Connectivity Standards in the Automotive Industry

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WWW.5GAA.ORG
5GAA brings together the automotive and telecommunications industries to accelerate the global deployment of Cellular Vehicle-To-Everything (C-V2X) as a first step towards a fully integrated intelligent transport system with 5G.

5GAA unites 120+ members* from around the world working together on all aspects of C-V2X including technology, standards, spectrum, policy, regulations, testing, business models and go-to-market.

*as of May 2019
C-V2X is a comprehensive road safety and traffic efficiency solution that allows vehicles to communicate with:

- **Other vehicles (V2V),**
- **Pedestrians and Cyclists via smartphones (V2P),**
- **Road Infrastructure (V2I),**

supported by the **Mobile network (V2N, P2N, I2N)** to guarantee **full coverage** and **continuity of services.**
C-V2X is a unified technology platform which integrates:

- **Short-range**, network-less, direct communications (LTE-V2X PC5 today)
- **Long-range** cellular network communications (LTE-V2X Uu today)
3GPP: Cellular-V2X (C-V2X)
# 3GPP time plan: from LTE-V2X to 5G NR-V2X

<table>
<thead>
<tr>
<th>Rel-8</th>
<th>Rel-12</th>
<th>Rel-14</th>
<th>Rel-15</th>
<th>Rel-16</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008/12</td>
<td>2015/03</td>
<td>2017/03</td>
<td>2018/06</td>
<td>2019/12</td>
</tr>
</tbody>
</table>

- Current version of C-V2X is called **LTE-V2X** as part of 3GPP Rel-14 & 15.
- **NR-V2X** as part of Rel-16 comes as an improvement to support automated driving.
- **NR-V2X** will complement, co-exist and support interworking with LTE-V2X i.e. operation of NR-V2X alone is not considered.

- **NR-V2X** study item started in June 2018.
- Subsequent **NR-V2X** work item by December 2019.
C-V2X has two complementary communication modes

**Direct ( = Sidelink)**

- **V2V**, **V2I**, and **V2P** operating in ITS bands (e.g. ITS 5.9 GHz) independent of cellular network

**Network ( = Up/Downlink)**

- **V2N** operates in traditional mobile broadband licensed spectrum

**It’s ONE cellular technology**

- fully integrated chipset solution
- one antenna system
- reduced complexity and cost (on-board & infrastructure)

**Short range** (<1 kilometer), location, speed

- Implemented over 3GPP’s “PC5 interface”

**Long range** (>1 kilometers). e.g. accident ahead

- Implemented over 3GPP’s “Uu interface”
C-V2X: Evolution to 5G maintains backward compatibility

3GPP Rel. 8-13
... – March 2016

3GPP Rel. 14
March 2017

3GPP Rel. 15
June 2018

3GPP Rel. 16
December 2019

LTE V2N Uu
Direct Communication
LTE V2V/V2I (PC5)

5G NR V2N Uu
High bandwidth/low latency

5G NR Uu URLLC
Direct Communication 5G NR V2V/V2I

Hazard warning
V2V safety use case
Enhanced Navigation & Infotainment
Cooperative automated driving

V2N
V2V/V2I
C-V2X: Evolution to 5G maintains backward compatibility

- **3GPP Rel. 8-13** (March 2016)
  - LTE V2N Uu
  - Hazard warning

- **3GPP Rel. 14** (March 2017)
  - Direct Communication LTE V2V/V2I (PC5)
  - V2V safety use case

- **3GPP Rel. 15** (June 2018)
  - 5G NR V2N Uu
  - High bandwidth/low latency
  - Enhanced Navigation & Infotainment

- **3GPP Rel. 16** (December 2019)
  - 5G NR Uu URLLC
  - Direct Communication 5G NR V2V/V2I
  - Cooperative automated driving

C-V2X: Evolution to 5G maintains backward compatibility
C-V2X Rel-14 deployment around the world
C-V2X has two complementary communication modes

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V2X via Mobile Network: E-Class 2016

- Cars are connected to the Daimler Vehicle Backend
- Data filtering and aggregation
- Markets: USA, EU, China
- Security and Privacy ensured
- OEMs and Data supplier are invited to share

- Event detection and plausibility check
- No additional components necessary

- Data relevance check
- Display icon on map and generate speech output

Source: Daimler

Mobile work zone live from the trailers (market dependent)

Cellular Radio

Communication Module

Navi

Daimler Vehicle Backend

Source: Daimler
## V2X via Mobile Network: E-Class 2016

<table>
<thead>
<tr>
<th>Event</th>
<th>Triggering Conditions</th>
<th>Icon on Map</th>
<th>Speech output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broken down vehicle</td>
<td>Vehicle system signals</td>
<td><img src="image" alt="Icon" /></td>
<td>Yes</td>
</tr>
<tr>
<td>Vehicle accident</td>
<td>Air bag inflation and others</td>
<td><img src="image" alt="Icon" /></td>
<td>Yes</td>
</tr>
<tr>
<td>Hazard lights</td>
<td>Hazard light on</td>
<td><img src="image" alt="Icon" /></td>
<td>Yes</td>
</tr>
<tr>
<td>Heavy Rain</td>
<td>Highest wiper level for 20 s</td>
<td><img src="image" alt="Icon" /></td>
<td>No</td>
</tr>
<tr>
<td>Slippery road</td>
<td>Antilook braking system intervention</td>
<td><img src="image" alt="Icon" /></td>
<td>No</td>
</tr>
<tr>
<td>Fog</td>
<td>Rear fog light on</td>
<td><img src="image" alt="Icon" /></td>
<td>No</td>
</tr>
<tr>
<td>Mobile work zone</td>
<td>External data from work zone trailers</td>
<td><img src="image" alt="Icon" /></td>
<td>Yes</td>
</tr>
<tr>
<td>General Warning</td>
<td>Driver manual input</td>
<td><img src="image" alt="Icon" /></td>
<td>Yes</td>
</tr>
</tbody>
</table>

Source: Daimler
Green Light information (based on SPAT)

**AUDI:** Real-time “time-to-green” information via 4G LTE data connection from the traffic management system

Deployed in 20+ cities in US & EU; Pre-deployment in **Wuxi, China**

Enables future integration within start/stop function, GLOSA, routing, and other predictive services

Source: Audi, Navinfo
V2N Application: Emergency corridor – A cooperation between BMW and the Bavarian emergency services

1. Authority transmits information about required emergency corridor
2. Mapping to vehicle navigation system
3. Delivery to affected vehicles
4. Display in HMI as soon as vehicle reaches end of jam

- Sovereign authorities are able to warn road users through back end systems at an early stage.
- Information is transmitted only to concerned cars; high level of reliability and low failure rate increase customer trust.

Source: BMW
1st Step: Predictability: C-V2X supported by Predictive QoS

1. Connected vehicle is driving
2. Vehicle receives in-advance notification of network quality degradation
3. V2X Application takes appropriate action/countermeasure (e.g., decreases speed)
4. Network QoS degradation takes effect. Necessary action has already been taken.
2\textsuperscript{nd} Step: Network Management and Guarantees
\rightarrow Ultra-reliable and Low Latency Communications

**Quality of Service / Network slicing**

- Resource isolation from other service
  \rightarrow No service impact caused by other slices failures

- Customized NW functions and/or capacities to ensure SLA's
Ultra-reliable and Low Latency Communications

**Edge Computing**

Applications can be hosted at “Edge-side”

→ Low Latency compared with centralized manner
What about V2V / V2I / V2P?
C-V2X has two complementary communication modes

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3. Integrated Short Range Mode, works also out-coverage (V2V, V2I)
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5GAA Timeline for deployment of C-V2X (V2V/V2I)

- **C-V2X (R14) chipsets from various vendors**
- **Integration, Validation Testing with OEMs (EU, China, US)**
- **C-V2X (R14) RSUs and OBUs (EU, China, US)**

**5.9 GHz Spectrum Target Availability**
- **EU:** Spectrum available
- **CHINA:** Test Spectrum Available
- **US:** Spectrum for Deployment 2020

**Event timeline:**
- **2017:** H1
  - Chipsets for tests
  - Inter-Operability Tests
  - Mode 4 Chips and Modules
- **2018:** H1/2018
  - Testing
  - Availability of products
- **2020:**
  - EU: Final CEPT report
  - Start of vehicle deployment
- **2021 ff:**
  - C-V2X is real and ready with commercial chipsets set for 2018
  - In-vehicle commercial deployment (i.e. type approved) is foreseen at the latest by 2020 globally
3. Make cutting-edge V2V/V2I technology available globally

Qualcomm® Connected Car Reference Design, Gen 2

Source: Qualcomm, Announced at the MWC2019, Barcelona
3. Integrated Short Range Mode, works also out-coverage (V2V, V2I)

Shadowing Test RESULTS

- 5GAA shadowing test is more demanding than CAMP test.
- C-V2X outperforms 802.11p in shadowing scenarios.

(*) Video: Paris July, 2018
Worldwide Trials of Rel-14 C-V2X

- C-V2X Connected Car Technology Trials
  - San Diego, USA
- V2V C-V2X radio performance tests
  - Michigan, USA
- CDOT traffic management trial
  - Colorado, USA
- UK CITE
  - UK
- Towards 5G
  - France
- InOut C-V2X Demo
  - France
- RACC track MWC 2017
  - Spain
- NordicWay
  - Sweden
- Mobilfunk (A9)
  - Germany
- DT (A9)
  - Germany
- Car2X (A9)
  - Germany
- 5G-CM (A9)
  - Germany
- MEC pilot project
  - Germany
- C-Roads project
  - Czech Republic
- C-V2X Performance Test @ SIAC
  - China
- Car2X Wuzhen
  - China
- ICV pilot projects
  - China
- Wuxi City-wide LTE-V2X Project
  - China
- C-V2X Trials
  - Japan
- 5G and cellular communication showcase trials
  - Korea
LTE-V2X Rel-14 interoperability tests in Shanghai (Nov 2018)

- First Triple-level Interoperability testing of LTE-V2X applications
- Multi-vendor Interoperability at module/device/OEM level
- Access layer implementing 3GPP R14 LTE-V2X PC5 standard

**Triple-level Interoperability**

- Communication Module (3)
  - CATT(Datang), Huawei Hisilicon, Qualcomm
- OBU Device (9)
  - Nebula Link, Genvict, Datang, Neusoft, Huawei, Huali-tec, China Transinfo Technology(CTFO), Savari, Wanji-Technology
- Vehicle OEM (12)
  - Changan, SAIC, BAIC, Ford, Geely Auto, Great Wall Motor, Dongfeng Motor, BJEV, General Motors, Audi, BMW, FAW
Enabling Deployment: lift barriers and accelerate time-to-market

• 5GAA C-V2X testing event in Europe successfully demonstrated exceptional level of interoperability (April 2019, Germany)

• Memorandums of Understanding signed in 2019 with leading interoperability and certification organisations to accelerate deployment roadmap:
LTE-V2X (PC5) Interoperability – Next Steps

What a great start to the @OmniAirCon #EuropeanPlugfest! Thank you to our keynote and opening presenters @SGAA_official, @DEKRA_Test_Cert, @DGTes, @maximflament! #V2X #CV2X

IMT-2020 Interoperability Plugtest, Shanghai, October 2019

Save the date! The 1st Cellular-#V2X Plugtests event, organized by ETSI #TheStandardsPeople in partnership with #5GAA @5GAA_official, will be held in Europe from 2 to 6 December 2019. More information available soon
4. Include pedestrians and cyclists

Source: Cobi
Source: BMW
Source: Cowboy
Source: Bosch
Path towards Rel-16 NR-V2X
C-V2X: Evolution to 5G maintains backward compatibility

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V2N V2V/V2I
Enable complex interaction Use Cases

Source: Continental
Collaboration
Beyond Automotive – Other 5G Automotive enabled applications

A major step stone for stakeholders in automotive, transportation, city management and well beyond
Driving innovation: Leveraging solutions together

• On-going dialogue between 5GAA and leading technology partner organisations to advance innovation in all world regions

• 5GAA to continue strengthen technical cooperation and maximise benefits with existing organisations or projects by reinforcing engagement via common members

• Develop new partnerships with relevant organisations on specific aspects e.g. vulnerable road users or road authorities
Conclusions

• 5GAA became a global reference association for cooperation between Automotive and Telecom sectors.
• 5GAA works closely with 3GPP as the global leader for standardization of 5G mobile networks
• 5GAA helps to meet the interests and needs of the Automotive industry when 5G is being deployed.
• C-V2X is evolving from LTE-V2X (Rel-14) towards 5G-V2X (Rel-16)
  • includes both Sidelink and Up/Downlink
  • supports both basic safety and advanced Use Cases
Thank you!