations to enhance overall user satisfaction.

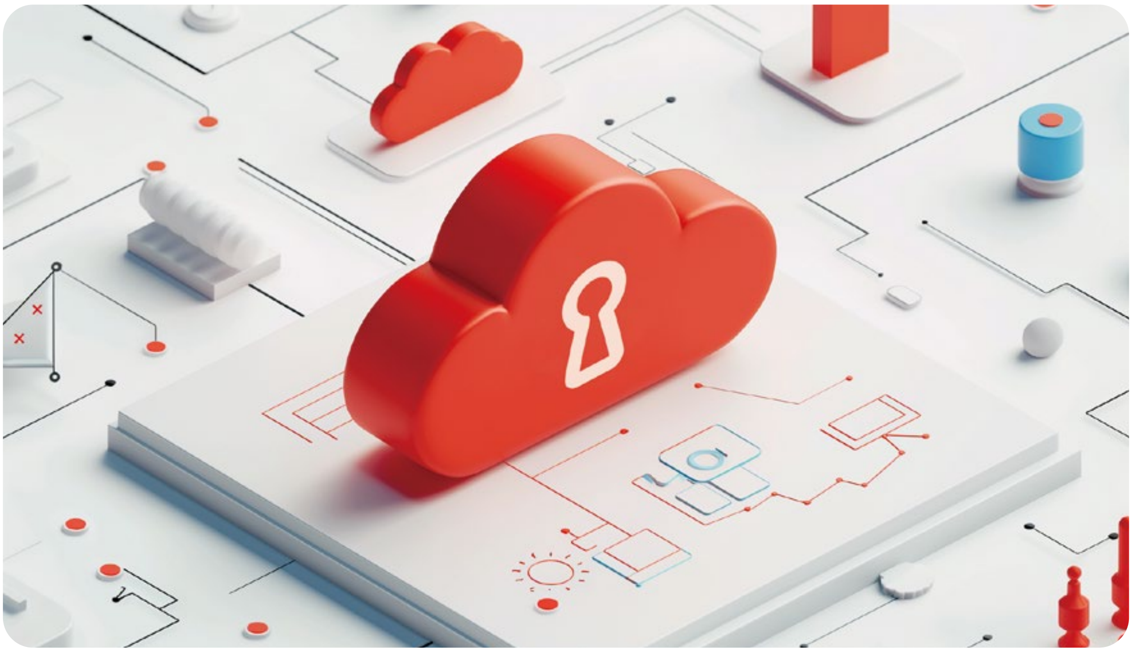
### (3) Enhancing service and business model innovation

The intelligent vehicle cloud's open data service capabilities enable the development of intelligent applications, allowing carmakers to build an innovation ecosystem that revolves around users' mobility and lifestyle needs and unlock data value faster than ever through data-driven services.

Through the intelligent vehicle cloud, carmakers and developers can offer users extensive, tailored services and intelligent applications, design novel service scenarios and business models, undergo service-oriented transformations, and ultimately boost service revenue.

## 3.5.3 Creating a secure defense system for vehicle-cloud collaboration to protect data and user privacy

As V2X applications are widely adopted, protecting vehicle data and user privacy becomes of vital importance. Considering this, the intelligent connected vehicle cloud platform must establish a robust security defense system that encompasses data, cyber security, and consumer privacy. Key aspects of this endeavor include:



#### (1) Developing cutting-edge encryption technologies and authentication mechanisms

This entails leveraging sophisticated encryption algorithms to ensure end-to-end secure communications, as well as introducing the two-way or multi-factor authentication mechanism to ensure secure interactions between vehicles and the cloud.

#### (2) Building a multifaceted security defense system across domains

By integrating automotive components with the cloud, a comprehensive vehicle security defense system can be built to guarantee the security of both software and hardware, as well as in-vehicle communication of intelligent connected vehicles through mechanisms like cross-component authentication, process-level software security protection, and vehicle-specific authorization.

#### (3) Establishing a cloud-based 24/7 security operations center to facilitate proactive defense and emergency response

As AI and machine learning continue to advance at an unprecedented pace, the intelligent connected vehicle cloud platform must be capable of detecting and responding to security threats with greater intelligence. Through the harnessing of real-time data analysis, tool-assisted inspections, and other methods, anomalies can be identified in time, triggering prompt defensive responses. Additionally, developing a robust security vulnerability management and emergency response system will be a major focus for the advancement of V2X security technologies.

#### (4) Enhancing privacy protection technology

Ensuring the confidentiality and security of personal information is a top priority for carmakers. To address this, intelligent connected vehicle cloud platforms must leverage advanced technologies such as data anonymization, intelligent data masking, differential privacy, and other robust measures to safeguard user privacy throughout the entire data lifecycle — from collection and aggregation to processing and application. Furthermore, stringent data access controls and auditing mechanisms should be deployed to prevent unauthorized access or exploitation of sensitive data.

### 3.5.4 Creating a cloud-based simulation platform for efficient intelligent driving algorithm training and iteration

To solve the long-tail problem with intelligent driving, cloud service providers need to continuously enrich corner case datasets and simulation scenario libraries for iteration of intelligent driving algorithms. Throughout this process, they need petabytes of data and a huge amount of computing power (more than 1,000 GPUs) for algorithm training, and must simulate driving astronomical distances (as far as 10 billion miles) to validate an algorithm. In addition to large storage capacity and computing power, the iteration of algorithms also requires reliable, secure, and scalable infrastructure services. The conventional model for data center construction puts the costs and O&M responsibility on intelligent driving developers, so we expect that cloud computing technologies will be widely applied in intelligent driving to address these challenges.

Cloud service providers will need to be capable of providing one-stop intelligent driving development platform on the cloud that provides a complete and automated development toolchain to help address complex engineering problems of intelligent driving, like data collection, data replay, automatic labeling, identification of corner cases, incremental dataset generation, model management, training task management, model delivery, simulation scenario library building, simulation test, and algorithm adaptation. Carmakers and developers will then be able to quickly build up their intelligent driving development and testing capabilities and allow for faster algorithm development and iteration. Specifically, cloud service providers need to:

**(1) Provide scalable, secure, and compliant infrastructure for intelligent driving algorithm development**

Hyperscale data storage and computing centers, built based on cloud platforms, can provide the massive uploading capacity, compliant storage services, and massive computing resources needed to handle the huge volumes of data that will soon be generated by intelligent vehicles. In this way, carmakers developing algorithms for intelligent driving will be able to access affordable, scalable, reliable, and secure infrastructure.

**(2) Address engineering incoherence and support the DevOps of intelligent driving algorithms**

A comprehensive development toolchain, preset algorithms, datasets, and scenario libraries, along with simulation and validation services, must be provided to ensure a closed-loop intelligent driving development process, from data collection and processing, and identification of scenarios (especially corner cases), to algorithm management, training, simulation, and validation. These capabilities will help enhance the efficiency of intelligent driving algorithm development and iteration.

**(3) Enhance scenario construction for improved cloud-based parallel simulation and accelerated algorithm verification and iteration**

To expedite cloud-based parallel simulation and accelerate algorithm verification and iteration, scenario construction capabilities must be enhanced. This involves developing quick test and verification capabilities on the cloud to meet the stringent demands of testing 10 billion miles of driving. Specifically, the cloud should possess the ability to rapidly build scenario libraries and generalize scenarios, as well as construct scenarios tailored to functional safety, safety of the intended functionality, and V2X applications. At the same time, vast cloud resources and container technologies should be employed for more efficient large-scale parallel simulation. Huawei's GIV predicts that by 2030, cloud-based daily simulations will cover tens of millions of miles of driving, greatly enhancing the efficiency of intelligent driving test and verification.

# Notes on the update:

Huawei collaborates with industry experts, customers, and partners to explore the intelligent world. The progress towards an intelligent world has accelerated significantly, with new technologies and scenarios emerging constantly, and industry-related parameters changing exponentially. As a result, Huawei has updated the *Intelligent Automotive Solution 2030* report released in 2021, providing insights into the scenarios and trends towards 2030, and adjusting the relevant forecast data.

**HUAWEI TECHNOLOGIES CO., LTD.**
Huawei Industrial Base
Bantian Longgang
Shenzhen 518129, P. R. China
Tel: +86-755-28780808
www.huawei.com