Vehicle to Everything (V2X) Communications

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Enabling Technologies

Autonomous Driving Systems

Communications + ADAS Sensors + Artificial Intelligence + Telematics

SAFETY ➔ NEW TECHNOLOGY ➔ COST

Keysight World
Role Of V2X Communications For Autonomous Driving
What Vehicle to Everything (V2X) Communications Is Not
Vehicle to Everything (V2X) Communications

**Enhanced Safety, Enabling Higher Levels of Automation**

**Vehicle-to-infrastructure (V2I)**
- e.g. traffic signal timing/priority

**Vehicle-to-network (V2N)**
- e.g. real-time traffic / routing, cloud services

**Vehicle-to-vehicle (V2V)**
- e.g. collision avoidance safety systems

**Vehicle-to-pedestrian (V2P)**
- e.g. safety alerts to pedestrians, bicyclists

Source: Qualcomm
Non Line-of-sight Sensing
Provides 360 NLOS awareness, works at night and in bad weather conditions

Conveying Intent
Shares intent, sensor data, and path planning info for higher level of predictability

Situational Awareness
Offers increased electronic Horizon to support soft safety Alerts and graduated warning
Battle Of The V2X Standards
DSRC vs. Cellular
## Competing Technologies: WiFi DSRC vs. Cellular C-V2X

<table>
<thead>
<tr>
<th>Radio Design</th>
<th>DSRC 802.11p</th>
<th>C-V2X Release 14/15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synchronization</td>
<td>Asynchronous</td>
<td>Synchronous</td>
</tr>
<tr>
<td>Channel size</td>
<td>10/20 MHz</td>
<td>Rel. 14: 10/20 MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rel. 15: 10/20 MHz/Nx20 MHz</td>
</tr>
<tr>
<td>Resource multiplexing across vehicles</td>
<td>Time division multiplexing (TDM) only</td>
<td>TDM &amp; frequency-division multiple (FDM) access</td>
</tr>
<tr>
<td>Data channel coding</td>
<td>Convolutional</td>
<td>Turbo</td>
</tr>
<tr>
<td>Hybrid automatic repeat request (HARQ) Retransmission</td>
<td>No</td>
<td>Rel. 14/15: Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rel. 15: Ultra-reliable communication possible</td>
</tr>
<tr>
<td>Waveform</td>
<td>Orthogonal frequency-division multiplexing (OFDM)</td>
<td>Single-carrier FDM (SC-FDM)</td>
</tr>
<tr>
<td>Resource selection</td>
<td>Carrier-sense multiple access with collision avoidance (CSMA-CA)</td>
<td>Semi-persistent transmission with frequency domain</td>
</tr>
<tr>
<td>MIMO support</td>
<td>No support standardized</td>
<td>Rx diversity for 2 antennas mandatory</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tx diversity for 2 antennas supported</td>
</tr>
<tr>
<td>Deployment</td>
<td>Since 2017. OEM rollout in 2019</td>
<td>2020/2021</td>
</tr>
<tr>
<td>Roadmap</td>
<td>802.11NGV: Targets interoperability with 802.11p</td>
<td>C-V2X Rel. 16 based on 5G New Radio</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rel. 16 will operate in different channel from Rel. 14/15</td>
</tr>
</tbody>
</table>

Source: Autotalk/5GAA/Qualcomm
What Is Dedicated Short Range Communication (DSRC)

**IEEE 802.11p**

- DSRC is an approved amendment to 802.11 for wireless access in vehicular environments (WAVE)
- ITS-G5 is the term used in Europe
- V2X communications such as vehicles and infrastructure (V2I) or vehicle to vehicle (V2V)
  - Vehicle safety services
  - Commerce transactions via cars
  - Toll collection
  - Traffic management
Shared ITS Stack Upper Layers For DSRC And C-V2X

C-V2X reuses upper layers defined by automotive industry

- Reuse established service and app layers
  - Already defined by automotive and standards communities, e.g., ETSI, SAE
  - Developing abstraction layer to interface with 3GPP lower layers (in conjunction with 5GAA)

- Reuse existing security and transport layers
  - Defined by ISO, ETSI, and IEEE 1609 family

- Continuous enhancements to the radio/lower layers
  - Supports the ever-evolving V2X use cases

DSRC/WAVE Protocol Stack

IEEE 1609.4
IEEE 1609.3
IEEE 1609.2
IEEE 802.11p
SAE J2735
SAE J2945

Security Services

SAFETY APPLICATIONS

- Safety App. Sublayer
- Message Sublayer
- Network and Transport Layers - WSMP
- Network Layer - IPv6
- LLC Sublayer
- MAC Sublayer Extension
- MAC Sublayer
- PHY Layer

NON-SAFETY APPLICATIONS

- Application Layer
- Transport Layer - TCP/UDP

IETF RFC 2460
IETF RFC 793/768
IEEE 802.2

USIM-less operation
C-V2X direct communications doesn't require USIM
DSRC 802.11p Challenges To Overcome

- Ensure Performance Meets Safety Requirements
- Conformance to Global and Regional Standards
- Interference Mitigation
- Interoperability
- Security
Cellular V2X (C-V2X)
What Is Cellular Vehicle-To-Everything (C-V2X)

V2X USING CELLULAR TECHNOLOGIES WITH OR WITHOUT NETWORK SERVICE

- Mobile LTE / Cellular Network
  - ITS apps
  - Edge cloud (MEC) + Core network
  - Roadside Infra (eNB-type RSU)
  - NB-IoT
  - Parking or House
  - LTE eMBMS
  - LTE V2N2I
  - LTE V2N2I
  - LTE V2N2I
  - LTE V2N2I
  - LTE V2N
  - LTE V2N2P
  - LTE V2V
  - LTE V2V
  - Vehicle mgt
  - OEM backend

- LTE V2X USING CELLULAR TECHNOLOGIES WITH OR WITHOUT NETWORK SERVICE

- local sensors

- local sensors
Advantages Of Cellular V2X Over WiFi-Based DSRC

LEVERAGING AN UBIQUITOUS STANDARD

- Evolution to 5G
- Better Security
- Improved Range
- Enhanced Reliability
- Vulnerable Road User (VRU) Use Cases
- Ecosystem of 100+ companies in the 5GAA
C-V2X Evolution To 5G
5G Will Change The World Including Automotive…

- 1 ms: Latency for new level of V2V
- 100 X: Densification for urban V2X supports
- 99.9%: Reliability for mission critical V2X
- 100 X: Data rates for HD map downloading, AR based service, entertainment
- 1000 X: Capacity for cloud based service
Are Car Makers Really Doing 5G?

YES INDEED!

- "Ford Will Equip All New U.S. Vehicles With 5G Technology Starting in 2022" – Fortune, Jan 2019 “… all its new U.S. models starting in 2022 with cellular vehicle-to-everything technology.”

- “5G for car manufacturing: Audi and Ericsson announce partnership” – ZDNet, Aug 2018
  - "Ericsson will fit out Audi’s production lab in Germany with 5G networking technology to test how it can be used in manufacturing vehicles.”

- “What’s Better Than 4G? 5G! And Kia’s Got It, at CES” – Car and Driver, Jan 2018

- "Toyota Unveils Autonomous Car Prototype ”…at CES – The Street, Jan 2019
  - “Efforts to integrate new radio technologies such as 5G and cellular vehicle-to-everything (C-V2X) within cars will also get talked up.”

- “CES 2019 preview: What to expect from the world’s biggest technology show” – gearbrain, Jan 2019 “…5G networks helps make this a more seamless experience. Harman says its Digital Cockpit concept will "set the stage for an entire new chapter in automotive technology.""
## 5G Scenarios And Use Cases

**NEW SERVICES AND CONNECTIVITY PARADIGMS**

<table>
<thead>
<tr>
<th>Amazingly Fast</th>
<th>Great Service In a Crowd</th>
<th>Best Experience Follows You</th>
<th>Real-Time &amp; Reliable Communications</th>
<th>Ubiquitous Things Communicating</th>
</tr>
</thead>
<tbody>
<tr>
<td>• All data, all the time</td>
<td>• 2 billion people on social media</td>
<td>• 30 billion “things” connected</td>
<td>• Ultra high reliability</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Low cost, low energy</td>
<td>• Ultra-low latency</td>
<td></td>
</tr>
</tbody>
</table>

Courtesy of METIS: 2014
5G NR-V2X Release 16 (Advanced Safety)

- Leveraging vehicles as moving sensor platforms (Bandwidth)
- With 5G comes Enhanced Security
- How to test?
- 3GPP delayed to mid-2020
  - Adding b/w to SL
- Ready to support NR

### NR-V2X requirements for autonomous driving (SA1 TS22.186)

<table>
<thead>
<tr>
<th>Use Cases</th>
<th>E2E latency (ms)</th>
<th>Reliability (%)</th>
<th>Data rate (Mbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Platooning</td>
<td>10</td>
<td>99.99</td>
<td>65</td>
</tr>
<tr>
<td>Advanced Driving</td>
<td>3</td>
<td>99.999</td>
<td>53</td>
</tr>
<tr>
<td>Extended Sensors</td>
<td>3</td>
<td>99.999</td>
<td>1000</td>
</tr>
<tr>
<td>Remote Driving</td>
<td>5</td>
<td>99.999</td>
<td>UL:25, DL:1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Lateral (m)</th>
<th>Longitudinal (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positioning Accuracy</td>
<td>0.1</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Note: 5GAA may adjust the above requirements according to inputs from car OEMs.

Source: 5GAA
C-V2X Challenges To Overcome

Ensure Performance Meets Safety Requirement
Ensure products meet performance specs (ETSI, 3GPP, SAE)

Interference Mitigation
Interference will be a critical factor to overcome as the spectrum between 2-6 GHz is extremely crowded and since V2X is a safety oriented system this is even more important to be tested.

Conformance to Global and Regional Standards
EU, North America, China and Japan all have different standards to adhere to. Conformance to these specs will be compulsory and therefore there is a need for test eqt and Test Labs to offer this service.

Interoperability
Multiple vendors developing V2X modules (C-V2X or DSRC) need to interoperate with each other and is a critical test that needs to be carried out.
Accelerating Deployments Of V2X Evolution

DEVELOP WITH CONFIDENCE AS V2X EVOLVES

**CHALLENGE**
- Ensure Performance Meets Safety Requirement
  - Holistic approach to testing RF, protocol & application
  - Achieve quality, performance & safety goals

**CHALLENGE**
- Interference Mitigation
  - R&D RF Physical layer measurement
  - Reduce the time you spend on multiple signal creation and analysis

**CHALLENGE**
- Multiple wireless application integrated in telematics module
  - 5GAA Contributing Member & Plugfest Participant
  - Test with Confidence and Leverage Ecosystem for Standards

**CHALLENGE**
- Conformance to Global and Regional Standards
  - OmniAir DSRC Certification
  - Single platform to be expanded for future V2X test needs

**BENEFITS**
- Same apps across whole lifecycle
- More features on bench-top instruments for RF engineers in R&D phase
C-V2X Performance And Safety Requirements

C-V2X PROTOCOL, FUNCTIONAL, RF TEST AND ITS STACK

- SIB 21
- RRC (Dedicated Msgs)
- DCI 5A
- UL SPS (Multiple)
- GNSS
  - Timing
  - Synchronisation
  - Position
  - Trajectory (dynamic)
- ITS Scenario Generator & Monitoring
- Uu
- PC5
- Multiple PC5 Schedulers
- PSSS/SSSS (Synch)
- PSBCH (Broadcast)
- PSCCH (Control SCI)
- PSSCH (Data)
- DMRS

Vehicle Under Test

Day 1 Use Cases

Custom Scenarios

Keysight World
Vehicle to Everything (V2X) Communications Summary

- The next generation of cars will communicate with others and the road.
- Continuous V2X technology evolution leads to more complexity.
- Develop V2X with confidence as 5G evolves.
Automotive & Energy Track Demos
SEE AND HEAR THE LATEST AND GREATEST FROM INDUSTRY EXPERTS

**E-Mobility**
- Scienlab EV Test Solutions
- Battery Test Systems
- HEV/EV Power Converter

**Autonomous Driving**
- Radar Signal Analysis
- Radar Signal Generation
- Radar Target Simulator
- SystemVue Radar Simulation Library

**Automotive Ethernet**
- Transceiver (Tx) Compliance
- Receiver (Rx) Compliance
- Link Segment (Lx) Solution
- Ixia Level 2-7 Network and Application Testing

**V2X Connected Car**
- Dedicated Short-Range Communications (DSRC)
- 5G/Cellular V2X (C-V2X)
- e-Call
Automotive & Energy Resources

FIND THE LATEST AND GREATEST FROM INDUSTRY EXPERTS

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Connected Car
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