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How NR based sidelink expands 5G C-V2X to support new advanced use cases

Qualcomm Technologies, Inc.

Qualcomm

Today's agenda

- Rel 14/15 C-V2X momentum
- How does NR C-V2X bring advanced use cases?
- NR C-V2X demos and over-the-air simulations
- Questions?

Our presenter

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C-V2X

Rel 14/15 C-V2X established basic safety

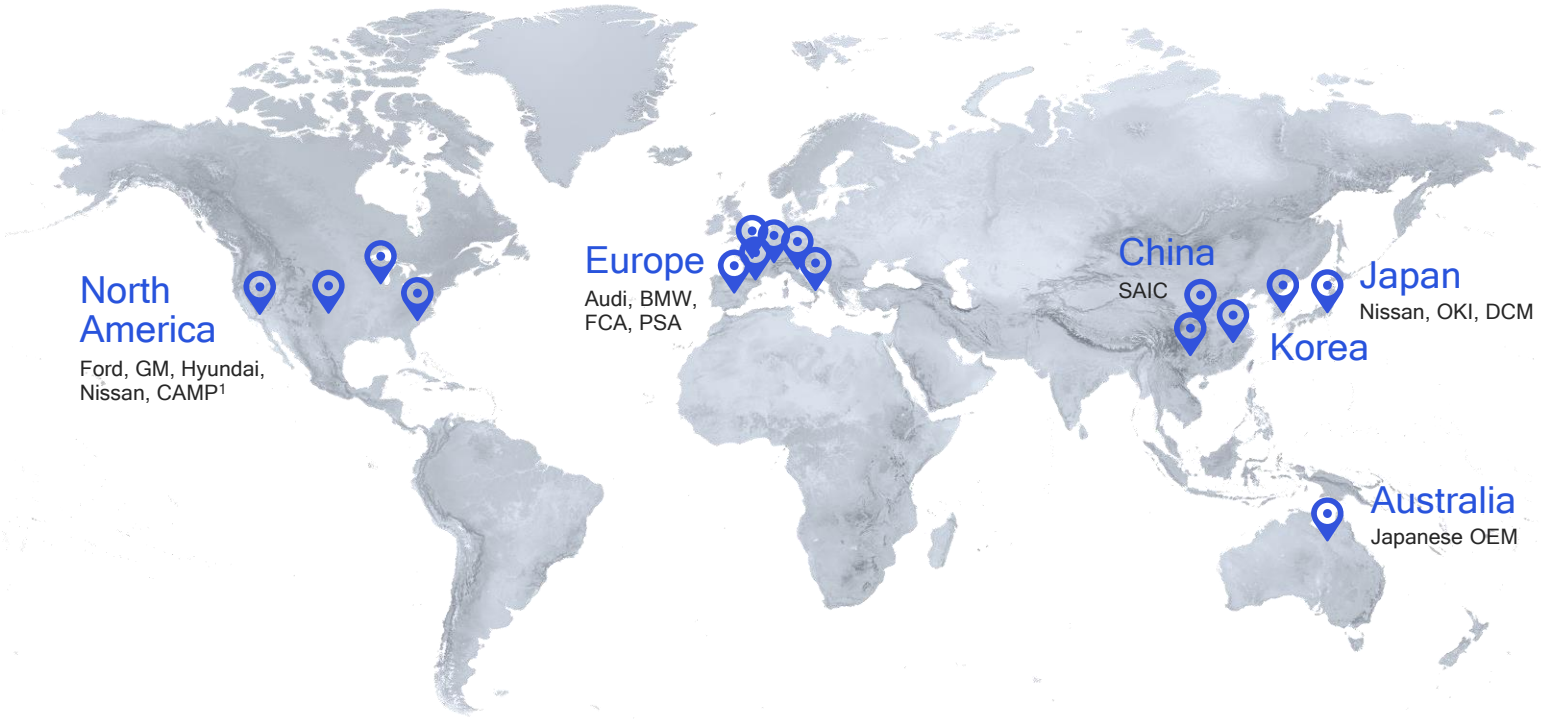
Rel 16 NR C-V2X saw continued evolution for advanced use cases

- Release 14/15 C-V2X standards completed
- Broad industry support with 5GAA
- Global trials started in 2017; first commercial deployment expected in 2020
- 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

Rel 14/15 C-V2X

Momentum and commercial deployments

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 initial deployments

1. CAMP = Crash Avoidance Metrics Partnership LLC and this project includes the listed OEMs and Qualcomm.

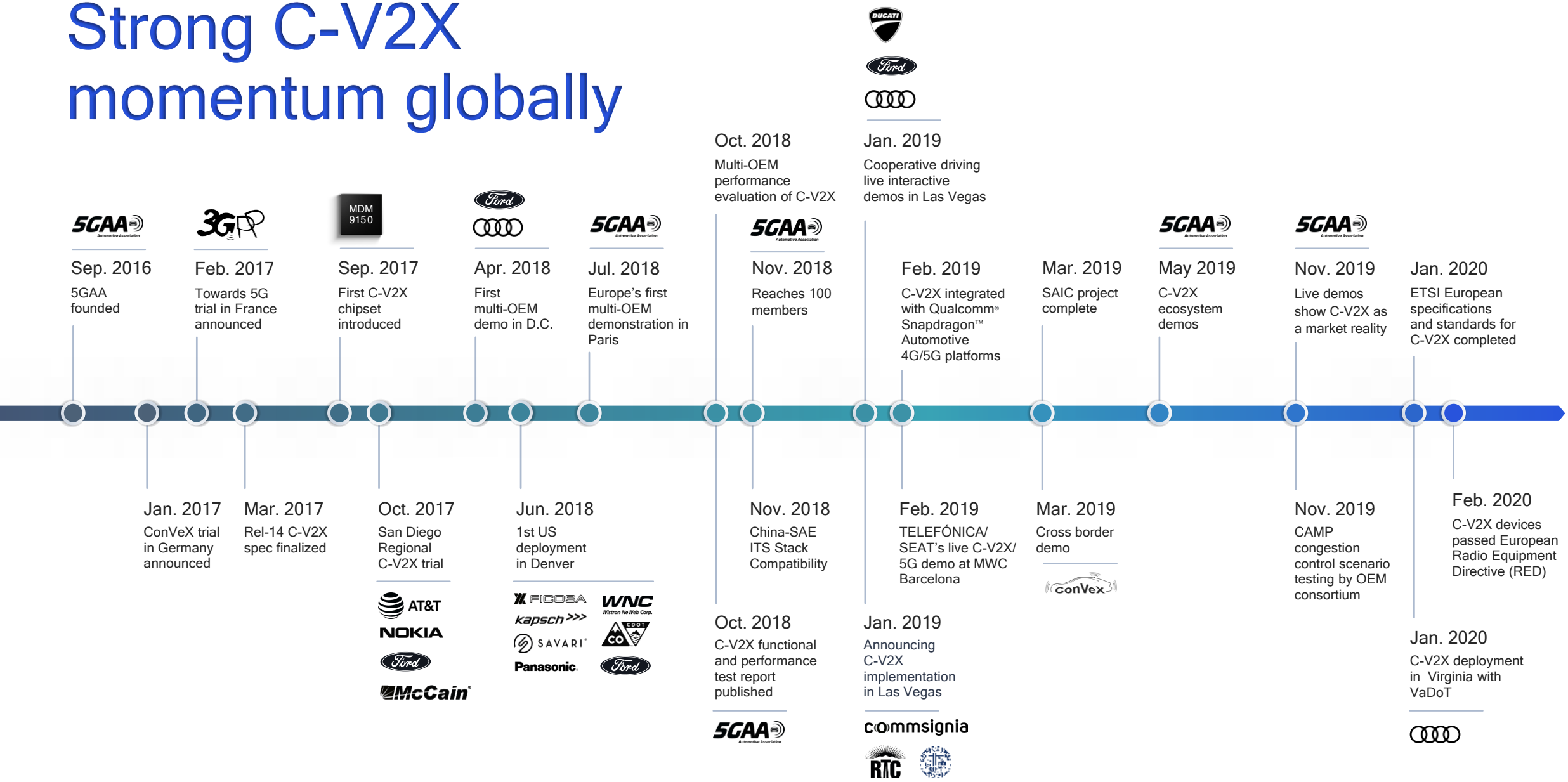
Collaborating with key ecosystem players

CAMP	Ford	Quectel	Kapsch
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	Ficosa	And more…
ZTE	McCain	Savari	

5GAA Automotive Association

- 8 of the top 9 global automakers
- Top automotive Tier 1 suppliers
- 9 of the top 10 global telecommunications companies
- Top 3 global smartphone manufacturers
- Top global semiconductor companies
- Top 5 global wireless infrastructure companies
- Top global test and measurement companies and certification entities
- Global representation from Europe, China, US, Japan, Korea, and elsewhere

Strong C-V2X momentum globally



Working with regional standards to define applications globally

SAE for North America, ETSI ITS for Europe, and C-SAE/C-ITS for China

Supporting emerging use cases

Standardizing messages for new use cases (e.g., sensor data sharing among vehicles)

Providing interoperability

Allowing vehicles from different automakers to benefit from new use cases

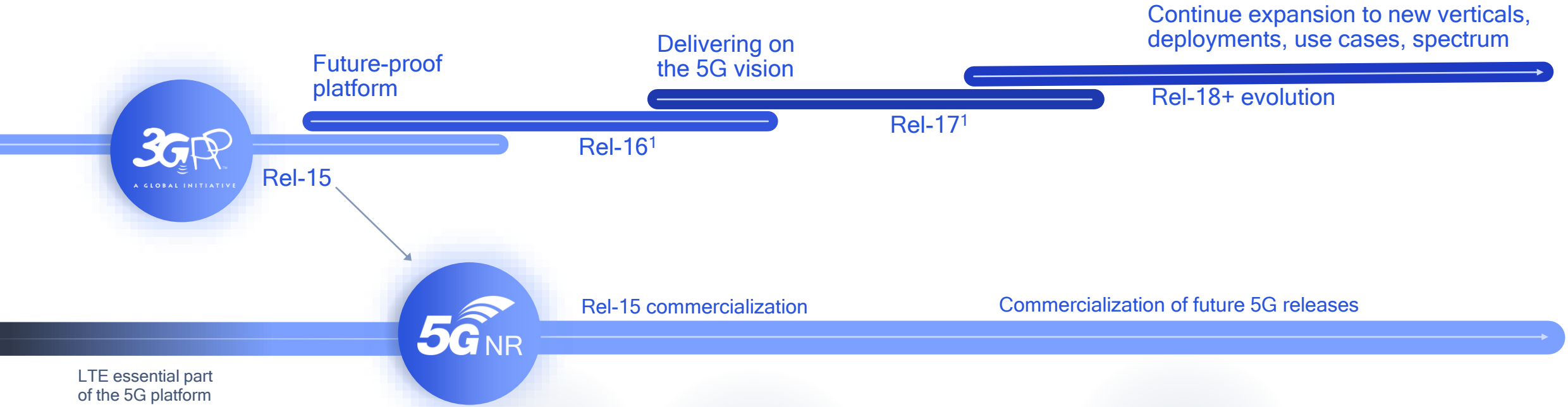
Specifying minimum requirements

Defining application layer-specific minimum requirements for new messages

NR C-V2X

Introduces complementary capabilities for advanced use cases

Driving the 5G technology evolution



2019 eMBB

- Global smartphone launches
- Fixed wireless access

2020 eMBB expansion

- Beyond smartphone (PC, FWA, …)
- New markets/regions
- Nationwide coverage and SA migration

Longer term expansion

- Industrial IoT, enterprise, automotive network
- Private networks
- Unlicensed spectrum

2018 | 2019 | 2020 | 2021 | 2022 | 2023+

1. 3GPP start date indicates approval of study package (study item->work item->specifications), previous release continues beyond start of next release with functional freezes and ASN.1

NR C-V2X builds on LTE C-V2X

with advanced use cases

Safety use cases

Advanced use cases

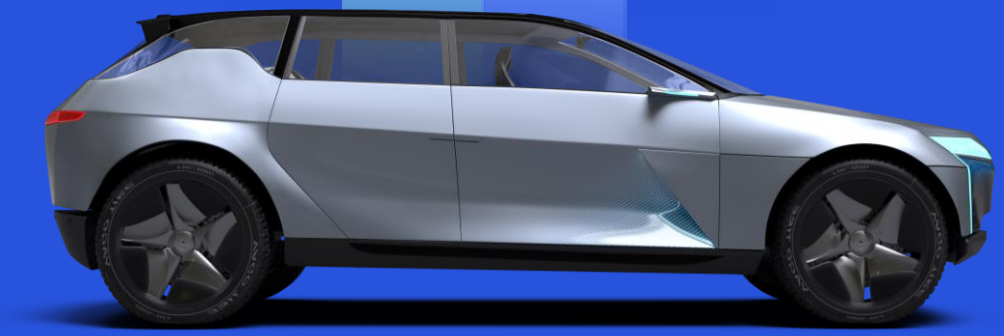
Upper layers

Mapping use cases to transport profile

C-V2X

Rel 14/15 sidelink

Broadcast messages



NR C-V2X

Rel 16+ sidelink

Multicast messages

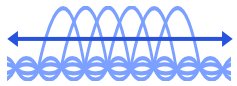
5G C-V2X sidelink

NR C-V2X introduces complementary capabilities for advanced use cases

Building on existing frameworks

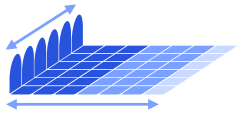
Utilizes NR flexible framework

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

Leverages LTE C-V2X concepts

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

5G C-V2X

Introduces advanced capabilities

- 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

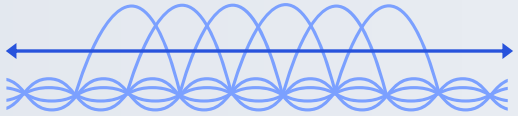
And increased performance

- Lower latency
- Higher spectral efficiency
- Higher capacity

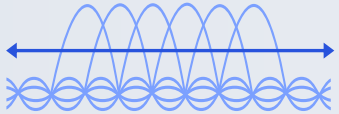
NR C-V2X delivers a design that addresses advanced use cases

NR C-V2X

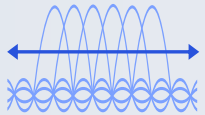
Higher spectral efficiency at high speeds



15 kHz spacing, wideband carrier support up to 100 MHz



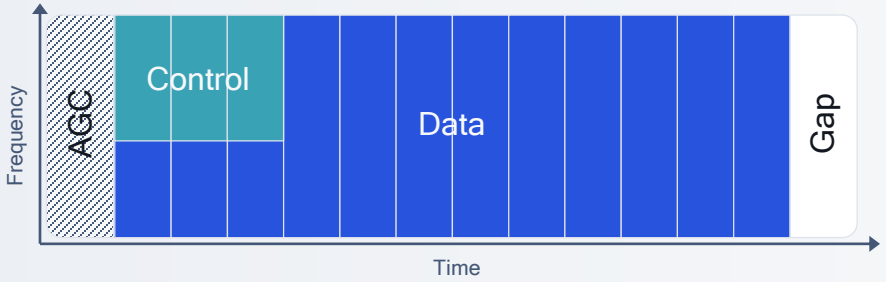
30 kHz spacing, wideband carrier support up to 100 MHz



60 kHz spacing, wideband carrier support up to 100 MHz

Enhanced reliability with feedback

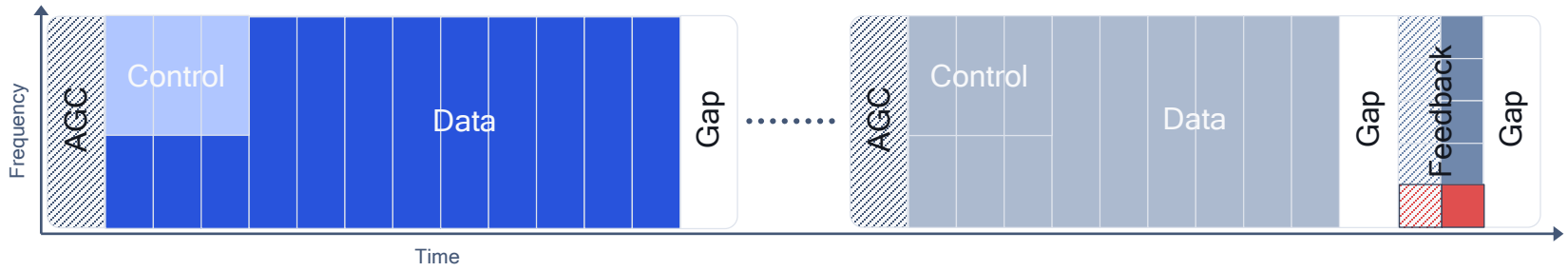
Slot structure without feedback

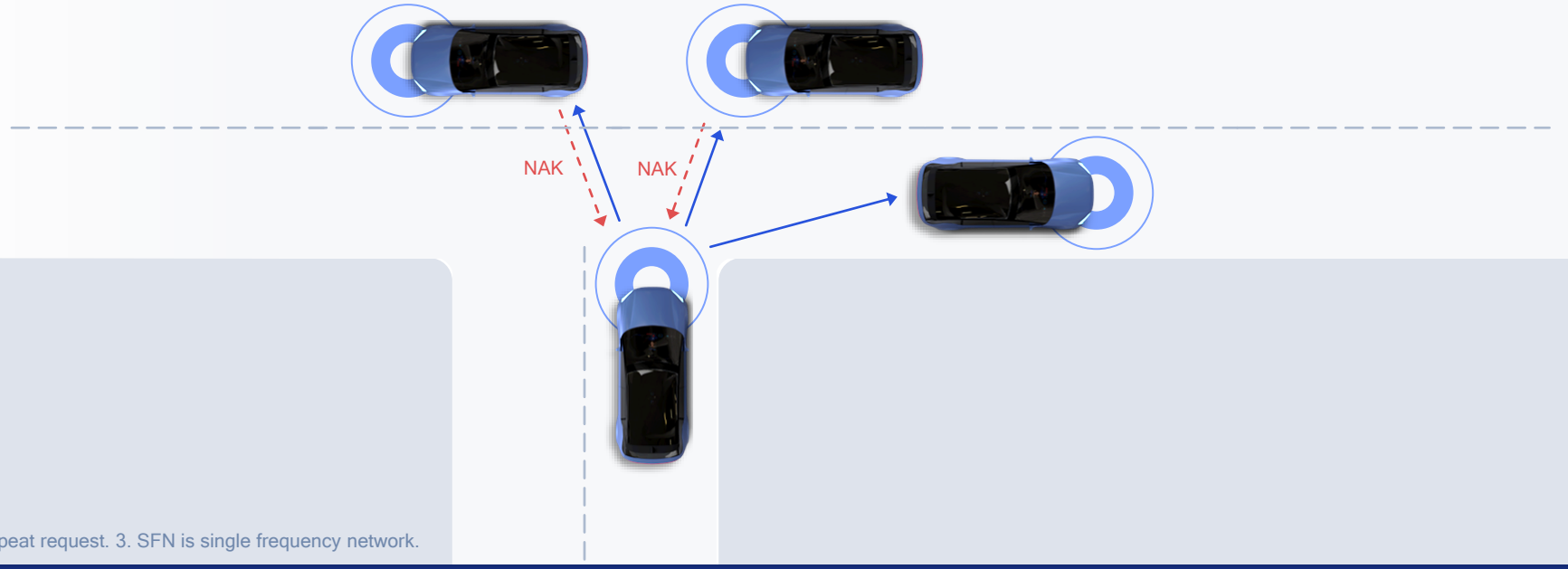


Slot structure with feedback

Scalable OFDM air interface and flexible slot structure

- Reliable multicast based on NAK[1] feedback from receivers
- Retransmission based on HARQ[2]
- Multiple receivers send NAK feedback using the same resource (time and frequency), also referred to as SFN[3].
- SFN of NAK keeps the feedback overhead constant, independent of the number of receivers.





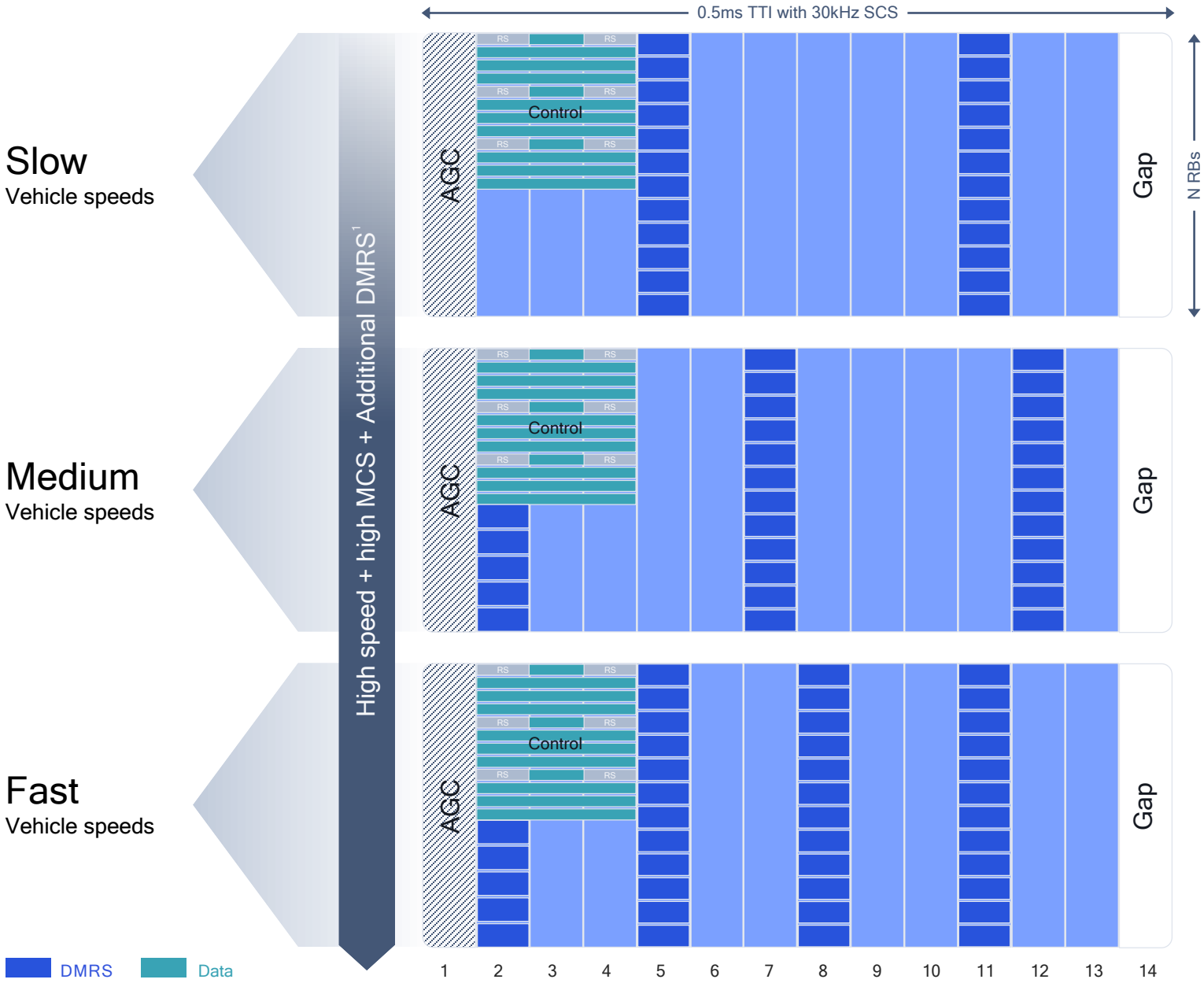
1. NAK is negative acknowledgement. 2. HARQ is hybrid automatic repeat request. 3. SFN is single frequency network.

Reliable and efficient multicast using SFN feedback

NR C-V2X supports adaptive 2-, 3-, 4-symbol DMRS for high-speed performance

Variable reference signal design density

Strategic placement of reference symbols



1. Demodulation Reference Signal

Uniform coverage by adding distance as a dimension

Location information shared efficiently in the physical layer control channel

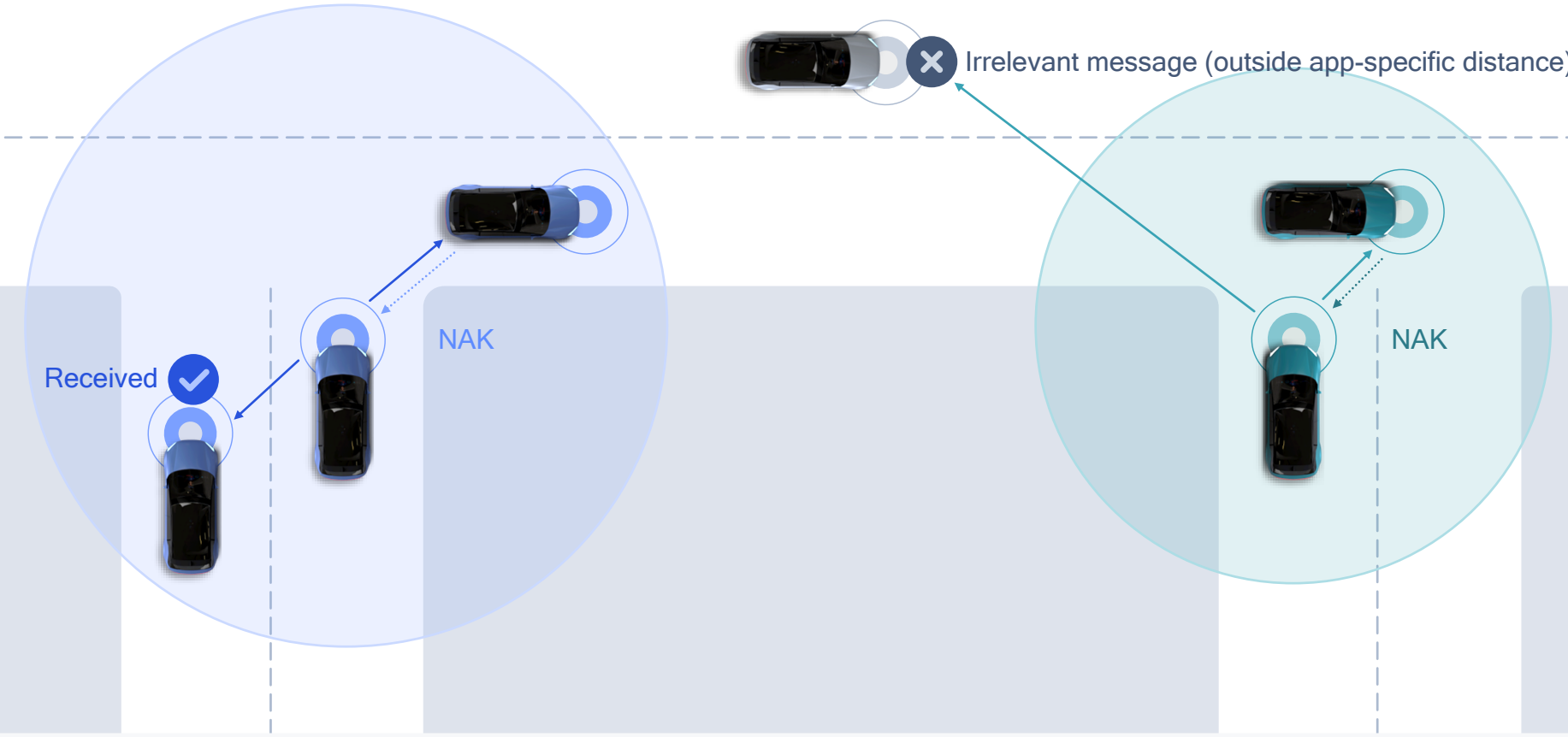
Enables NAK feedback with HARQ based on distance

Groups can reliably connect based on distance

Vehicles within a certain distance and interested in same services form an ‘on-the-fly’ group

Application A

Application B

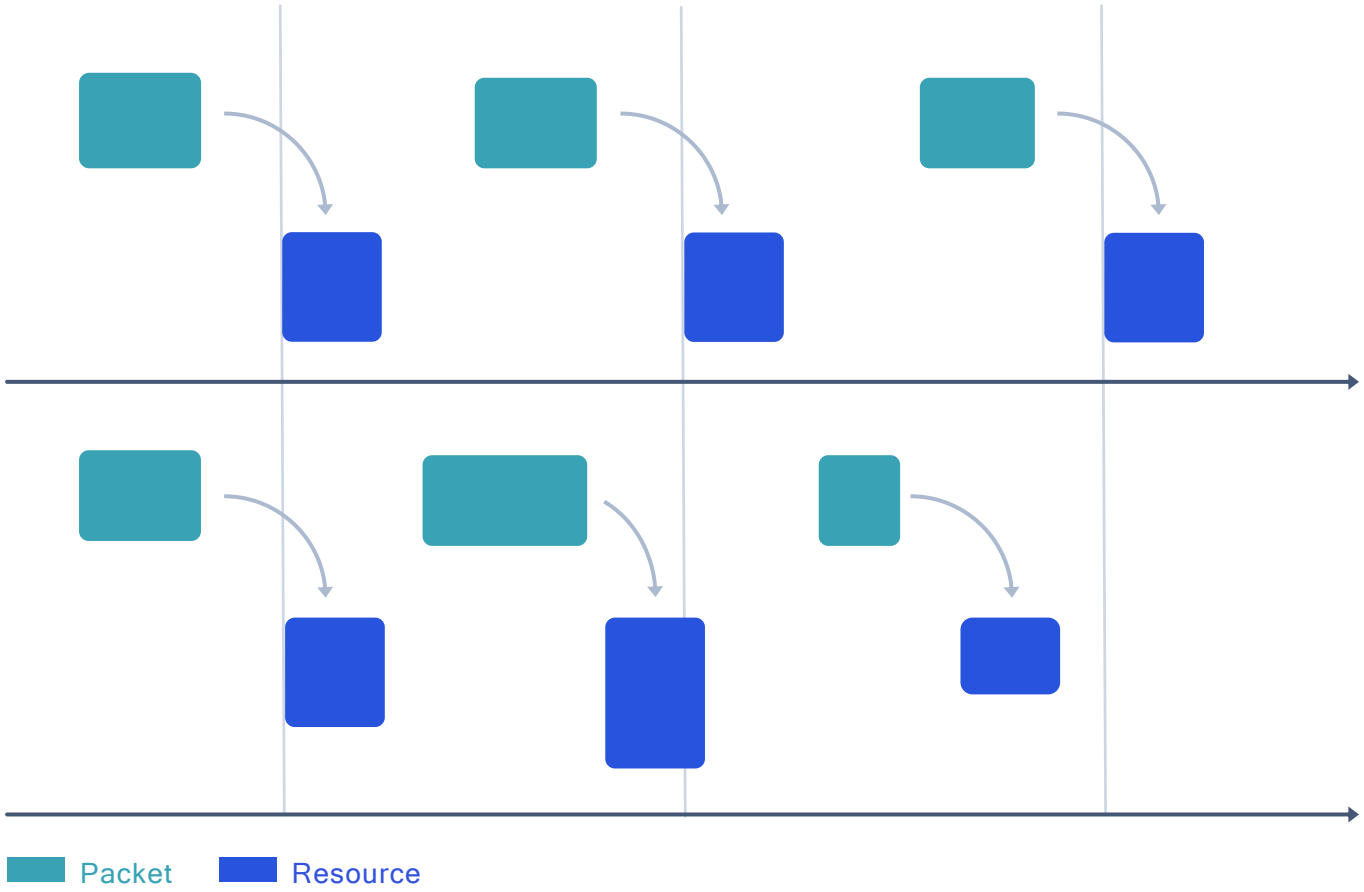


Application-aware, distance-based multicast communication

Application-specific distance is determined based on relevancy

Transmitting vehicles adapt transmission to relevant vehicles within range

Receiving vehicles only acknowledge (NAK) relevant messages



Semi-persistent scheduling

Suitable for basic safety messages with similar packet sizes

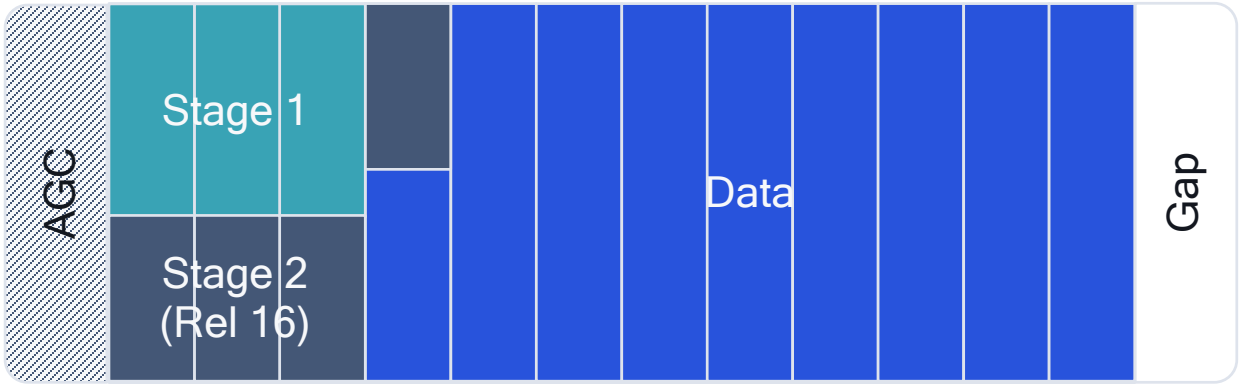
Periodic transmission (typically ~100 ms)

Per packet scheduling

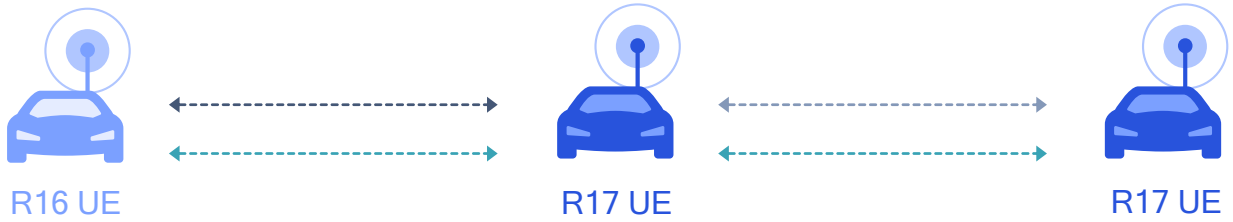
Variable traffic model based on the varying packet sizes

Lower latency (< 100 ms)

Efficient and flexible resource allocation for advanced applications with variable traffic



Slot structure showing two-stage control



Stage 1 format for resource allocation

Stage 2 format for a Rel 16 application

Stage 2 format for a Rel 17 application

Two-stage control allows efficient and flexible support for current and future applications

Stage 1

Common across releases and provides resource allocation information

Stage 2

Provides application-specific information and also facilitates forward compatibility

Significant physical layer gains

NR C-V2X enhancements

Spectral efficiency: up to 2x for broadcast

Scalable OFDM and flexible DMRS provide higher spectral efficiency, which reduces bandwidth usage and allow for more capacity

Lower latency: Tx latency as low as 1.5 ms

Due to shorter slots and resources allocation enhancements

Higher capacity: 2x for per packet scheduling

Achieved through link-level gain, HARQ feedback, and resource allocation enhancements

NR C-V2X

Over-the-air demos and simulations

Qualcomm 5G

5G C-V2X Technology Evolution - Interactive Simulation

Clear Results

Obstruction

Light | Medium | **Heavy**

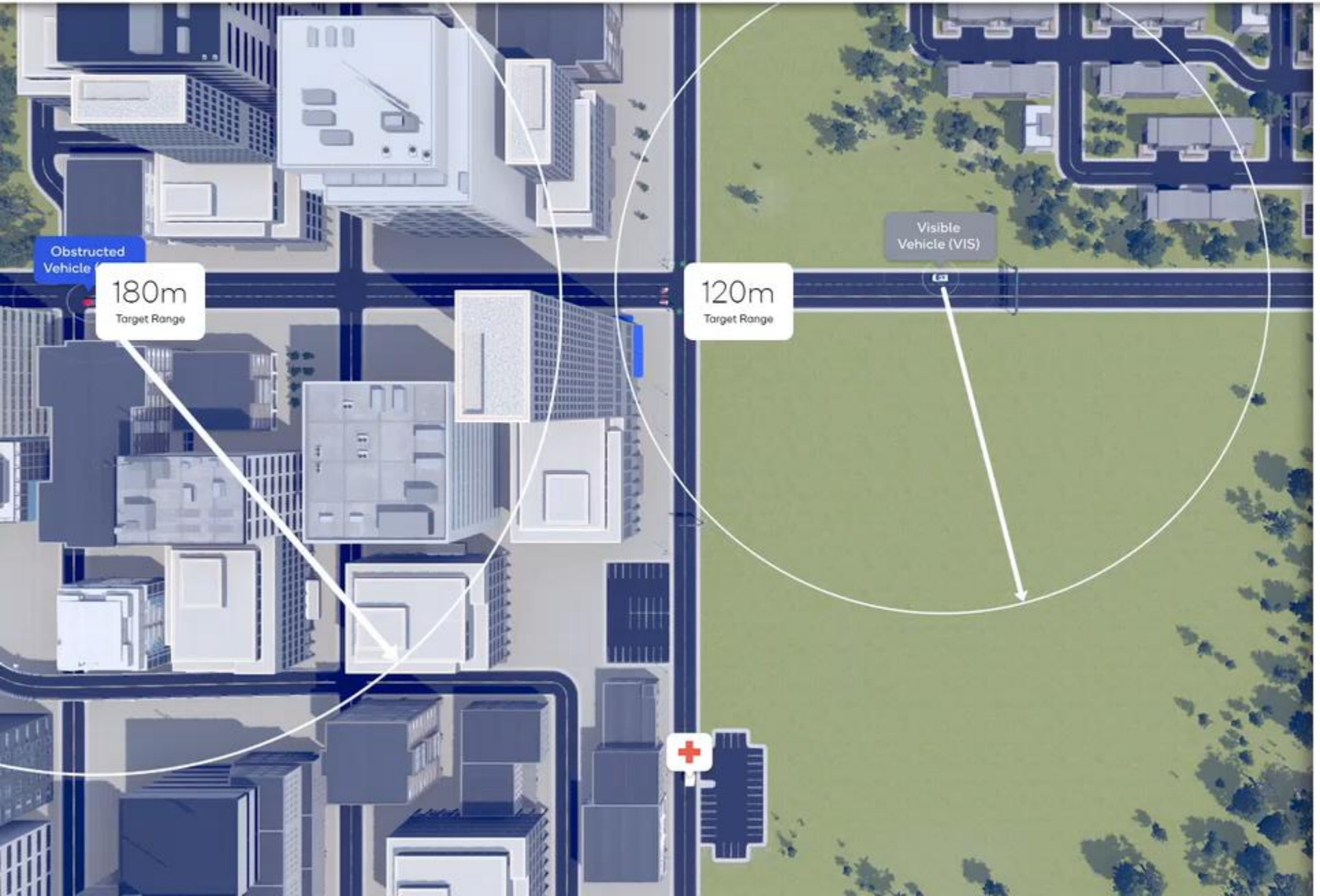
Obstructed Vehicle Speed	**25 mph** / 45 mph
Visible Vehicle Speed	25 mph
Emergency Vehicle Speed	25 mph

C-V2X Enabled	Non C-V2X Vehicles Present
Off	Off

Start Test

Qualcomm 5G | 5G C-V2X Technology Evolution - Interactive Simulation

Clear Results



Obstruction

Light | Medium | Heavy

Obstructed Vehicle Speed: 25 mph | 45 mph

Visible Vehicle Speed: 25 mph

Emergency Vehicle Speed: 25 mph

C-V2X Enabled: On

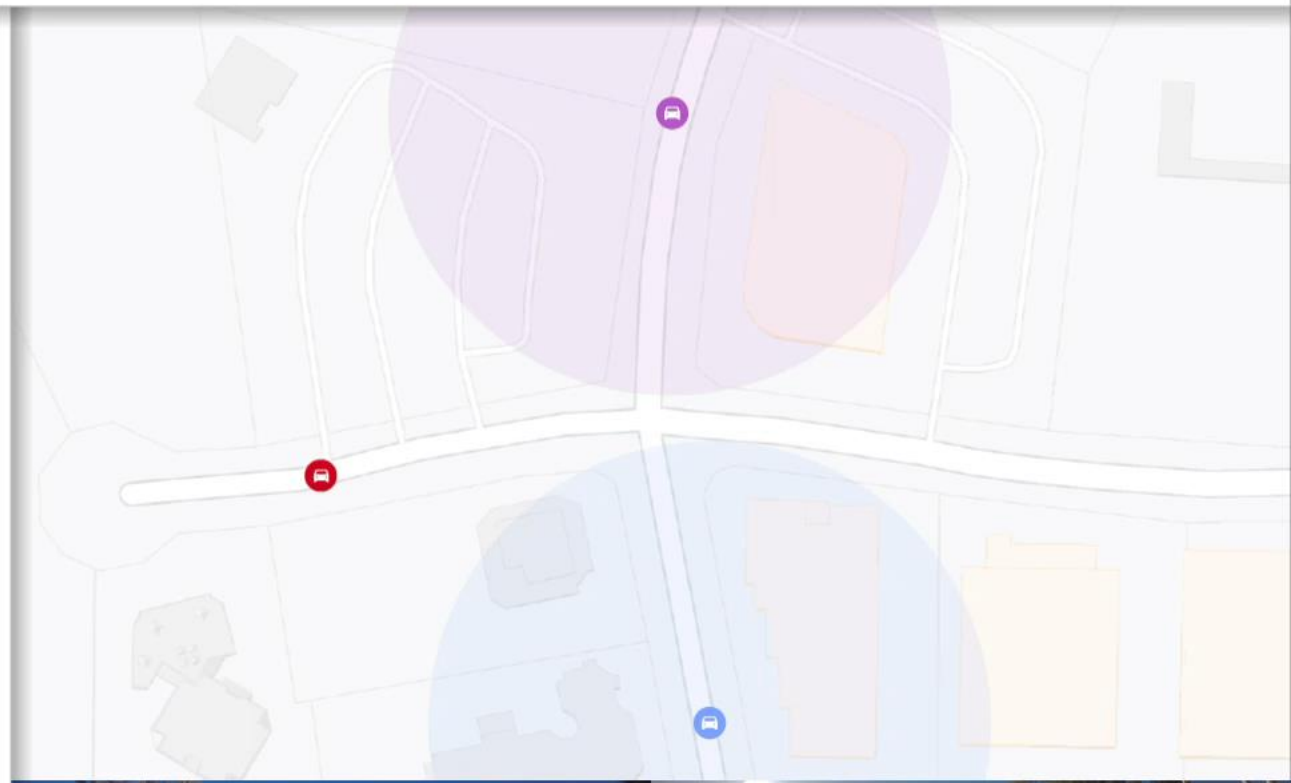
Non C-V2X Vehicles Present: Off

Start Test

5G C-V2X prototype platform

Qualcomm

Emergency Vehicle



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