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

Qualcomm Technologies, Inc.

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

Shailesh Patil

Principal Manager/Engineer
Qualcomm Technologies, Inc.

C-V2X

Rel 14/15 C-V2X established basic safety

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

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☑ Release 14/15 C-V2X standards completed

5G 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

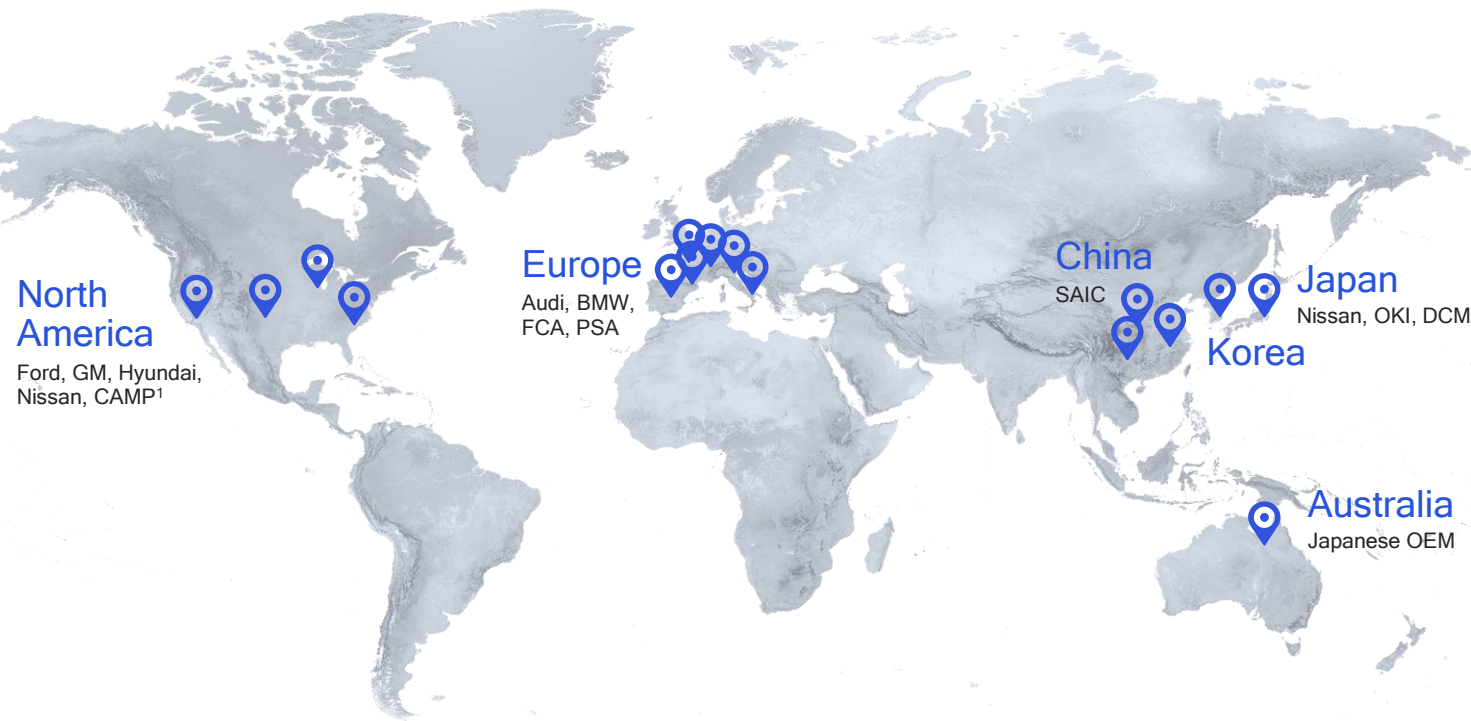Ⓢ Integration of C-V2X into the Qualcomm® Snapdragon™ Automotive 4G and 5G Platforms announced in February, 2019

V2V
Vehicle-to-vehicle
e.g., collision avoidance safety systems

V2I
Vehicle-to-infrastructure
e.g., roadside 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

Qualcomm 9150 C-V2X and Qualcomm Snapdragon Automotive 4G/5G Platforms are products of Qualcomm Technologies, Inc. and/or its subsidiaries.

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Rel 14/15 C-V2X

Momentum and commercial deployments

Driving C-V2X global presence with trials and demos

North America
Ford, GM, Hyundai, Nissan, CAMP[1]

Europe
Audi, BMW, FCA, PSA

China
SAIC

Japan
Nissan, OKI, DCM

Korea

Australia
Japanese OEM

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 partners and customers

- Tier 1s and OEMs
- Third-party software providers
- Test equipment, module, component, and antenna suppliers
- Road infrastructure providers
- Mobile network operators
- Design services
- Service providers

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

Sep. 2016
5GAA founded

Feb. 2017
Towards 5G trial in France announced

Jan. 2017
ConVeX trial in Germany announced

Mar. 2017
Rel-14 C-V2X spec finalized

Sep. 2017
First C-V2X chipset introduced

MDM 9150

Oct. 2017
San Diego Regional C-V2X trial

AT&T
NOKIA
Ford
McCain

Apr. 2018
First multi-OEM demo in D.C.

Jun. 2018
1st US deployment in Denver

FICOSA   WNC Wistron NeWeb Corp.
kapsch>>>
SAVARI   CDOT CO
Panasonic   Ford

Jul. 2018
Europe's first multi-OEM demonstration in Paris

Oct. 2018
Multi-OEM performance evaluation of C-V2X

Nov. 2018
Reaches 100 members

Nov. 2018
China-SAE ITS Stack Compatibility

Oct. 2018
C-V2X functional and performance test report published

5GAA

Jan. 2019
Cooperative driving live interactive demos in Las Vegas

DUCATI
Ford
Audi

Feb. 2019
C-V2X integrated with Qualcomm® Snapdragon™ Automotive 4G/5G platforms

Feb. 2019
TELEFÓNICA/ SEAT's live C-V2X/ 5G demo at MWC Barcelona

Jan. 2019
Announcing C-V2X implementation in Las Vegas

commsignia
RTC

Mar. 2019
SAIC project complete

Mar. 2019
Cross border demo

ConVeX

May 2019
C-V2X ecosystem demos

Nov. 2019
Live demos show C-V2X as a market reality

Nov. 2019
CAMP congestion control scenario testing by OEM consortium

Jan. 2020
ETSI European specifications and standards for C-V2X completed

Feb. 2020
C-V2X devices passed European Radio Equipment Directive (RED)

Jan. 2020
C-V2X deployment in Virginia with VaDoT

Audi

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
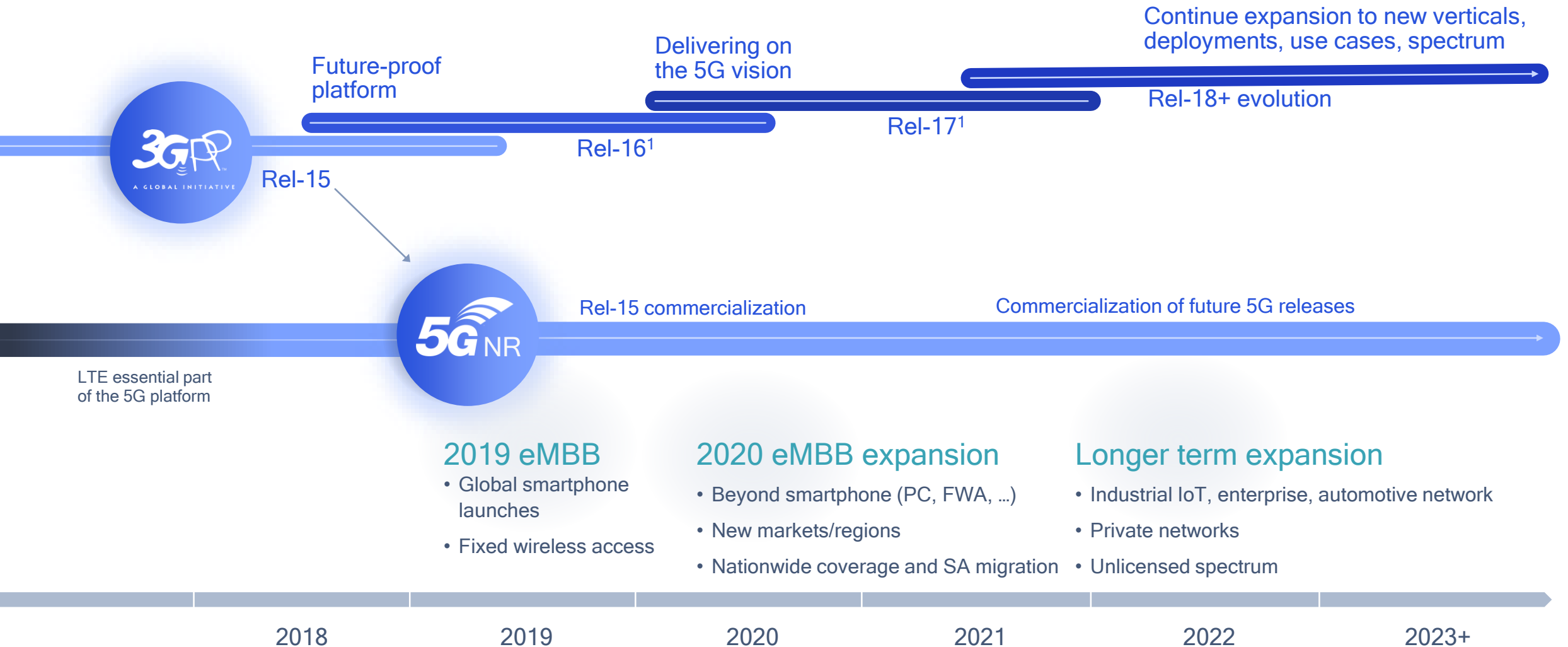
Future-proof
platform

Delivering on
the 5G vision

Continue expansion to new verticals,
deployments, use cases, spectrum

Rel-16[1]

Rel-17[1]

Rel-18+ evolution

Rel-15

3GPP
A GLOBAL INITIATIVE

5G NR

Rel-15 commercialization

Commercialization of future 5G releases

LTE essential part
of the 5G platform

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+ |

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
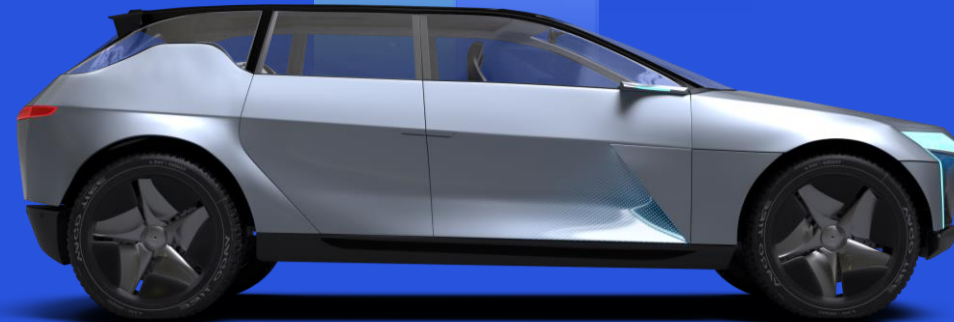
5G C-V2X sidelink

NR C-V2X introduces complementary capabilities for advanced use cases

Rel 14 C-V2X only car
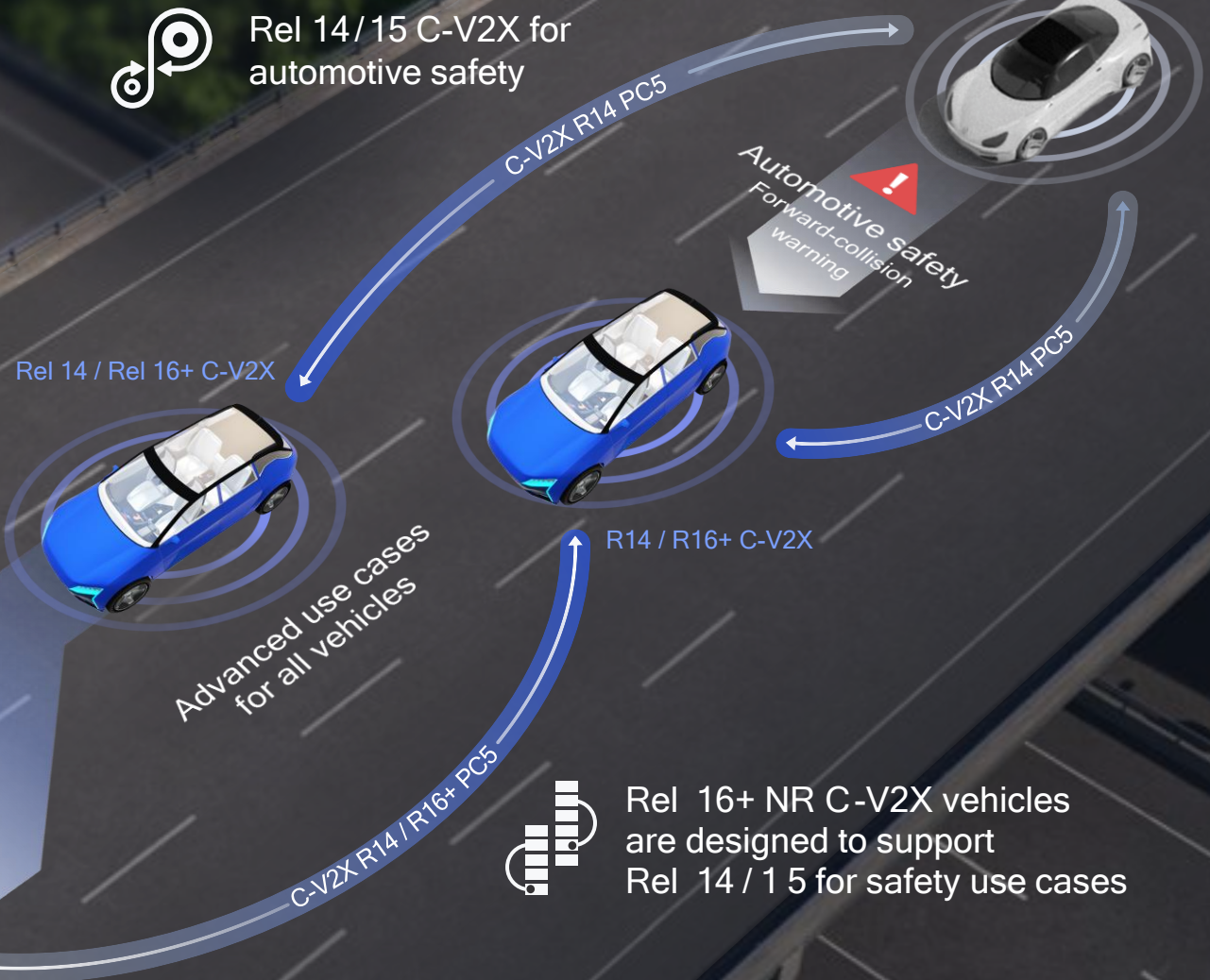
Rel 14 / 15 C-V2X for automotive safety

C-V2X R14 PC5

Rel 14 / Rel 16+ C-V2X

Automotive safety
Forward-collision warning

C-V2X R14 PC5

R14 / R16+ C-V2X

Advanced use cases for all vehicles

Autonomous driving

C-V2X R14 / R16+ PC5

Rel 16+ NR C-V2X vehicles are designed to support Rel 14 / 15 for safety use cases

5G

Building on existing frameworks

Utilizes NR flexible framework

Scalable OFDM-based air interface
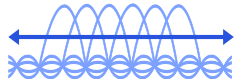
Such as wideband carrier support (>20 MHz) and different sub-carrier spacing

Flexible slot-based framework
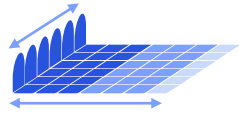
Such as adding sidelink and dynamic reference signal for various speed

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

Higher spectral efficiency at high speeds

Enhanced reliability with feedback
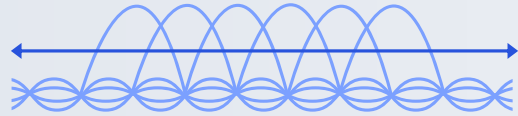
15 kHz spacing, wideband carrier support up to 100 MHz
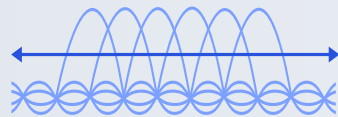
30 kHz spacing, wideband carrier support up to 100 MHz
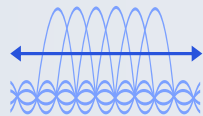
60 kHz spacing, wideband carrier support up to 100 MHz

Slot structure without feedback

Frequency

AGC

Control

Data

Gap

Time

Slot structure with feedback

Frequency

AGC

Control

Data

Gap

Feedback

Gap

Time

NR C-V2X

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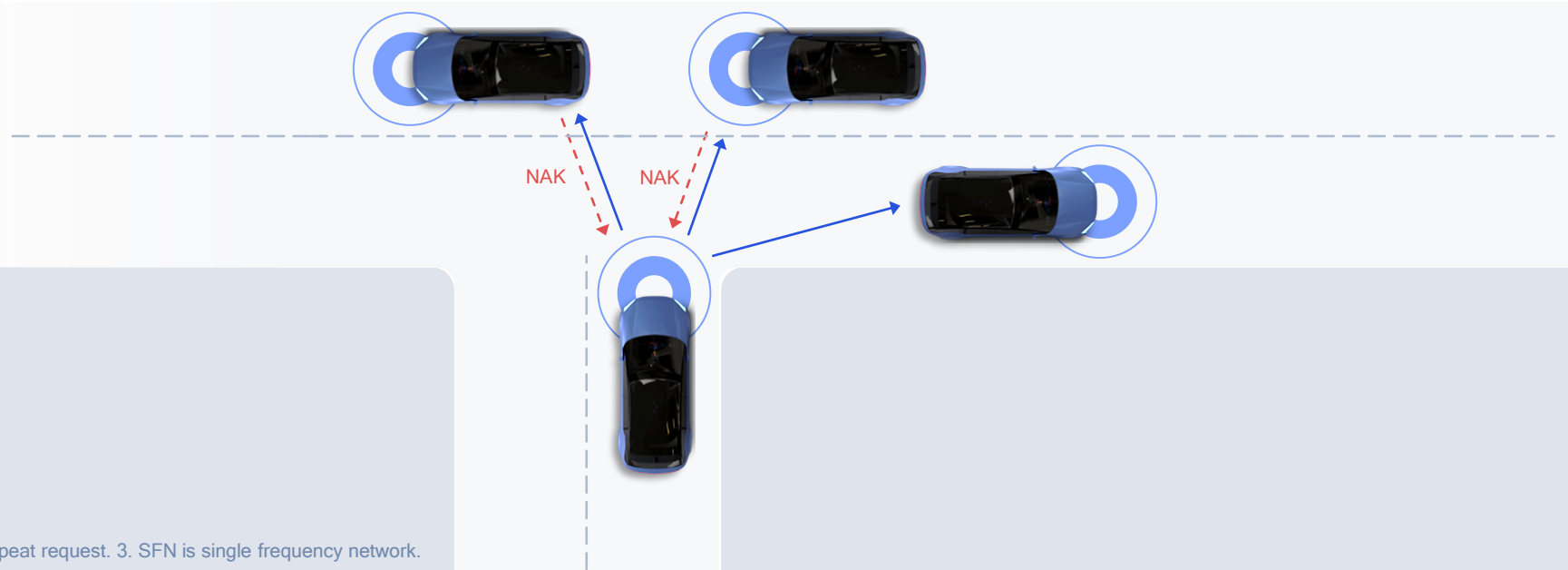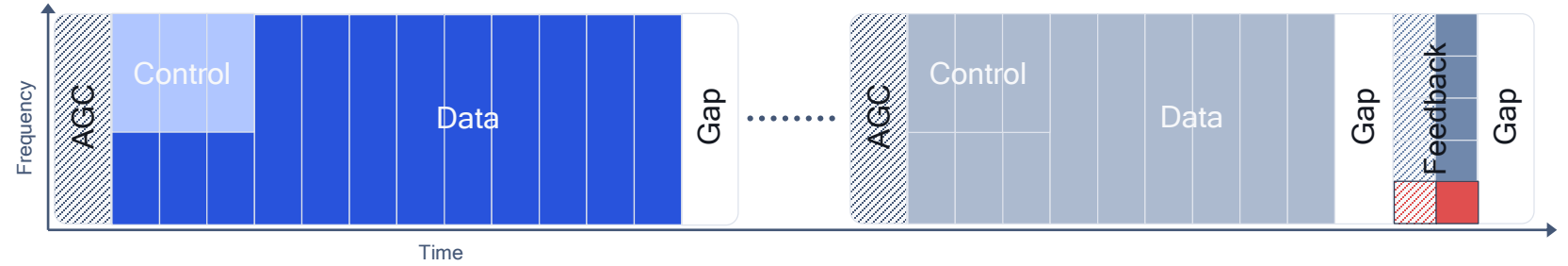
1. NAK is negative acknowledgement. 2. HARQ is hybrid automatic repeat request. 3. SFN is single frequency network.

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

Slow Vehicle speeds

Medium Vehicle speeds

Fast Vehicle speeds

High speed + high MCS + Additional DMRS[1]

0.5ms TTI with 30kHz SCS

N RBs

AGC

Control

RS

Gap

DMRS · Data

1 2 3 4 5 6 7 8 9 10 11 12 13 14
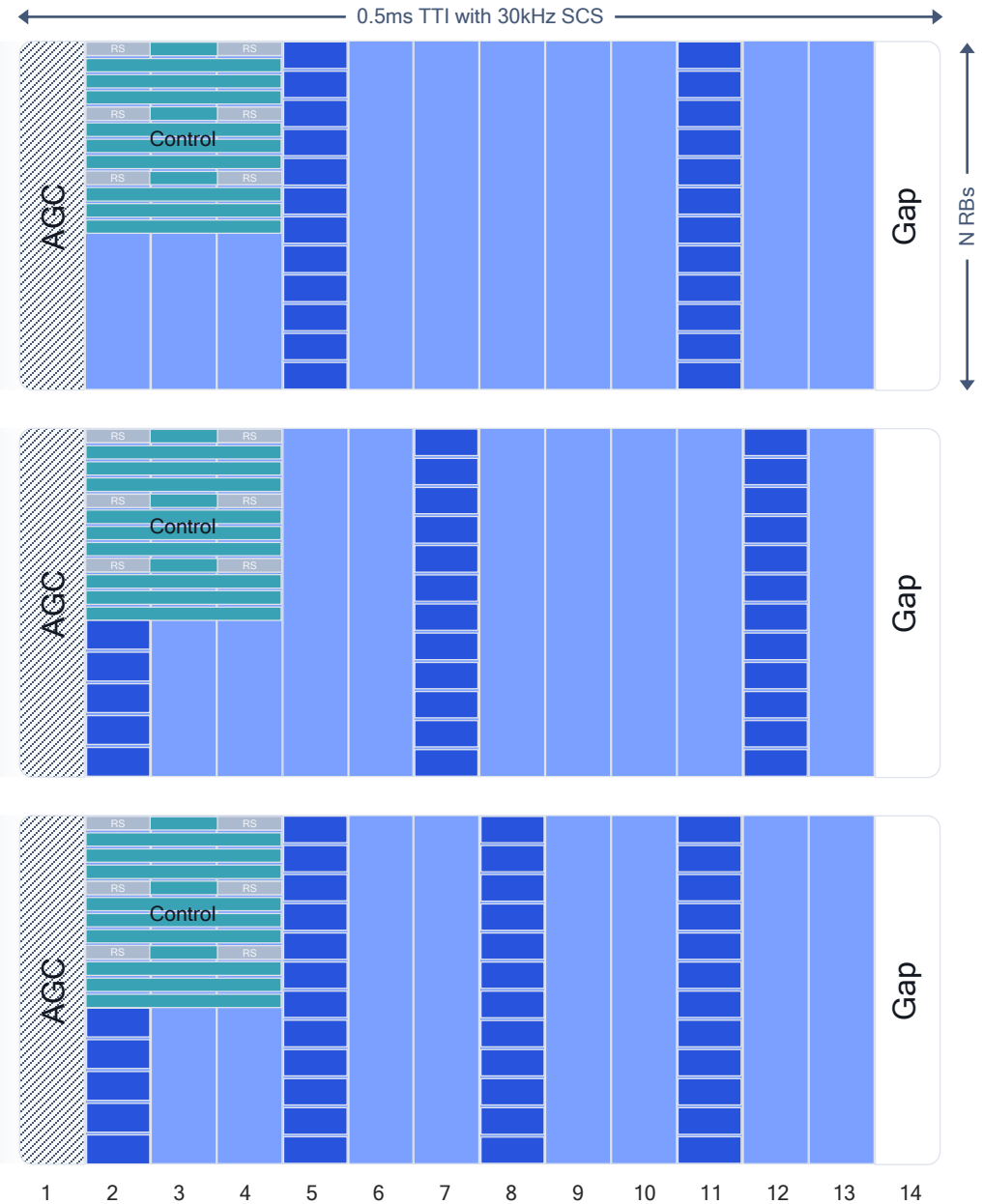
Uniform coverage by adding distance as a dimension

Should be notified, but does not get signal
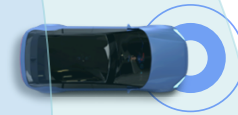
Does not need to be notified, but gets signal
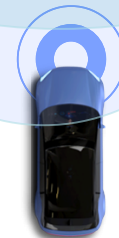
Location information shared efficiently in the physical layer control channel

Enables NAK feedback with HARQ based on distance

Groups can reliably connect based on distance
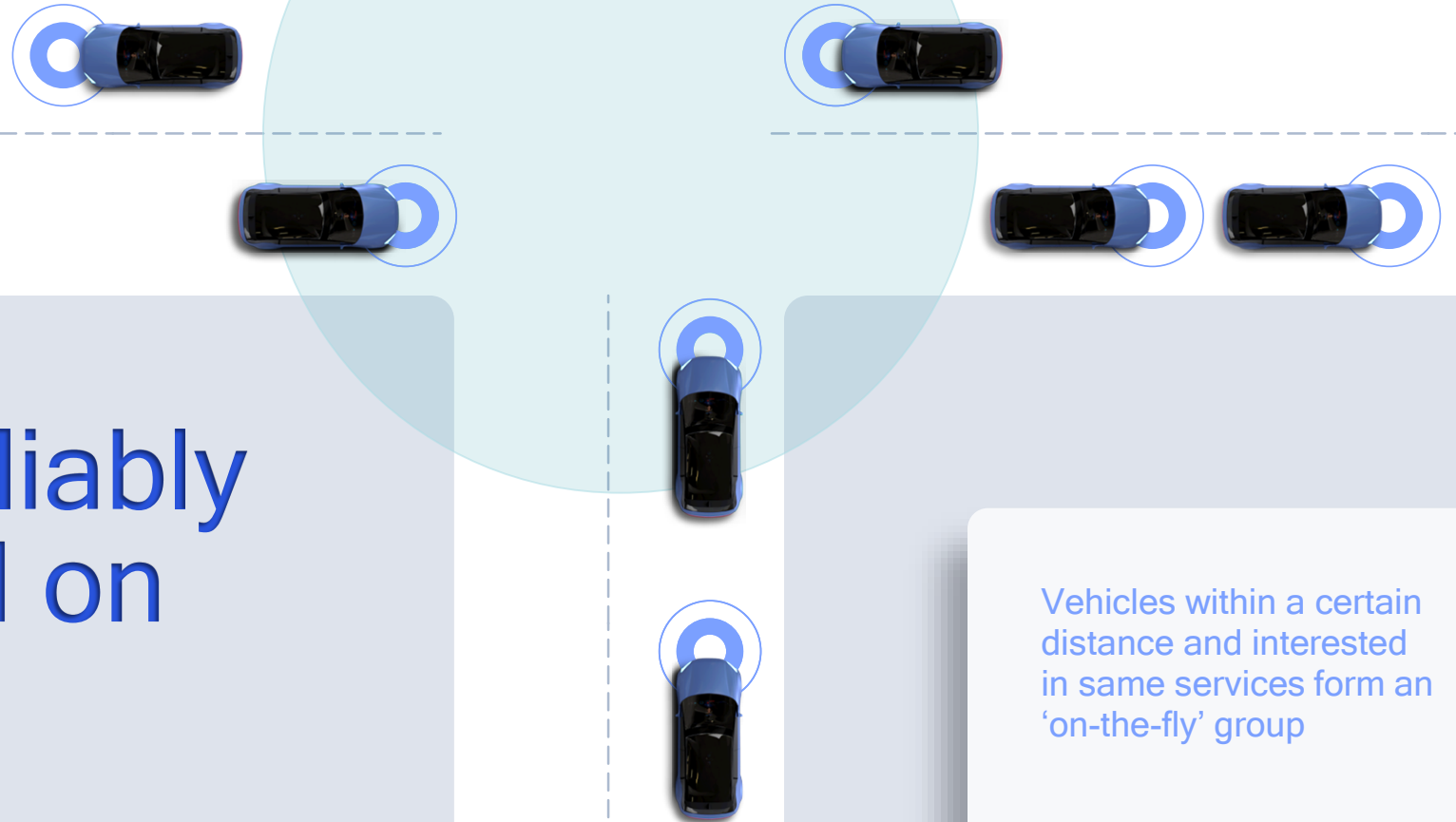
Vehicles within a certain distance and interested in same services form an 'on-the-fly' group

Application A

Application B

Irrelevant message (outside app-specific distance)

NAK

Received ✓

NAK
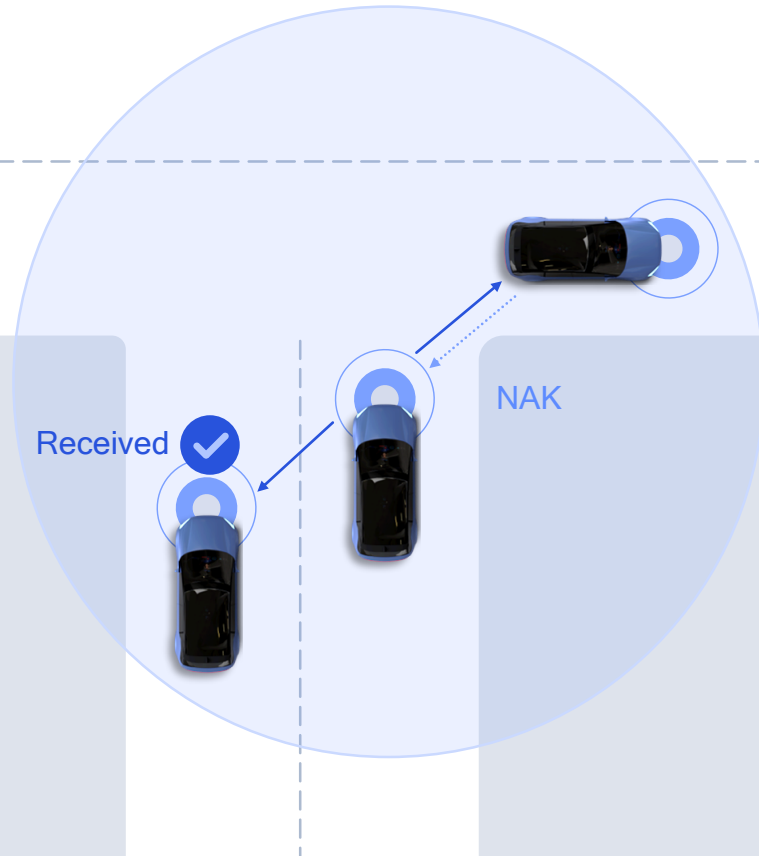
Application-aware, distance-based multicast communication
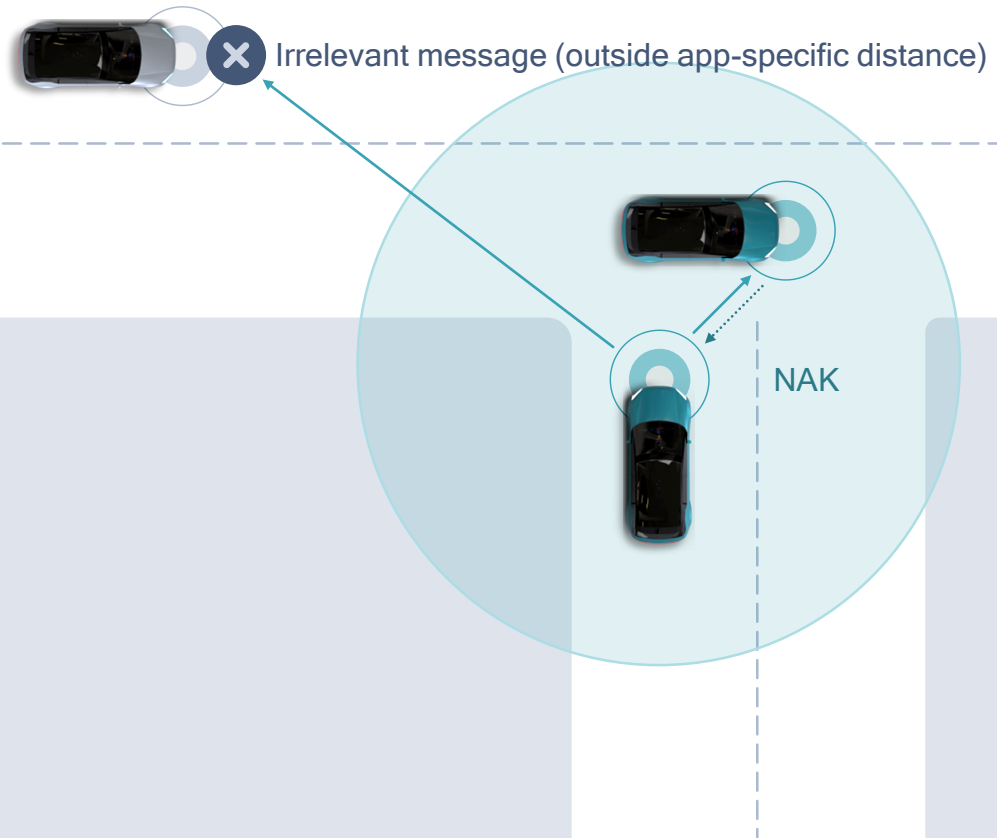
Application-specific distance is determined based on relevancy

Transmitting vehicles adapt transmission to relevant vehicles within range

Receiving vehicles only acknowledge (NAK) relevant messages

C-V2X vehicle detects
non-C-V2X vehicle

1

2

Inform other C-V2X vehicles
with the presence
of non-C-V2X vehicles
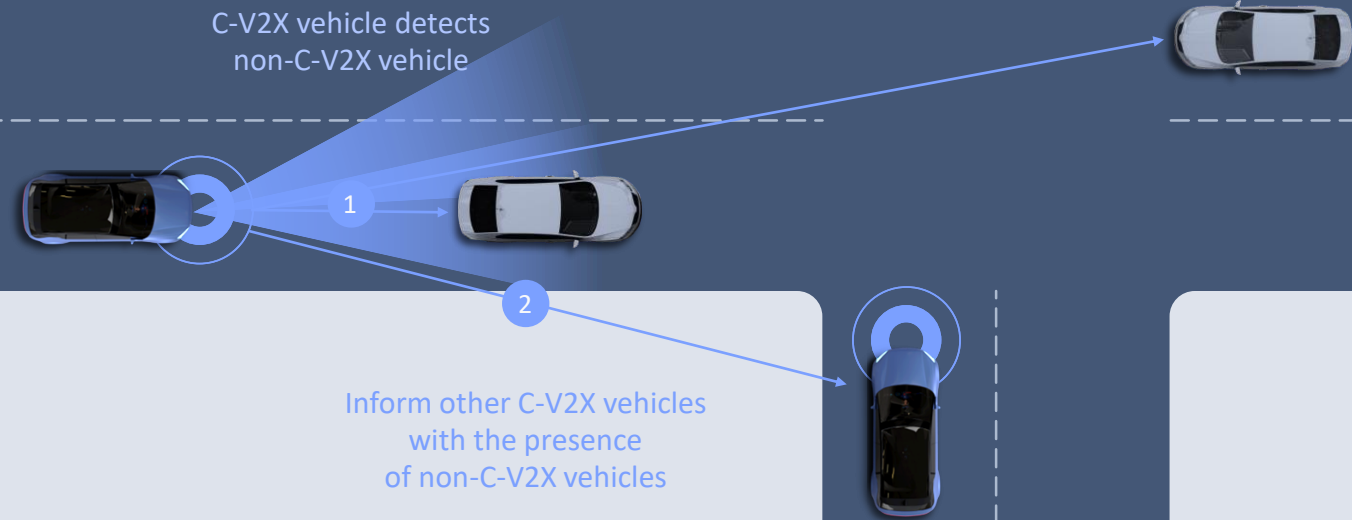
Rich sensor
sharing

With proxy forwarding, these
benefits can be realized even
with limited deployment
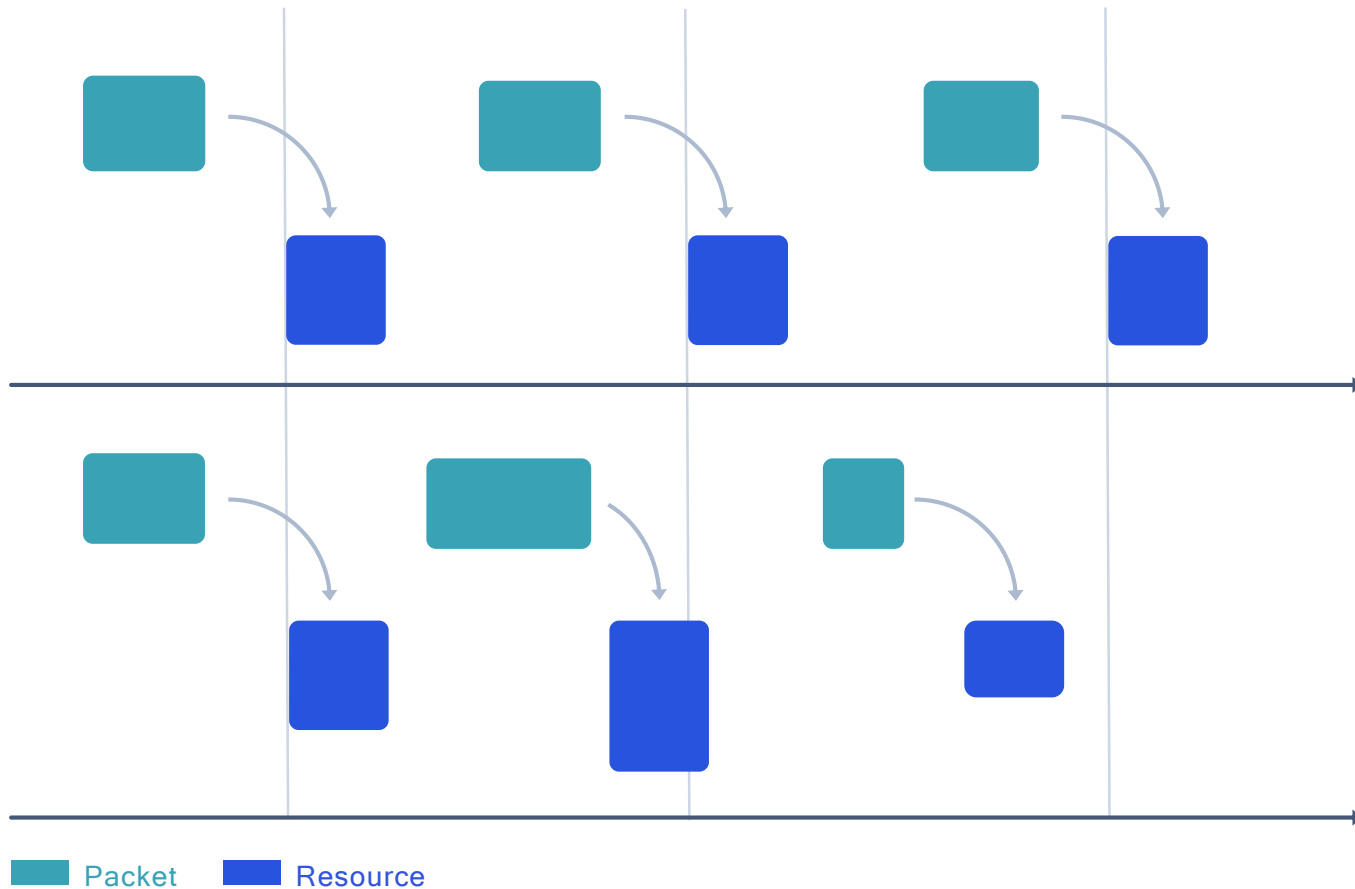
Semi-persistent scheduling

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)

Packet Resource

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

Benefits

Rich sensor sharing
Enables perception and intent sharing among vehicles

On-the-fly connectionless groups
Enabled by distance-based reliability

Benefits in addition to safety
Coordinated driving brings reduced congestion, shorter trip time, and energy savings
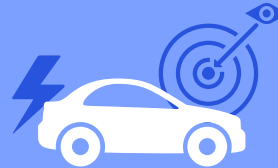
NR C-V2X
NR C-V2X builds on LTE C-V2X

NR C-V2X

Over-the-air demos and simulations

Qualcomm 5G

5G C-V2X Technology Evolution - Interactive Simulation

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Clear Results

Obstructed Vehicle (OBS)

Visible Vehicle (VIS)

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

5G C-V2X prototype platform

Qualcomm
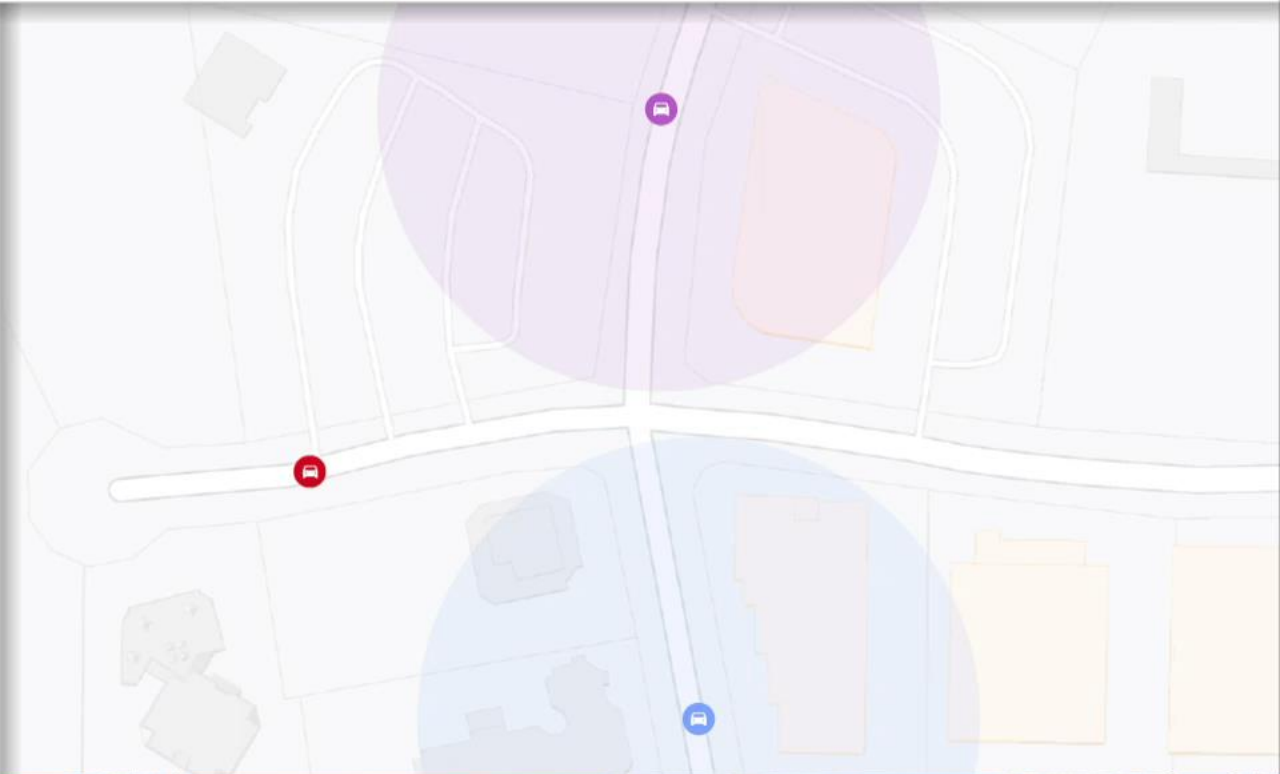
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