Updates on C-V2X Standardization in ETSI and C-V2X Deployments Globally

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Vision for Smart Transportation
Shaping the Future of Smart Transportation
Roads safety
Transportation efficiency
Automated driving
Mobility services

New vehicle experiences
Road safety
Transportation efficiency
Automated driving
Mobility services

Our Foundational Technologies

Artificial intelligence
C-V2X/5G Connectivity
Heterogeneous Computing
Precise positioning
Smart transportation infrastructure enabled by our foundational technologies

Smart RSU/Small cell
- 4G/5G small cell
- Integrated C-V2X support
- Infrastructure-to-vehicle (I2V)
- AI/perception and sensor fusion
- AI-based camera, radar, lidar
- Precise positioning and 3D HD mapping

Smart connected cars
- 4G/5G support
- Integrated C-V2X support
- Precise positioning
- AI/perception and sensor fusion

Artificial intelligence
Mobile Edge Compute
Sensor fusion
Multimode 4G/5G
C-V2X
Precise positioning
Computer vision
Power management
Security
Bringing a comprehensive ecosystem together
Working across industries to forge sustainable relationships, unlocking new value

- Automotive
  - Vehicle OEMs
  - Tier 1 suppliers
- Transportation
  - Road operators
  - Traffic industry suppliers
- Telecom
  - Mobile operators
  - Telecom suppliers
- Internet/cloud
  - Cloud service providers
  - Map providers

Software companies
Test equipment vendors

Standards development organizations
Telecom and auto industry organizations
ITS organizations
Robust Global C-V2X Ecosystem is Ready

<table>
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<th>9150 Modules</th>
<th>RSU vendors</th>
<th>Tier1s/OBU vendors</th>
<th>System Integrators</th>
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<tr>
<td>- WNC</td>
<td>- US: Savari, Kapsch, Commsignia, McCain</td>
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<td>- Quectel</td>
<td>- EU: Swarco, Lacroix, Aximum, Marben</td>
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<tr>
<td>- ZTE</td>
<td>- China: Nebulalink, Genevict, Neusoft</td>
<td>- Cohda</td>
<td>- Integration &amp; support</td>
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<tr>
<td>- LG</td>
<td>- RoW: Cohda, Cybercom, Oki</td>
<td>- Valeo</td>
<td>- Integration &amp; support</td>
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<tr>
<td>- LG Innotek</td>
<td>16+ RSU products slated. Commercial ready in Q1 2019</td>
<td>- Savari</td>
<td>- Integration &amp; support</td>
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<tr>
<td>- Telit</td>
<td>10+ OBU suppliers slated. Commercial ready in Q1 2019</td>
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<td>- SIMCom</td>
<td>Global foot print to support system Integration</td>
<td>- Continental</td>
<td>- Integration &amp; support</td>
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</tbody>
</table>

*C-V2X is ready for deployment*
Qualcomm® connected car reference design, Gen 2

Qualcomm automotive Snapdragon 4G/5G platforms

- **5G**
  - Rel-15 5G NR
  - Rel-14/Rel-15 C-V2X
  - 5G / 4G spectrum sharing
  - Dual SIM Dual Active (DSDA)
  - Multi-frequency GNSS with QDR3
  - RF management with envelope tracking
  - On-board processing with telematics SDK and apps
  - IP acceleration (IPA)

- **4G**
  - Rel-14 LTE Advanced Pro
  - FDD
  - TDD
  - FD-MIMO
  - Up to 5 aggregated LTE carriers

**Security**
- ECDSA
- VEPP

**Telematics Apps**
- Qualcomm application processor
  - With telematics SDK
  - Stack apps
  - VEPP
  - Security verifies
  - Multicore CPU
  - Multicore DSP
  - Accelerator ECDSA

**Wi-Fi 6 BT5.1**

**SDRs**

**PMIC**

**HSM**

**RF ICs + antenna modules**

**RF front-end**

**Memory**
Standards Update

EU (ETSI), US (SAE, IEEE, OmniAir), China (C-ITS, C-SAE, NTCAS)
C-V2X Status Overview (EU)

• **Standards:** ETSI TC ITS
  ◦ Access layer specifications, i.e., TS 103 613 and TS 103 574 completed
  ◦ Amendments of higher layer specifications/standards to support an ITS-station with LTE-V2X access layer technology completed (i.e., CAM/DENM/BTP/GeoNetworking)
  ◦ Further standardization work ongoing (three EN approvals targeted for Mar 2019)

• **Profiles:** 5GAA and C2C-CC
  ◦ Media agnostic amendments to C2C-CC, Triggering Profiles, and RSP completed in 5GAA
  ◦ Media agnostic BSP WI approved for C2C-CC
  ◦ Conformant with Basic System Profile (BSP) and Triggering Profiles + C-ROADS Roadside System Profile (RSP) (assuming inclusion of identified amendments)

• **Certification:** 3GPP, GCF, ETSI CTI, and 5GAA
  ◦ Conformance:
    • Tests specs for radio layers defined by 3GPP/RAN5 and GCF
    • Tests specs for higher layers defined by ETSI (common to ITS-G5 and LTE-V2X)
  ◦ Interoperability:
    • ETSI Centre for Testing and Interoperability (CTI) has already proposed ETSI Plugtests™ of LTE-V2X
    • ETSI CTI coordinating with 5GAA on planning for interoperability testing
Facilities Layer (ETSI TC ITS WG1)

• **Cooperative Awareness Basic Service (aka CAM)**
  - ETSI EN 302 637-2 V1.4.1 (2019-01), which has been approved by ETSI TC ITS and published on ETSI website, supports both ITS-G5 and LTE-V2X.

• **Decentralized Environmental Notification Basic Service (aka DENM)**
  - ETSI EN 302 637-3 V1.3.0 (2018-08), which has been approved by ETSI TC ITS and published on ETSI website, supports both ITS-G5 and LTE-V2X.
Transport and Network Layers (ETSI TC ITS WG3)

• **Basic Transport Protocol (BTP)**
  - ETSI TS 102 636-7-2 V1.1.1 (2019-01), which has been approved by ETSI TC ITS and published on ETSI website, specifies amendments for LTE-V2X to be used in conjunction with ETSI EN 302 636-5-1 (i.e., not a replacement).
  - ETSI EN 302 636-5-1 V2.2.0 (2019-02), which has been approved by ETSI TC ITS and is published on the ETSI website, is agnostic to the underlying access layer technology and thus is compatible with both ITS-G5 and LTE-V2X.

• **GeoNetwork, Media-Independent Functionality (GN-MIF)**
  - ETSI TS 102 636-7-1 V1.1.1 (2019-01), which has been approved by ETSI TC ITS and published on ETSI website, specifies amendments for LTE-V2X to be used in conjunction with ETSI EN 302 636-4-1 (i.e., not a replacement).
  - ETSI EN 302 636-4-1 is currently being updated under an active work item in WG3 to be truly “media-independent” in accordance with title/scope/intent of the specification.
    - Since the updated document will be agnostic to the underlying access layer technology, it will be compatible with both ITS-G5 and LTE-V2X.
    - Submitted for ETSI TC ITS approval at March 2019 meeting.
Access Layer (ETSI TC ITS WG4)

• **LTE-V2X**
  ◦ [ETSI TS 103 613 V1.1.1 (2018-11)](https://www.etsi.org/deliver/etsi_ts/103600_103699/103613/1.1.1/files/ts_103613v111.pdf), which has been approved by ETSI TC ITS and published on ETSI website, is the access layer specification for LTE-V2X in 5.9GHz.
  ◦ [ETSI EN 304 613](https://www.etsi.org/deliver/etsi_en/300300_300519/304613/1.1.1/files/en_304613v111.pdf) is currently being prepared under an active work item in WG4.
    • The content of the EN is adapted from ETSI TS 103 613.
    • Submitted for ETSI TC ITS approval at March 2019 meeting.

• **Congestion Control**
  ◦ [ETSI TS 103 574 V1.1.1 (2018-11)](https://www.etsi.org/deliver/etsi_ts/103500_103599/103574/1.1.1/files/ts_103574v111.pdf), which has been approved by ETSI TC ITS and published on ETSI website, is the congestion control specification for LTE-V2X.
SAE V2X Communications Steering Committee

Steering Committee Structure

- Motor Vehicle Council
- V2X Communications Steering Committee
- DSRC TC
- Advanced Applications TC
- C-V2X TC
- Cross-cutting TC
- Security TC
- Traffic Signal Applications TC
- Tolling Applications TC
- Vehicular Applications TC
- Infrastructure Applications TC
Scope of J3161
Adaptation of SAE J2945/1 for PC5 LTE-V2X

Scope: “This standard specifies the system requirements for an on-board vehicle-to-vehicle (V2V) safety communications system for light vehicles, including standards profiles, functional requirements, and performance requirements. The system is capable of transmitting and receiving the SAE J2735-defined Basic Safety Message (BSM) over a PC5 V2X wireless communications link as defined in 3GPP Release 14.”
Overview (1/2)

• Replace J2945/1 Radio Access Technology with 3GPP Rel-14 PC5
  ◦ Use of time-frequency OFDMA Resource Blocks in the PHY and scheduled MAC transmissions

• Layers above radio access layer almost identical
  ◦ Same message set dictionary as DSRC (J2735), including BSM
  ◦ Slight difference in congestion control, since PC5 is a scheduled MAC
  ◦ Same security certificates - IEEE 1609.2
    • Maintain; make minor updates to reflect recent changes in 1609.2a
    • Determine how to most effectively accommodate P2P cert distribution via LTE
  ◦ IEEE 1609.12
    • PSID still used to support security
    • Does not need Ethertype references
  ◦ (IEEE 1609.3 - updates under way within open PAR to make medium agnostic)

• Positioning and Timing
  • No necessary changes - GNSS used not only for position but timing for PC5 PHY/MAC
  • May incorporate new features uniquely available with LTE and PC5 V2X
Overview (2/2)

• BSM Transmission Requirements
  ◦ BSM will be transmitted using Semi-Persistent Scheduling (SPS)
    • Reservation based instead of contention based like DSRC
    • One-shot scheduled transmissions can be used for non-periodic events

• BSM Scheduling and Congestion Control
  ◦ Determines all of the BSM scheduling and corresponding transmit power
    • After the first BSM generated (upon system startup)
  ◦ Algorithm needs to be adjusted for LTE features/terminology
    • Currently based on 802.11 CCA mechanism and measurement intervals that may need to be made consistent with LTE features)
  ◦ Congestion control in C-V2X will be a modified version of the algorithm in J2945/1 - will use 3GPP defined power control algorithm in Layer 1 & 2

• Antenna coverage specification updated to reflect current OEM antenna deployment strategies
Certification

• OmniAir has an extensive base of existing DSRC certification tests that will be directly applicable to C-V2X

• OmniAir will use J3161 as the basis for C-V2X certification
  ◦ C-V2X Certification technical committee expected to be announced in late Q1/2019
  ◦ Will reuse upper layer certification tests from existing DSRC certification program
    • Will leverage existing DSRC tests drawn from IEEE 1609, SAE J2735
  ◦ Some changes will be required
    • Lower layer certification - could be GCF or other body
    • Congestion control is different from J2945/1
    • Multichannel operation (IEEE 1609.4) is different from DSRC
  ◦ One informal C-V2X plugfest has already been held (Oct 2018)
    • Another is planned for May 2019 (Montreal)
Summary

- J3161 is a modified version of J2945/1
  - 3GPP Rel-14 PC5 Sidelink PHY & MAC
  - Upper layers almost identical
  - Congestion control slightly different to adapt to 3GPP specs
- Updated antenna specs to reflect OEM deployment strategies
- Initial ballot in Q2/2019
  - Goal for completion by end 2019
- Will be used by OmniAir as the basis for C-V2X certification
  - Existing test specs will be modified from extensive DSRC certification test suite that is mature and already in use for DSRC RSU and OBU certification
5GAA Automotive Association

Airgain • Alpine Electronics • Analog Devices • Anritsu EMEA Ltd
AT&T • Audi BAIC • Beijing University • Bell Mobility • BMW • Bosch
CATT • Cetecom • China Transinfo • China Unicom • CMCC
Continental Daimler • Danlaw • DEKRA Denso • Deutsche Telekom
Ericsson • FEV • Ficosa • Ford • Fraunhofer Gemalto Hirschman Car
Hitachi Automotive US • Honda • Huawei Infinion • Intel Inteldigital
Jaguar Land Rover • Juniper • KDDI Keysight • KT • Laird Tech • LG
Murata • Nissan • Nokia • NTT DoCoMo • OKI • Orange • P3 Group
Panasonic • Proximus • PSA • Qualcomm • Rohde & Schwarz Rohm
SAIC • Samsung • Savari • SIAC • SK Telecom • Skyworks Softbank
Sumitomo • Telefonica • Telekom Austria • Telstra • TÜV • Valeo
Veniam • Verizon • Viavi • Vodafone • Volkswagen • ZF • ZTE

Key participants
driving global C-V2X activities with Qualcomm Technologies

Ford
PSA
BMW
Daimler
SAIC
China Domestic OEMs
Continental
Bosch
LG
ZTE
Quectel
Lear
Valeo
WNC
CMCC
AT&T
DoCoMo
CMRI
McCain
Kapsch
SWARCO
Genvict
Nebula
R&S
Datang
Ficosa
And more …

Driving C-V2X global presence

Tremendous traction across regions and broad industry sectors
From standards completion to independent field testing to early commercialization
C-V2X Deployment Program
Strong C-V2X momentum globally

- **Sep 2016**: 5GAA Founded
- **Jan 2017**: ConVeX trial in Germany announced
- **Mar 2017**: Rel-14 C-V2X spec finalized
- **Sep 2017**: First C-V2X chipset introduced
- **Jun 2018**: 1st US deployment in Denver
- **Oct 2018**: Multi-OEM performance evaluation of C-V2X
- **Oct 2018**: China-SAE ITS Stack Compatibility
- **Nov 2018**: Reaches 100 members
- **Jan 2019**: Cooperative driving live interactive demos in Las Vegas

**Key Events**:
- **Jun 2018**: 1st US deployment in Denver
- **Oct 2018**: Multi-OEM performance evaluation of C-V2X
- **Nov 2018**: China-SAE ITS Stack Compatibility
- **Jan 2019**: Cooperative driving live interactive demos in Las Vegas
Current deployment in Colorado

90 mile stretch of I-70
From Golden, CO to Vail, CO
CDOT Live Environment

I-70 Mountain Corridor
- 90 miles equipped in 2019
- 500 CDOT fleet vehicles equipped in 2019
- High visibility, high impact corridor
- Steep grades, sharp curves, tunnels, and extremes winter weather conditions
OBU Installs - First production-grade aftermarket C-V2X OBUs
RSU installs – First production-grade dual DSRC+C-V2X RSUs
Cellular technologies expected to be the connectivity fabric for transportation networks

Neighborhood traffic management
- Leverages mobile edge computing to manage a neighborhood or a freeway segment using 4G/5G networks

Centralized TMC
- Overall traffic management (e.g., traffic advisory, static 3D HD maps) leveraging 4G/5G macro networks

Collocated RSU/small cell
- Leverages cell densification by using a combined RSUs and small cells to manage urban intersections

C-V2X-based RSU
- Leverages direct communications for latency critical, local safety, and traffic management applications at one intersection

4G/5G network communications
- Direct link C-V2X communications
Existing Cellular Site Density for two major US cities

- **San Francisco**
- **Manhattan**

### Cellular Site Density (Sites/km²)

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<tr>
<th></th>
<th>Macro Site Density</th>
<th>Small Cell Density</th>
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<tr>
<td><strong>US City 1</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>US City 2</strong></td>
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</tbody>
</table>

- **US City 1**: [Graph showing site density]
- **US City 2**: [Graph showing site density]