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CONNECTED VEHICLES: V2X AND C-V2X

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Technology roadmap that scales to empower innovation across segments



Qualcom

A global leader in wireless innovation

Transforming how the world connects, computes, and communicates



in cumulative R&D¹

140,000+

Granted patents / pending applications²

Snapdragon



Bilion+ Snapdragon Install Base

Diversified Sourcing Model Leveraging Strong Foundry Relationships



Driving digital transformation across industries



Qualcom

20+Years



in telematics and wireless car connectivity

250 Million+

vehicles produced with Snapdragon automotive technologies



36% year-over-year revenue growth in

FY2022

global automakers

> have selected Snapdragon® Cockpit Platform

Leader

in premium next-gen infotainment wins for production vehicles starting 2020 16+ C-V2X design wins worldwide

5G-enabled commercial vehicle (Great Wall Motor

st





Haval H6 SUV)



(Human Horizons HiPhi-X)

commercial vehicle

Source: Internal data; 1. As of November 2, 2022. The design-win pipeline reflects the current estimated future size of awarded automaker programs, based on forecasts provided directly by automakers and Tier-1 suppliers.

Empowering the Global Automotive Ecosystem



C-V2X, the fundamentals

C¹-V2X enables network independent communication

Direct safety communication independent of cellular network

Low latency Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I), and Vehicle to Person (V2P) operating in ITS² bands (e.g. 5.9 GHz)

Direct PC5 interface

Cellular

З.

e.g. location, speed, local hazards

Network communications for complementary services

Vehicle to Network (V2N) operates in a mobile operator's licensed spectrum

Network Uu interface e.g. accident 2 kilometer ahead





5G¹ V2X has a rich roadmap of features in each 3GPP² release

Applications C-V2X Features	Basic safety messages between vehicle-to- vehicle and vehicle-to- infrastructure 2017/2018 LTE-V2X Rel-14/15	Rich sensor sharing Coordinated driving Application dependent distance-based reliability NR-V2X Rel-16	Pedestrian and other vulnerable road user safety Enhanced network coverage via relaying Greater reliability and performance for advanced applications	Flexible deployment, positioning enhancements 2023 Rel-18+
	Operation without SIM enabled GNSS-based timing High reference signal density Improved high density operations Guaranteed maximum Tx latency	Scalable OFDM-based air interface Flexible slot-based framework Distance-based reliability Adaptive reference signal Reliable multicast communication	Advanced sidelink resource coordination Power savings for power constrained devices	<i>Co-channel LTE V2X and NR V2X coexistence Sidelink ranging and positioning</i>

Building on decades of research in foundational technologies

Efficient deployment, advanced safety applications, and new opportunities

C-V2X is designed to work without network assistance

USIM-less operation

Autonomous resource selection

GNSS time synchronization

5.9 GHz ITS band support

Reuse established service & app. layer

Direct communication doesn't require USIM

Scalable distributed scheduling, where vehicles selects resources without network assistance

GNSS used for time synchronization without relying on cellular networks

High speed direct communication support add for ITS band

Defined by ISO, ETSI, SAE for security and transport layer



(via PC5 interface on 5.9GHz)

C-V2X, use cases



Rel14/Rel15 C-V2X Use Cases examples (focused on safety)

Coordinated driving



Rel 16 C-V2X example (1/2):

Intention sharing allows more efficient maneuvers for coordinated driving

Highway Coordinated highway entrance and lane changes Urban

Vehicles can navigate intersections without stopping

Autonomous driving

Benefits from real-time update from infrastructure



Rel 16 example (2/2):

RSU sends a 3D HD map update to oncoming vehicles with the lane reconfiguration due to construction

V2X, perspectives



C-V2X sidelink complements 5G networks

Managing intersections combining C-V2X with 5G





Cellular networks (TMC-based traffic monitoring and advisory)



Edge AI (AI-based vision systems for enhanced safety)

Smart RSUs with on-device processing form a connected intelligent edge



Central cloud

Traffic management center

Big data, AI training, less delay sensitive content, storage,...



Compute intensive, real-time data

· Local analytics, management

Neighborhood/city/highway

Compute/processing, context, control, storage, closer to vehicular network Vehicular networks are highly dynamic



New deployments, (private networks)

Realize 5G's low latency

Scalability

Performance

Additional

resources

Latency could be over 100s ms today	 Cooperation between road operators, MNOs ¹ , infra vendors, cloud providers,		
	 5G value maximizes from operators and services Deliver enhanced and new services Host, content, processing for 3rd party 	 Immediacy–tasks on device Efficient use of bandwidth Scalability 	

Safer and smarter arterials and other urban roads Combining C-V2X RSUs and cellular networks

Transportation efficiency

Pre-trip route and mode planning

(via cellular networks)

Road safety Hazard warning (via V2I sidelink)

TMC¹-based traffic

monitoring and advisory

Road safety Forward collision avoidance (via V2V sidelink) Al/edge processing

Pedestrian

etv warning

rip and mode planning

Smart parking

Connectivity 5G

New direct communication

• Massive Internet of Things

1 TMC is Traffic Management Center

Advanced traffic management

Smart lighting

Smooth traffic flow delivered by C-V2X









1111

Traffic management

Roadside 8







3 Rerouting



Live 3D Maps

Smart transportation with C-V2X can revolutionize logistics

Al traffic analysis of the second sec

Monitoring sensors Freight pressure / temperature/Asset tracking Driver monitoring

85%

Mileage

Traffic

monitoring

Smart road technology

Electronic toll booths



Protecting VRUs

2019 National Highway Traffic Safety Association stats for pedestrian and cyclists

6,205 pedestrians were killed in traffic crashes

- ~one person every 85 minutes, up 27% since 2015
- 17% of all traffic fatalities

846 pedal cyclist fatalities, accounting for 2.3% of all traffic fatalities

~49,000 pedal cyclists were injured, a 5.4% increase over 2018



C-V2X use cases continue to grow

From Day One safety for vehicles and VRUs to enabling new use cases for intelligent transportation

Conclusion

C-V2X is a critical component of our vision

The safety component of the Digital Chassis

Vehicle-to-Infrastructure (V2I)

e.g. Red Light Violation Warning

> Vehicle-to-Vehicle (V2V)

> e.g. collision avoidance safety systems

Enhanced range and reliability for direct communication without network assistance



Qualcomm[®] 9150 C-V2X chipset commercialized starting 2018



Integration of C-V2X into the Snapdragon Automotive 4G (SA415M) and Snapdragon 5G (SA515M) Platforms starting 2019

Vehicle-to-Network (V2N)

e.g. real-time traffic / routing, cloud services



Vehicle-to-Pedestrian (V2P)

e.g. safety alerts to pedestrians, bicyclists

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« Inventer, c'est penser à côté. »

A. Einstein

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