5G and Automotive
Cellular Vehicle-to-Everything (C-V2X)

March 2017
Our vision for the autonomous vehicle of the future

Intelligently connected
Efficiently shared
Increasingly electric
Increasingly autonomous
5G will be a key enabler for our automotive vision

Enhanced mobile broadband
Mission-critical services
Massive Internet of Things

Unifying connectivity platform for future innovation
Starting today with Gigabit LTE, C-V2X Rel-14, and massive IoT deeper coverage
ADAS
Advanced Driver Assistance Systems
Brain of the car to help automate the driving process

V2X offers high level of predictability and autonomy

Complementing other sensor technologies

V2X wireless sensor
See through, 360° non-line of sight sensing, extended range sensing

3D HD maps
HD live map update, sub-meter level accuracy of landmarks

Precise positioning
GNSS positioning, dead reckoning, VIO

Radar
Bad weather conditions, long range, low light situations

Camera
Interprets objects/signs, practical cost and FOV

Lidar
Depth perception, medium range

Ultrasonic
Low cost, short range
The path to 5G will enable safer, autonomous driving
Starting with C-V2X release 14 - specification completion and global trials in 2017

Synergistic with existing automotive cellular connectivity platform\(^1\)
Cellular already delivering key services today, e.g. telematics, eCall, connected infotainment

Delivers enhanced range and reliability for V2X direct communications
Improvements over 802.11p, ~2x range\(^2\), or more reliable performance at the same range

Leverages existing cellular infrastructure for network communications
Offering new business models and economic benefits (e.g. combined RSUs and eNBs)

Rich roadmap towards 5G with strong ecosystem (infra, MNO, smartphone)
Technology evolution to address expanding capabilities/use cases

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1. 60% Cellular penetration in new light vehicles sales by 2021; 2. Based on Qualcomm Research simulations
C-V2X defines two complementary transmission modes

**Direct communications**
V2V, V2I, and V2P on “PC5” Interface, operating in ITS bands (e.g. ITS 5.9 GHz) independent of cellular network

**Network communications**
V2N on “Uu” interface operates in traditional mobile broadband licensed spectrum

**PC5 interface**
e.g. location, speed

V2I (PC5)

V2I (PC5)

RSU

V2V (PC5)

V2P (PC5)

V2P (PC5/)

**Uu interface**
e.g. cloud services

V2N (Uu)

eNodeB

V2N (Uu)
C-V2X is designed to work without network assistance\(^1\)

V2V/V2I/V2P direct communications enables low latency applications

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<tr>
<th>USIM-less operation</th>
<th>C-V2X direct communications doesn’t require USIM</th>
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<tr>
<td>Autonomous resource selection</td>
<td>Distributed scheduling, where the car selects resources from resource pools without network assistance</td>
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<td>GNSS time synchronization</td>
<td>Besides positioning(^2), C-V2X also uses GNSS for time synchronization without relying on cellular networks</td>
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1. 3GPP also defines a mode, where eNodeB helps coordinate C-V2X Direct Communication; 2 GNSS is required for V2X technologies, including 802.11p, for positioning. Timing is calculated as part of the position calculations and it requires smaller number of satellites than those needed for positioning
Continuous V2X technology evolution required
Accommodating ever-evolving use cases and safety requirements

Evolution to 5G, while maintaining backward compatibility

Basic safety
802.11p or C-V2X R14
Established foundation for basic V2X services
Forward collision warning

Enhanced safety
C-V2X R14
Better link budget leading to longer range and more reliability

Advanced safety
C-V2X R15+ (building upon R14)
Higher throughput
Higher reliability
Wideband ranging and positioning
Lower latency

See-through / camera sensor sharing
Cooperative driving
Bird’s eye view / HD map updates

Disabled vehicle
Disable vehicle after blind curve
LTE Advanced Pro establishes the foundation for 5G

Pioneering 5G NR technologies and verticals

Significantly improve performance, scalability, and efficiency

5G New Radio (NR)

- Multi-Gbps eMBB (sub-6 GHz and mmWave)
- NR-based LAA+
- Ultra-reliable & low-latency

Further enhancements and new capabilities

New verticals

- Cellular V2X (C-V2X)
- Ultra-low latency
- Digital TV
- Internet of Things
- Unlicensed spectrum
- Mobile broadband

LTE Advanced Pro

Rel-13: Today
Rel-14
Rel-15
Rel-16+

C-V2X safety features

- eMBMS enhancements
- eMTC, NB-IoT
- LAA
- Gigabit LTE

New C-V2X capabilities

- Ultra-low latency
- enTV, e.g., shared broadcast
- FeMTC, eNB-IoT
- eLAA
- Enhancements, e.g., FD-MIMO

Further enhancements towards IMT-2020 in existing spectrum
C-V2X gaining support from automotive and telecom leaders

5GAA is a cross-industry consortia helps define 5G V2X communications

End-to-end solutions for intelligent transportation mobility systems and smart cities

Audi  BMW  MINI  Rolls-Royce  China Mobile  Continental  Daimler  Danlaw
Denso  Ericsson  Ficosa  Ford  Gemalto  Huawei  Intel  LG
NTT DoCoMo  Qualcomm  Rohde & Schwarz  Saic Motor  Samsung  SK Telecom
T Mobile  Valeo  Verizon  VLAVI  Vodafone  ZTE  Nokia

Source: http://5gaa.org; accurate as of February 1st, 2017
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