How 5G and C-V2X are Creating a Smarter More Connected Car Experience

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Transformations underway

- Transportation networks are evolving as 5G & edge AI are upon us

- The in-vehicle experience is evolving from Infotainment to Digital Cockpit
Qualcomm in Automotive
Connecting cars for 15+ years

- Remote lock/unlock
- Car sharing credentials management
- Sensor sharing
- Big data analytics
- Stolen vehicle recovery
- Driver monitoring
- Bundled content
- Over-the-air updates
- Diagnostics
- Wi-Fi hotspot
- Remote lock/unlock
- Automated driving support
- Driver monitoring
- Connected navigation
- App-enabled vehicle management
- Smartphone integration and mirroring
- Phone-based access and personalization
- Video and audio streaming
- Multi-operator connectivity and subscription management
- Infotainment

~3 out of 4 new vehicles are projected have cellular connectivity by 2024”

* Visual inertial odometry
** Strategy Analytics, Oct. '17
Car Connectivity in the 5G era

Heterogeneous Connectivity

Secure, virtualized wireless links

Advanced Positioning

Multi-environment implementation

Precise positioning
Lane-level accuracy anywhere, anytime

Bluetooth
For high quality voice and audio

Wi-Fi
For in-car experiences and car OEM services

4G/5G
For car OEM services

4G/5G
For driver and passengers

C-V2X
For car to infrastructure communication

C-V2X
For car to car communication

Bluetooth
For high quality voice and audio

Wi-Fi
For in-car experiences and car OEM services

4G/5G
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C-V2X
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C-V2X
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4G/5G
For car OEM services
World’s leading automakers build with our solutions

#1
In telematics and Bluetooth for automotive

A leader
In premium next-gen infotainment design-wins for production vehicles starting 2019-2020

18
Automakers have selected the Qualcomm® Snapdragon™ Automotive Infotainment Platform

$5.5B+
Design-win pipeline for telematics, infotainment, and in-car connectivity

Source: Company data
Qualcomm Automotive Infotainment Platform is a product of Qualcomm Technologies, Inc. and/or its subsidiaries.
Pioneering advanced 5G NR technologies
To meet smart transportation requirements

Mission-critical services
- Cellular Vehicle-to-Everything (C-V2X)
- Drone communications
- Private Networks
- Ultra Reliable Low Latency Comms (URLLC)

Enhanced mobile broadband
- Spectrum sharing
- Flexible slot-based framework
- Scalable OFDM
- Massive MIMO
- Mobile mmWave
- Dual Connectivity
- Advanced channel coding

Massive Internet of Things
- Enhanced power save modes
- Deeper coverage
- Grant-free UL
- Narrow bandwidth
- Efficient signaling

10x Decrease in end-to-end latency
10x Experienced throughput
3x Spectrum efficiency
100x Traffic capacity
100x Network efficiency
10x Connection density

Based on ITU vision for IMT-2020 compared to IMT-advanced; URLLC: Ultra Reliable Low Latency Communications; IAB: Integrated Access & Backhaul
Qualcomm® Connected Car Reference Design, Gen 2

Snapdragon Automotive 4G/5G platforms

- **5G**
  - Rel-15 5G NR
  - Standalone
  - Non-standalone
  - FDD
  - TDD

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

- 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)

Qualcomm Connected Car Reference Design and Qualcomm Snapdragon Automotive 4G/5G Platforms are products of Qualcomm Technologies, Inc. and/or its subsidiaries
1. Elliptic Curve Digital Signature Algorithm
2. Vision Enhanced Precise Positioning (VEPP)
C-V2X
C-V2X
Established the foundation of C-V2X for safety in Rel-14/15 with continued evolution in Rel-16 5G NR for advanced use cases

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

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

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

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

- **5G**
  - API enabled for advanced use cases
  - API for advanced use cases

- **Release 14/15 C-V2X standards completed**

- **Broad industry support with 5GAA**

- **Global trials started in 2017**

- **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**
Evolving C-V2X Direct Communications towards 5G NR
While maintaining backward capabilities

Evolution to 5G NR, while being backward compatible
C-V2X Rel-14 is necessary and operates with Rel-16

Basic and enhanced safety
C-V2X Rel-14/Rel-15 with enhanced range and reliability

Basic safety
IEEE 802.11p

Autonomous driving use cases
5G NR C-V2X Rel-16
Backward compatible with Rel-14/Rel-15 enabled vehicles

Higher throughput
Higher reliability
Wideband carrier support
Lower latency
Emergence of new automotive and transportation use cases
Requiring a more flexible and efficient direct communication design

New autonomous driving use cases
Perception and intention sharing for coordinated driving

New smart transportation use cases
Vehicles and infrastructure need to exchange new kinds of information, such as, real time 3D HD map updates.

More sensor data needs to be shared
Vehicles have new and more sensors, generating more information that needs to be shared

Automotive industry is undergoing a significant transformation
5G standardization and projected ecosystem expansion

We are here

Rel-15
Rel-16
Rel-17+ evolution

Standalone (SA)
Non-Standalone (NSA)
IoDTs
Field trials

5G NR C-V2X Study Item
5G NR C-V2X Work Item

Rel-15 Commercialization
Rel-16 Commercialization
Rel-17+

eMBB deployments in both mmWave and sub-6 GHz
New 5G NR technologies to evolve and expand the 5G ecosystem
Expanded ecosystem

2017
2018
2019
2020
2021
2022
2023+

Smartphone formfactor, connected laptops, CPE fixed access
Private network, industrial IoT indoor mmW for enterprises, Boundless XR...
Industrial IoT with eURLLC, 5G NR C-V2X...
Integrated access and backhaul, unlicensed/shared spectrum,... continued eMBB evolution
5G NR C-V2X is backward compatible at upper layers

By enabling coexistence of Rel16 with previous releases

Rel-16 C-V2X vehicles will be designed to support Rel-14/Rel-15 for safety
Higher throughput
High spectral efficiency to achieve higher throughput

Lower latency
Connectionless “on-the-fly” groups and distance-based design

Higher reliability
Multicast support using efficient feedback

High-speed performance
Up to 3.5 higher spectral efficiency at 500kmph relative speeds

Application aware
Performance tailored to application requirements, such as minimum distance

Backward compatibility
Vehicles with Rel-16 will also support Rel-14 for safety

Resulting in a 5G NR C-V2X design that addresses tomorrow’s vehicle use case requirements
Autonomous driving

Benefits from real-time update from infrastructure

RSU sends a 3D HD map update to oncoming vehicles with the lane reconfiguration due to construction.
Intention sharing allows more efficient maneuvers for coordinated driving.

**Highway**
Coordinated highway entrance and lane changes

**Urban**
Vehicles can navigate intersections without stopping.
Sensor sharing

Sensor object sharing enables benefit of V2X with limited penetration rate

C-V2X vehicle
Detects non-C-V2X vehicle via its on-board sensors (e.g. camera)

Non-C-V2X vehicle

C-V2X vehicles
Inform other vehicles with the presence of non-C-V2X vehicles
Connectionless ‘on-the-fly’ distance-based groups

Vehicles within a certain distance and interested in same services form a group
Rel-14 C-V2X
Broadcast without feedback, which can't ensure reliability

Rel-16 5G NR C-V2X
Multicast with feedback for higher reliability; if signal can't be decoded, NACKs are sent on the same radio resources (SFN-like approach)

Multicast support for higher reliability
HARQ feedback to achieve higher reliability  |  Introducing efficiency by sending only NACKs using SFN
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 relevant messages
5G NR takes C-V2X to the next level

R16 5G NR C-V2X builds on R14 C-V2X, which is gaining momentum and getting ready for launch for automotive safety.

5G NR brings complementary advanced use cases via a new direct communication link design with higher throughput, better reliability, lower latency and application aware performance.

5G NR allows vehicles to share more information such as richer sensor data and intended actions with each other and their surroundings, realizing benefits even with initial limited deployments.

5G NR provides increased situational awareness for safer driving; and coordinated driving for shorter travel time and energy efficiency.
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