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
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 solve the prominent social problems

Traffic safety

Transpiration efficiency

Green development

To accelerate the integration of new technologies

Accelerate IoT technologies evolution into a new stage of “Cross integration, integrated innovation and large scale 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 Vision**

- **eMBB**
  - User experienced data rate: 0.1~1 Gbps
  - Peak data rate: 10~20 Gbps
  - Network energy efficiency: 100 x
  - Area traffic capacity: 10 Mbps/m²
  - Spectrum efficiency: 3~5x
- **mMTC**
  - Connection density: 1M/km²
- **URLLC**
  - Latency: 1 ms (AI)
  - User experienced data rate: 0.1~1 Gbps
  - Mobility: 500km/h

**Three scenarios**

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

ITU IMT-2020 Vision: 5G from mobile internet to IoT, Connected Vehicles is the key scenario.
Mobile communication technology & Connected and Automated Vehicles

1G
Voice
Data rate: 10~300kbps
Delay: 1.5s

2G
Data rate: 300k~50Mbps
Delay: 50ms

3G
Data rate: 50M~1Gbps
Delay: 1ms

4G
Data rate: 1~10Gbps
Delay: 1ms

5G

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

V2X solves safety

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

Advanced and fully autonomous driving

Remote controlled driving
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Technical Architecture for CAVs

- **Regulation and Management**
- **Platform**
- **Sensing**:
  - Sensors: Ladder, Lidar, Camera
  - Map and Localization
  - RSU
  - LTE-V2X/5G
  - Telematics
  - SATCOM
- **Decision**:
  - Processing platform
  - Performance, Power Consumption
  - Algorithm
  - Planning etc
- **Control**:
  - Controller
  - self-adaption and cooperative
  - HiMi
  - 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.

### 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 Cadilic 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
The current stage of LTE-V2X technology International

3GPP:

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

**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**

**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:

<table>
<thead>
<tr>
<th>Use case</th>
<th>Illustration</th>
<th>Description</th>
<th>Payloads (Bytes)</th>
<th>Latency (ms)</th>
<th>Data rate (Mbps)</th>
<th>Range (meters)</th>
<th>Reliability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicles platooning</td>
<td></td>
<td>Vehicles dynamically form a platoon traveling together. Vehicles in the platoon obtain information from the leading vehicle to manage this platoon.</td>
<td>50 - 6500</td>
<td>10 – 25</td>
<td>0.012 - [65]</td>
<td>80 - 350</td>
<td>95 - 99.99</td>
</tr>
<tr>
<td>Advanced driving</td>
<td></td>
<td>Vehicle/RSU shares its own perception data obtained from its local sensors with vehicles in proximity and that allows vehicles to coordinate their trajectories.</td>
<td>300 - 12000</td>
<td>3 – 100</td>
<td>10 - 53</td>
<td>[360] - [700]</td>
<td>95 - 99.99</td>
</tr>
<tr>
<td>Extended sensors</td>
<td></td>
<td>Exchange of data gathered through local sensors or live video images among vehicles, RSUs, Pedestrian and V2X server.</td>
<td>[1600]</td>
<td>3 - 100</td>
<td>10 - 1000</td>
<td>50 - 1000</td>
<td>90 – 99.99</td>
</tr>
<tr>
<td>Remote driving</td>
<td></td>
<td>Enables a remote driver or a V2X application to operate a remote vehicle.</td>
<td>-</td>
<td>5</td>
<td>UL: 25 DL: 1</td>
<td>-</td>
<td>99.999</td>
</tr>
</tbody>
</table>

- 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.
China: Progresses Achieved in V2X Technology Research and Development, Test, and Verification

Datang Telecom launches prototype devices of LTE-V2X wireless products.

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.

Spreadtrum Communications focuses on the prototyping and SoC design of LTE-V2X.
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

Gartner, the market scale of hardware of Connected and Automated Vehicles could achieve 48.6 billion US dollar
Trend 1: 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 ecosystem
- 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
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
“Sharing, Automated, Connected, Electric”, to construct a new ecosystem

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

Not only

A data platform with information and things integrated

But also

A new ecological system of services and business models

Active safety warning application

Entertainment and transportation integrated information service

Traffic guidance and traffic control management

Production and manufacturing such as personalized customization

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.
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.

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.

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.
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.

- 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 convenient 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.
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
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 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)*.
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.
Challenges and Difficulties: Cross Industry

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

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

- **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.

- **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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