Intelligent Connected Vehicles in 5G Era

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Chief scientist of Datang telecom group
From CAA (2015.10): ICV are equipped with advanced automotive sensors, controllers, actuators and other devices. ICV are integrated by modern communications and network technology to achieve the car and X (people, cars, roads, background, etc.) intelligent information exchange sharing, with complex environment perception, intelligent decision making, collaborative control and execution functions. ICV can be safe, comfortable, energy efficient, efficient driving, and ultimately replace the people to operate a new generation of cars.
ICV is Supported in Global

- **ITS Strategic Plan (2015-2019)**: “Connected Vehicle” and “Advancing Automation” are two main aims.
- **V2V mandatory regulations** are expected in 2020, and V2V system will be installed in 90% of vehicles in 2040.

- **The Cabinet Office**: commercial ICV in late 2020.
- **High level intelligence traffic**: good infrastructure, good government support.

- **Close collaboration** among EU member states, with a complete top-level design, leading research in intelligent network of energy-saving and environmental protection.
- **Automatic cars** are expected with massive production in 2025.

- **Strategy and roadmap** of ICV are being developed.
- **For national auto companies**, the total progress of ICV is in pace with international companies.
China Government’s Policies in ICV

**MIIT**
- ICV is one of ten key sectors within “Made in China 2025” strategy
- Technology roadmap of ICV
- Automobile Industry Developing Policy in Mid/long Term
- ICV related Pilot projects, e.g. Intelligent Manufacturing, Enhancing Industry Foundation

**MOT**
- Implementation scheme on promoting internet plus convenient transportation & improving ITS development for “Internet Plus” strategy
- Preparing roadmap of Commercial Autonomous Driving Vehicle
ICV Develops with Mobile Communication

1G: Voice (Data rate: 10~300kbps)  
2G: Basic Connection (Data rate: 10~300kbps, Delay: 1.5s)  
3G: Limited Connection (Data rate: 300k~50Mbps, Delay: 1.5s)  
4G: Rich Connection (Data rate: 50M~1Gbps, Delay: 50ms)  
5G: Ubiquitous Connection (Data rate: 1~10Gbps, Delay: 1ms)

Connectivity
ICV Requirements in 5G

5G system will support hybrid access technologies, promoting ICV application with multi-mode.

- AIR Delay: 1 ms
- E2E Delay: 5 ms
- Reliability: nearly 100%
- Experience data rate: xGbps

**LTE V2X**
Awareness, Sensing

**Enhanced Mobile Broadband**

**5G V2X**
Cooperative, Control

**Ultra-reliable and Low Latency**

**5G: NR plus LTE-A Pro**

**Standard Timetable for 3GPP V2X**

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<thead>
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<tbody>
<tr>
<td>R14</td>
<td>R15</td>
<td>5G phase 1</td>
<td>5G phase 2</td>
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<tr>
<td>SA1 LTE V2X需</td>
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<td>eMBB</td>
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<td>URLLC enhc</td>
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<td>RAN V2X</td>
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<td>mMTC</td>
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<td>LTE eV2X</td>
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<td>WI</td>
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<td>NR eV2X</td>
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New interfaces

4.5G (LTE-V)

5G-V (eV2X)

mMTC

URLLC

eMBB

WLAN

3G/4G及其他

新空口NR
<table>
<thead>
<tr>
<th>Application Scenarios</th>
<th>Function</th>
<th>System</th>
<th>Coverage</th>
<th>Traffic</th>
<th>Delay</th>
<th>Data rate</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor data sharing</td>
<td>Auto-driving</td>
<td>V2V , V2I</td>
<td>Small (100m level)</td>
<td>High (100Mbps)</td>
<td>Low (ms)</td>
<td>High</td>
<td>~100%</td>
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<tr>
<td>Road test equipment real-time traffic information broadcast</td>
<td>Auto-driving</td>
<td>V2I</td>
<td>Small (100m level)</td>
<td>High (100Mbps)</td>
<td>Low (ms)</td>
<td>High</td>
<td>~100%</td>
</tr>
<tr>
<td>3D map download</td>
<td>Auto-driving</td>
<td>V2I , V2N</td>
<td>Large (km level)</td>
<td>High (100Mbps~1Gb ps)</td>
<td>High (s)</td>
<td>Best Effort</td>
<td></td>
</tr>
<tr>
<td>Sensor data cloud upload</td>
<td>Auto-driving</td>
<td>V2N</td>
<td>Large (km level)</td>
<td>High (s)</td>
<td>Medium</td>
<td>Best Effort</td>
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<tr>
<td>Multimedia information download</td>
<td>Media entertainment</td>
<td>V2N</td>
<td>Large (km level)</td>
<td>High (100Mbps~1Gb ps)</td>
<td>High (s)</td>
<td>Best Effort</td>
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<tr>
<td>Video stream application</td>
<td>Media entertainment</td>
<td>V2N</td>
<td>Large (km level)</td>
<td>High (100Mbps~1Gb ps)</td>
<td>Low (100ms)</td>
<td>Best Effort</td>
<td></td>
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<tr>
<td>Mobile information relay</td>
<td>Media entertainment</td>
<td>V2N</td>
<td>Large (km level)</td>
<td>High (100Mbps~1Gb ps)</td>
<td></td>
<td>Best Effort</td>
<td></td>
</tr>
</tbody>
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ICV Application in 5G (1): Automotive Driving

- **Information sharing among vehicles**, expanding sensing area to achieve oversight perception
  - Safe, efficient, supporting automatic driving
  - Improve road traffic supervision
- **High precision map downloading from the roadside/cloud in strange areas**
  - No need to store the map locally in advance
  - Map upgrading is quick and easy
ICV Application in 5G (2): Information & Entertainment

- **Large bandwidth Internet access support for car infotainment**
  - Enhance the traveler’s journey experience
  - Provide fruitful multimedia applications
  - High speed hot spot access, such as BYOD
ICV Application in 5G (3): Vehicle Formation

Queue - Passenger vehicles

- Intensive formation fleet, reduce the distance between vehicles
  - Improve road utilization
  - Reduce overall wind resistance and energy consumption
- Communication mode
  - Formation Discovery/Join/Adjust/Leave
  - Frequent news

Queue - Commercial vehicles

- Connect all vehicles using D2D technology
  - Full team synchronization control in sudden situation
  - Avoid accumulative transfer of sensor delay
- Application mode
  - Mode 1: head car man-driven, following cars unmanned
  - Mode 2: head car unmanned, following cars unmanned
ICV Application in 5G (4): Remote Driving

- **High reliability:** Accurate reception of control signals
  - Identity authentication mechanism
  - Data reliability authentication mechanism
- **Low delay:** Control signal is received in time
  - Meet the human body limit reaction speed (ms)
  - New network architecture reduces latency
- **High bandwidth:** Remote video stream backhaul
  - Support UHD video streaming
### Mapping of ICV Application with 5G Scenarios

<table>
<thead>
<tr>
<th>ICV Application Scenarios</th>
<th>eMBB</th>
<th>URLLC</th>
<th>mMTC</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-precision map upload and download</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information distribution (sensor/video/intention)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Vehicle formation</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Remote driving</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Crew broadband access</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Roadside facilities interconnection</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
eMBB Solution for ICV

**Typical Application Scenarios**
- High-precision map upload and download
- Car audio and video entertainment applications
- In-car video conference

**Requirements:** large wideband, high traffic; not strict with delay and reliability

**Key Technologies:** massive MIMO, UDN, High mobility enhancement...
URLLC Solution for ICV

- **Typical Application Scenarios**
  - Road environment perception
  - Remote driving
  - Fleet

- **Requirements:** low delay, high reliability, indoor/outdoor coverage

- **Key Technologies:** D2D, short TTI, MEC...
mMTC Solution for ICV

**Typical Application Scenarios**

ITS infrastructure information, low-cost high-density roadside sensors achieve road prediction system, improve traffic efficiency, reduce emissions.

**Requirements:** low cost, high density, high path loss

**Key Technologies:** NOMA for massive connection, Massive MIMO, low power consumption, enhanced coverage...
LTE-V: Solutions for CV/ITS

LTE-V: LTE based V2X system solution for connected vehicles/ITS

LTE-V-Cell: LTE centralized enhancements

LTE-V-Direct: LTE decentralized design

Based on LTE
Customized ITS solution
Road Safety support
Contribution on C-V2X

- Proponent pioneer of LTE-V concept
- Promote LTE-V study in 3GPP
- Promote LTE-V study in China
- Reporter of 3GPP RAN LTE-V SI/WI
- Complete V2V standardization in 3GPP
- Complete V2X standard in 3GPP
- Start eV2X study in 3GPP

2013
- Key technology research

2014
- First LTE-V Prototype
- The 2nd generation LTE-V equipment
- Field Demonstration
  - Hannover, CEBIT
  - Nanjing, 14th Asia-Pacific ITS forum
  - Wuhan, 3rd ICTIS
  - Shanghai, SAE

2015
- Release the chip-level LTE-V pre-commercial products: OBU and RSU
- Co-operation with companies in automotive and transportation industry, e.g. FAW, Chang’an, GAC, Chery, BAIC

2016
- Complete V2X standard in 3GPP

2017
- 3GPP R14 Commercial LTE-V products
C-V2X Product: OBU/RSU

**OBU**
- Size: 185*124*23mm  Weight: 1kg
- Supporting LTE-V-Direct and LTE-V-Cell based on Datang-designed chipset
- Linux/Android OS
- Diverse interfaces of CAN, Serial Ports, RJ45, USB

**RSU**
- Size: 212*204*53.5mm  Weight: 2.5kg
- High reliability with Water-proof, dust prevention and anti-corrosion, protection grade IP65
- Integral-designed product with small size, plug and play
- High-gain antennas with the coverage of 1.5Km
Live demo

- Partners: Tsinghua university, Chang An automobile, Datang
- Public road in AUTO-EXPO
- 2 OBUs, 5 RSUs
- Use cases
  - V2V safety warning, Speed advisory, Pedestrians detection, green wave tape

Live demo on public road
Real Road Test: Chong Qing Pilot Area

Deployment Solution
- 8 RSU, 4 OBU, 2 eNB
- 8 use cases, 1.5KM road

Show Cases
- Intersection movement assist
- Emergency brake warning
- Pedestrian warning
- Over speed warning
- Curve warning
- Speed advisory
- Road construction warning
- Malfunction alert
China’s Future Testing Plan for LTE-V2X

• LTE-V2X Protocol Agreement Test
  - CAICT
    - Comm Vendor
      - Datang
      - Huawei
    - Automobile
      - ChangAn
      - SAIC
    - Other
      - CMCC
      - Chongqing Univ
      - Qinghua Univ

• LTE-V2X Frequency Test
  - TIAA
    - Requirement WG
      - FAW
      - GWM
    - Product WG
      - Datang
      - Huawei
    - Test WG
      - SRTC

Laboratory Test: 2017Q3 - 2017Q4
Field Test: 2017Q3 - 2017Q4
Thanks for your attention