How NR based sidelink expands 5G C-V2X to support new advanced use cases

Qualcomm Technologies, Inc.
Today’s agenda

• Rel 14/15 C-V2X momentum
• How does NR C-V2X bring advanced use cases?
• NR C-V2X demos and over-the-air simulations
• Questions?
C-V2X
Rel 14/15 C-V2X established basic safety
Rel 16 NR C-V2X saw continued evolution for advanced use cases

- Release 14/15 C-V2X standards completed
- Broad industry support with 5GAA
- Global trials started in 2017; first commercial deployment expected in 2020
- Qualcomm® 9150 C-V2X chipset announced in September, 2017
- Integration of C-V2X into the Qualcomm® Snapdragon™ Automotive 4G and 5G Platforms announced in February, 2019
Rel 14/15 C-V2X
Momentum and commercial deployments
Driving C-V2X global presence with trials and demos

Gaining traction across numerous regions and industry sectors. From standards completion to independent field testing to initial deployments.

Collaborating with partners and customers:
- Tier 1s and OEMs
- Third-party software providers
- Test equipment, module, component, and antenna suppliers
- Road infrastructure providers
- Mobile network operators
- Design services
- Service providers

5GAA Automotive Association:
- 8 of the top 9 global automakers
- Top automotive Tier 1 suppliers
- 9 of the top 10 global telecommunications companies
- Top 3 global smartphone manufacturers
- Top global semiconductor companies
- Top 5 global wireless infrastructure companies
- Top global test and measurement companies and certification entities
- Global representation from Europe, China, US, Japan, Korea, and elsewhere

1. CAMP = Crash Avoidance Metrics Partnership LLC and this project includes the listed OEMs and Qualcomm.
Strong C-V2X momentum globally

- **5GAA founded** (Sep. 2016)
- **Towards 5G trial in France announced** (Feb. 2017)
- **First C-V2X chipset introduced** (Sep. 2017)
- **First multi-OEM demo in D.C.** (Apr. 2018)
- **Europe's first multi-OEM demonstration in Paris** (Jul. 2018)
- **Reaches 100 members** (Nov. 2018)
- **C-V2X integrated with Qualcomm Snapdragon Automotive 4G/5G platforms** (Feb. 2019)
- **SAIC project complete** (Mar. 2019)
- **C-V2X ecosystem demos** (May 2019)
- **Live demos show C-V2X as a market reality** (Nov. 2019)
- **ETSI European specifications and standards for C-V2X completed** (Feb. 2020)

**Key Dates:**
- **Jan. 2017:** ConVeX trial in Germany announced
- **Mar. 2017:** Rel-14 C-V2X spec finalized
- **Oct. 2017:** San Diego Regional C-V2X trial
- **Jun. 2018:** 1st US deployment in Denver
- **Nov. 2018:** China-SAE ITS Stack Compatibility
- **Oct. 2018:** C-V2X functional and performance test report published
- **Jan. 2019:** Cooperative driving live interactive demos in Las Vegas
- **Feb. 2019:** TELEFÓNICA/SEAT’s live C-V2X/5G demo at MWC Barcelona
- **Mar. 2019:** Cross border demo
- **Nov. 2019:** CAMP congestion control scenario testing by OEM consortium
- **Jan. 2020:** C-V2X deployment in Virginia with VaDoT
Working with regional standards to define applications globally

SAE for North America, ETSI ITS for Europe, and C-SAE/C-ITS for China

Supporting emerging use cases

- Standardizing messages for new use cases (e.g., sensor data sharing among vehicles)

Providing interoperability

- Allowing vehicles from different automakers to benefit from new use cases

Specifying minimum requirements

- Defining application layer-specific minimum requirements for new messages
NR C-V2X

Introduces complementary capabilities for advanced use cases
Driving the 5G technology evolution

2019 eMBB
- Global smartphone launches
- Fixed wireless access

2020 eMBB expansion
- Beyond smartphone (PC, FWA, ...)
- New markets/regions
- Nationwide coverage and SA migration

Longer term expansion
- Industrial IoT, enterprise, automotive network
- Private networks
- Unlicensed spectrum

Rel-15 commercialization
Rel-16
Rel-17
Rel-18+
Future-proof platform
Delivering on the 5G vision
Continue expansion to new verticals, deployments, use cases, spectrum

LTE essential part of the 5G platform

1. 3GPP start date indicates approval of study package (study item->work item->specifications), previous release continues beyond start of next release with functional freezes and ASN.1.
NR C-V2X builds on LTE C-V2X with advanced use cases

Safety use cases

Advanced use cases

Upper layers
Mapping use cases to transport profile

C-V2X
Rel 14/15 sidelink
Broadcast messages

NR C-V2X
Rel 16+ sidelink
Multicast messages

5G C-V2X sidelink
NR C-V2X introduces complementary capabilities for advanced use cases

Rel 14 / 15 C-V2X for automotive safety

Rel 14 / Rel 16+ C-V2X

Rel 16+ NR C-V2X vehicles are designed to support Rel 14 / 15 for safety use cases

Advanced use cases for all vehicles
NR C-V2X delivers a design that addresses advanced use cases

Building on existing frameworks

Utilizes NR flexible framework
- Scalable OFDM-based air interface
  - Such as wideband carrier support (>20 MHz) and different sub-carrier spacing
- Flexible slot-based framework
  - Such as adding sidelink and dynamic reference signal for various speeds
- Advanced channel coding
  - State of the art LDPC/polar coding to deliver performance

Leverages LTE C-V2X concepts
- Such as frequency division multiplexing, guaranteed latency performance and prioritization support

Introduces advanced capabilities
- Efficient sidelink link level design for optimized performance at all speeds
- Connectionless ‘on-the-fly’ distance-based groups
- Multicast with distance-based reliability and application relevancy

And increased performance
- Lower latency
- Higher spectral efficiency
- Higher capacity
Scalable OFDM air interface and flexible slot structure

**Higher spectral efficiency at high speeds**
- 15 kHz spacing, wideband carrier support up to 100 MHz
- 30 kHz spacing, wideband carrier support up to 100 MHz
- 60 kHz spacing, wideband carrier support up to 100 MHz

**Enhanced reliability with feedback**

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NR C-V2X

Enhanced reliability with feedback
Reliable multicast based on NAK\(^1\) feedback from receivers

Retransmission based on HARQ\(^2\)

Multiple receivers send NAK feedback using the same resource (time and frequency), also referred to as SFN\(^3\).

SFN of NAK keeps the feedback overhead constant, independent of the number of receivers.

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1. NAK is negative acknowledgement. 2. HARQ is hybrid automatic repeat request. 3. SFN is single frequency network.
NR C-V2X supports adaptive 2-, 3-, 4-symbol DMRS for high-speed performance

Variable reference signal design density
Strategic placement of reference symbols
Uniform coverage by adding distance as a dimension

Should be notified, but does not get signal

Does not need to be notified, but gets signal

Location information shared efficiently in the physical layer control channel

Enables NAK feedback with HARQ based on distance
Groups can reliably connect based on distance. Vehicles within a certain distance and interested in same services form an 'on-the-fly' group.
Application-aware, distance-based multicast communication

Application-specific distance is determined based on relevancy
Transmitting vehicles adapt transmission to relevant vehicles within range
Receiving vehicles only acknowledge (NAK) relevant messages
Rich sensor sharing

C-V2X vehicle detects non-C-V2X vehicle

Inform other C-V2X vehicles with the presence of non-C-V2X vehicles

With proxy forwarding, these benefits can be realized even with limited deployment.
Semi-persistent scheduling
Suitable for basic safety messages with similar packet sizes
Periodic transmission (typically ~100 ms)

Per packet scheduling
Variable traffic model based on the varying packet sizes
Lower latency (< 100 ms)

Efficient and flexible resource allocation for advanced applications with variable traffic
Stage 1 format for resource allocation

Stage 2 format for a Rel 16 application

Stage 2 format for a Rel 17 application

Two-stage control allows efficient and flexible support for current and future applications

Stage 1
Common across releases and provides resource allocation information

Stage 2
Provides application-specific information and also facilitates forward compatibility
NR C-V2X enhancements

Significant physical layer gains

Spectral efficiency: up to 2x for broadcast
Scalable OFDM and flexible DMRS provide higher spectral efficiency, which reduces bandwidth usage and allow for more capacity

Lower latency: Tx latency as low as 1.5 ms
Due to shorter slots and resources allocation enhancements

Higher capacity: 2x for per packet scheduling
Achieved through link-level gain, HARQ feedback, and resource allocation enhancements
Rich sensor sharing
Enables perception and intent sharing among vehicles

On-the-fly connectionless groups
Enabled by distance-based reliability

Benefits in addition to safety
Coordinated driving brings reduced congestion, shorter trip time, and energy savings

NR C-V2X
NR C-V2X builds on LTE C-V2X
NR C-V2X

Over-the-air demos and simulations
5G C-V2X prototype platform
Thank you!

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