Research on the Key Technology and Industry Development of Connected and Automated Vehicles

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Outline

1. **The Concept of Connected and Automated Vehicles**

2. **The Key Technologies of Connected and Automated Vehicles**

3. **The Industry Development of Connected and Automated Vehicles**

4. **The Future View of Connected and Automated Vehicles**

The Concept of Connected and Automated Vehicles

Connected and Automated Vehicles (CAVs) is a new Industry, which integrate the traditional industries of Automobile, ICT, Transportation and Traffic Management. Basing on the new generation of ICT technologies, which could realize the full V2X (Vehicle to Vehicle, Person, Infrastructure and Service Platform) connectivity and data interaction, so to construct a new Auto Society, and to improve traffic efficiency and users' driving experience
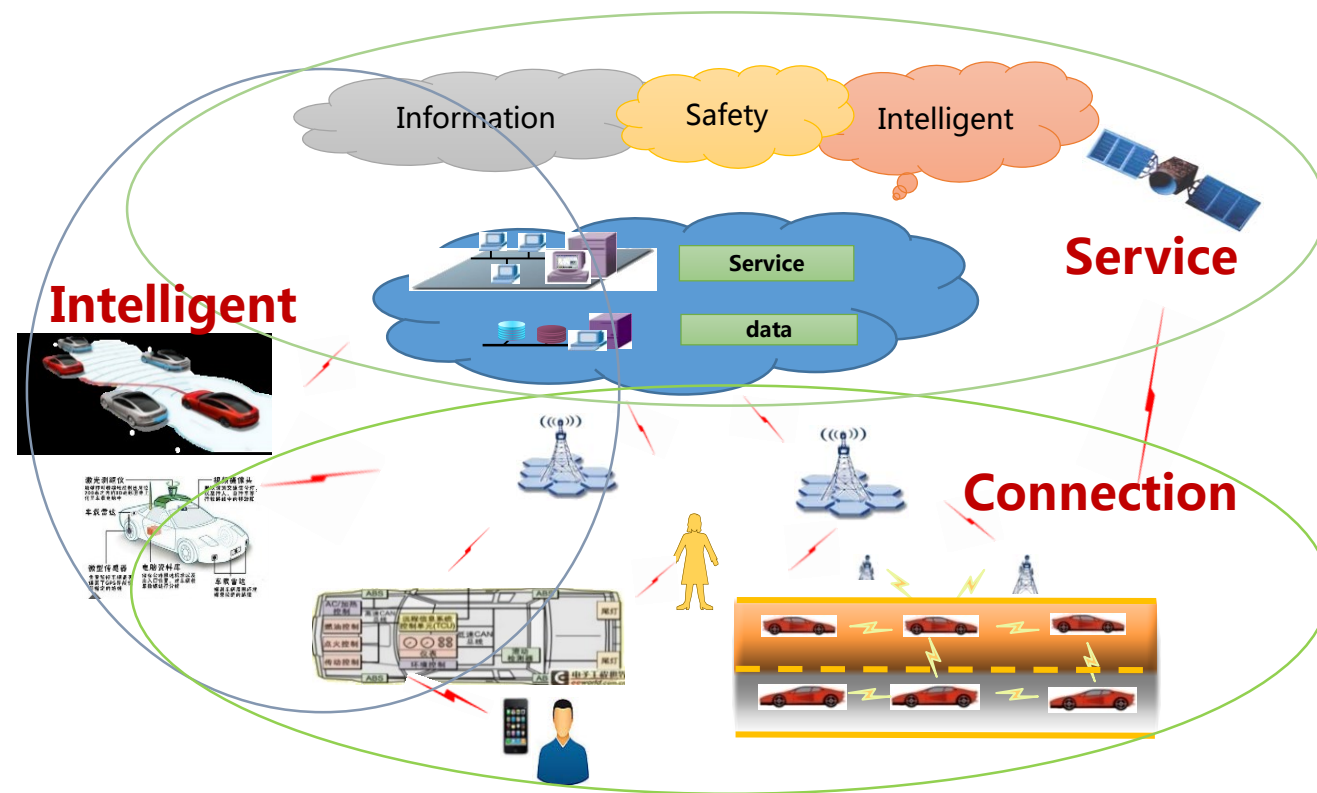
Related Items

CITS, Cooperative Intelligent Transportation System

Automatous Driving

Internet of Vehicles

ICV, Intelligent Connected Vehicles

Intelligent Traffic Management

3

Why we need the Connected and Automated Vehicles

Connected and Automated Vehicles becomes a highly integration and application of the IoT and smart vehicles, is an important field of the integration of informationization and industrialization

To promote industrial transformation and upgrading

Manufacturing → Service
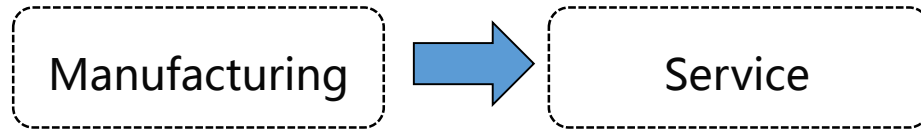
Connected and Data

To accelerate the integration of new technologies

Accelerate IoT technologies evolution into a new stage of "Cross integration, integrated innovation and large scale development "

To solve the prominent social problems
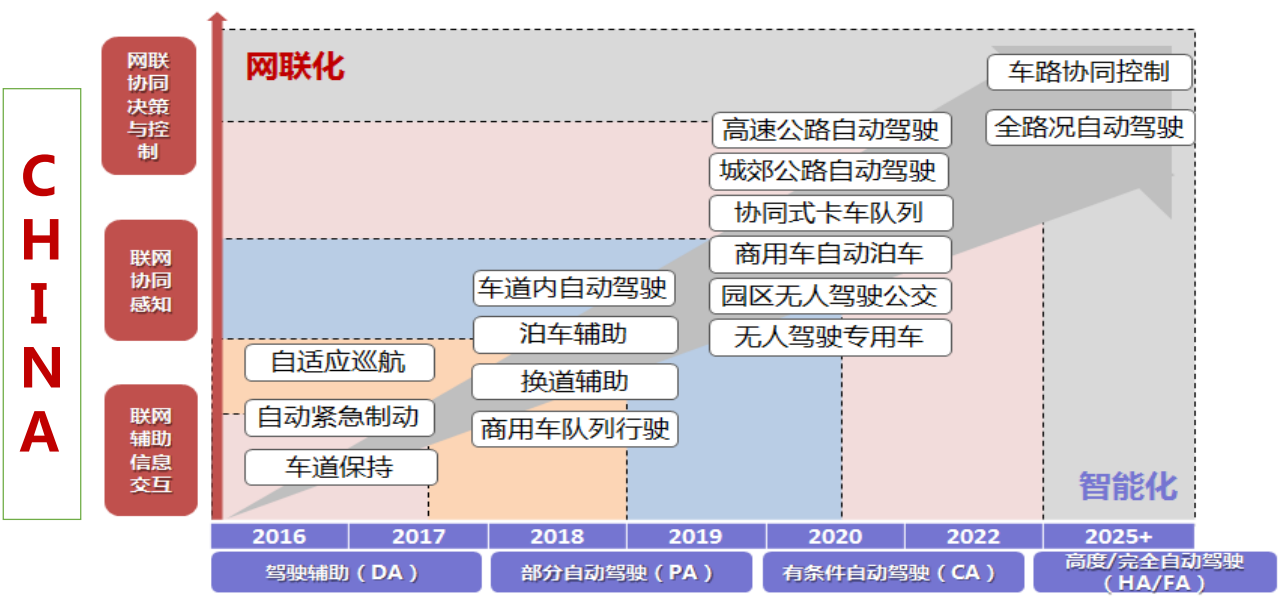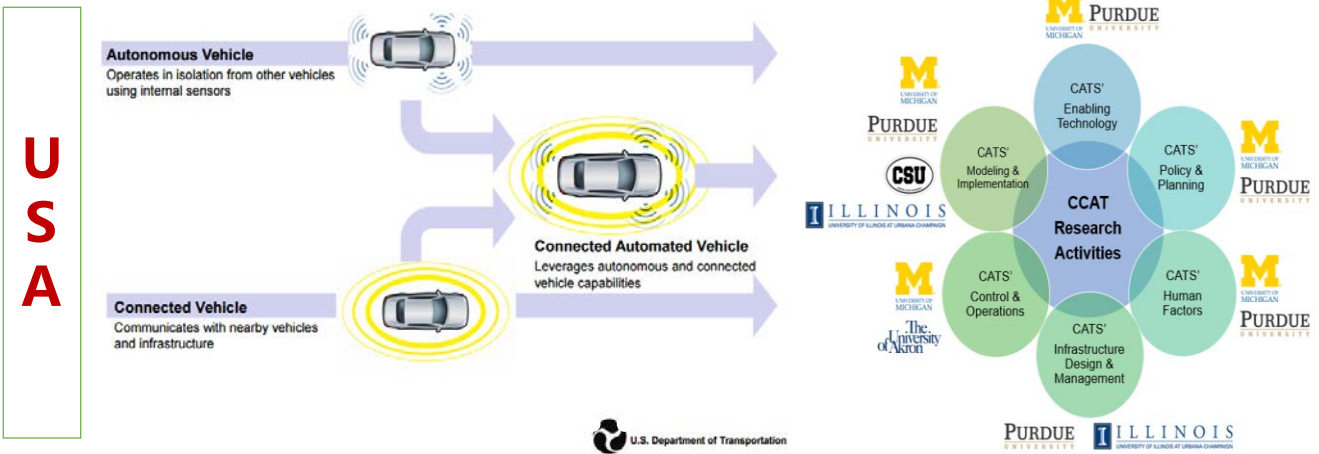

traffic safety

Transpiration efficiency

Green development

Networking and intelligence of automobile becomes the global consensus

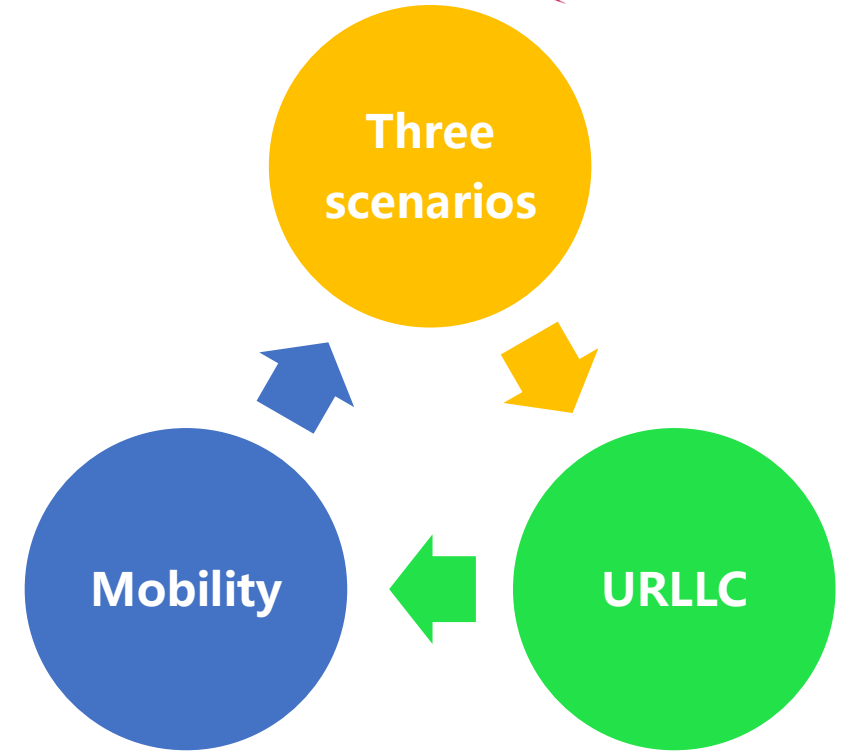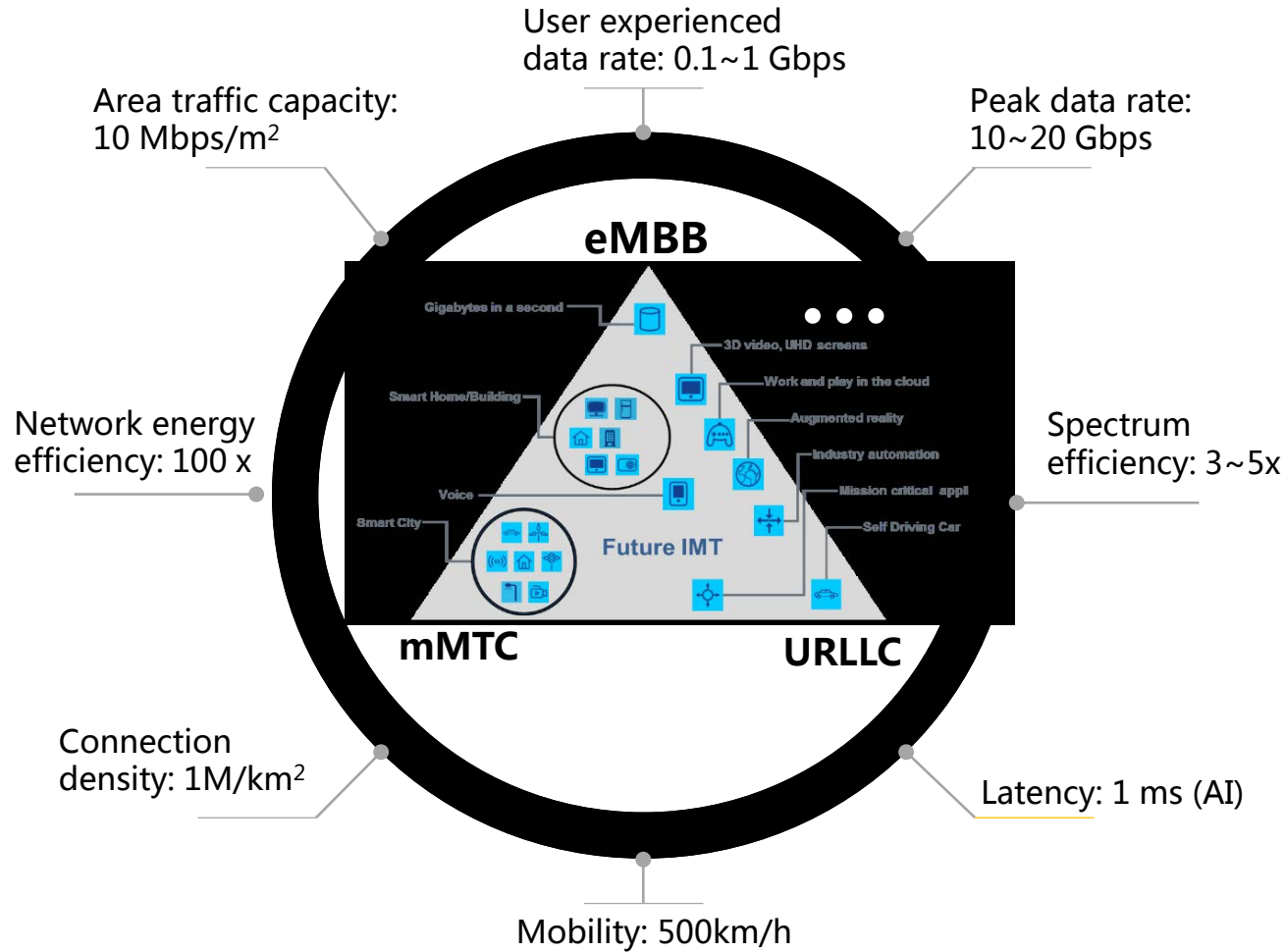USA: Autonomous driving regulation, V2X NPRM, CCAT Lab;

EU: H2020 Projects, CITS corridor, Autonomous driving regulation；ETSI、3GPP Standardization

China: CAVs Technology roadmap, Industry Policies, National Projects

5G from mobile internet to IoT, Connected Vehicles is the key scenario

ITU IMT-2020 Vison

User experienced data rate: 0.1~1 Gbps

Peak data rate: 10~20 Gbps

Area traffic capacity: 10 Mbps/m^2

Network energy efficiency: 100 x

Spectrum efficiency: 3~5x

Connection density: 1M/km^2

Latency: 1 ms (AI)

Mobility: 500km/h

eMBB

mMTC

URLLC

Three scenarios

Mobility

URLLC

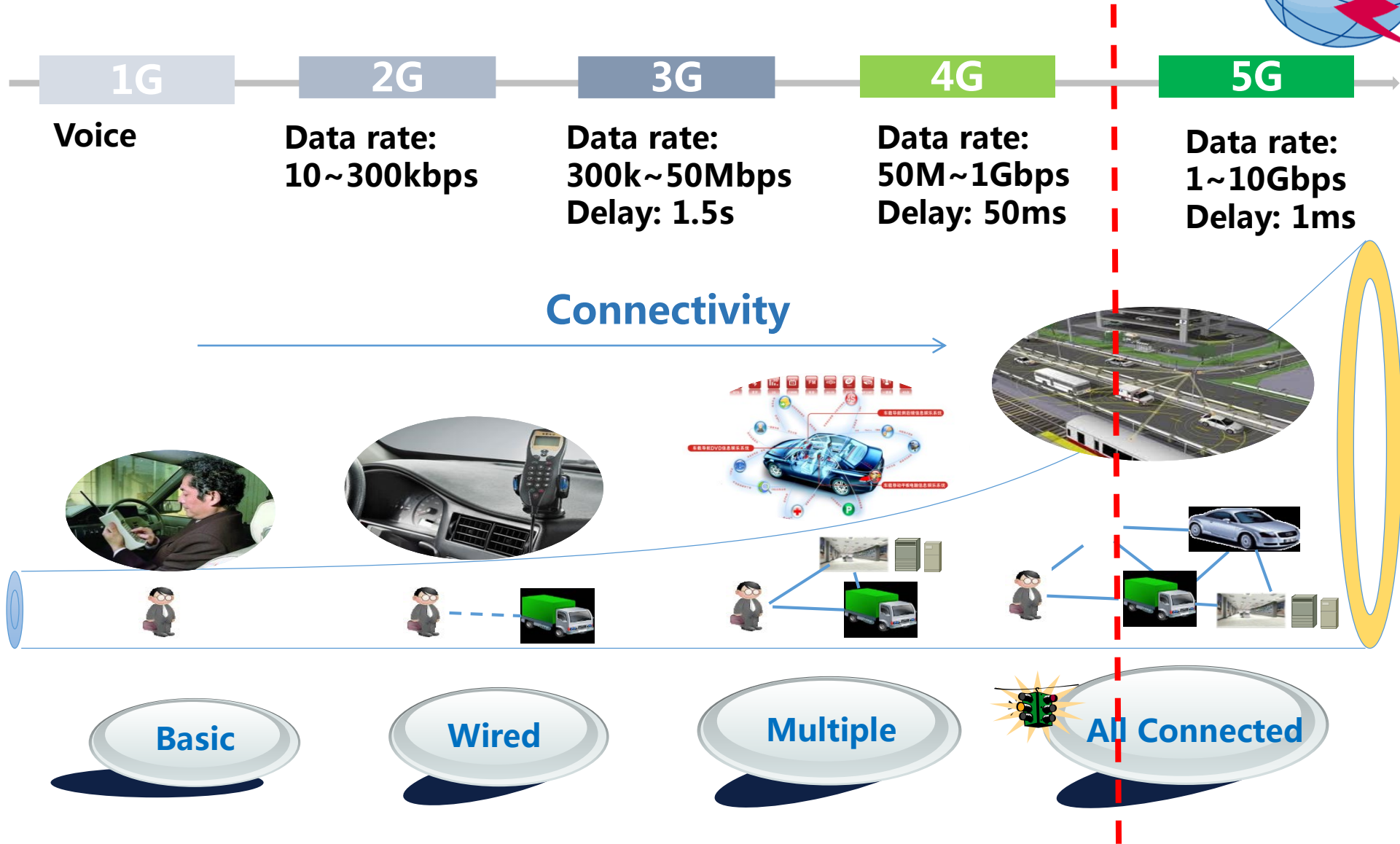**URLLC is the key technology for Vehicles, Industry and other related vertical industries**

Mobile communication technology & Connected and Automated Vehicles

1G	2G	3G	4G	5G
Voice	Data rate: 10~300kbps	Data rate: 300k~50Mbps Delay: 1.5s	Data rate: 50M~1Gbps Delay: 50ms	Data rate: 1~10Gbps Delay: 1ms

Connectivity

Basic   **Wired**   **Multiple**   **All Connected**

Information service: entertainment, navigation has become an indispensable part; new business models such as Sharing, insurance

Entertainment, navigation service based on 2G/3G/4G public mobile network

online navigation

Congestion notification

Multimedia Downloads

Mobile navigation and positioning technologies widely used, and the influence of Sharing economic, **emerging out of the generation of car sharing services, service scale hits 400 million users in China**

based on information collection + cloud platform + big data analysis technologies, through the analysis of driver's behavior, **innovative services such as personalized experience, online car insurance have appeared**

Safety and efficiency service: V2X technology improve traffic safety

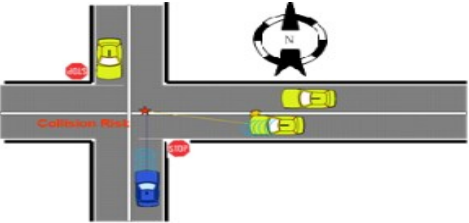"high reliability and low delay "services like **safety warning and traffic efficiency**

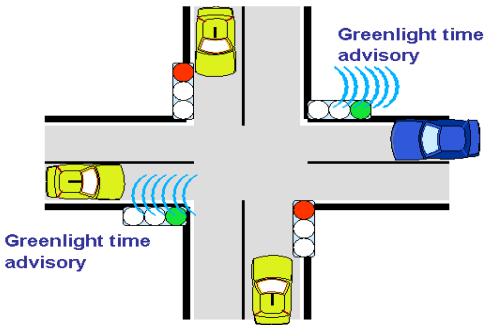are realized

safety warning
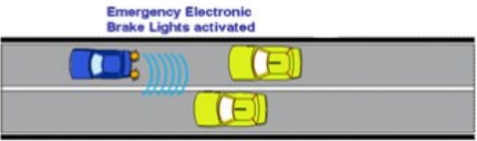
emergency brake

Cross warning

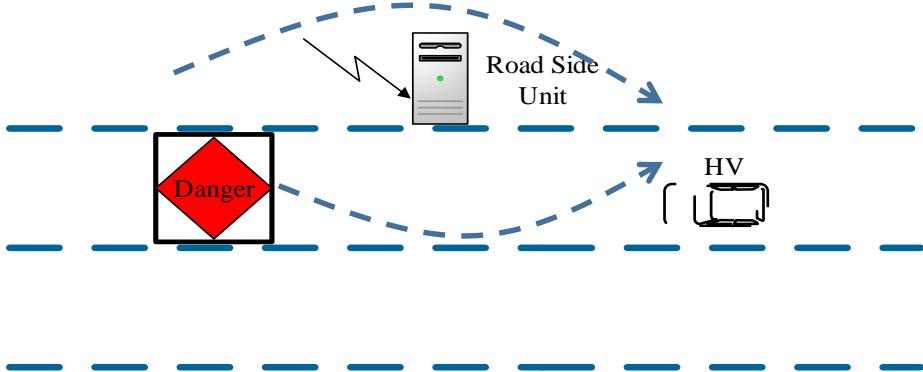Cross - road collision warning

traffic efficiency

Road speed limit warning

Traffic light reminder

V2X solves safety

Road Side Unit

Danger

HV

By providing enhanced driving environment awareness, the V2X communication avoids most crashes

Cooperative service: complete autonomous driving will completely liberate human hands and feet

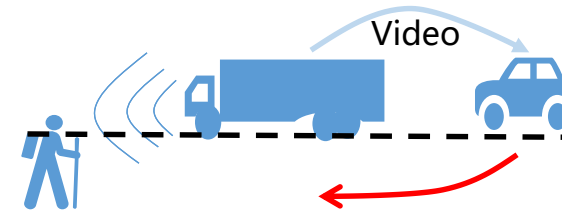In the future, new generation ICT technologies such as 5G, AI will support to build a **V2X based highly cooperative intelligent transportation system**. mobile travel services will be toward collaborative, intelligent, finally realizes the fully automatic driving.

The vehicle platooning

highly coordinated sensing and control

Video

Advanced and fully autonomous driving
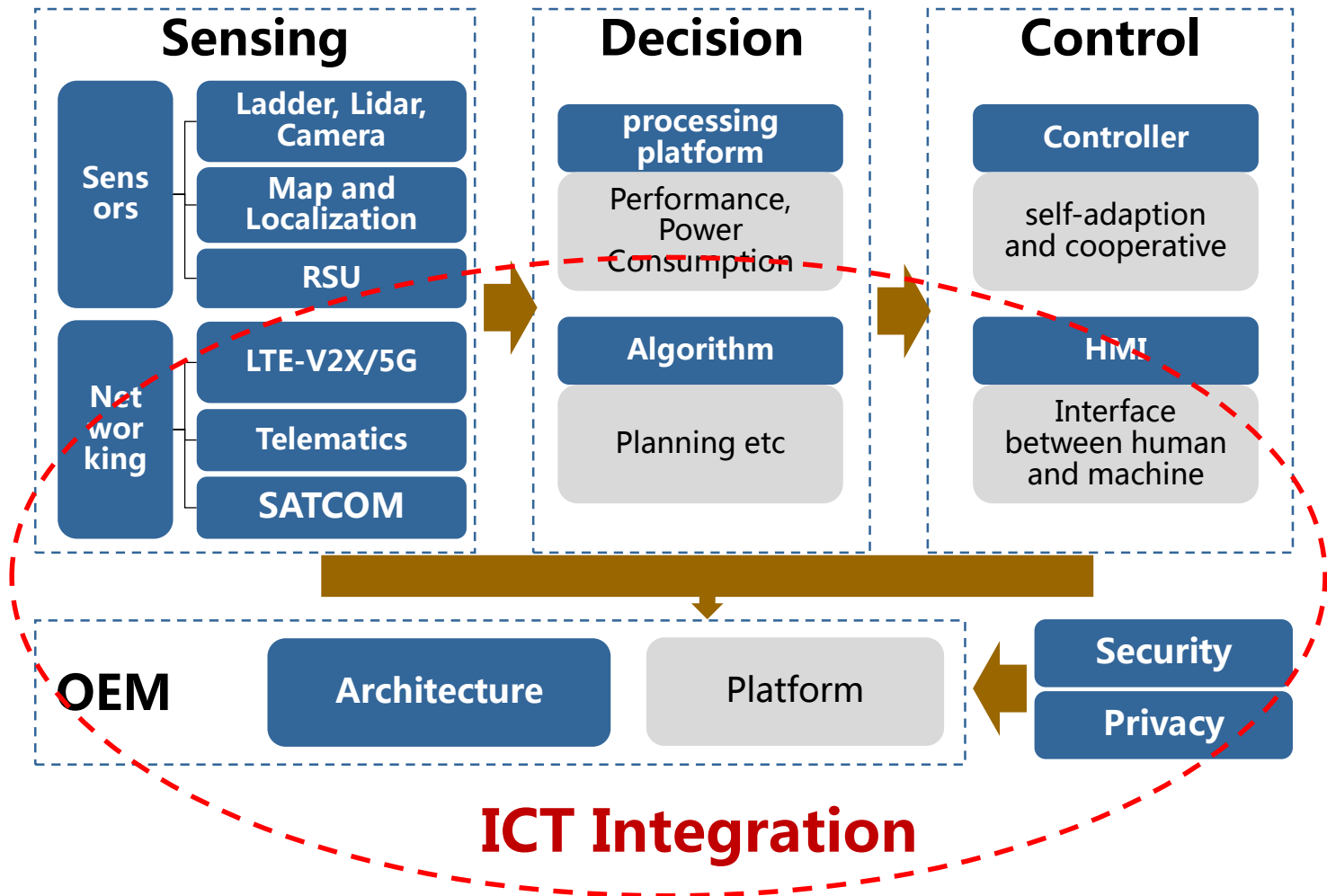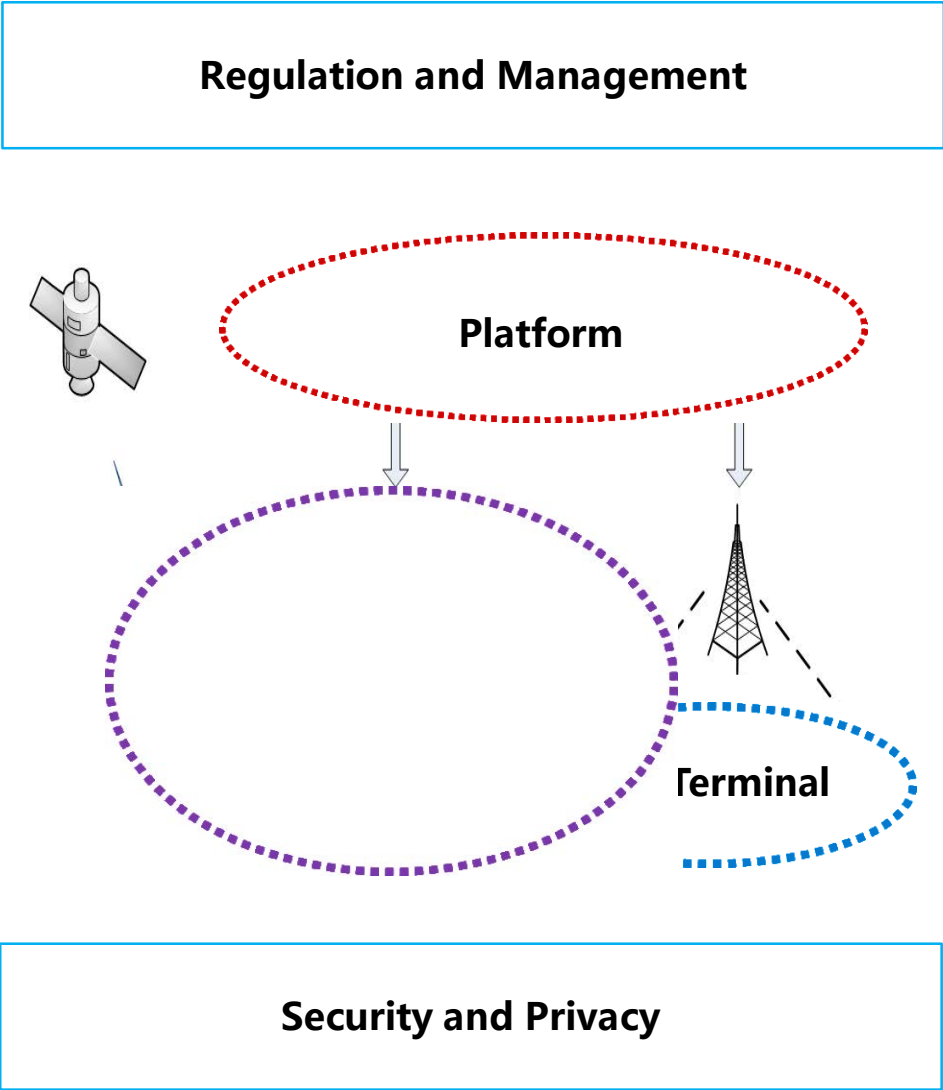
Driver free

Remote controlled driving

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Technical Architecture for CAVs

Regulation and Management

Platform

Terminal

Security and Privacy

Sensing

Sensors	**Ladder, Lidar, Camera**
	Map and Localization
	RSU
Networking	**LTE-V2X/5G**
	Telematics
	SATCOM

Decision

processing platform

Performance, Power Consumption

Algorithm

Planning etc

Control

Controller

self-adaption and cooperative

HMI

Interface between human and machine

OEM

Architecture

Platform

Security
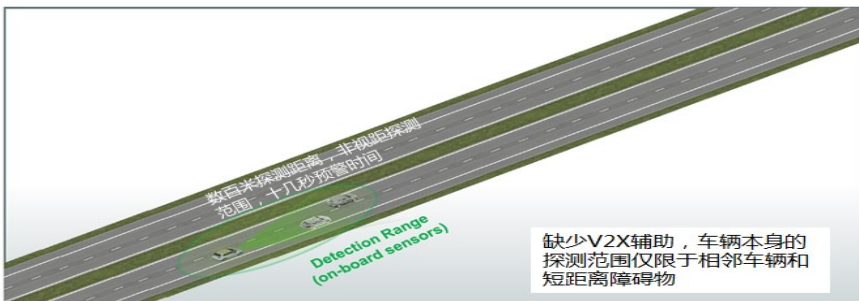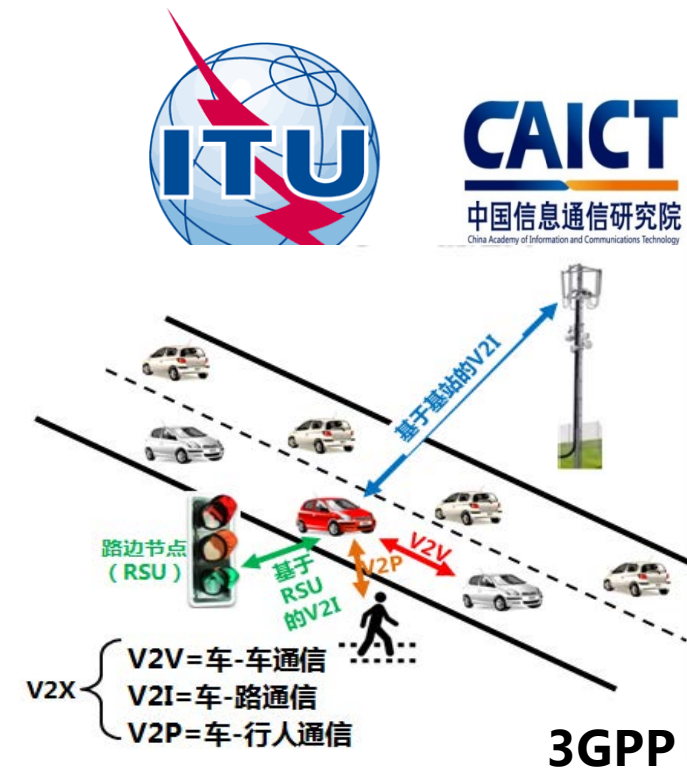
Privacy

ICT Integration

V2X is the key technology of CAVs

V2X (Vehicle to Everything) technology, which operates the communications and information interaction between V2V, V2I, V2P and V2C unit. Which could support the assist driving and extend the sensing scope.

IEEE 802.11p	LTE-V2X

路边节点（RSU）　基于RSU的V2I　V2P　V2V　基于基站的V2I

V2X { V2V=车-车通信　V2I=车-路通信　V2P=车-行人通信 }

3GPP

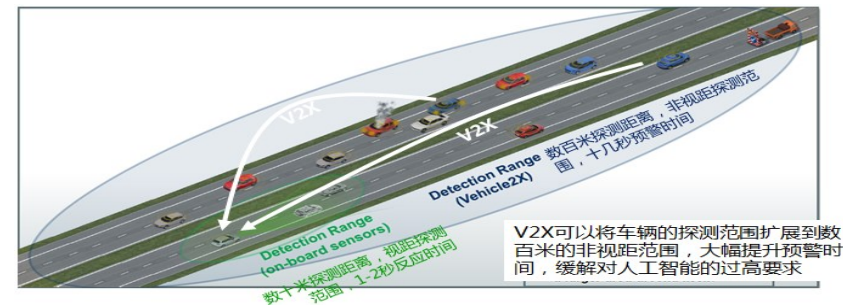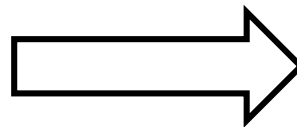缺少V2X辅助，车辆本身的探测范围仅限于相邻车辆和短距离障碍物

V2X可以将车辆的探测范围扩展到数百米的非视距范围，大幅提升预警时间，缓解对人工智能的过高要求

Sensors (Single sensing) :
◆ Limited distance, less reaction time, Inside view and crash warning nearby vehicles

V2X (Cooperative Sensing):
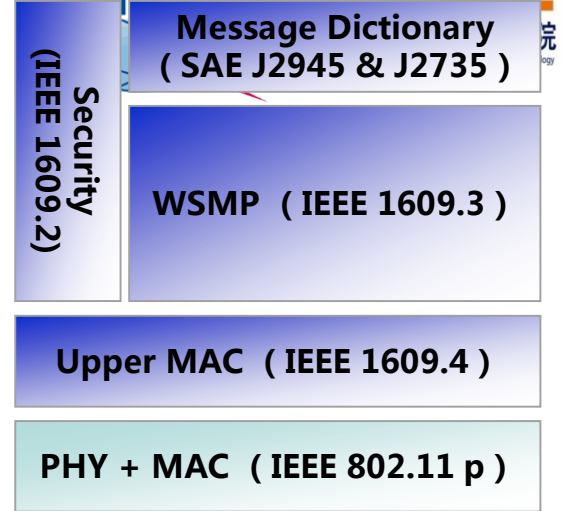◆ hundred of meters, out of View, route plan and assist driving

The current stage of 802.11P technology International

USA、EU and Japan mainly support IEEE 802.11p DSRC technology, and the safety applications. From the industry vies, the chip are already developed, about 2017 to enter the market maturity period.
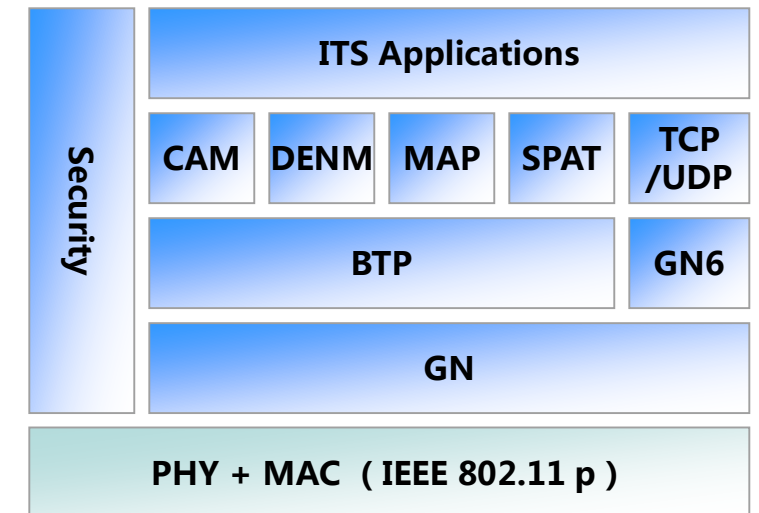
- ANN Arbor and other demonstration areas to test the DSRC technologies
- using DSRC technologies to solve the crowd and other traffic problems
- GM 2017 Cadiliac CTS has the DSRC module

- EU C-ITS basing on ETSI ITS-G5 technology, the development of ITS and Intelligent Vehicle
- France project Scoop @F C-ITS

- Japan has the ITS Connect V2V and V2I system, a important part of C-ITS system
- Toyota、Honda、Denso and others, DSRC products research and test

ITU CAICT

Security (IEEE 1609.2)	Message Dictionary (SAE J2945 & J2735)
	WSMP (IEEE 1609.3)
	Upper MAC (IEEE 1609.4)

PHY + MAC (IEEE 802.11 p)

USA Frequency 5.850-5.925 GHz

Security	ITS Applications
	CAM	DENM	MAP	SPAT	TCP/UDP
	BTP				GN6
	GN

PHY + MAC (IEEE 802.11 p)

EU Frequency 5.855-5.925 GHz

14

The current stage of LTE-V2X technology International

	2014		2015				2016			2017	
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2

3GPP:

Release 13 | **Release 14**

LTE-V2X SI → LTE-V2V WI → **Closure**

LTE-V2X WI → **Closure**
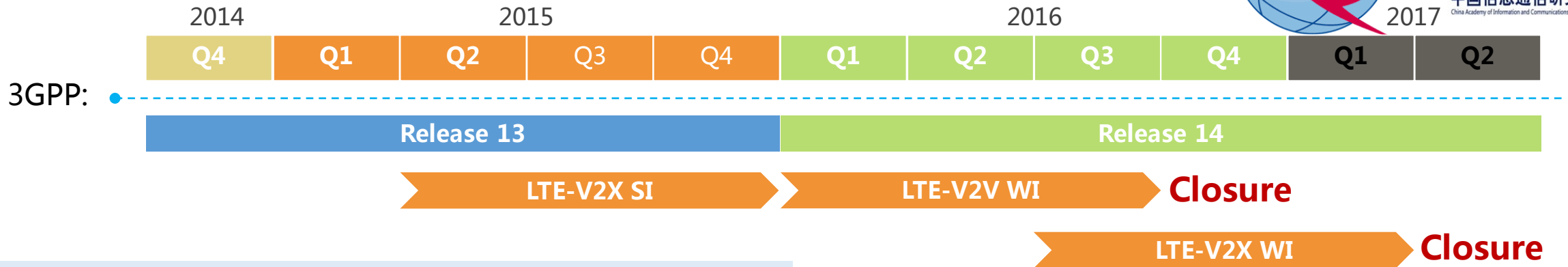
LTE-V2X VS 802.11P

- ☐ LTE-V2X comprehensive support V2V、V2I、V2P、V2N all kinds of applications

- ☐ Network support, better performance, and could satisfy more service requirements

- ☐ Technical Roadmap clear, form LTE-V2X evolve to 5G-V2X
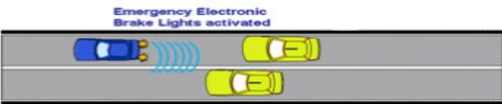
5GAA Automotive Association

- ☐ V2X Scenarios and Business models
- ☐ Technical Selection and Roadmap, including strategy, spectrum and other related issues
- ☐ Influence Standardization, regulation and authentication

The application and enhancement of LTE-V2X technology
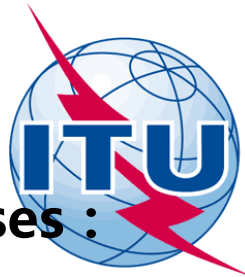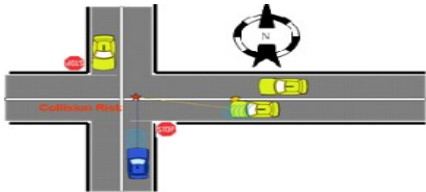
LTE-V2X Applications :

Safety :

FCW: Forward Collision Warning

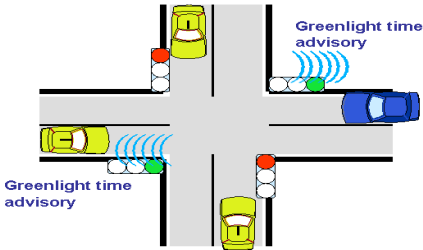DNPW: Do Not Pass Warning

ICW: Intersection Collision Warning

Efficiency :

SLW: Speed Limit Warning

TLOSA: Traffic light optimal speed advisory

3GPP SA1 eV2X User Cases :

| Use case	Illustration	Description	Payloads (Bytes)	Latency (ms)	Data rate (Mbps)	Range (meters)	Reliability (%)
Vehicles platooning		Vehicles dynamically form a platoon travelling together. Vehicles in the platoon obtain information from the leading vehicle to manage this platoon.	50 - 6500	10 – 25	0.012 - [65]	80 - 350	90 - 99.99
Advanced driving		Vehicle/RSU shares its own perception data obtained from its local sensors with vehicles in proximity and that allows vehicles to coordinate their trajectories.	300 - 12000	3 – 100	10 - 53 (including UL: 50 DL: 0.5)	[360] - [700]	90 - 99.999
Extended sensors		Exchange of data gathered through local sensors or live video images among vehicles, RSUs, Pedestrian and V2X server.	[1600]	3 - 100	10 - 1000	50 - 1000	90 – 99.999
Remote driving		Enables a remote driver or a V2X application to operate a remote vehicle.	-	5	UL: 25 DL: 1	-	[99.999]

□ 3GPP start R15 LTE-V2X enhancement research, plan to finish 2018.06. Maintain the compatibility with R14 LTE-V2X, to improve PC5 performance, including reliability, data rate and delay

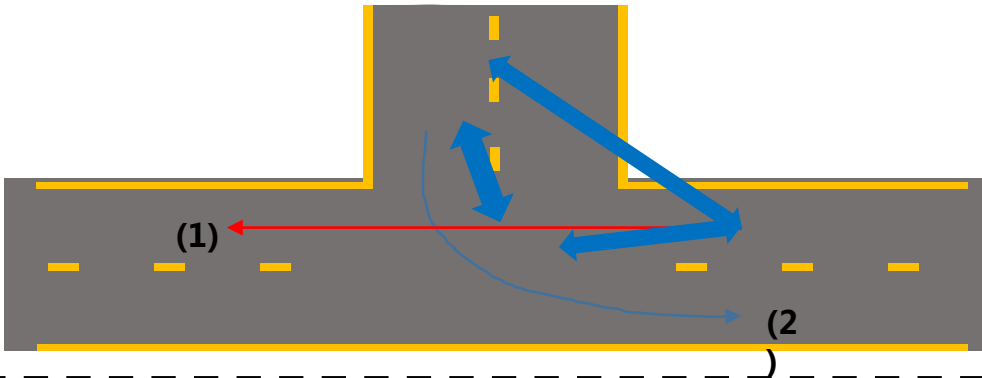# 5G-V2X, high level and more complexity applications

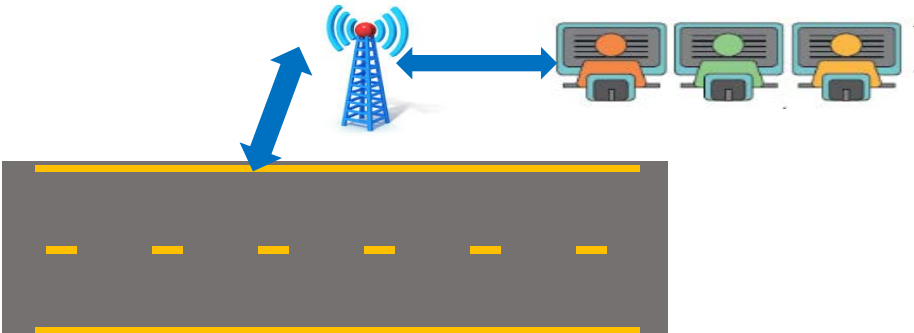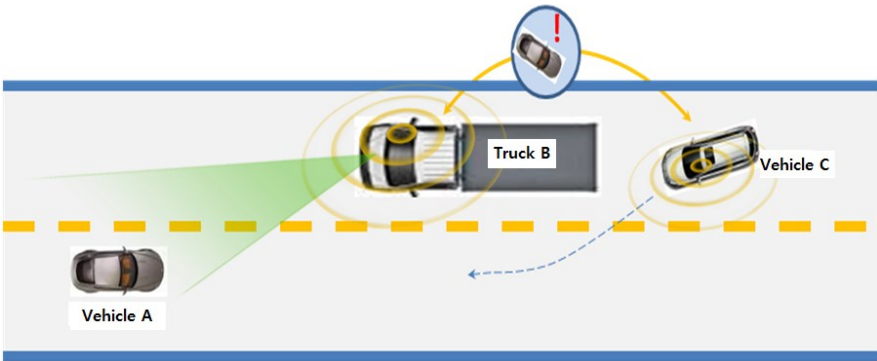## 5G Stage, vehicle networking evolution to cooperative, final to support Full Automatous

Platooning
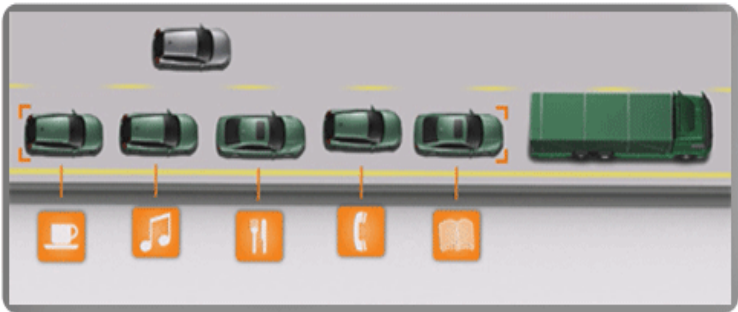
Information Sharing

Remote Driving

Video, sensing information exchange

China: Actively Participating in 3GPP Standard Formulation and Synchronizing China's Standards

Datang Telecom, Huawei, ZTE, and China Mobile actively promote the 3GPP standard research and formulation.

The standard-related organizations in China are also actively participating in the C-V2X standard research and formulation and will complete the standard formulation at the end of 2017, the same completion time as the 3GPP organization.

The commercial use of LTE-V2X standards is expected in the industry.

2015	2016	2017
Release 13	Release 14	Release 15

CCSA LTE-V2X requirements

CCSA V2X spectrum

CCSA LTE-V2X architecture

CCSA LTE-V2X wireless interface

V2X network and application

CCSA LTE-V2X security
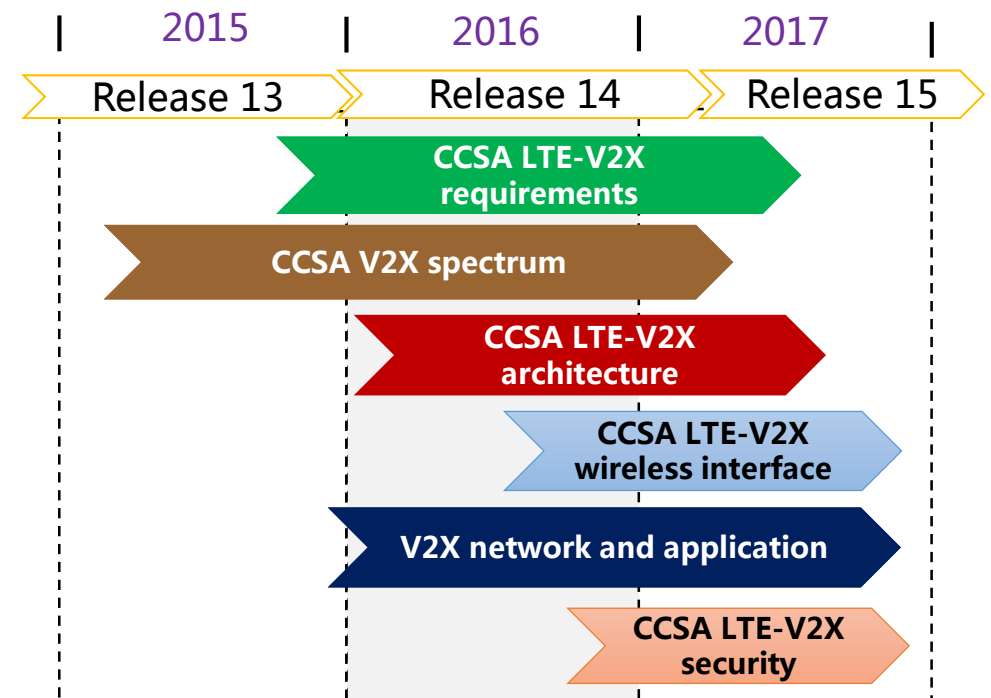
China: Progresses Achieved in V2X Technology Research and Development, Test, and Verification

Datang Telecom launches prototype devices of LTE-V2X wireless products.
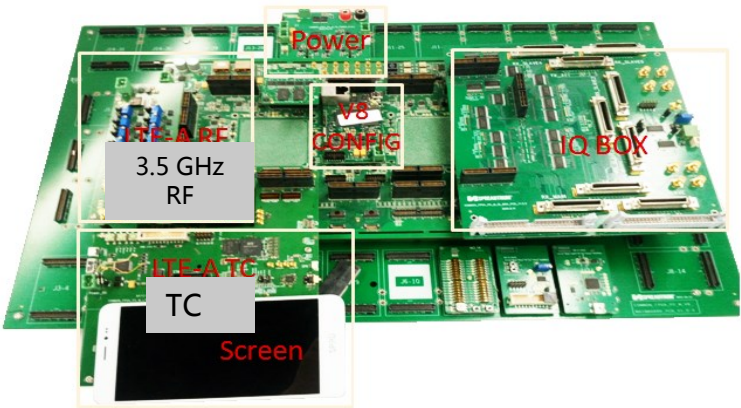
Spreadtrum Communications focuses on the prototyping and SoC design of LTE-V2X.
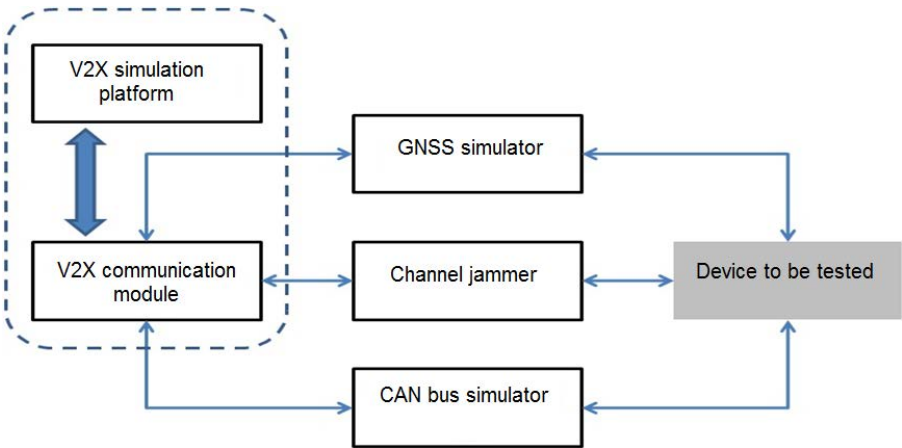
CAICT and CYIT build lab environments for the V2X function, interconnectivity and interworking, as well as interoperability tests.
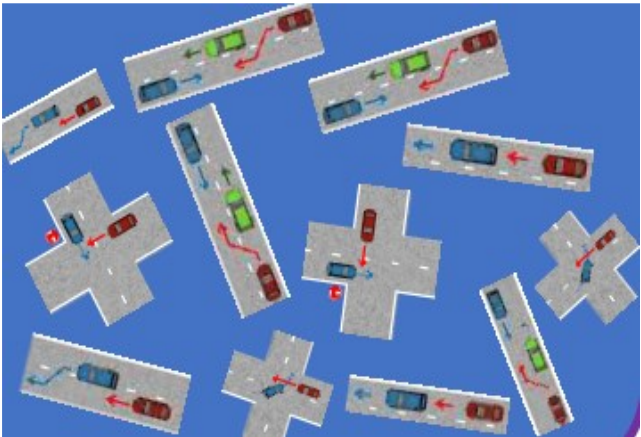
Chang'an Automobile, FAW, SAIC MOTOR, and some other automobile groups have designed V2X application scenarios covering various road conditions and working conditions.

China: Commercial Solutions Released Successively

Enterprise cross-industry cooperation provide **LTE-V2X demonstration**,

promote solution to the ground

China mobile, saic and others in Shanghai
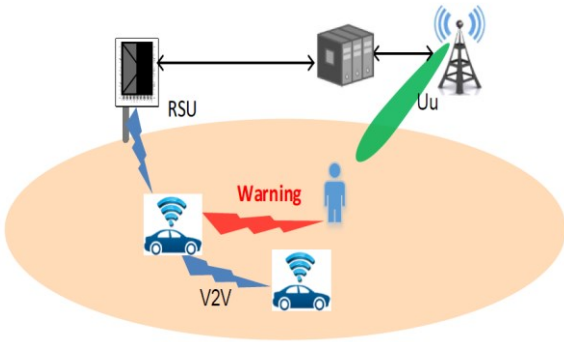
China unicom, with ford and faw V2P demonstration
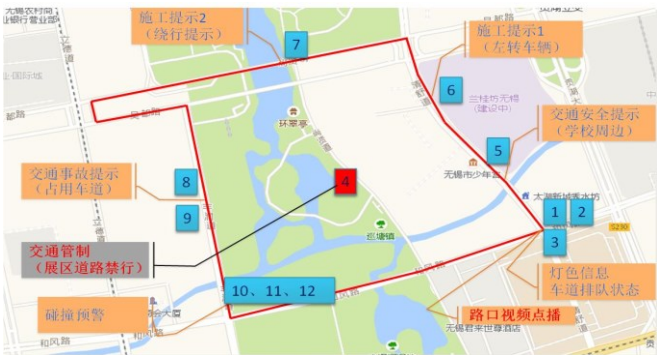
The TMRI, faw in wuxi

Beijing nebula Link, test area and demonstration city V2X deployment
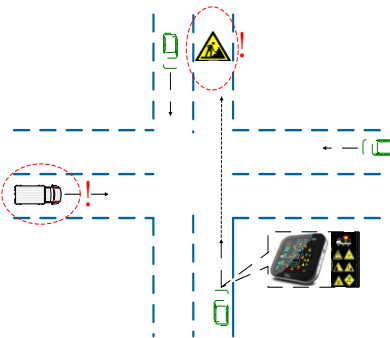
RIOH, huawei in Beijing

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CAVs will take new economic growth
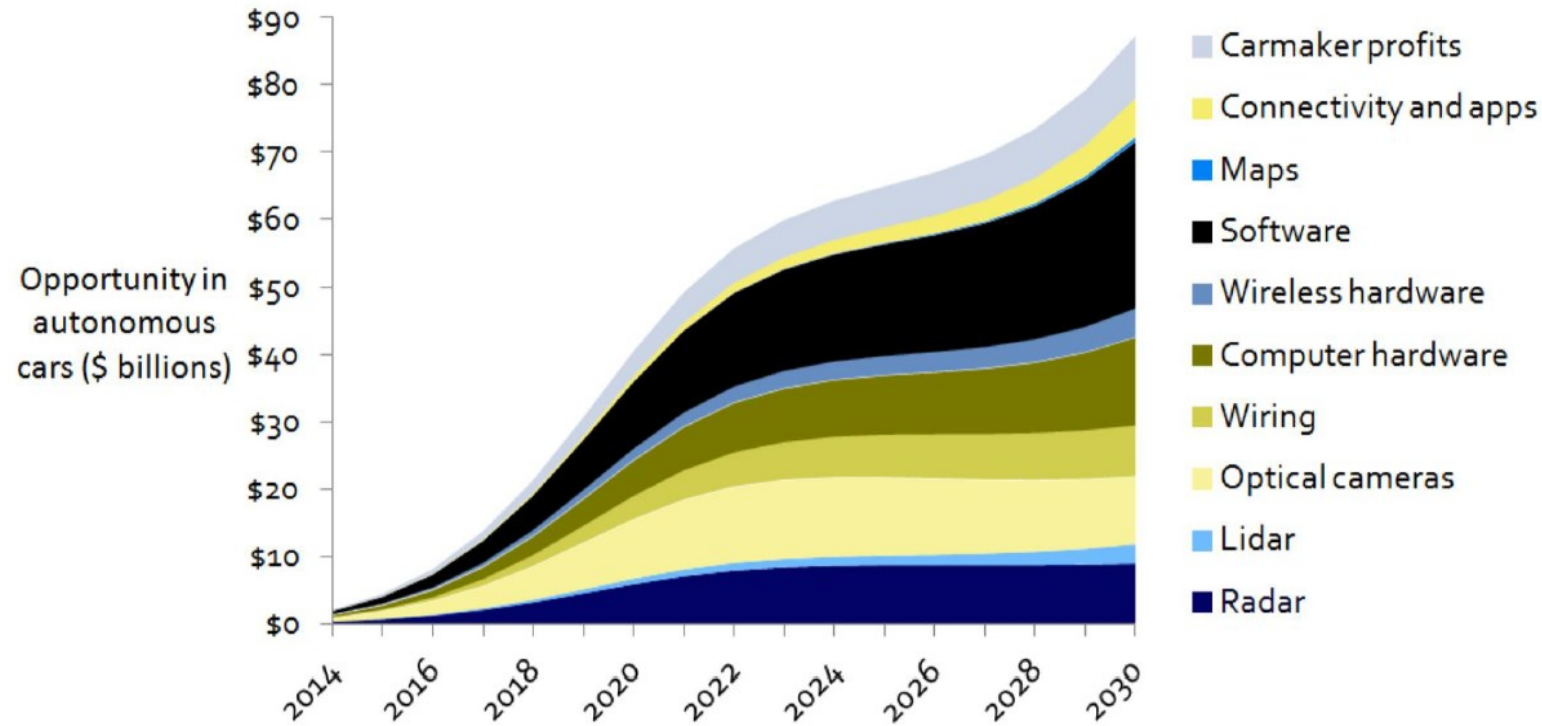
LuxResearch, "Set Autopilot for Profits: Capitalizing on the $87 Billion Self-Driving Car Opportunity", 2014

Gartner, the market scale of hardware of Connected and Automated Vehicles could achieve 48.6 billion US dollar

Trend1: Tradition automobile company using AI and ICT technologies actively

Daimler AG in CES2017 publish "**CASE-Connected、Automated、Sharing、Electronic**" strategy

Basing on AI and other related new generation ICT technologies, also with the development of ADAS evolution, the Automated Driving technology is develop from **Level 2 to Level 3**, and toward to the development of Level 4 automatous driving
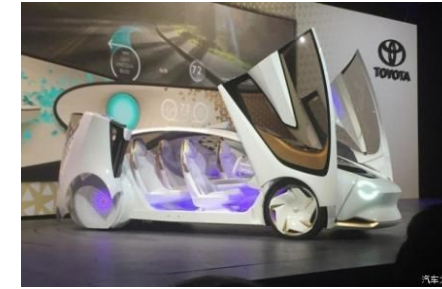
Toyota using new AI technology develop a **car emotion engine**
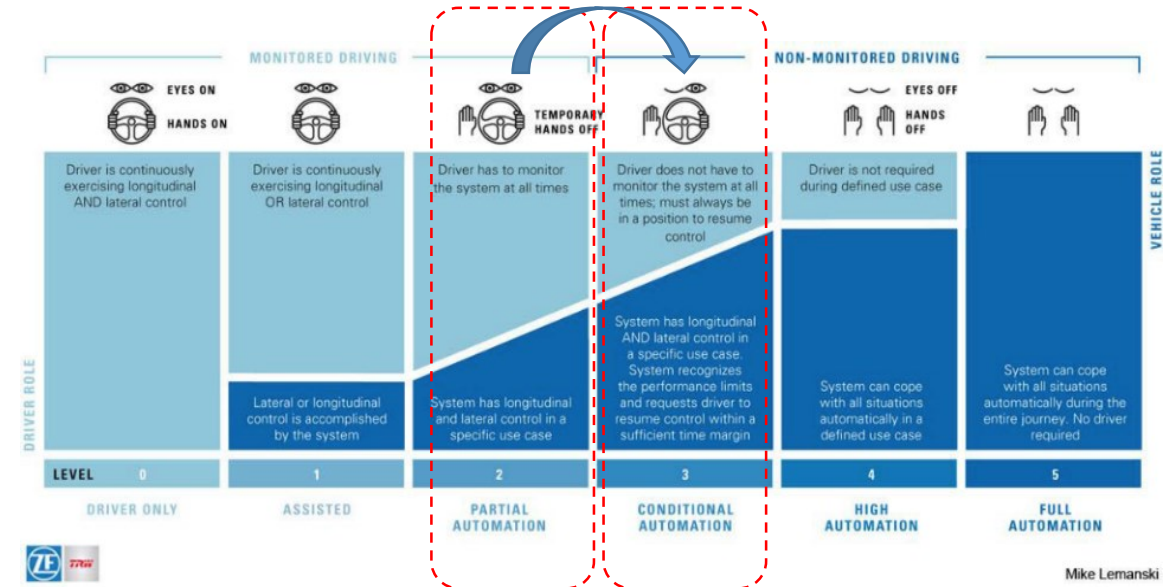
Trend2: ICT companies expand the layout of automobile field actively

Connectivity

Google, Android Auto, the ecosystme

Apple, Carplay more than 3000 users

Baidu, Carlife the HMI connection

DATANG LTE-V2X car terminal

Automated Driving

UBER Automated driving cars research and test

Lyft and NuTonomy, automated driving car sharing

Innovative Car company

Tesla

NEXTEV, high performance electromobile

UISEE

Trend3: Cross Industry cooperation

AUTONOMOUS DRIVING PARTNERSHIPS AMONG LARGEST PLAYERS
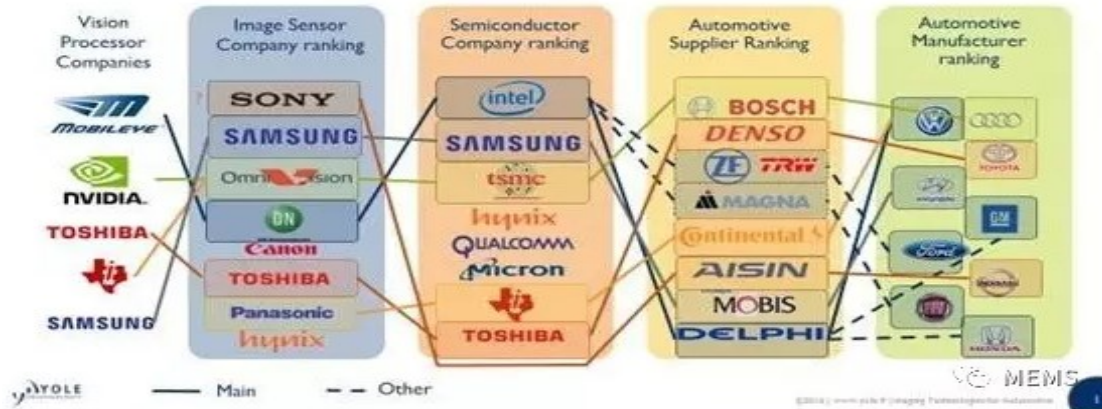
The cross industry cooperation between traditional automobile company and ICT company is more becoming more and more obvious, like BMW, Intel and Mobileye, Lyft and GM, BOSCH and NVIDIA

The same situation in China, **ICT company joint with automobile company to promote the development of CAVs**, like Baidu and Chery, Alibaba and SAIC, like changan and huawei

The integration of Industry Chain

Operation

- After Service → User ← Automobile
- Content provider → TSP ← Network Operator

Application

- System integrator ← Software platform

Hardware

- Module provider
- Hardware provider
- Sensors provider

Service
- Data and Content: Map, Data, Content...
- 服务提供商: Public, Industry

Communication
- Device: Communication infrastructure, RSU
- Communication: Basic, dedicated

Device
- Automobile: tradition, New ones
- Electronic system: Controller, TSP, ADAS
- component: electronics
- Software: OS, APPs

Service

manufacturing

"Sharing, Automated, Connected, Electric", to construct a new ecosystem

An interconnected network for information exchange among people, vehicles, roads, and cloud

Active safety warning application

Entertainment and transportation integrated information service

Not only

A data platform with information and things integrated
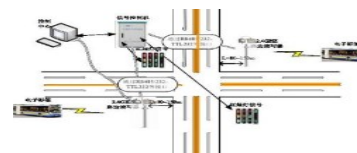
Traffic guidance and traffic control management
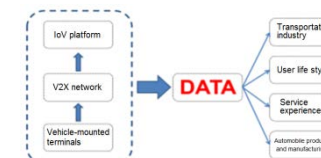
Production and manufacturing such as **personalized customization**

But also

A new ecological system of services and business models

Self-driving applications such as vehicle queuing

Smart traveling applications such as vehicle sharing

Smart transportation system

The market potential of Chinese CAVs

Market Scale of Automobile

Until September 2016, the number of vehicles has reached 285 millions, and the number of cars is approximately 190 millions. The number is estimated to increase 5% in the next 5 years. In 2020, the sale of motor vehicles is expected to reach 30 million per year , and the number of cars will reach 260 millions.

User Scale of Mobile Internet

The number of internet users has breakthrough 650 million, and almost 90% of them are mobile internet users. 4G users has topped 200 million, smartphone users has topped 900 million. Chinese users showed a relatively high acceptance of connected vehicles and automatic drive technology.

Year	Internet Users
2009	3.84
2010	4.57
2011	5.13
2012	5.64
2013	6.18
2014	6.49
2015.6	6.63
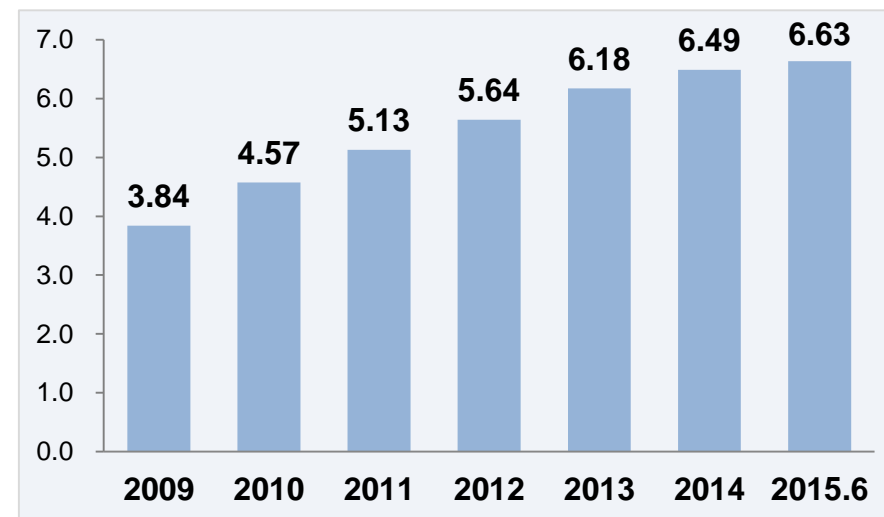
Internet Users (ten thousand)

The industrial foundation of Chinese CAVs

The traditional Automobile Company

FAW announced its ZHITU system. SAIC announced IGS autonomous vehicle. ChangAn outlined the development program of the intelligent car "654", and announced the autonomous vehicles.

ChangAn autonomous vehicle

ICT enterprise and innovative car company

Huawei and Datang are actively promoting LTE-V2X standardization and R&D on wireless devices and chips prototype; Newly established automobile enterprises cut into the market with there connected vehicles such as NextEV.

BAIDU autonomous vehicle

Universities and Research institutions

Tsinghua University, Tongji University and other research institutions collaboratively promote R&D on Vehicle road coordination and Autonomous vehicle. National research institutions such as CAICT and RIOH can provide complete technical testing and evaluation environment for connected vehicles.

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Improving Integration and Innovation Environments

The collaborative development of intelligent and internet of **automobile** has become a global consensus. As **new-generation information communications technologies, such as 5G,** are increasingly integrated into Internet of Things (IoT), cellular vehicle-to-everything (C-V2X) has become an important application scenario.

Strengthen Top-level Design

Key tasks

| Key technology research and development | Research on standards and spectrum | Trials and demonstration |

Assurance measures

| Enhanced department coordination | Enhanced international cooperation |

Policy Environment: Strengthen Top-level Design and Issue Guidance

Ma Kai, the deputy prime minister, has officially approved to establish **CAV industry development inter-ministry coordination mechanism** under the **great country of manufacturing leadership team**, with the joint effects from 20 departments under the Ministry of Public Security, the Ministry of Transport, and the National Development and Reform Commission, in order to tackle the major challenges of CAV development.

国务院关于积极推进"互联网+"行动的指导意见
国发 〔2015〕40号

- In May 2015, the state council officially launched **Made in China 2025**.
- To promote R&D and industrialization of **intelligent transportation tools**
- The technology roadmap for key fields has been worked out, and the following systems will be established : **smart vehicle self-development innovative system,** and **smart vehicle industry chain** and **smart transportation system**.

- In July 2015, the State Council officially issued **Guidance on Internet+ Action Promotion**.
- **Internet+ based conevient Transportation** helps promote intellectual technology applications, such as Internet of Vehicles (CAV).
- **Internet+ based Artificial Intelligence** helps quickly accelerate the development and application of intelligent-assisted driving, complex environment awareness, and vehicle-mounted smart devices.

- In June 2016, the China Ministry of Industry and Information Technology strengthened top-level design, assigned overall planning and key tasks for CAV, and launched **Promotion Plan on CAV Innovation and Development**.
- The CAV development has been promoted from the following six key tasks (involving 20 sub-tasks): **key technology research and development, research on standard systems, establishment of platforms and experimental sites, infrastructure development, application and promotion, as well as network and information security protection**.

- In April 2017, the China Ministry of Industry and Information Technology, together with NDRC and Ministry of Science and Technology (MOST), issued **Medium-and Long-term Automobile Industry Development Plan**.
- Green and smart automobiles are taken as breakthrough points to lead the industry transformation and upgrade. **The smart automobile promotion project has been proposed, with specified goals at the DA, PA, and CA phases.**

National **CAV industry integration and innovation guidance** and **Guidelines for construction of CAV industry standard system** will be issued.

Innovation Environment: Government-delivered Special Funds to Support Key Technology Research and Development

Key national science and technology projects support the research and development of key technologies regarding advanced sensors, vehicle-mounted operating systems, and V2X communications.

2016 Key National Science and Technology Project "Core Electronic Components, High-end Universal Chips, and Basic Software Products

Topic 1-1: Research & development and industrialization of CAV-oriented vehicle-mounted operating system platforms

■**Develop vehicle-mounted operating system platforms to make a breakthrough on key technologies, such as multi-core real-time scheduling management, data security assurance, and vehicle-mounted application management, vehicle diagnostic services, and vehicle communications.**

2016 Key National Science and Technology Project "New-generation Wireless Broadband Mobile Communications Network"

Topic 1-12: Research and demonstration on self-driving-oriented 5G key technologies

■Do research on auto-pilot-induced 5G technical requirements, propose a **self-driving-supported 5G system architecture and transmission technology solution**, and assess performance simulation results. Develop a self-driving-supported 5G system and a **high-precision 3D map and self-driving integrated application**, and set up a demonstration platform.

Topic 2-10: Standardization of LTE-V wireless transmission technologies, and research & development and verification of sample devices

■Complete **the research on LTE-V wireless transmission technologies and the network architecture and protocol design**, start system performance evaluation, and ensure the compliance with 3GPP standards. Develop LTE-V sample devices and build the test and verification platform to complete technical verification.

Experimental Environment: Opening Test Frequency Bands and Speeding up Spectrum Planning, Research, and Experiment

Officially approving that IMT-2020 5.905 GHz to 5.925 GHz frequency bands (20 MHz bandwidth in total) are used for testing wireless communications applying the LTE-V2X direct communication technology

- ☐ Cities: Beijing, Shanghai, Chongqing, and Hangzhou (in Zhejiang province)
- ☐ Test on the performance of LTE-V2X vehicle-vehicle and vehicle-road communications
- ☐ Test on interoperations among different LTE-V2X equipment suppliers and automobile manufacturers
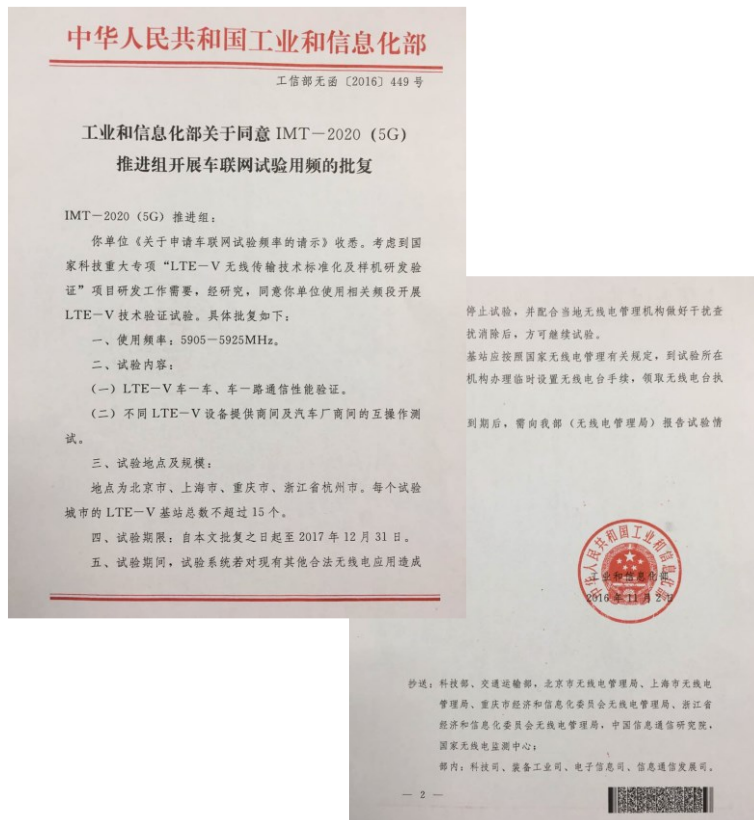
Europe @5.9 GHz

Japan @760 MHz& 5.8GHz

USA @5.9 GHz

Demonstration Environment: Holding the Principle "Try First, Come First", Completing Industrial Concentration and Application Promotion

The "5+2" CAV demonstration pattern has taken initial shape.

Broadband mobile Internet-based smart automobile and smart transportation demonstration

The China Ministry of Industry and Information Technology, together with the Ministry of Public Security and Jiangsu provincial government, seeks cooperation on the establishment of Wuxi "National Smart Transportation

The China Ministry of Industry and Information Technology and the local governments jointly carry out demonstration projects in regions, such as **Zhejiang, Beijing-Hebei, Chongqing, Jilin, and Hubei**, which provide applications and test and verification environments for technical convergence and collaborative innovation.
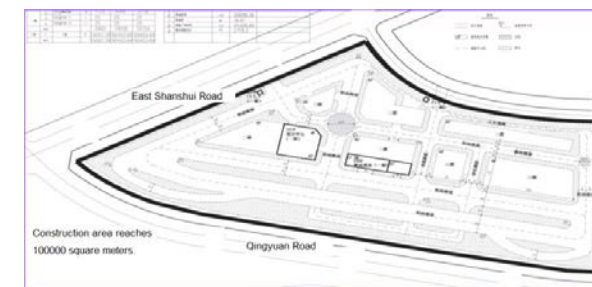
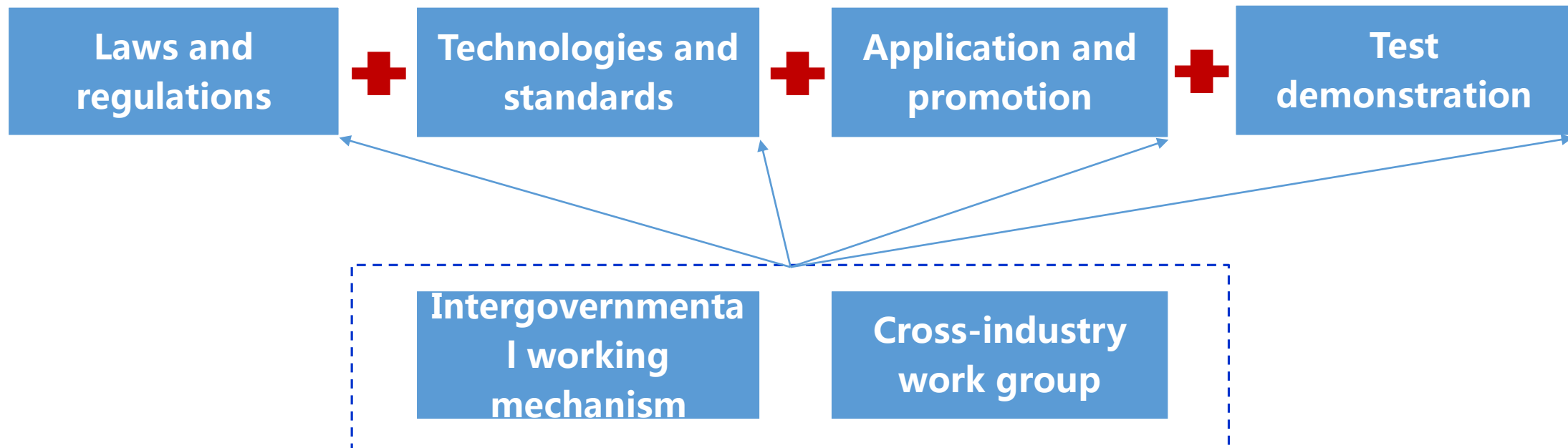**Intelligent manufacturing demonstration pilot project**

The China Ministry of Industry and Information Technology officially approved the establishment of "National Smart Automobile Demonstration Project (**Shanghai**) in the Shanghai International Automobile City.

International Cooperation: Promoting Cooperation in Laws and Regulations, Standards, Technologies, and Applications
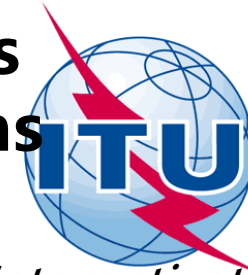
Carry out the contents in *China-German Smart Manufacturing and Production Internetization Cooperation DOU*. Initiate the project **China-German Cooperation on CAV and Smart Automobile Standards and Test and Verification**, driven by technologies and standards and focusing on project cooperation. Hold seminars under the framework of **China-US Joint Commission on Commerce and Trade (JCCT)**.

Laws and regulations	**+**	Technologies and standards	**+**	Application and promotion	**+**	Test demonstration

Intergovernmental working mechanism	Cross-industry work group

Official Approval of IMT2020 C-V2X Work Groups

On April 23, 2017, the IMT-2020 (5G) Promotion Group agreed to set up a **C-V2X work group** in the 12th meeting. The C-V2X work group will focus on **technical research, conducting related experiments and verification, and promoting industries and applications for LTE-V2X.** The C-V2X work group will also **study the requirements for 5G V2X.**

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                    ┌─────────────────────────┐
                    │       Secretariat        │
                    └─────────────────────────┘
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| Requirement group | Spectrum group | Technology group | Test group | Standard group | C-V2X group | IPR group | International cooperation group |
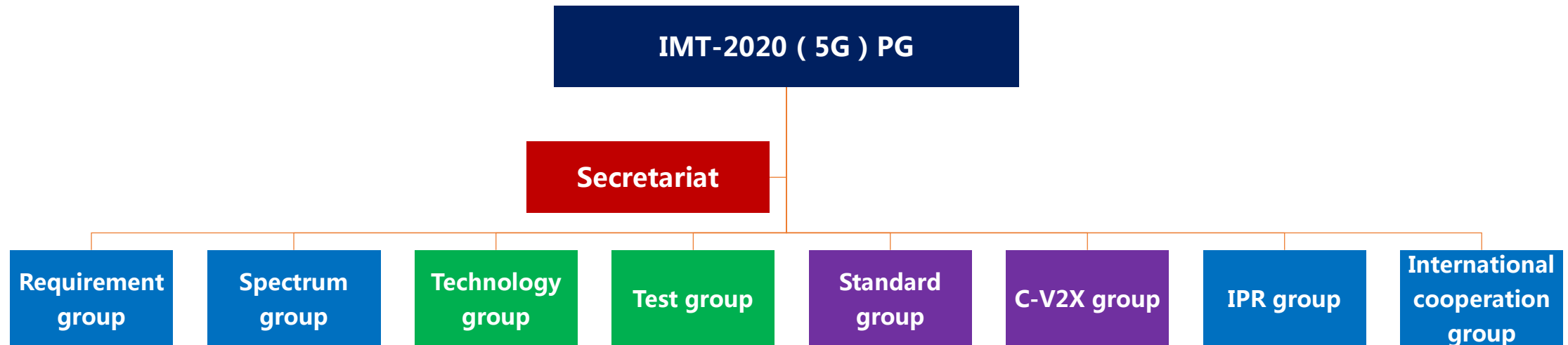
Challenges and Difficulties: Cross Industry

1

- **Overall Planning and Coordination**. Connected and Automated Vehicles involve several industries, automobile, ICT, transportation, traffic management. The coordination between different administrative departments should be strengthen, technical roadmap, national industry policy.

2

- **Technology innovation and standardization**. The technology innovation between different industries should be strengthen, like Networking, information fusion, High precision map and other related ICT integration technologies, carry forward the interface specification and standardization.

3

- **Key laws and regulations**. For demonstration, some of the laws and regulations need to be revised, example allow the driverless vehicles on the road test, promote V2X module installation. Countries, like USA and German, are walk in the front.

4

- **Security and privacy**. While the vehicle connected to the internet and the CAN opened, it could be attacked and remote controlled. Otherwise, basing on the connection, the data could be collected and shared privacy is another serious problem for drivers.

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