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Fierce Wireless Webinar

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Evolution of C-V2X for advanced automotive use cases

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Rel-14 C-V2X
momentum
and commercial
readiness





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



V2I

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



V2P

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



V2N

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



Release 14/15 C-V2X standards completed



Broad industry support with 5GAA



Global trials started in 2017

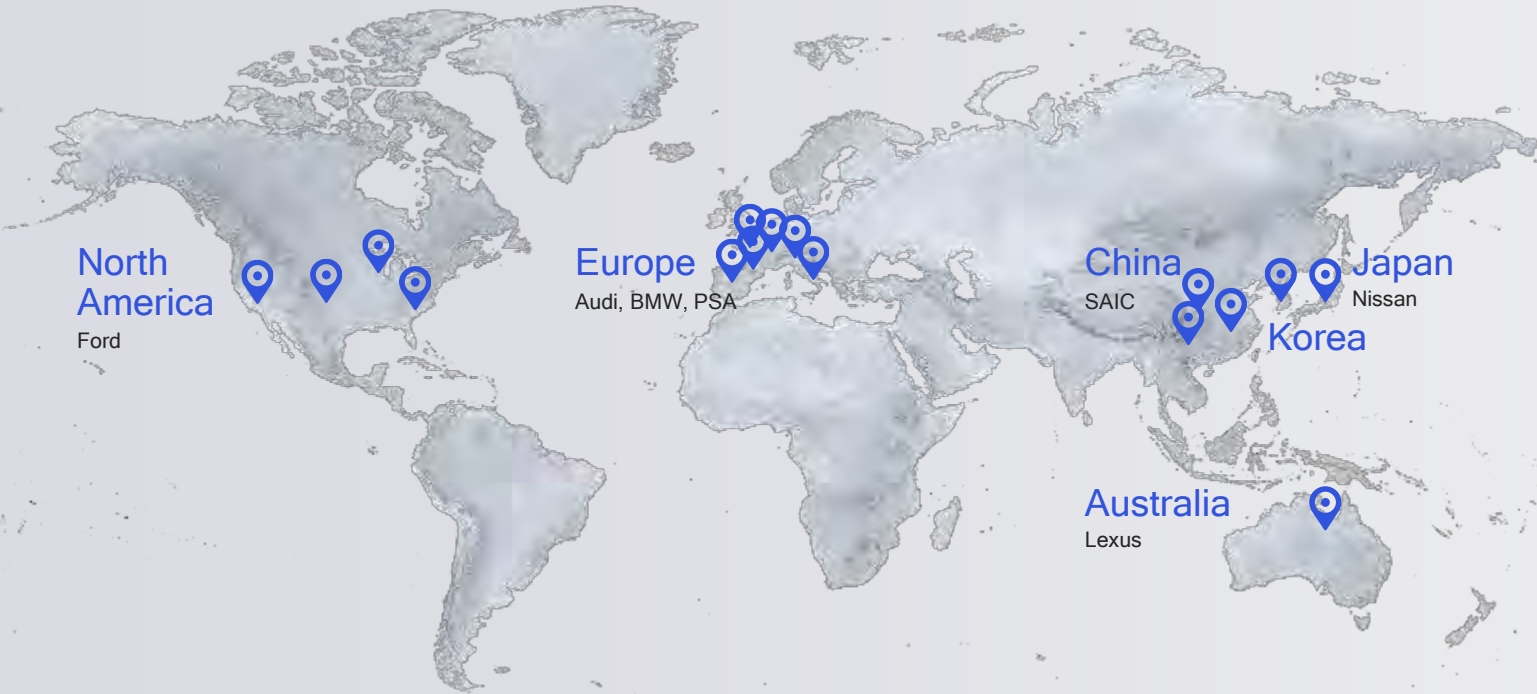


Qualcomm® 9150 C-V2X chipset announced in September, 2017



Integration of C-V2X into the Qualcomm® Snapdragon™ Automotive 4G and 5G Platforms announced in February, 2019

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 early commercialization

5GAA Automotive Association

Airbus • Airgain • Alpine Electronics • American Tower Corporation • Analog • Anritsu
 Applied information • AT&T • Audi • BAIC • Baidu • Baoneng • Beijing University
 of Technology • Bell • Blackberry • BMW Group • Bosch • CATT • Cetecom • China Mobile
 China Transinfo • China Unicom • Cohda Wireless • CMCC • Commsignia • Continental
 Daimler • Danlaw • Derka • Denso • Dt&C Co • Deutsche Telekom • Equinix • Ericsson
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 Telekom • Telekom Austria • Telstra • Telus • TerraNet AB • TUV • Valeo • Veniam
 Verizon • Viavi • Vodafone • Volkswagen • Volvo Cars • VT iDirect • WNC • ZF • ZTE

Key participants

Driving global C-V2X activities with Qualcomm Technologies

Ford	Quectel	Kapsch	On Board Security
PSA	Lear	SWARCO	Neusoft Reach
BMW	Valeo	Commsignia	Simcom
Daimler	WNC	Genvict	Sasken,
SAIC	CMCC	Nebulalink	Thundersoft
Continental	AT&T	R&S	Telit
Bosch	NTT DoCoMo	Datang	Lacroix
LG	CMRI	Ficoso	And more...
ZTE	McCain	Savari	

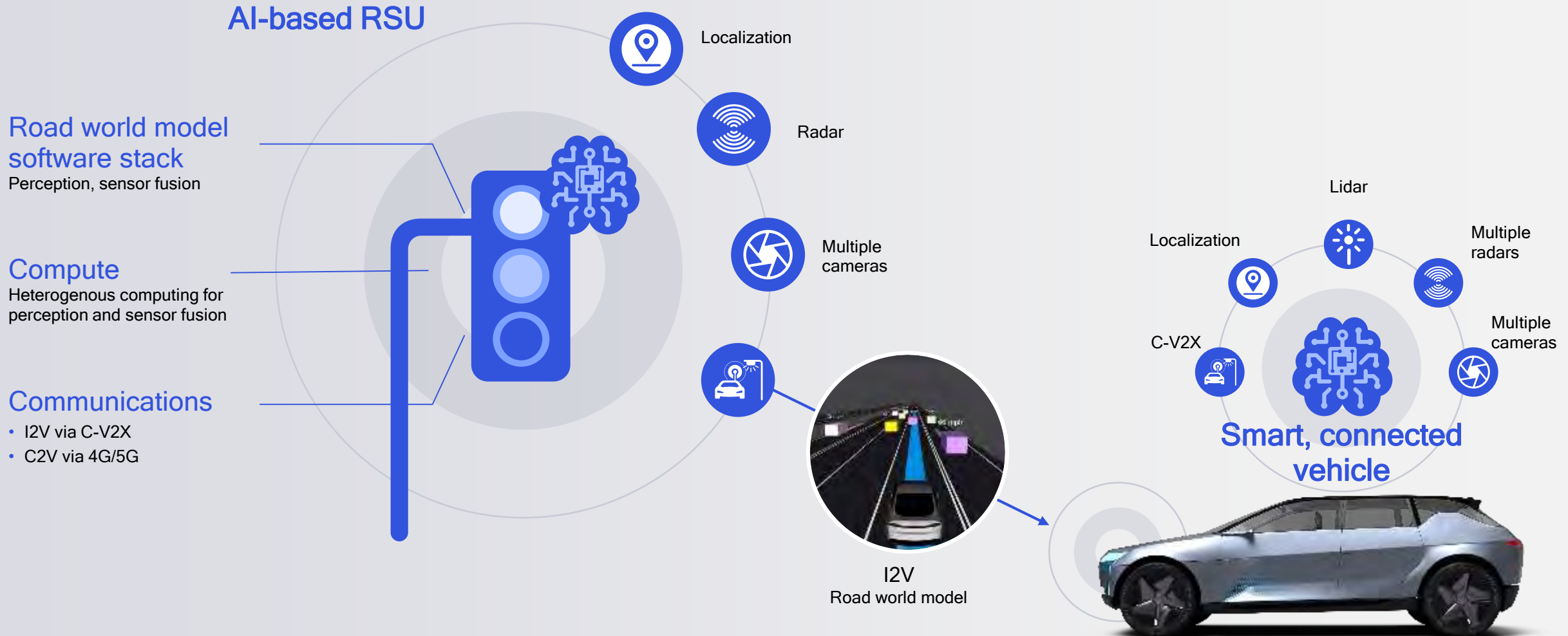
5G and AI aim to transform automotive and the whole transportation industry

Evolution to 5G NR is designed to serve as the unified connectivity fabric



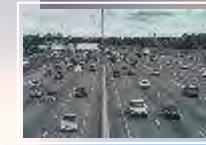
Smarter transportation infrastructure

Requiring next level of connectivity and intelligence



A unified connectivity fabric for distributed intelligence

Smart cloud



Road world model over I2N for teleoperation

Smart infrastructure (RSU/small cell)



Road world model over I2V to augment car perception

- Artificial intelligence
- Mobile edge computing
- Computer vision
- Precise positioning and 3D HD map updated
- Sensor fusion

Smart car

AI-based cockpit

- Artificial intelligence
- Heterogeneous computing
- Computer vision
- Precise positioning
- Audio

Autonomous driving

- Artificial intelligence
- Heterogeneous computing
- Computer vision
- Precise positioning
- Sensor fusion

5G connected car

- Multimode 4G/5G
- C-V2X
- Precise positioning
- Wi-Fi/BT



Teleoperations
Data analytics

Enhanced network communication

Faster access to cloud for in-vehicle experiences, car OEM services and telematics



New direct communication

V2V, V2I, and V2P communications for latency-sensitive use-cases, e.g. collision avoidance



Massive Internet of Things

Deeper coverage to connect road infrastructure (e.g. sensors and traffic cameras)



V2N

V2N



Road hazard warning

V2I

RSU



Smart city



Sensors



Utilities

Speed harmonization



V2V



Connected car services



In-vehicle experiences



Road safety



Transportation efficiency



Connected road sensors

Evolution to 5G is designed to serve as the unified connectivity fabric



RSU with AI-based camera

Traffic hazard warning

AI-based camera detects a hazard on the right lane and alert other cars on the road; via precise positioning other cars avoid the lane with the hazard

RSU with AI-based camera

Pedestrian alert

Traffic light detects a pedestrian crossing the street and alert oncoming cars via I2V; Also, possible via direct V2P communication

Road Safety

V2V/V2I: Intersection management assist

Send updated 3D HD map with the hazard via 5G NR C-V2X

I2V

V2P

Burger spot
5 miles

Subway

Shaping the future of automotive and smart transportation



Edge AI
E.g. for detecting pedestrians or hazards



C-V2X (I2V)
E.g. send 3D HD map updates or hazard warning



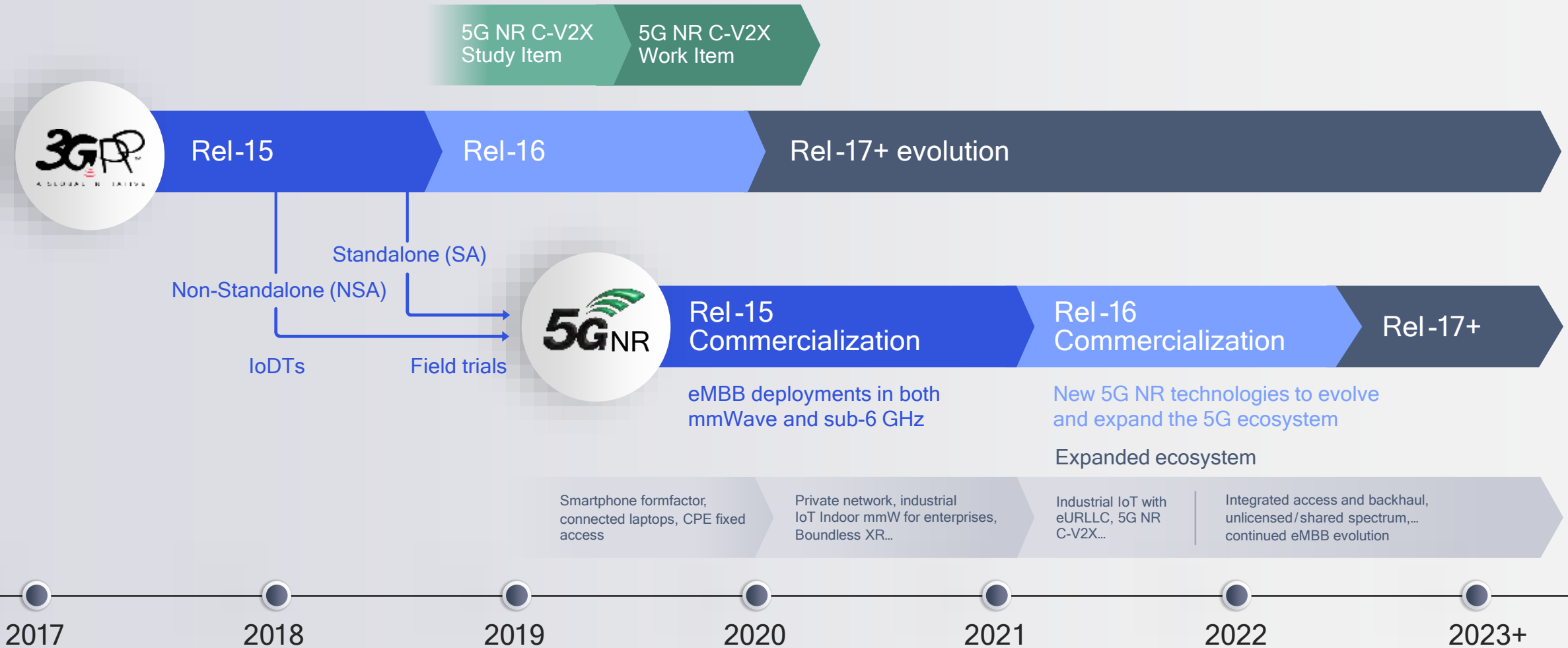
Localization
E.g. for lane-level warning, and navigation

Backward compatible evolution to Rel-16 5G NR C-V2X

New use cases require a more
flexible and efficient direct
communication design



5G standardization and projected ecosystem expansion



Evolving C-V2X direct communications towards 5G NR

Rel-16 5G NR C-V2X vehicles is designed to support Rel-14/Rel-15 for safety

5G



R14/R15 C-V2X for automotive safety



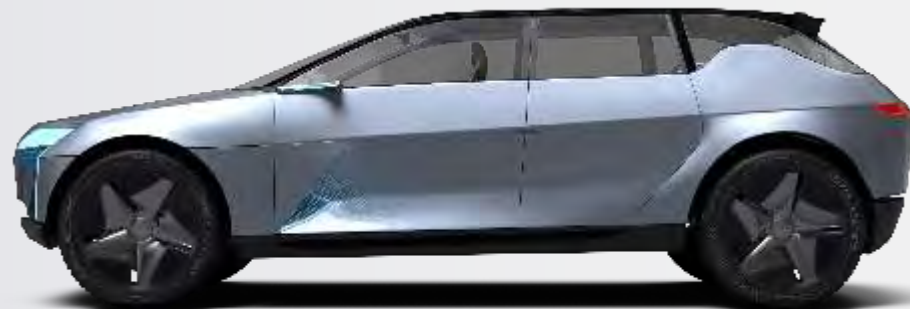
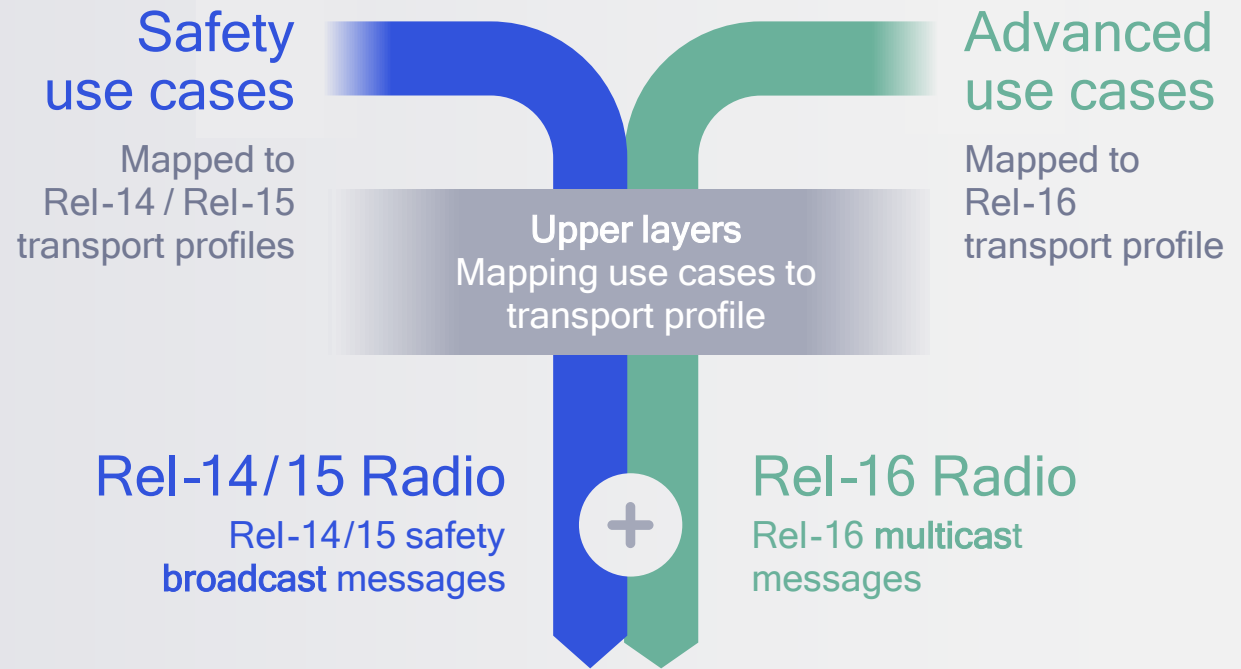
Advanced use cases for all vehicles



5G NR C-V2X brings about complementary capabilities while being backwards compatible

5G NR C-V2X is backward compatible at upper layers

By facilitating coexistence of Rel16 with previous releases



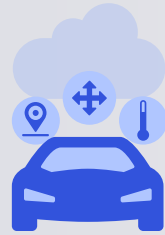
Rel-16 C-V2X vehicles are expected to be designed to support Rel-14/Rel-15 for safety

5G NR C-V2X facilitates advanced use cases



Increased situational awareness

Sharing of vehicle-specific info with other vehicles and road infrastructure (e.g. door open warning)



Sensor sharing

Sharing of sensor data, e.g., vehicle's perception, including road world model



Coordinated driving/ intention sharing

Exchanging intention and sensor data for more predictable, coordinated autonomous driving



Real-time infrastructure updates

Real-time sharing of 3D HD map and other information between vehicles and infrastructure

Higher
throughput

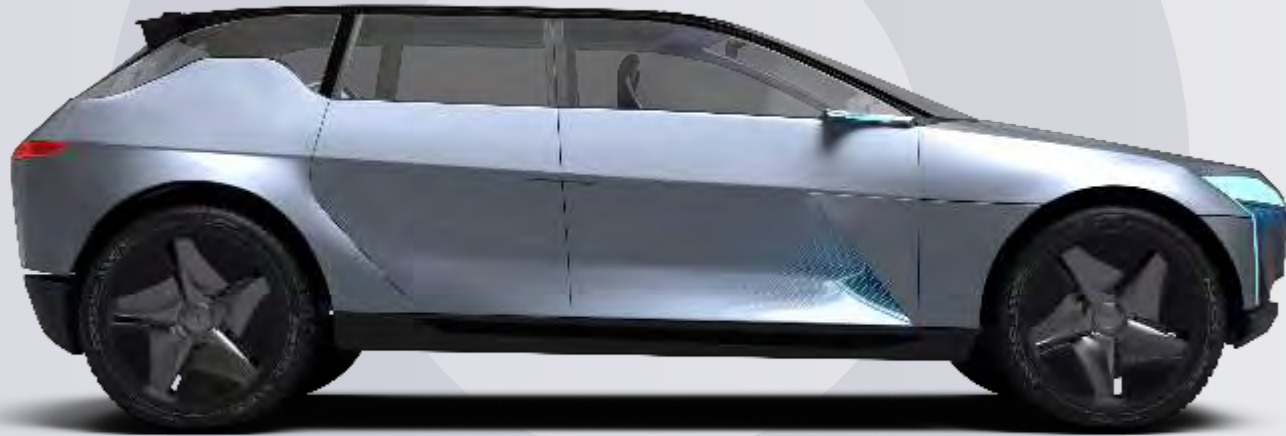
Lower
latency

Higher
reliability

Application
aware

5G NR C-V2X

Brings new benefits



Increased situational awareness

Sensor sharing

Coordinated driving / intention sharing

Real-time infrastructure updates



Advanced safety

Real-time situation awareness and sharing of new kinds of sensor data take safety to the next level



Faster travel / energy efficiency

More coordinated driving for faster travel and lower energy usage

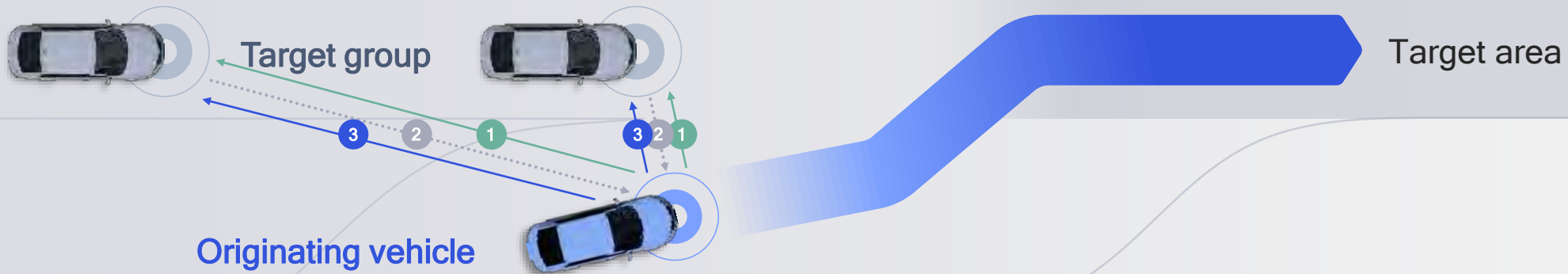


Accelerated network effect

Sensor sharing and infrastructure deployment bring benefits, even during initial deployment rollouts

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

Autonomous driving

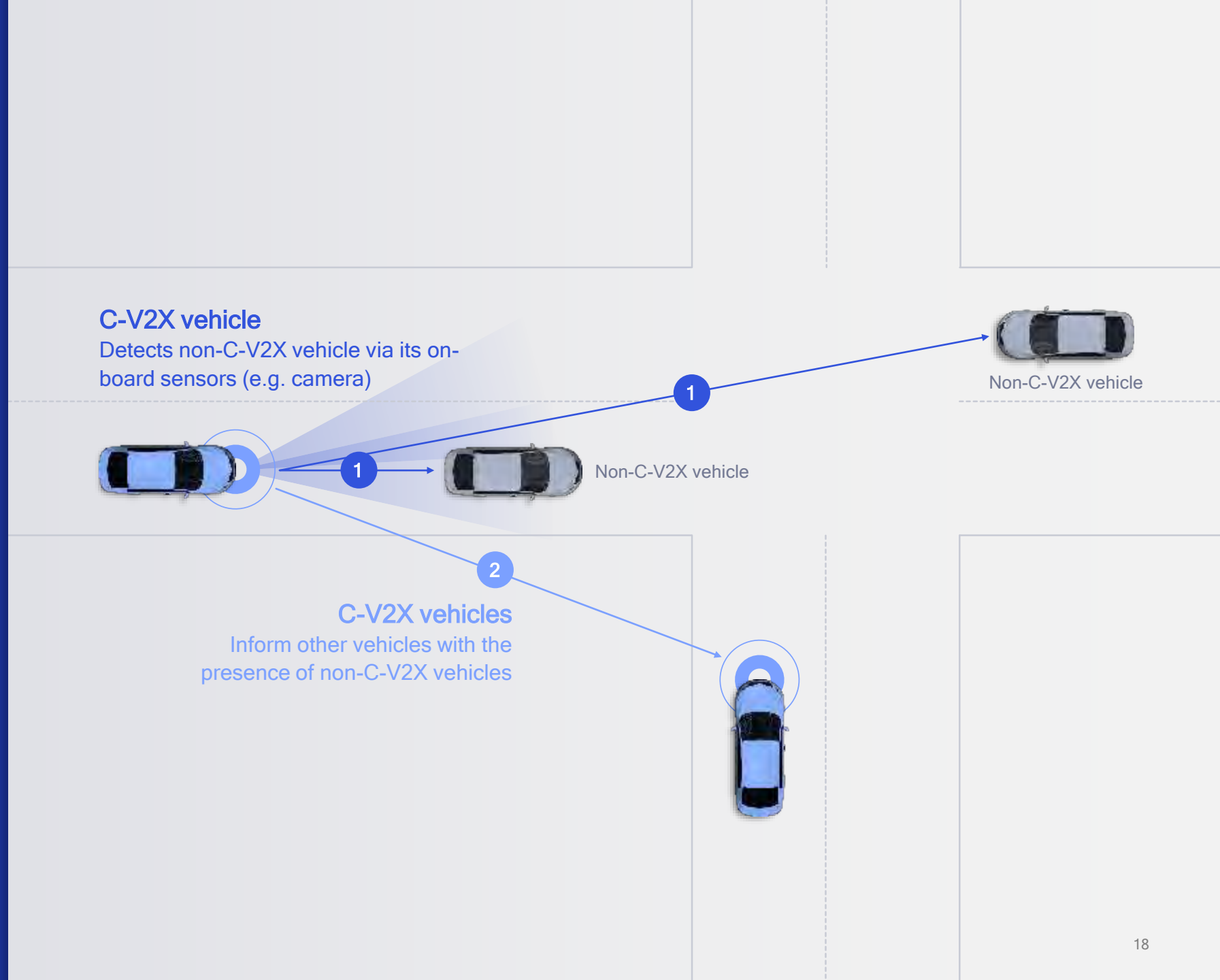
Benefits from real-time update from infrastructure



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

Sensor sharing

Sensor object sharing supports benefit of V2X with limited penetration rate

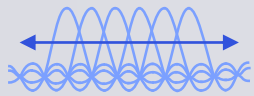


Introducing a new communication design paradigm



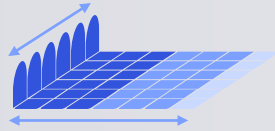
Adapting R15 5G NR flexible framework to vehicles

Scalable OFDM-based air interface



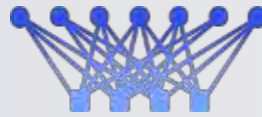
Such as wideband carrier support (>20 MHz) and different sub-carrier spacing

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

Facilitating 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 facilitates a new paradigm of communication design

5G NR C-V2X

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

High-speed performance with adaptive reference signal

Rel-16 C-V2X can support ~3.5x higher spectral efficiency as compared to Rel-14 at high speeds

- Higher carrier spacing allows better handling of Doppler and frequency offset
- Variable reference signal design density
- Strategic placement of reference symbols
- Up to ~3.5x higher spectral efficiency at 500kmph relative speed

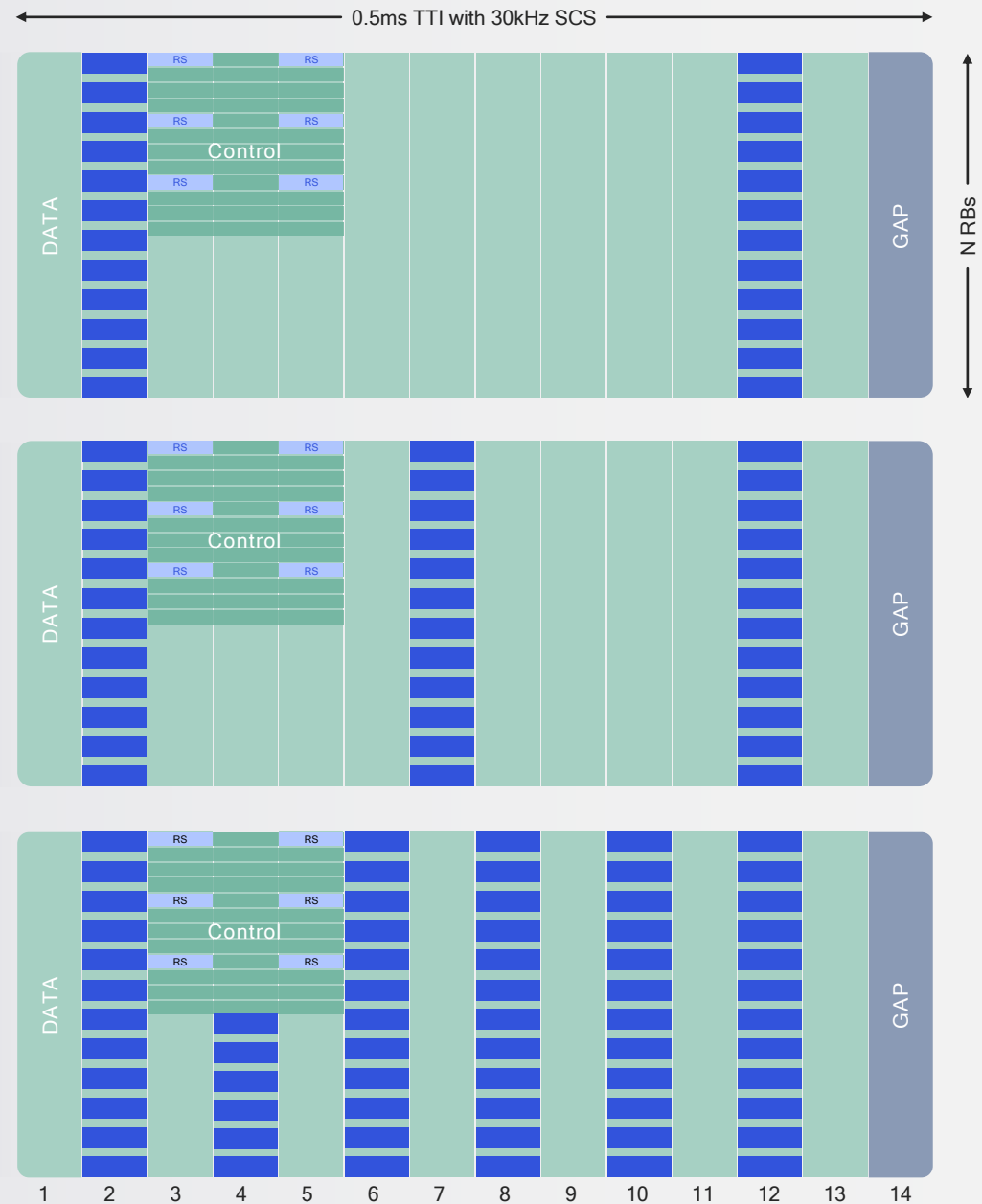
DMRS Data

Slow
Vehicle speeds

Medium
Vehicle speeds

Fast
Vehicle speeds

High speed + high MCS + Additional DMRS¹

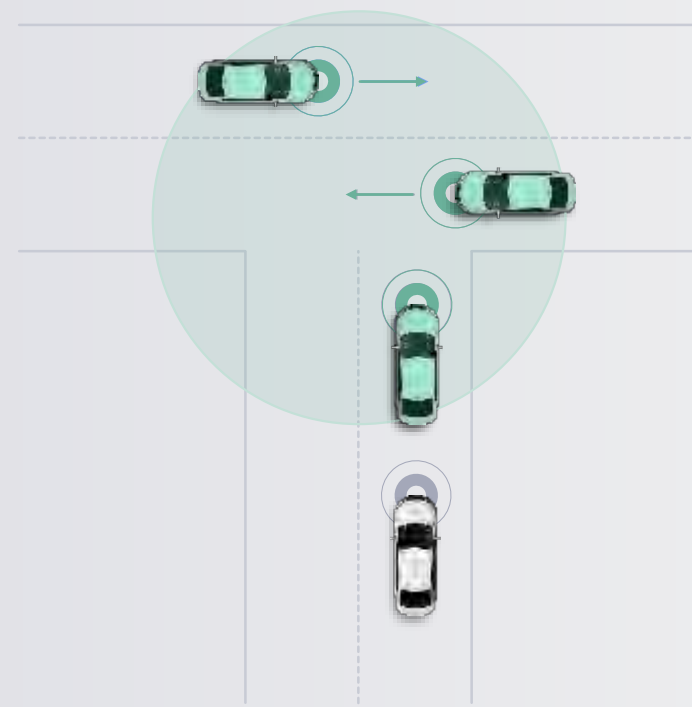
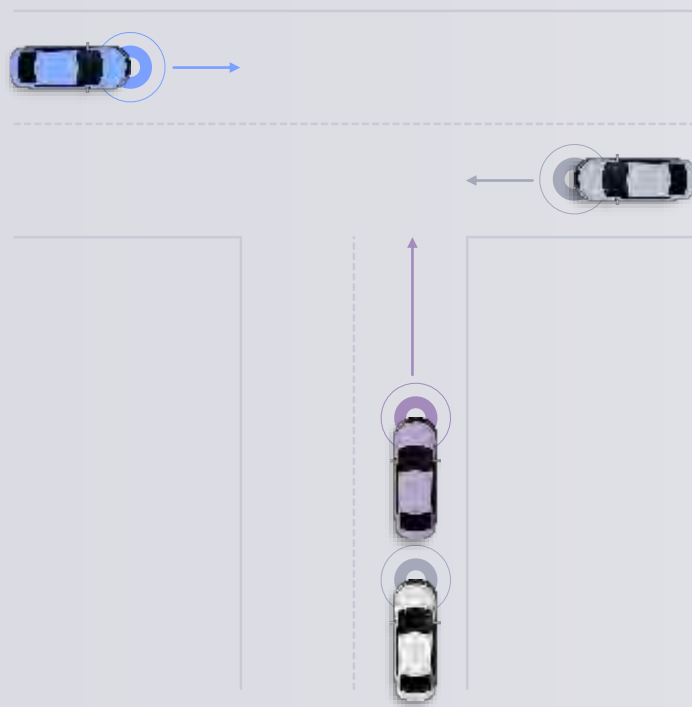


1. Demodulation Reference Signal

Vehicles approaching intersection

Group formed among vehicles for coordinated intersection management

Group disbanded after intersection is navigated



Connectionless 'on-the-fly' distance-based groups

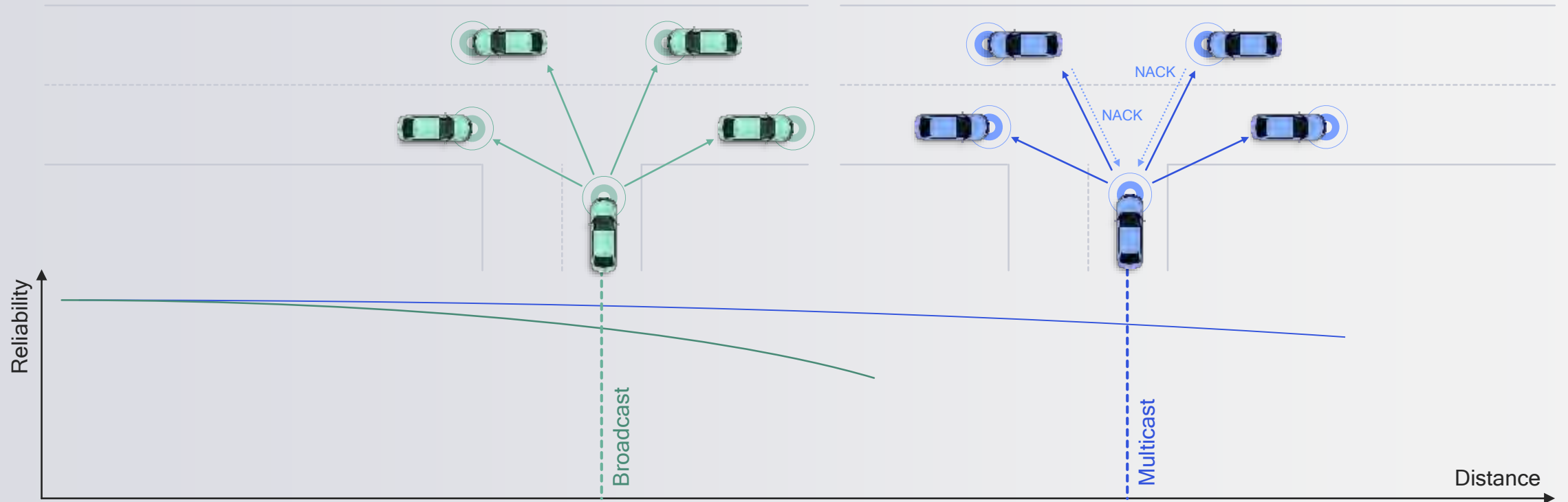
Vehicles within a certain distance and interested in same services form a group

Rel-14 C-V2X

Broadcast without feedback, which can't ensure reliability

Rel-16 5G NR C-V2X

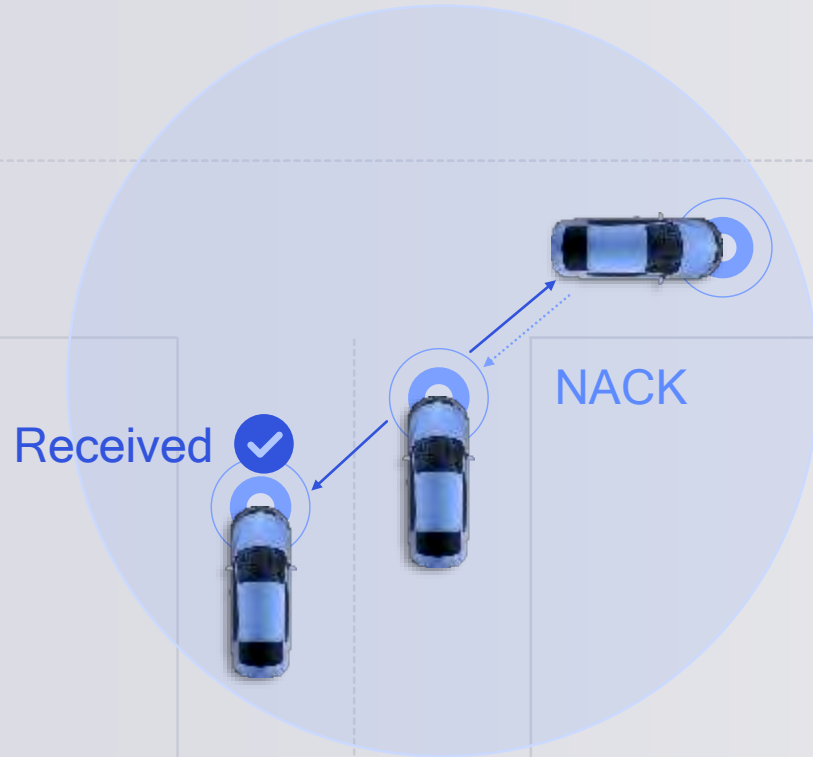
Multicast with feedback for higher reliability; if signal can't be decoded, NACKs are sent on the same radio resources (SFN-like approach)



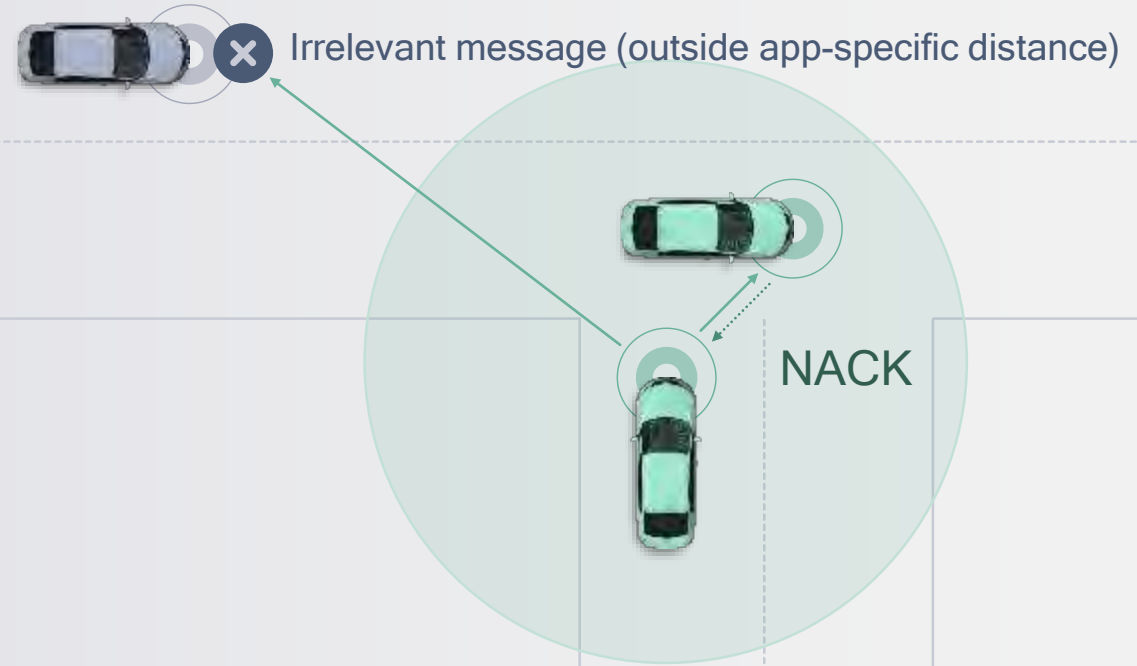
Multicast support for higher reliability

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

Application A



Application B



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



Supporting emerging use cases

Introducing new messages for emerging use cases, (e.g. sensor object sharing between vehicles needs to be standardized)



Providing interoperability

Allowing vehicles from different manufacturers to benefit from new evolving use cases



Specifying minimum requirements

Defining application layer-specific minimum requirements for new messages

Participating in higher layer protocol stacks' regional standards including SAE, ETSI ITS and C-SAE/C-ITS

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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