C-V2X - A Communication Technology for Cooperative, Connected and Automated Mobility

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Outline

- Motivation
- Introduction of C-V2X
- LTE-V2X basic and enhanced safety use case examples
- Evolution towards 5G NR use cases
- Conclusions

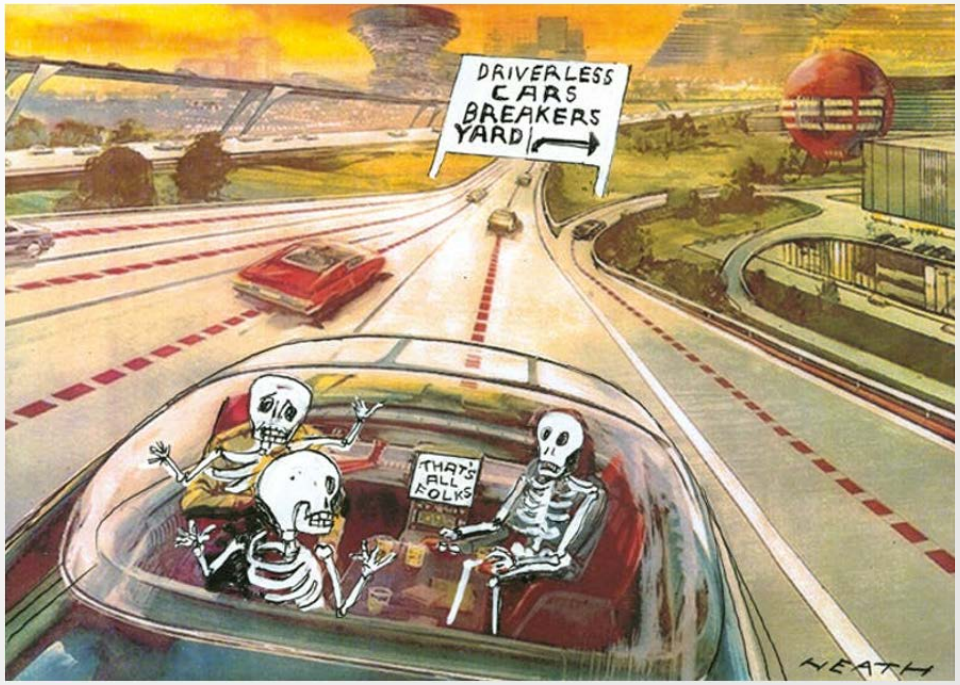
Motivation

Prospects of future of driving

How it is envisaged …

Source: www.mondaynote.com - Courtesy: Popular Mechanics

How it should not end …

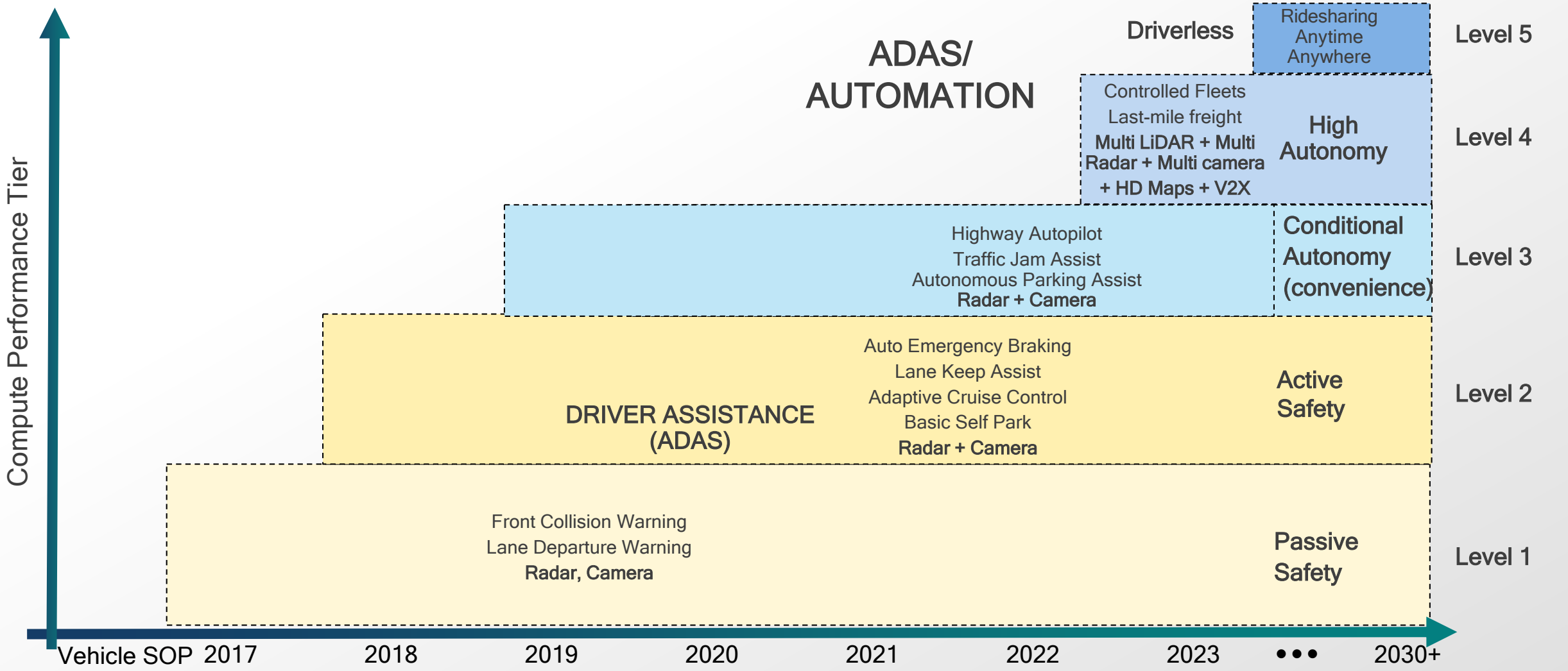


Source: www.spectator.co.uk

Envisioned Evolution of Automated Driving

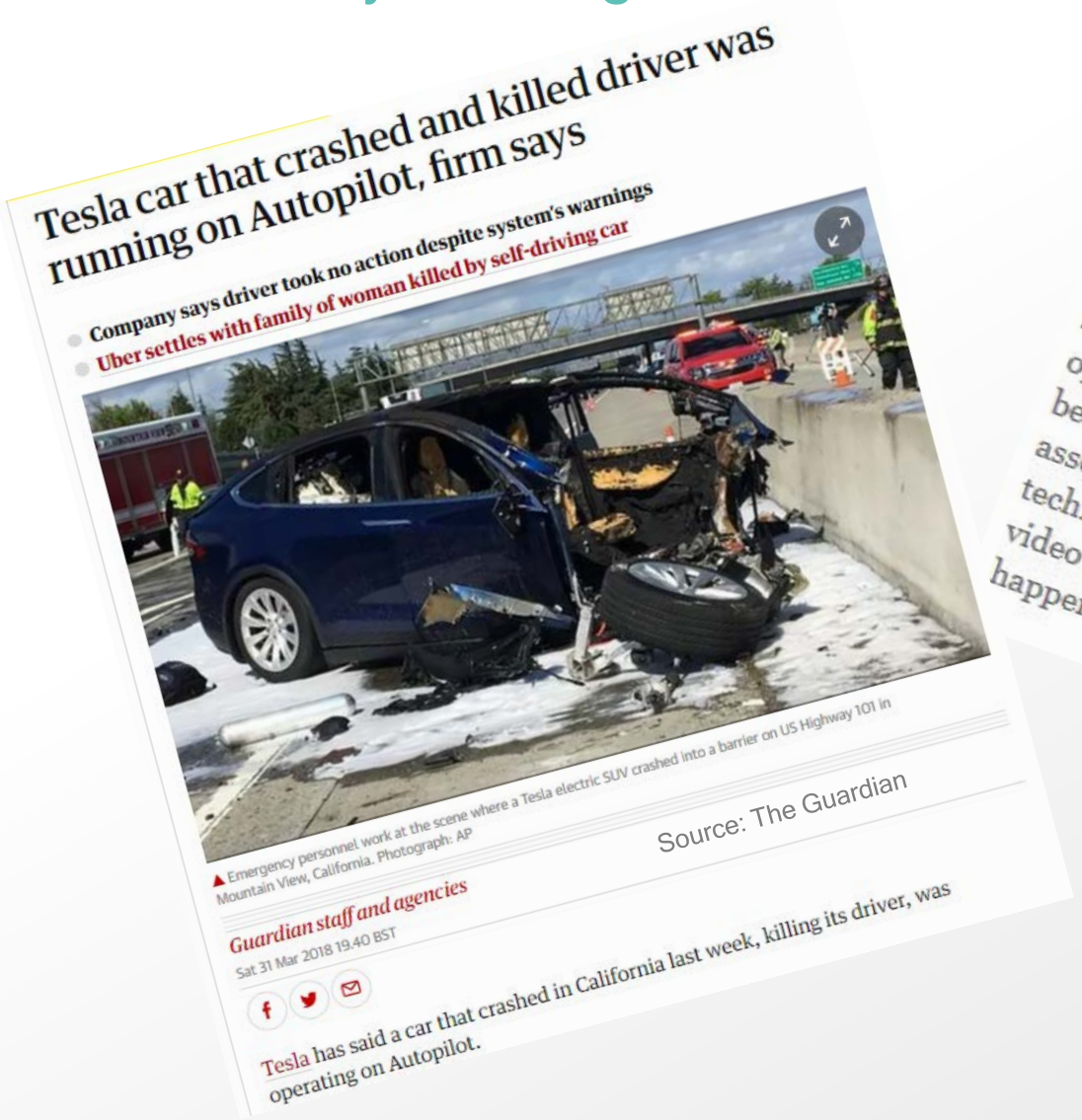
Today - L2+ autonomy emerging in premium tier segment

L3 mass market adoption beginning 2022?



Motivation (cont'd)

Connectivity can augment vehicle sensors to reduce accidents



Tesla car that crashed and killed driver was running on Autopilot, firm says

Company says driver took no action despite system's warnings

Uber settles with family of woman killed by self-driving car

▲ Emergency personnel work at the scene where a Tesla electric SUV crashed into a barrier on US Highway 101 in Mountain View, California. Photograph: AP

Guardian staff and agencies

Sat 31 Mar 2018 19.40 BST

Tesla has said a car that crashed in California last week, killing its driver, was operating on Autopilot.

Source: The Guardian

How a Self-Driving Uber Killed a Pedestrian in Arizona

The death of a woman who was struck by an autonomous car operated by Uber is believed to be the first pedestrian fatality associated with self-driving technology. Newly released video offers clues about what happened.

Source: New York Times

The New York Times

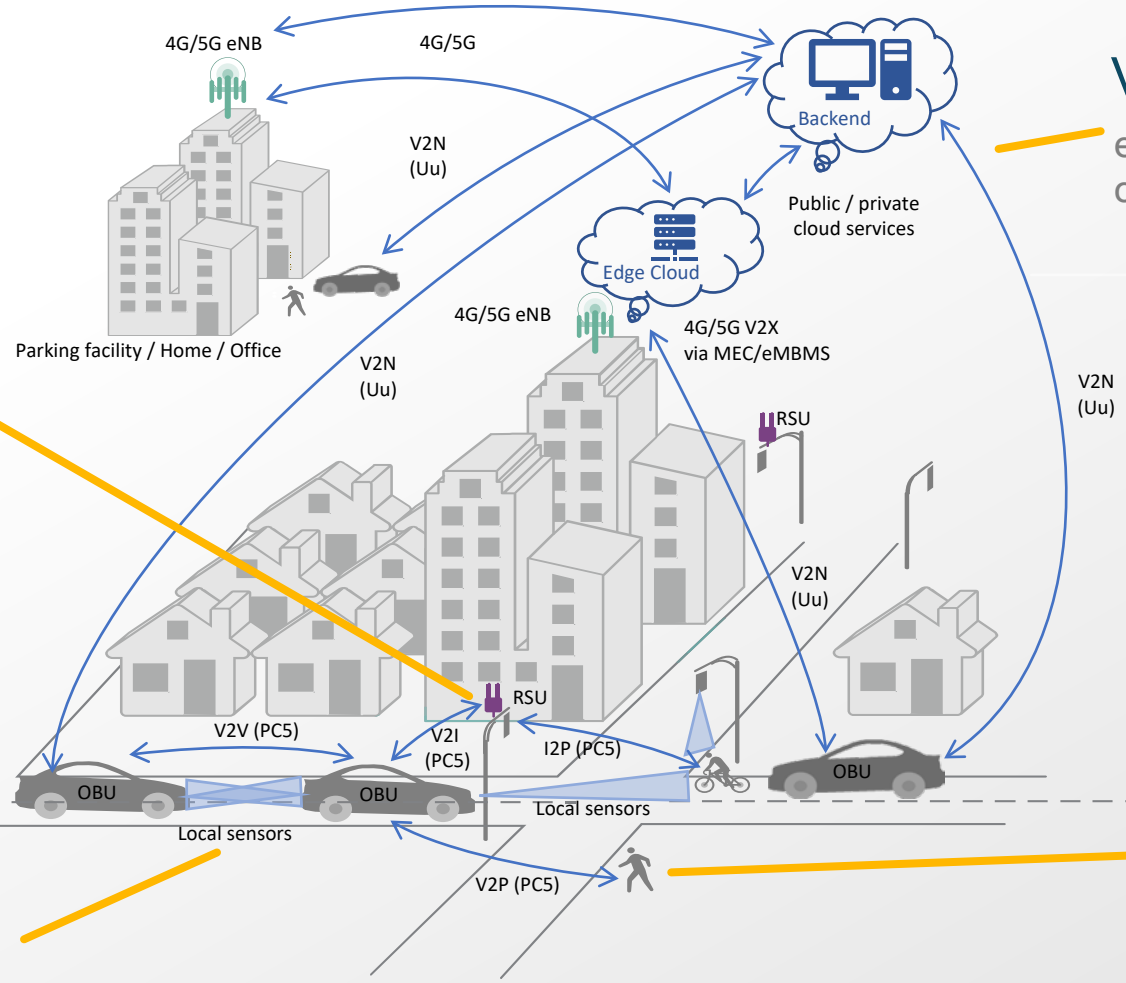
Pedestrian struck crossing street

Body seen here

Self-driving Uber

Cellular Vehicle-to-Everything Communication (C-V2X)

Provides connectivity for coordinated, connected and autonomous mobility



Vehicle-to-network (V2N)

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

Vehicle-to-infrastructure (V2I)

e.g. traffic signal timing / priority

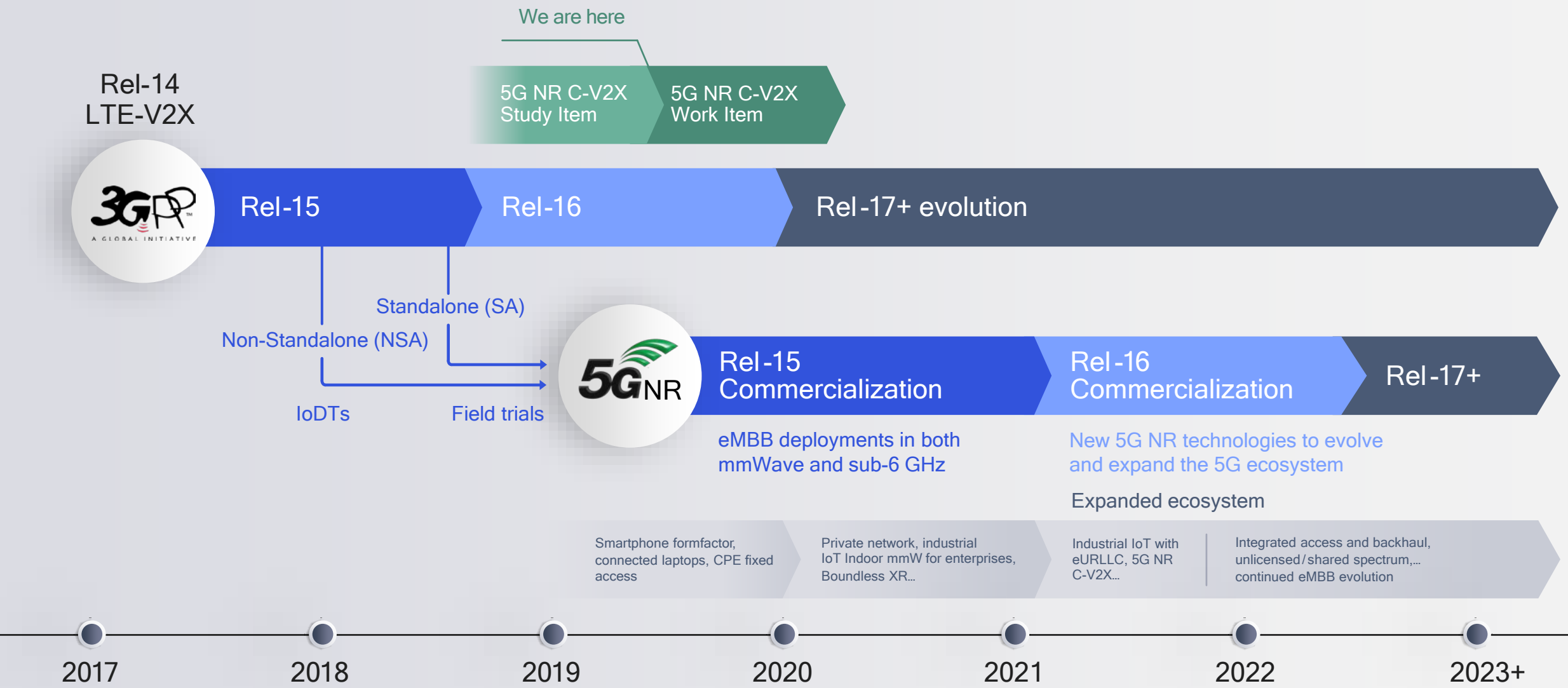
Vehicle-to-pedestrian (V2P)

e.g. safety alerts to pedestrians, bicyclists

Vehicle-to-vehicle (V2V)

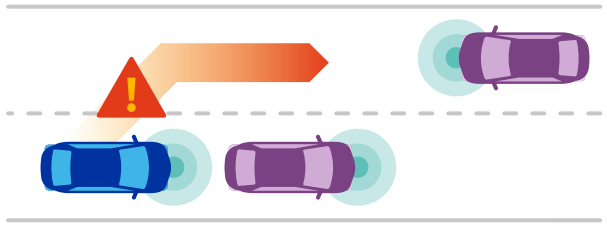
e.g. collision avoidance safety systems

5G standardization and projected ecosystem expansion

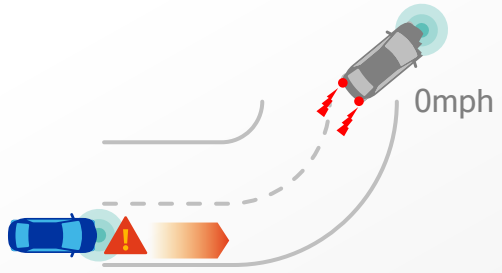


LTE-V2X providing support for enhanced safety use cases

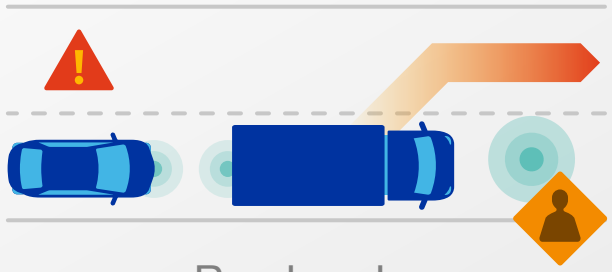
By extending electronic horizon, providing more reliability, and better NLOS performance



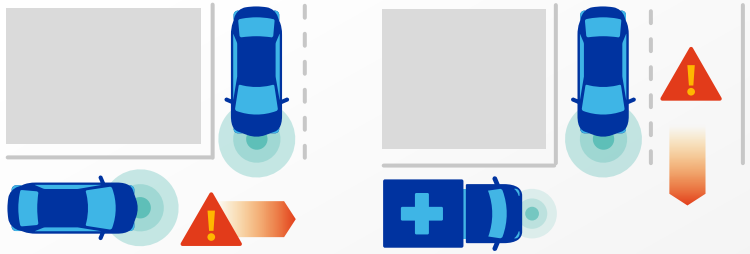
Do not pass warning (DNPW)



Blind curve / local hazard / emergency break warning (EEBL)

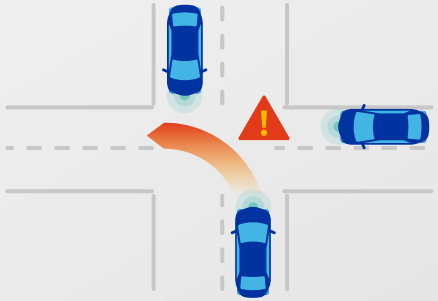


Road works warning



Intersection movement assist (IMA) at a blind intersection

Vulnerable road user (VRU) alerts at a blind intersection



Left turn assist (LTA)

LTE-V2X Example: Intersection Movement Assist (IMA)

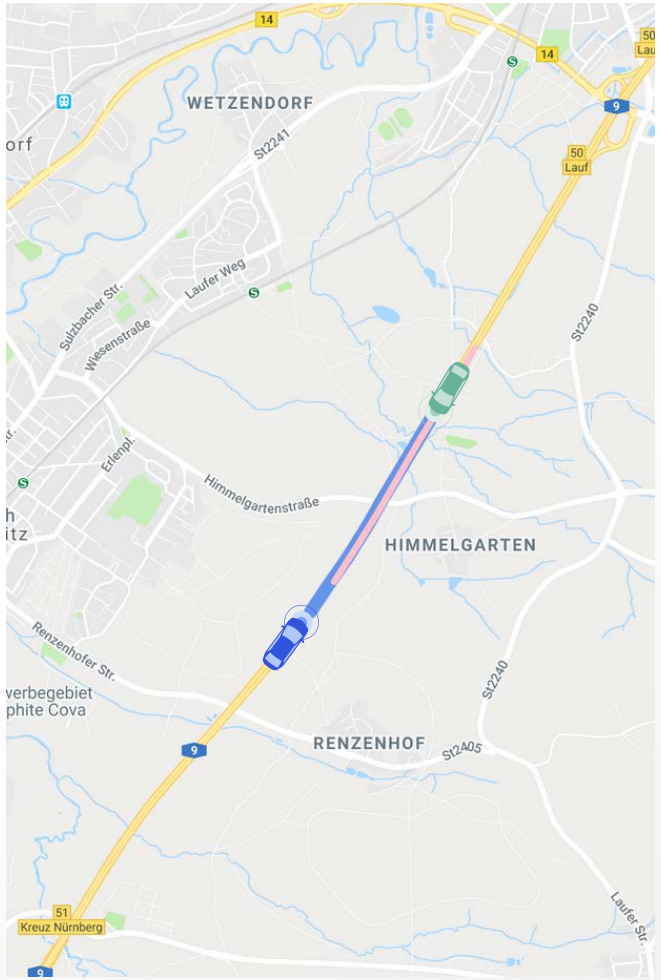
Conducted as part of the ConVeX Project Demo Event July 6, 2018

LTE-V2X Examples: EEBL, LTA, IMA

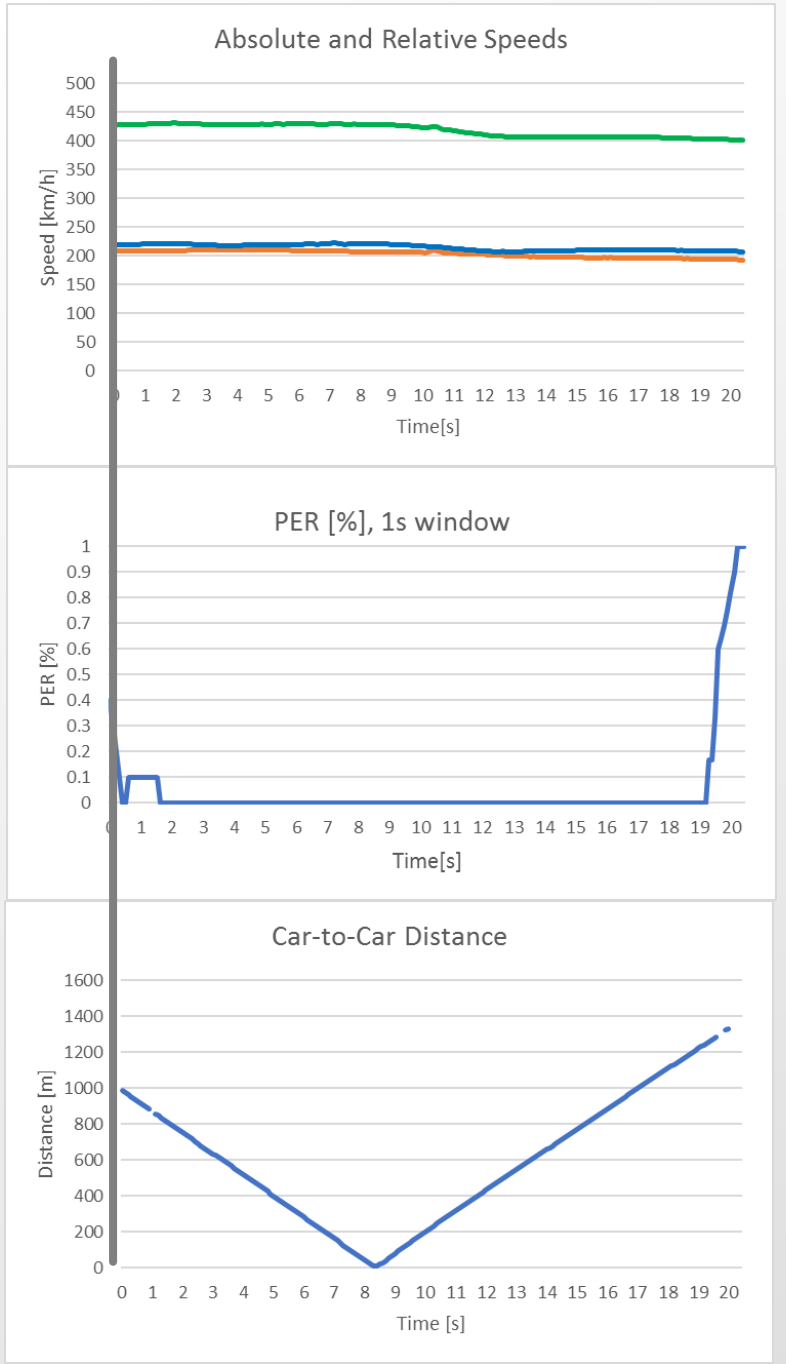
Conducted as part of the ConVeX Project Demo Event July 6, 2018

LTE-V2X High Vehicular Speed Testing

Conducted as part of the ConVeX Project



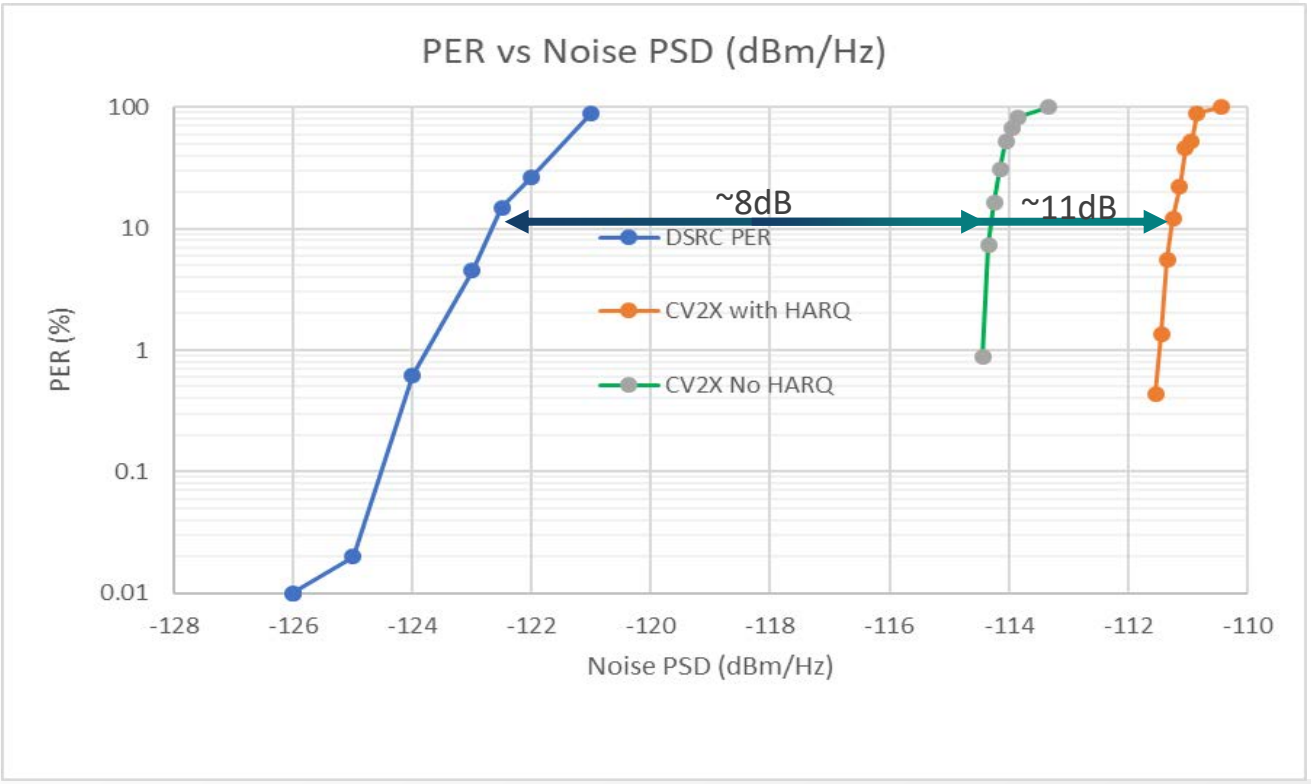
- Two cars driving in opposite direction on Autobahn A9 with highest possible speeds
- Close to error free communication between the cars when in LOS
- Range for this run was limited to ~ 1.2km due to morphology
- No impact of the high relative speed of more than 400 km/h (max. 430 km/h for this run)



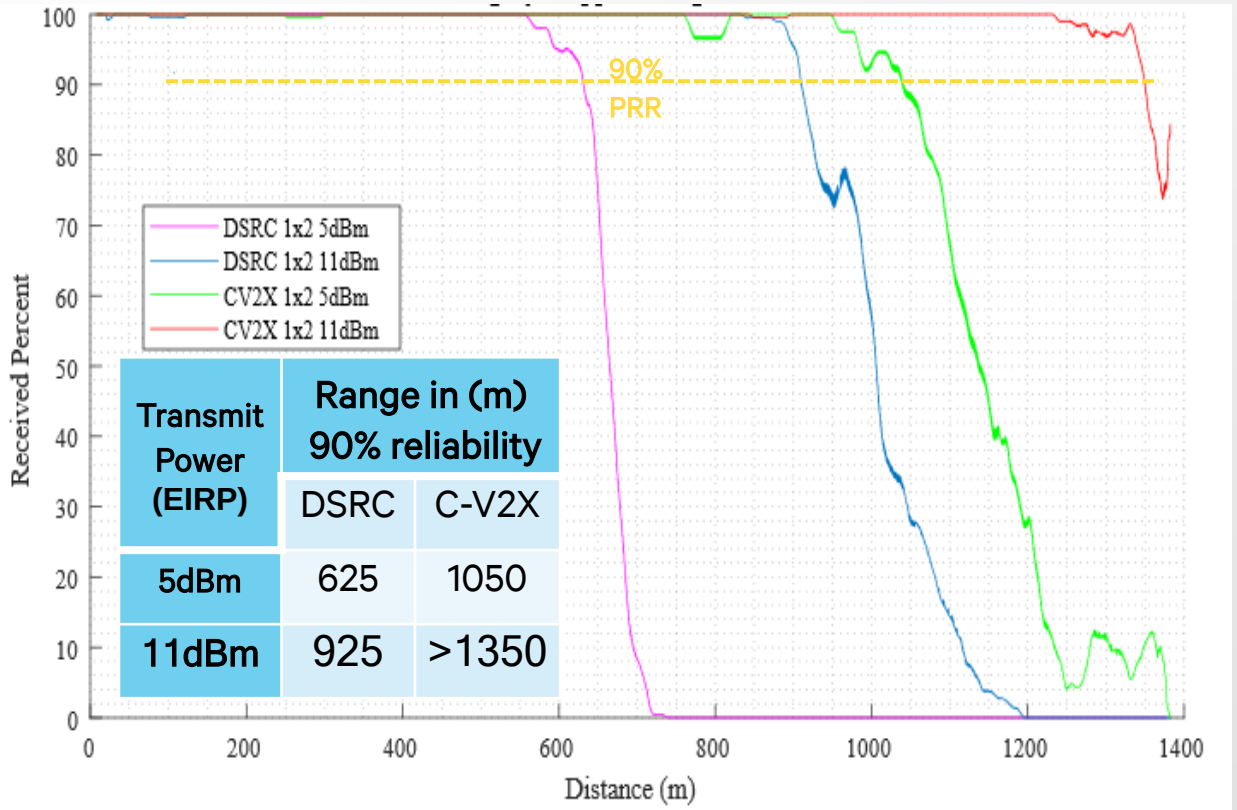
LTE-V2X vs DSRC/ITS-G5 Comparison Examples

LTE-V2X provides superior performance compared to DSRC/ITS-G5

- Measured radio performance with added channel impairment (AWGN)



- Measured Line-of-Sight Field Test Results



Transmit Power (EIRP)	Range in (m) 90% reliability	
	DSRC	C-V2X
5dBm	625	1050
11dBm	925	>1350

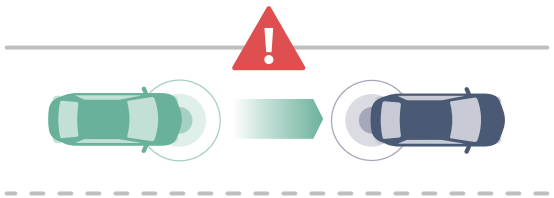
Source: 5GAA (http://5gaa.org/news/5gaa-report-shows-superior-performance-of-cellular-v2x-vs-dsrc/)

Evolving C-V2X Direct Communications towards 5G NR

While maintaining backward compatibility

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

Basic safety
IEEE 802.11p

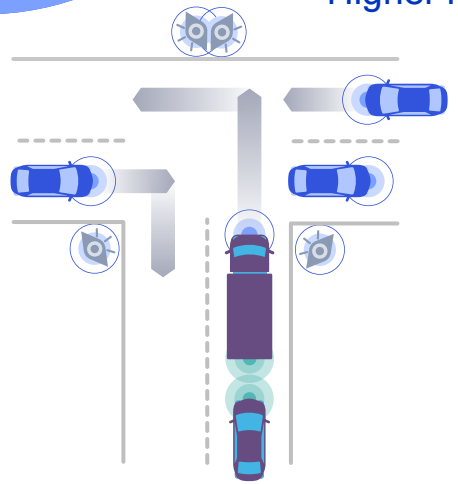


Basic and enhanced safety
C-V2X Rel-14/Rel-15 with enhanced range and reliability

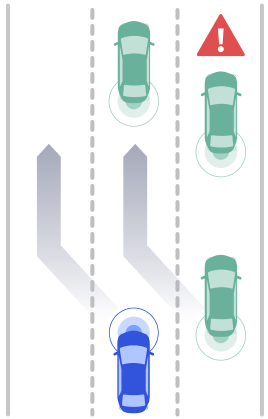
Autonomous driving use cases
5G NR C-V2X Rel-16

Backward compatible with Rel-14/Rel-15 enabled vehicles

Higher throughput
Higher reliability
Wideband carrier support
Lower latency

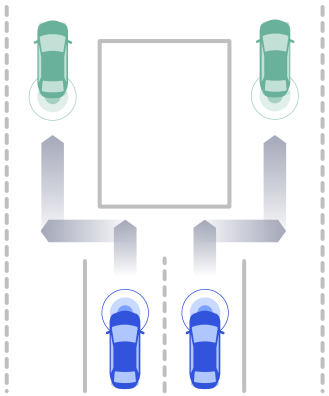


Sensor Sharing



Sudden braking and lane change on a freeway

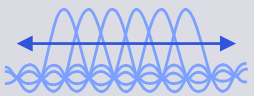
Intention Sharing



Coordinated Driving

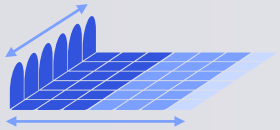
Adapting R15 5G NR flexible framework to vehicles

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 speed

Advanced channel coding

State of the art LDPC / polar coding to deliver performance

Building on R14/15 C-V2X framework with backward compatibility

Such as frequency division multiplexing, guaranteed latency performance and prioritization support

5G NR C-V2X

Enabling a new paradigm of communication design

- 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

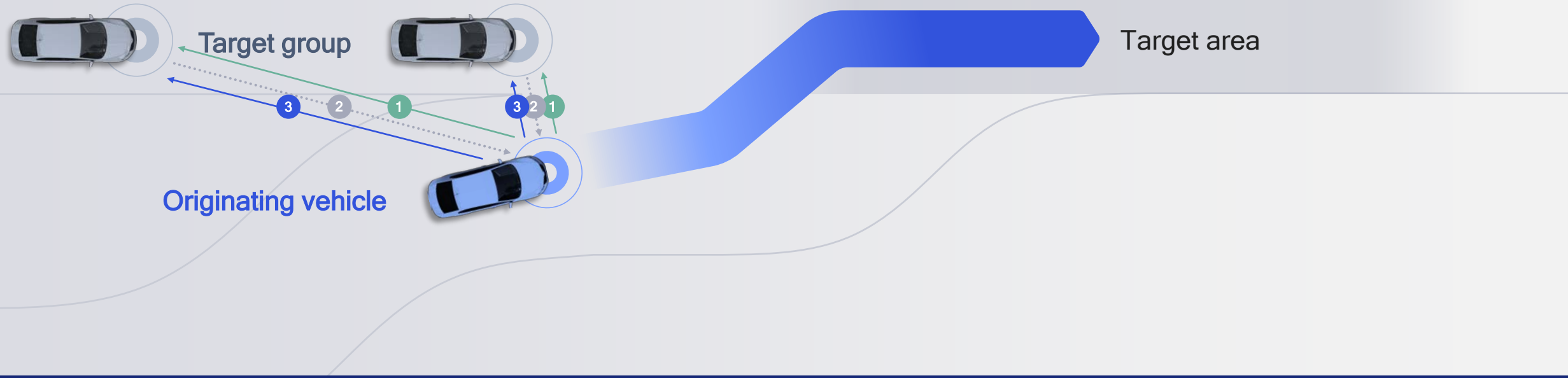
5G NR C-V2X builds on existing frameworks and enables a new paradigm of communication design

Coordinated driving

1 Originating vehicle sends a lane change request to target group

2 Target group responds with confirmation or denial

3 Sends lane prepared or abort message, then change lane in group



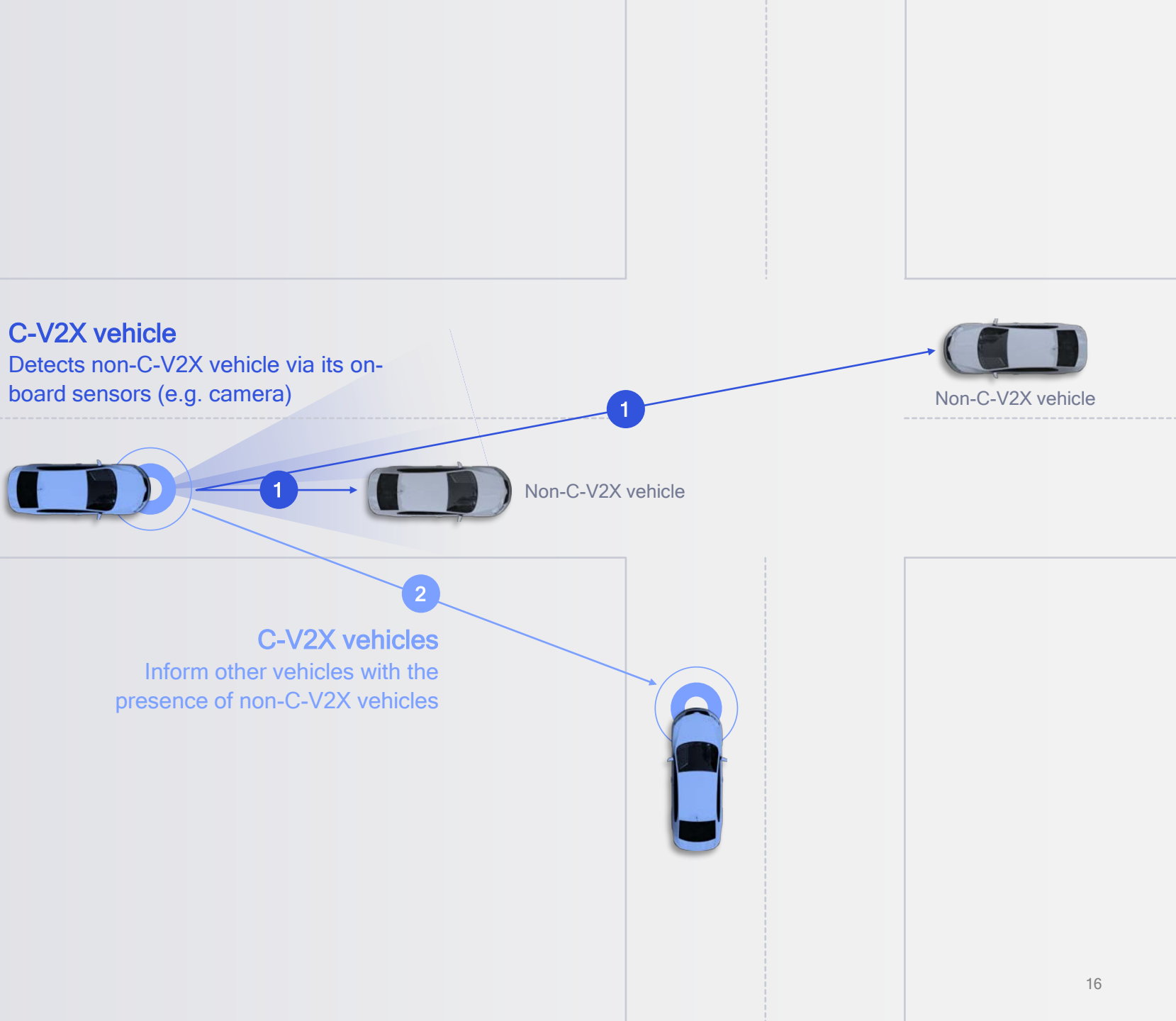
Intention sharing allows more efficient maneuvers for coordinated driving

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

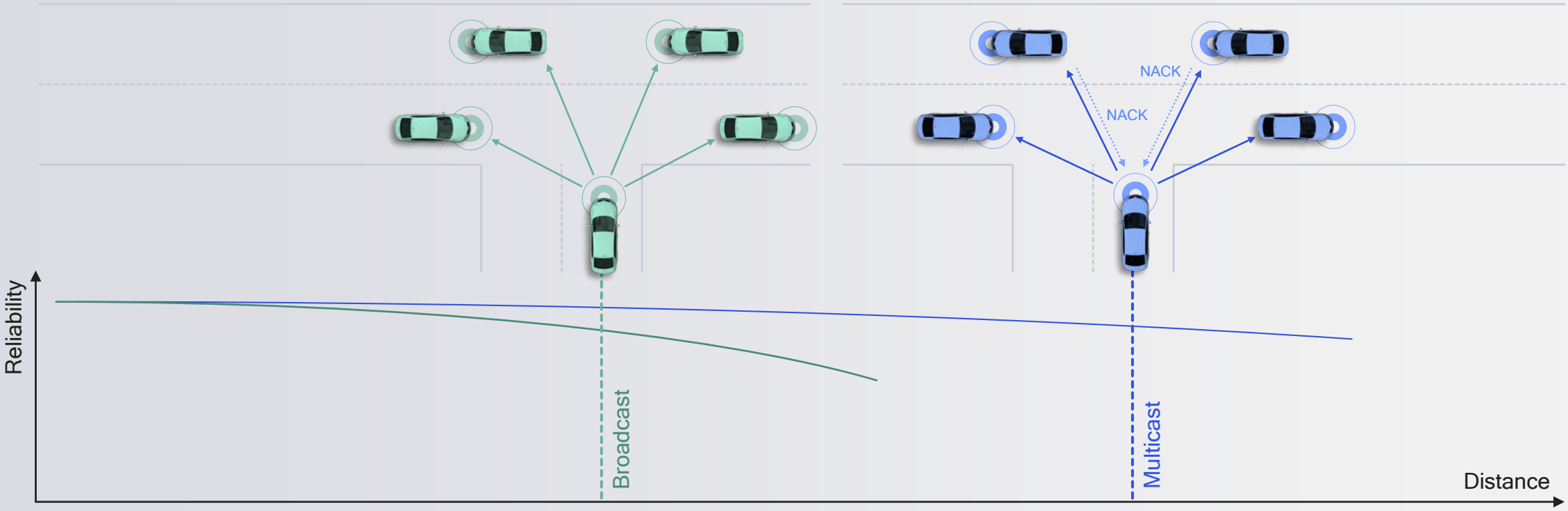


Rel-14 C-V2X

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)

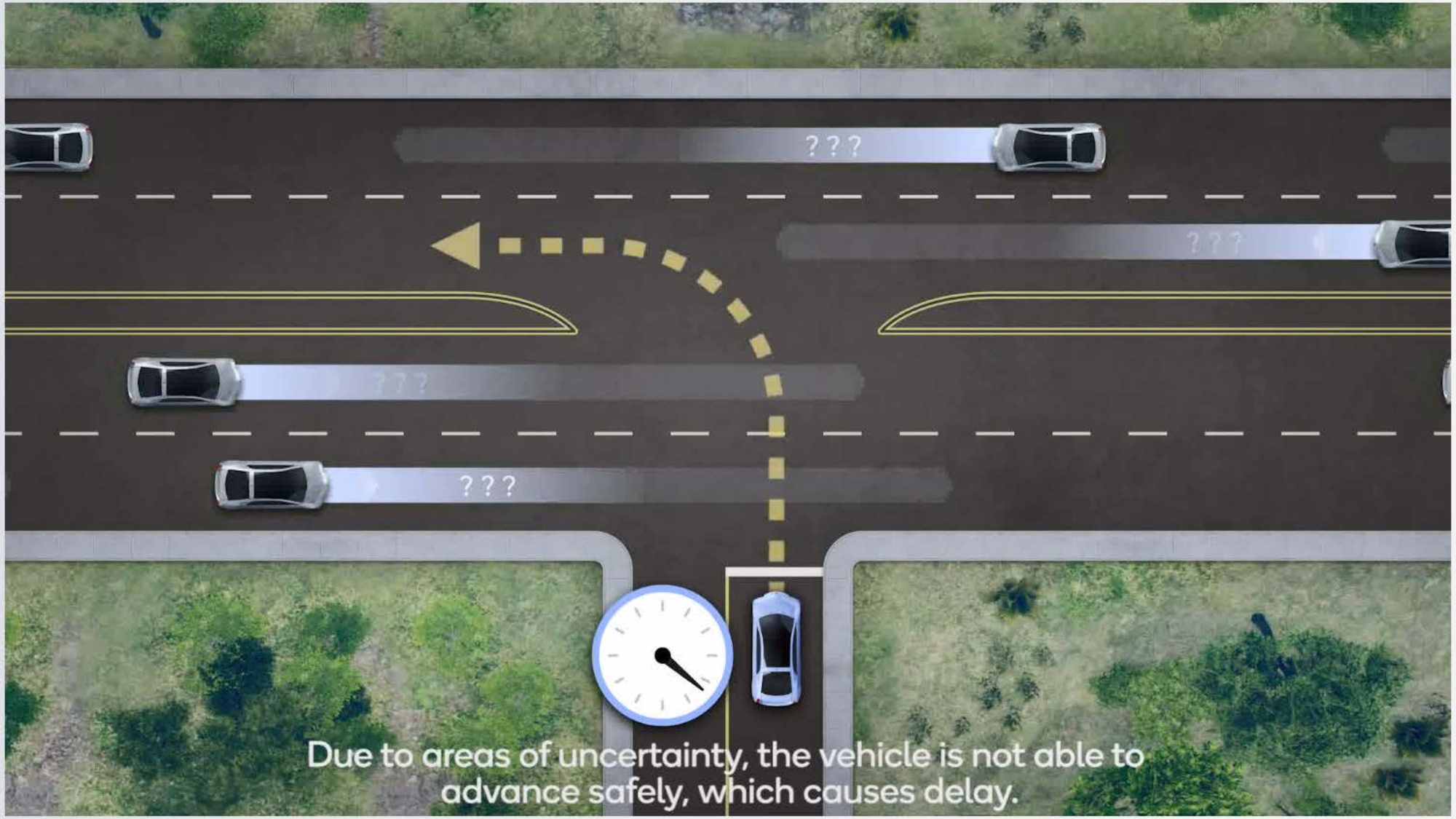


Multicast support for higher reliability

HARQ feedback to achieve higher reliability | Introducing efficiency by sending only NACKs using SFN

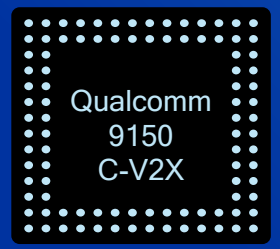
Intent/trajectory sharing for faster yet safe maneuvers

A vehicle trying to do a **left turn** is demonstrated for two scenarios




Evolving C-V2X Direct Communications towards 5G NR by ensuring backward compatibility through anchoring of use cases to deployment releases
5G NR C-V2X will be backwards compatible with C-V2X R14/R15
C-V2X R14 only car
C-V2X R14 PC5
Automotive safety
Forward-collision Warning (FCW) / Emergency Break Light (EEBL)
C-V2X R14 PC5
C-V2X R14 / R16
C-V2X R14 / R16
Autonomous driving
Autonomous driving use cases
C-V2X R14 / R16 PC5
5G
5G NR C-V2X brings about complementary capabilities for autonomous driving

Conclusion



C-V2X establishes the foundation for Cooperative, Connected and Automated Mobility (CCAM) in Rel. 14/15 with continued evolution towards 5G NR C-V2X Rel. 16 for advanced use cases

C-V2X Rel. 14/15 employs newer and more advanced technologies than WiFi-based systems, providing better performance, while reusing upper layers defined by the automotive industry

5G NR Rel. 16 brings further improvements via a flexible sidelink design using distance-based multicast communication with HARQ feedback allowing even higher throughput, better reliability, and lower latency

Future 5G NR Rel. 16 and beyond will be backward compatible with earlier C-V2X releases by anchoring use cases to deployment releases

5G NR provides advanced safety and better travel efficiency through increased situational awareness, sensor sharing, and coordinated driving

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

Thank you

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