Leading the world to 5G: Cellular Vehicle-to-Everything (C-V2X) technologies

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Our vision for the always-connected vehicle of the future

A safer, more efficient, more enjoyable driving experience

Highly intelligent

Always connected

Increasingly autonomous

Highly secure

Increasingly electric (or hybrid)

Safer–towards zero road accidents

Greener–reduce air pollution & emissions

More predictable and productive travel

V2X is a critical component to our vision

Giving vehicles the ability to communicate with each other and beyond

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

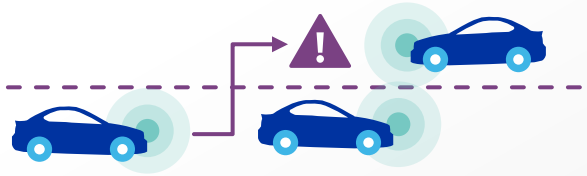
Vehicle-to-pedestrian (V2P)

e.g. safety alerts to pedestrians, bicyclists

V2X enables a broad and growing set of use cases

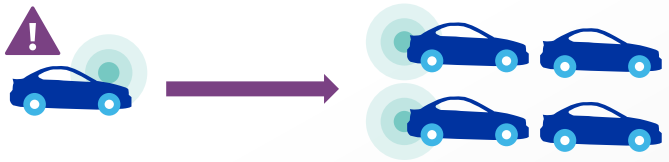
Much more than collision avoidance

Forward collision warning



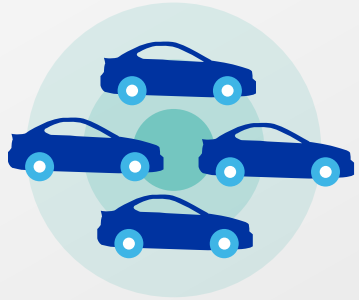
Do Not Pass Warning (DNPW)

Blind intersection

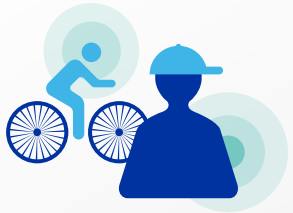


Queue warning

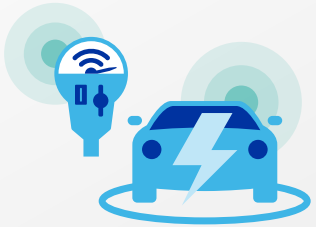
Curve speed warning



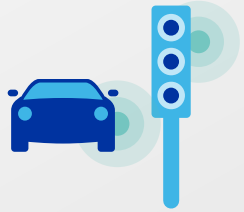
Cooperative adaptive cruise control & platooning



Vulnerable Road User (VRU) alerts



Discover parking and charging

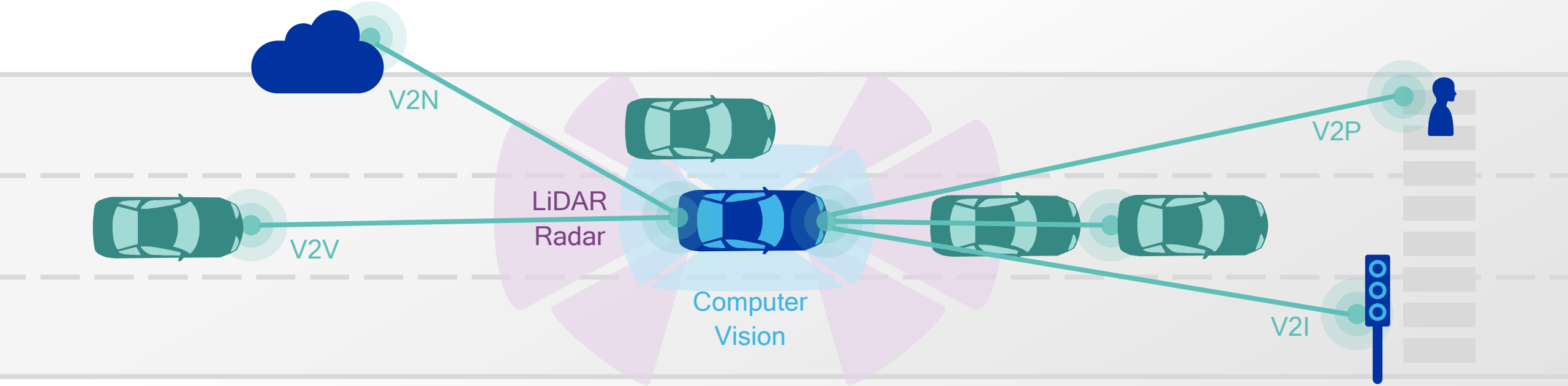


Traffic signal priority and optimal speed advisory

Emergency vehicle alert

V2X is a key technology enabler to enhanced ADAS

Bringing significant value to Advanced Driver Assistance Systems (ADAS)



Improved active safety

Provides 360° non-line-of-sight awareness, e.g. intersections/on-ramps, environmental conditions

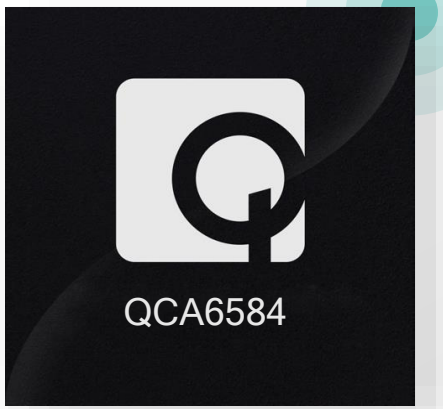
Better traffic efficiency

Allows vehicles to safely drive closer to each other and enables optimization of overall traffic flow

Increased situational awareness

Provides ability to gather data from further ahead to deliver a more predictable driving experience

802.11p has established the foundation for V2X



2nd generation Qualcomm Technologies 802.11p offering with integrated Wi-Fi LAN and Bluetooth

Wi-Fi based technology – 802.11p standard

Adapted for latency-critical V2X communications in the 5.9 GHz band

Established security and upper layer specifications

With service layer / performance requirements defined by SDOs, e.g.SAE, ETSI-ITS[1]

Path to DSRC[2] rulemaking in USA by NHSTA[3] expected to start in 2016[4]

Based on 802.11p standard

Large scale field trials completed over the last decade

Commercially available technology here today

[1] Standard Development Organizations, e.g. Society for Automotive Engineers, European Telecommunications Standards Institute – Intelligent Transport Systems; [2] Dedicated Short Range Communications (DSRC); [3] National Highway Traffic Safety Administration; [4] To improve road safety for future 'light vehicles' – Qualcomm has conducted extensive research into various use cases for DSRC, including V2P applications that could extend the safety benefits to vulnerable road users such as pedestrians and cyclists

Introducing Cellular V2X (C-V2X)

A unified connectivity platform for the connected vehicle of the future

Part of Release 14 of the global 3GPP standard

Target C-V2X specification completion end of 2016[1]

Builds upon existing LTE connectivity platform for automotive

LTE already delivering key services today, e.g. telematics, eCall, connected infotainment

Enhances LTE Direct for V2X direct communications

Improvements over 802.11p – up to a few additional seconds of alert latency and 2x range[2]

Leverages existing LTE networks for V2X network communications

Using LTE Broadcast optimized for V2X to offer additional applications/services

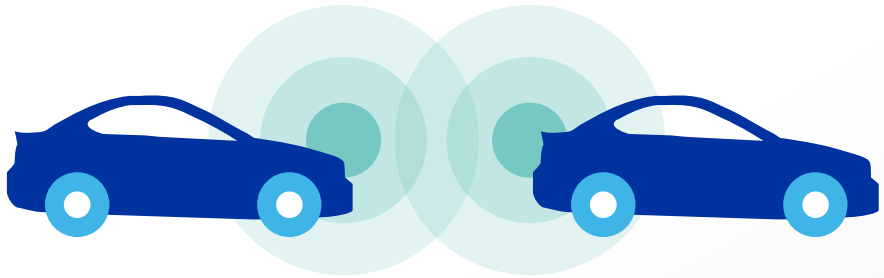
Rich roadmap towards 5G with strong ecosystem support

Technology evolution to address expanding capabilities/use cases

[1] For Direct communications component (enhancements to LTE Direct) – overall spec completion expected mid-2017; 2 Based on Qualcomm Research simulations (see future slides for further information)

C-V2X defines two complementary transmission modes

PC5 interface
e.g. location, speed

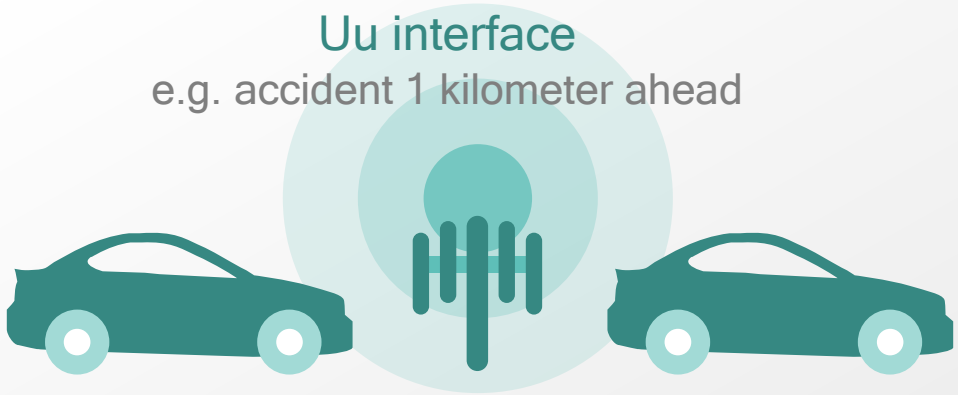


Direct communications

Building upon LTE Direct device-to-device design with enhancements for high speeds / high Doppler, high density, improved synchronization and low latency

- Proximal direct communications (100s of meters)
- Operates both in- and out-of-coverage
- Latency-sensitive use cases, e.g. V2V safety

Uu interface
e.g. accident 1 kilometer ahead



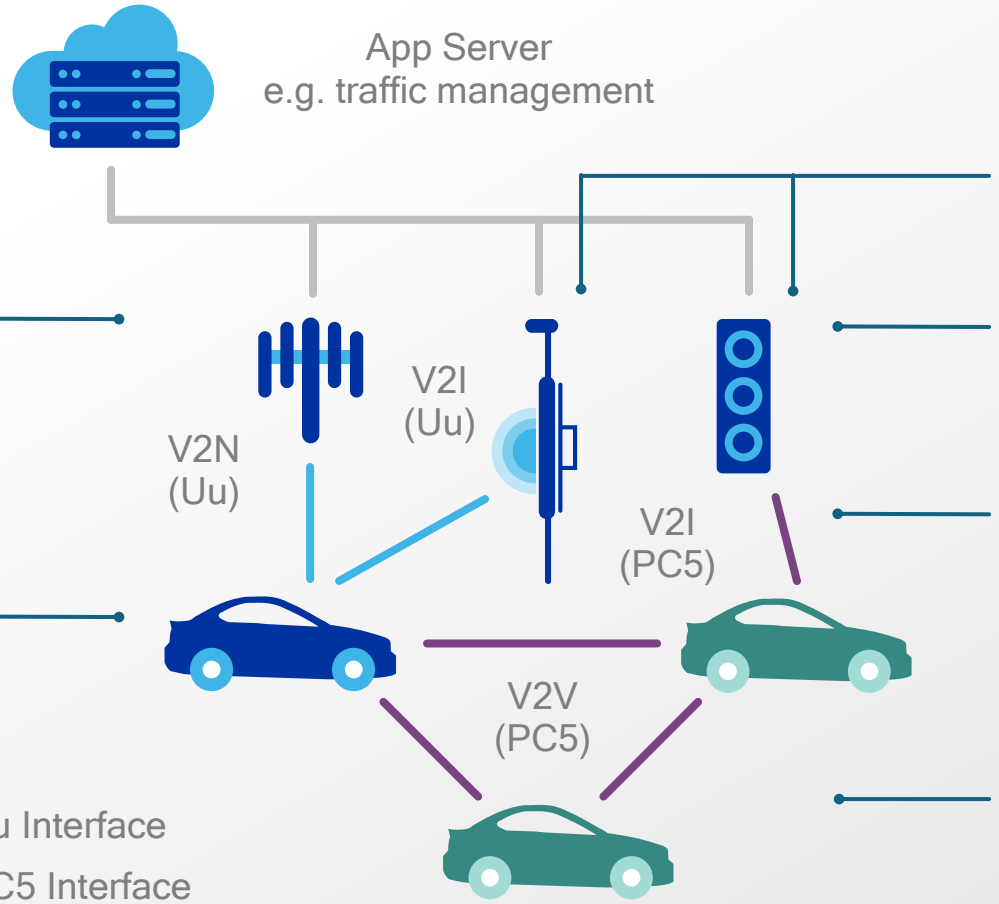
Network communications

Using LTE Broadcast to broadcast messages from a V2X server to vehicles and beyond. Vehicles can send messages to server via unicast.

- Wide area networks communications
- Leverages existing LTE networks
- More latency tolerant use cases, e.g. V2N situational awareness

Delivering advanced services to vehicles

Opening up new opportunities and diverse business models for MNOs



V2N provides over-the-top cloud services

Most use cases use a combination of interfaces

RSUs can be eNodeBs or standalone roadside devices

RSUs[1] can connect to network for cloud services

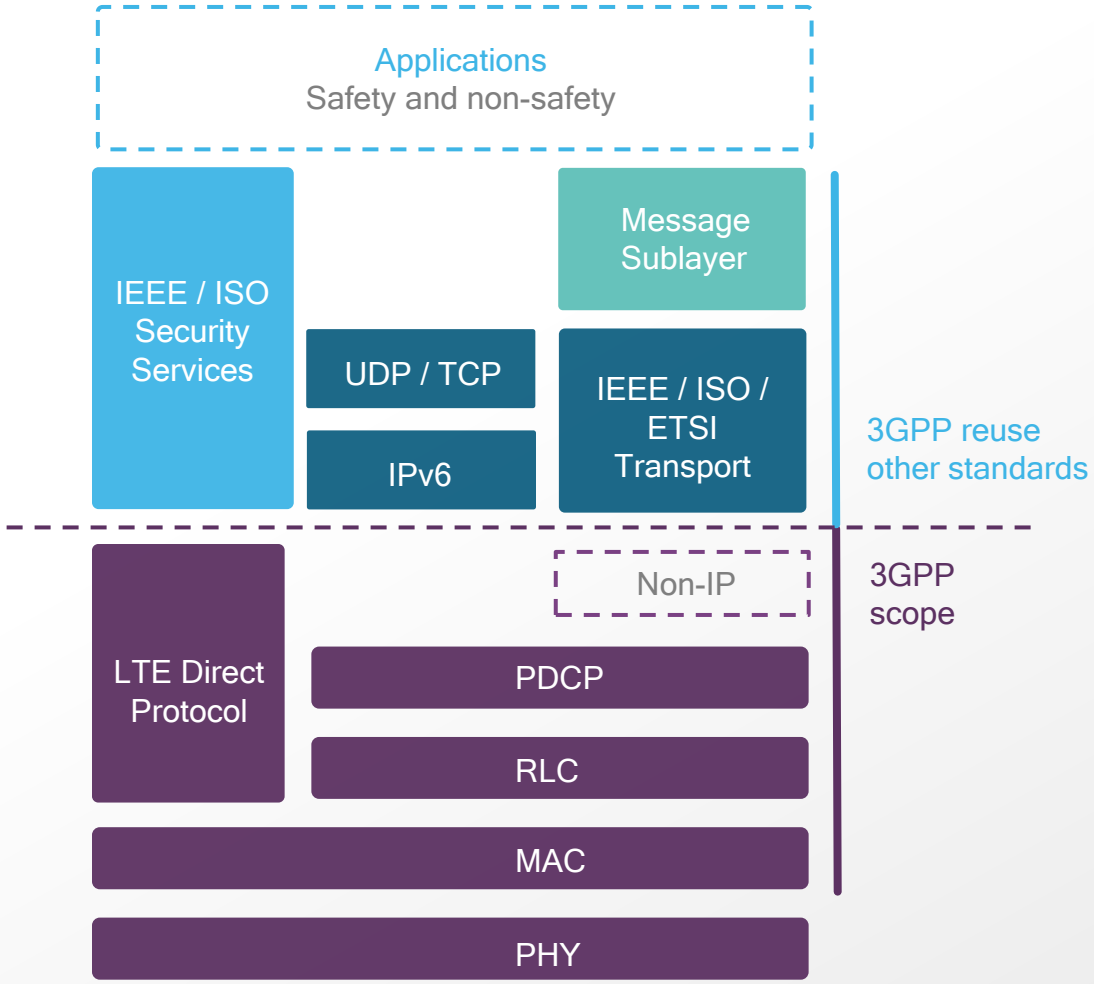
V2I allows RSUs to monitor traffic, e.g. traffic signals, tolls

V2V mostly for safety and ADAS services

[1] Road Side Units

C-V2X builds upon LTE Direct D2D communications

With enhancements to address V2X requirements



Reuse established service & app layers

Already defined by automotive community, e.g. SAE

Reuse existing security and transport layers

Defined by ISO, ETSI, and IEEE 1609 family

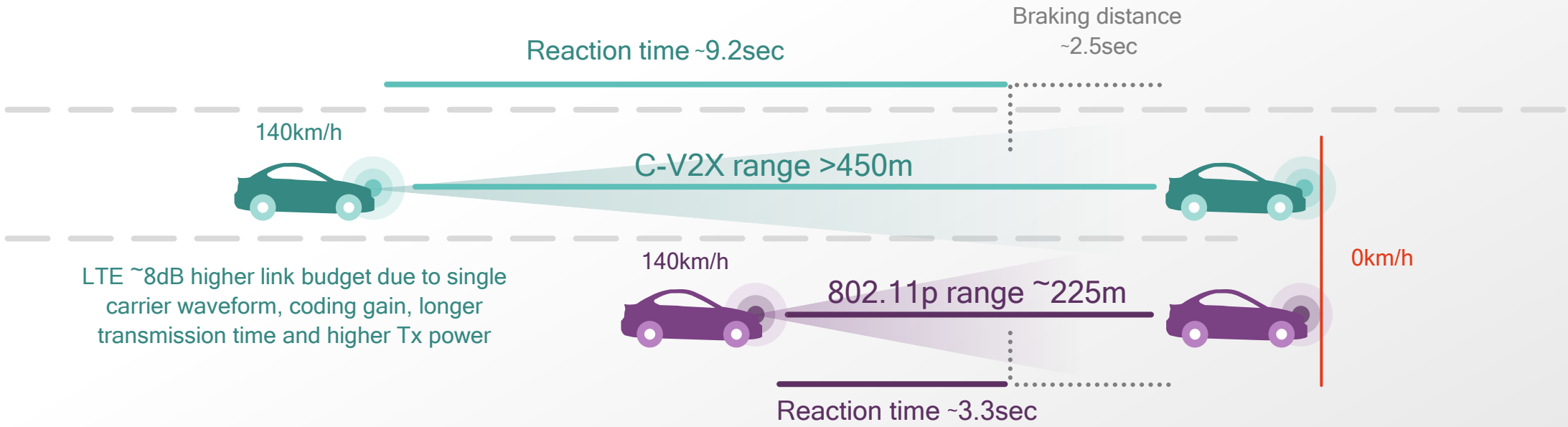
Enhancements to LTE Direct PHY/MAC

To address latency-critical, reliable V2X communications

Note: Also enhancements to the LTE Direct network architecture / system design to support V2X

C-V2X increases reaction time over 802.11p/DSRC

For improved safety use cases – especially at high-speeds, e.g. highway



Safer driving experience

Increased driver reaction time

Support for high speeds

Relative speeds up to 500km/h

Increased situational awareness

Gather data from further ahead

Based on link level curves and the 3GPP LOS path loss model @ 10% Packet Error - Actual performance varies significantly with vehicle density and environment

5G will bring new capabilities for the connected vehicle

New OFDM-based 5G air interface scalable to an extreme variation of requirements

Extreme throughput

Up to multi-Gpbs with more uniformity–wider bandwidths, advanced antenna techniques

1ms end-to-end latency

Through a faster, more flexible frame structure; also new uplink RSMA non-orthogonal access

Edgeless connectivity

New ways of connect, e.g. multi-hop to extend coverage, plus natively incorporate D2D

High availability

Multi-connectivity to provide multiple links for failure tolerance and mobility

High reliability

Ultra-reliable transmissions that can be time multiplexed with nominal traffic through puncturing

[1] Also exploring alternative roots of trust beyond the SIM card

5G will build upon and enhance C-V2X

New 5G platform will augment / complement C-V2X—no 'rip and replace'

Multi-mode vehicle with simultaneous connectivity across 4G LTE, C-V2X and 5G

4G LTE

Continue to evolve and provide ubiquitous coverage as 5G is rolled out

C-V2X

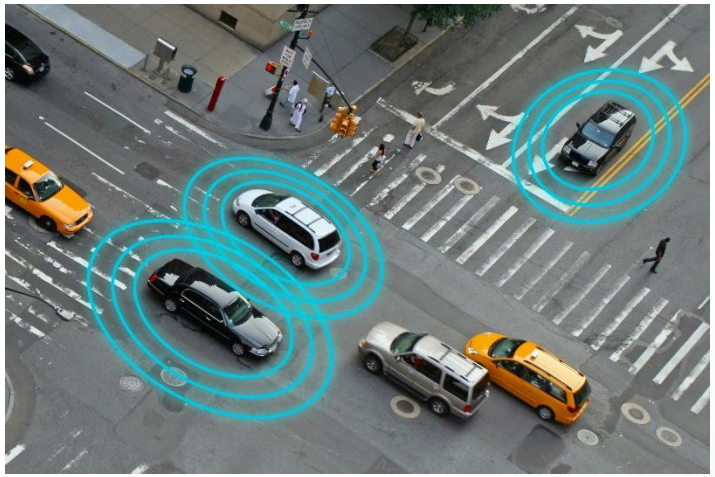
C-V2X direct and network communications

5G

Bring new capabilities for C-V2X network communications and augment C-V2X direct communications over time

Enabling the next gen of connected vehicle experiences

Sample use cases



Fully autonomous driving

e.g. cooperative collision avoidance and high-density platooning which requires new levels of latency and reliability, plus larger message sizes

V2X augmented reality

e.g. see-through capability when driving behind truck or leveraging real-time video feeds for navigation systems

Extreme mobile broadband

Passengers can enjoy the next generation of connected immersive experiences, e.g. Virtual Reality, 3D/UHD video telepresence

In summary

V2X is a critical component of our vision for the always-connected, more autonomous vehicle of the future

Cellular V2X brings improvements over 802.11p/DSRC for active safety use cases and beyond – part of 3GPP Release 14

Roadmap to 5G will bring even more potential for the connected vehicle–built upon C-V2X, so no ‘rip or replace’

Qualcomm is leading the way to the connected vehicle of the future – pushing wireless boundaries and brining new levels of on-device intelligence

Learn more at: www.qualcomm.com/C-V2X

Thank you

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