V2X
Vehicle to Everything
Communication is no more just limited to life forms

5G unified connectivity

Intelligently connecting the car to cloud and surroundings

Vehicle-to-vehicle

Vehicle-to-infrastructure
3D HD live map updates

Vehicle-to-network

Vehicle-to-pedestrian

Teleoperation
AR/VR
HD video

Source: Qualcomm

LITEPOINT
Agenda

- What is V2X?
- Wireless Technologies in V2X – DSRC, C-V2X
- Autonomous vehicle ecosystem and Key players
- Market adoption
- 3GPP Evolution to C-V2X
- Testing challenges
- LitePoint solution offerings
What is V2X?
Vehicle to Everything Communication

Facilitates road safety, traffic flow optimization, & autonomous driving, by enabling vehicles to directly communicate with each other and with the infrastructure around.
Three Different Profiles of V2X Direct Communication

- Vehicle to Vehicle (V2V)
- Vehicle to Pedestrian (V2P)
- Vehicle to Infrastructure (V2I)
Wireless Technologies in V2X
Two Competing Standards

- **DSRC (Dedicated Short Range Communication)**
  - Defined by IEEE
  - Supports direct communication (V2V, V2I, V2P)
  - Operates in 5.9 GHz ITS band, uses 802.11p at PHY layer
  - Key features - speed detection, collision avoidance, real-time road condition, toll payments, autonomous driving vehicle

- **C-V2X (Cellular V2X)**
  - Defined by 3GPP
  - Builds on the capabilities of DSRC. Additionally capable of using optimized cellular technology
  - Supports direct communication (V2V, V2I, V2P) + enables network assisted communication (V2N)
  - Dedicated radio in the 5.9 GHz band*, additional cellular radio (LTE, 5G NR sub 6Ghz and mmWave)
  - Support for advanced features – autonomous/ coordinated driving, situational awareness, precise positioning and path planning

*E-UTRA Bands of operation: **46D** (5150 – 5925 MHz); **47** (5855 - 5925 MHz)
Modes of Communication

Direct Communication/
(PC5/Sidelink)

Network Communication
(Uu Interface)

V2X Vehicle to Everything

V2X Vehicle to Network

Direct Communications
DSRC/C-V2X (PC5) for V2X
Operates in the ITS Band (5.9 GHz)

Network Communications
LTE/5G for V2N Operates in Licensed Cellular Spectrum

Source: AutoTalks
## Technology Comparison & Similarities

<table>
<thead>
<tr>
<th>Radio Design</th>
<th>DSRC</th>
<th>C-V2X (Cellular + Sidelink)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>IEEE</td>
<td>3GPP</td>
</tr>
<tr>
<td>Radio Technology</td>
<td>802.11p</td>
<td>Optimized Cellular technology (Rel-14/15/16)</td>
</tr>
<tr>
<td>Frequency Band</td>
<td>Dedicated radio in 5.9GHz</td>
<td>Dedicated radio 5.9GHz. With optional support for cellular radio</td>
</tr>
<tr>
<td>Channel Size</td>
<td>10/20MHz</td>
<td>Rel 14/15 - 10/20MHz Rel 16 - 10/20/40/60/80/100/…MHz</td>
</tr>
<tr>
<td>Waveform</td>
<td>OFDM</td>
<td>SC-FDM</td>
</tr>
<tr>
<td>Transmission Mode</td>
<td>TDM</td>
<td>TDM &amp; FDM (Longer transmission time provides better quality of service)</td>
</tr>
<tr>
<td>Resource Selection</td>
<td>Carrier Sense Multiple Access – Collision Avoidance</td>
<td>Semi-persistent scheduling based on relative energy; eNB based scheduling</td>
</tr>
<tr>
<td>Latency</td>
<td>&lt;10 msec</td>
<td>&lt;10 msec</td>
</tr>
<tr>
<td>Modulation Support</td>
<td>Up to 64QAM</td>
<td>Up to 64QAM direct comm Up to 256QAM with cellular support</td>
</tr>
<tr>
<td>Transmission Range</td>
<td>Up to ~250m</td>
<td>~250m using direct communication Large via cellular network infrastructure</td>
</tr>
</tbody>
</table>
## Technology Comparison & Similarities

<table>
<thead>
<tr>
<th>General</th>
<th>DSRC</th>
<th>C-V2X (Cellular + Sidelink)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication</td>
<td>Supports only direct communication (V2V, V2P, V2I)</td>
<td>Includes both direct and network communication (V2V, V2P, V2I and V2N)</td>
</tr>
<tr>
<td>Target Use Case</td>
<td>Mainly for safety</td>
<td>Safety, precise positioning, autonomous driving</td>
</tr>
<tr>
<td>Performance</td>
<td>Packet loss at high density</td>
<td>Promise for almost no packet loss at higher densities</td>
</tr>
<tr>
<td>High Mobility Support</td>
<td>Up to relative speeds of 500km/hr</td>
<td>For relative speeds much &gt; 500km/hr</td>
</tr>
<tr>
<td>Advantages</td>
<td>Mature technology</td>
<td>Leverages LTE infrastructure</td>
</tr>
<tr>
<td></td>
<td>Reliable, road-tested</td>
<td>3GPP viewed as high reliability</td>
</tr>
<tr>
<td>Limitations</td>
<td>Short range comm.</td>
<td>Long range communication</td>
</tr>
<tr>
<td></td>
<td>Limited scalability</td>
<td>Scalable (better spectral efficiency)</td>
</tr>
<tr>
<td></td>
<td>Vehicular speed limitations</td>
<td>For speeds &gt;500Km/hr</td>
</tr>
<tr>
<td></td>
<td>No cloud/local area update</td>
<td>Capable of real time updates</td>
</tr>
</tbody>
</table>
V2X Ecosystem and Market Adoption
Ecosystem

- Chipset Makers
- Module Makers
- Cellular Carriers
- Vehicle OEMs
- (RSU) Road Side Unit
- (OBU) On board Unit Suppliers
- V2X Stack Providers
## Key Players

### Chipset Makers
- **C-V2X**
  - Qualcomm - 9150
  - Huawei - Balong5000

- **DSRC**
  - NXP - RoadLINK® SAF5400
  - Marvell - 88W8987xA

- **Hybrid**
  - Auto Talks - AEC-Q100 grade 2

### Module Makers
- **C-V2X**
  - Quectel
  - WNC
  - ZTE
  - SIMCOM

- **DSRC**
  - LG Innotek

- **IOT**
  - Telit

### Road Side Unit and On Board Unit Providers
- **C-V2X**
  - Commsignia (OB4, RS4)
  - Kapsch (RIS 9260 road side unit)
  - Genevict (OBU)
  - Neusoft (OBU, RSU)

- **DSRC**
  - Fiasco FITAX (DSRC based OBU)

- **Hybrid**
  - Savari (MobiWAVE2000 OBU)
    (StreetWAVE2000 RSU)
Market Adoption

Market Adoption for C-V2X and DSRC is a fine mesh.

- **France**: Orange with Ford and PSA group conducted C-V2X trials

- **Germany**: Ericsson, Qualcomm with Audi and Ducati conducted C-V2X trials

- **China**: Huawei has conducted trials with China Mobile, Audi, Toyota

- **Japan**: Continental, Ericsson, Nissan, NTT DOCOMO, OKI, Qualcomm conducted C-V2X trials

- **USA**:
  - Ford and Geely partnering with Qualcomm and Huawei, to integrate C-V2X in their vehicles by 2021 and 2022
  - BMW, Daimler, Groupe PSA, SAIC, Audi, and JLR (Jaguar Land Rover) favoring C-V2X
  - Toyota and General Motors leaning towards DSRC in North America

Some automakers are trying to adopt a flexible approach and deploying technologies based on the region.

- e.g.: GM has its Cadillac equipped with DSRC in N.America and plans to deploy C-V2X in its vehicles across China.
3GPP Evolution to C-V2X
C-V2X Evolution with 3GPP Release

Source: http://5gaa.org
Newer Capabilities with Sidelink

<table>
<thead>
<tr>
<th>NR Design</th>
<th>5G NR C-V2X capabilities for autonomous driving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scalable OFDM-based air interface</td>
<td>5G C-V2X is expected to efficiently addresses diverse spectrum bands for different use cases. Leveraging wideband carrier support and OFDMA to deliver higher data rates</td>
</tr>
<tr>
<td>Self-contained slot structure</td>
<td>Smaller slot structure with immediate feedback to enable ultra reliable low latency communications</td>
</tr>
<tr>
<td>Advanced channel coding</td>
<td>State of the art LDPC/polar coding to deliver higher reliability with low complexity</td>
</tr>
<tr>
<td>Wideband carrier support</td>
<td>Wideband carrier based higher data rates and system capacity</td>
</tr>
<tr>
<td>Larger number of antenna</td>
<td>Efficiently utilize larger number of antennas than Rel-14 to deliver higher data rate and long range</td>
</tr>
</tbody>
</table>

Source: Qualcomm
# LTE-V2X and NR-V2X

## Basic safety application by LTE-V2X (PC5) @ 5.9 GHz

New vehicles deploy both LTE-V2X and NR-V2X to enable the inter-operability with old vehicles:

1. **LTE-V2X (PC5):** Basic safety
2. **NR-V2X (sidelink):** Autonomous Driving

## Flexible selection between LTE-V2X and NR-V2X

Provide policies/criteria to UE to assist radio technology selection, according to V2X application type, QoS requirements, etc.

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**V2X Application**

- CAM
- DENM
- Platooning
- Auto Driving

**V2X Adaptation Layer**

- LTE-V2X
- NR-V2X

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Source: 3gpp.org
**Cellular-V2X**

- **Manned Vehicle without C-V2X**
  - No blind Spot detection
  - Chances of collision

- **Smart Vehicle without C-V2X**
  - Still less reliable
  - Higher latency & response time

- **Smart Vehicle with 5GNR + C-V2X**
  - Highly reliable, safe & fast

**Sensor data sharing**

**Path Planning**

**Real time Updates**

**Coordinated Driving**

**Wideband Carrier Support**

**High Throughput**

**Low Latency**

**Ultra High Reliability**

Sources:
- highwaysafety.utah.gov pololu.com
Timeline for Deployment

**Timeline for deployment of C-V2X (V2V/V2I)**

- **H1/2017**
  - C-V2X (R14) chipsets from various vendors
  - Integration, Validation Testing with OEMs (EU, China, US)
  - C-V2X (R14) RSUs and OBUs (EU, China, US)

- **H2/2017**
  - Chips for tests
  - Inter-Operability Tests
  - Mode 4 Chips and Models

- **H1/2018**
  - Testing
  - Availability of products

- **H2/2018**
  - CHINA: Spectrum for Deployment
  - US: Spectrum for Deployment

- **2019**
  - 5.9 GHz Spectrum Target Availability
  - EU: Final CEPT report
  - Start of vehicle deployment
  - In-vehicle commercial deployment (i.e., type approved)

- **2020**
  - C-V2X is real and ready with commercial chipsets set for 2018

- **2021 ff**

**Source:** 5gaa.org
Innovation Does Not Come Easy
Physical Layer Test Challenges

- Scalability
- Rx Sensitivity (PER)
- Latency
- Calibration
- Small Error Tolerance
- Wide Area Network (range enhancement)
LitePoints Solution

- Upgradable
- Cost Effective

Source: abroadship.org
Our Portfolio Spans Over The Ecosystem

- **Chipset**
- **Module**
- **Product**
- **OEM / CM**

Calibration Algorithms
Measurement Algorithms

Characterization
Data Visualization

Automation
Solutions

R&D
IC / Module
development Test

DVT
Design Verification
Testing

Final Product
Manufacturing Test
C-V2X Waveform Analysis

- Power vs Time
- Power Spectral Density
- EVM
- Modulation quality
Testing Made Much Simpler and Faster

- Higher Throughput with multi DUT testing
- Shorter time to market
- Reduced Testing cost
- Customer Support

Chipset or Module we test it all

Source: barcodedatalink

Source: cloudlibrariandownunder.wordpress.com

Source: entrepreneur.com