Qualcomm

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Communications for Connected and Automated Vehicles

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Elektrobit
Google
seeingmachines
QNX
Vector
Valeo
Zong Mu

Driver Monitoring

Perception

Localization

Ground Truth Tools

Radar

Map

Lidar

Car-to-Cloud continuous updates

Central Compute

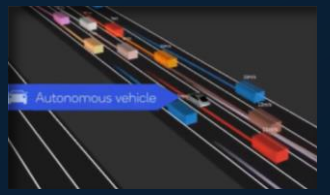
Camera

C-V2X

Ultrasonic

Sensor Fusion

Environment Model



Drive Policy

Simulation Tools

Data Labeling Tools

Snapdragon ride platform

A comprehensive ADAS development system

Agenda

Where we are: Basic safety communications

a. C-V2X defined
   i. Communications links / interfaces
   ii. The argument for heterogeneity
b. Spectrum
c. Voluntary deployment vs mandate or NCAP
d. "Day 1", which I will define, then elaborate based on work that a coalition of stakeholders, to include what vehicle OEMs are defining
   i. Use cases
   ii. Practical realization
e. Security: Security Credential Management and security services

Where we want to be: Cooperative maneuvers with advanced vehicle safety communications

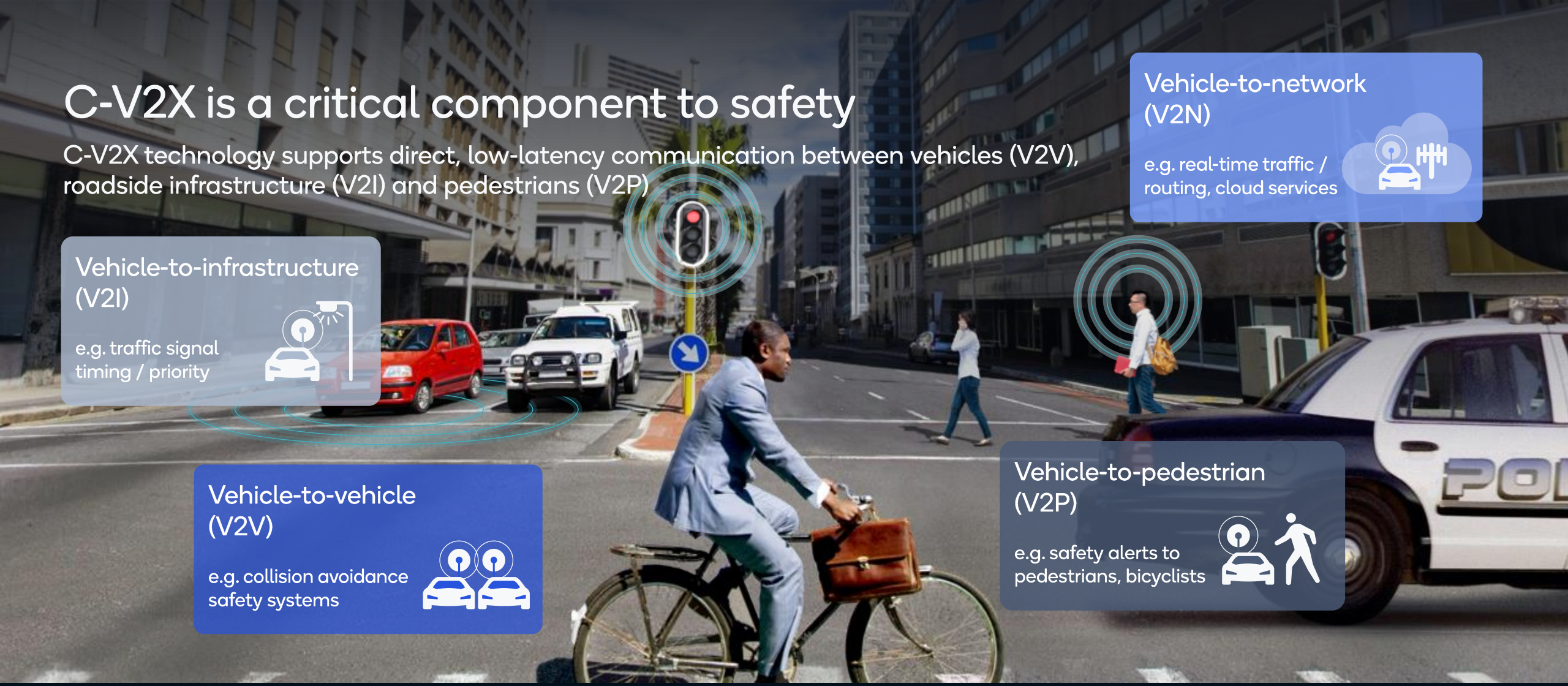
a. Emerging cooperative perception / sensor sharing standards
b. Use cases
c. Paths to realization

Summary: Some next steps to get from where we are to our collective aspiration

Where we are:
Basic Safety Communications

C-V2X is a critical component to safety

C-V2X technology supports direct, low-latency communication between vehicles (V2V), roadside infrastructure (V2I) and pedestrians (V2P)



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)

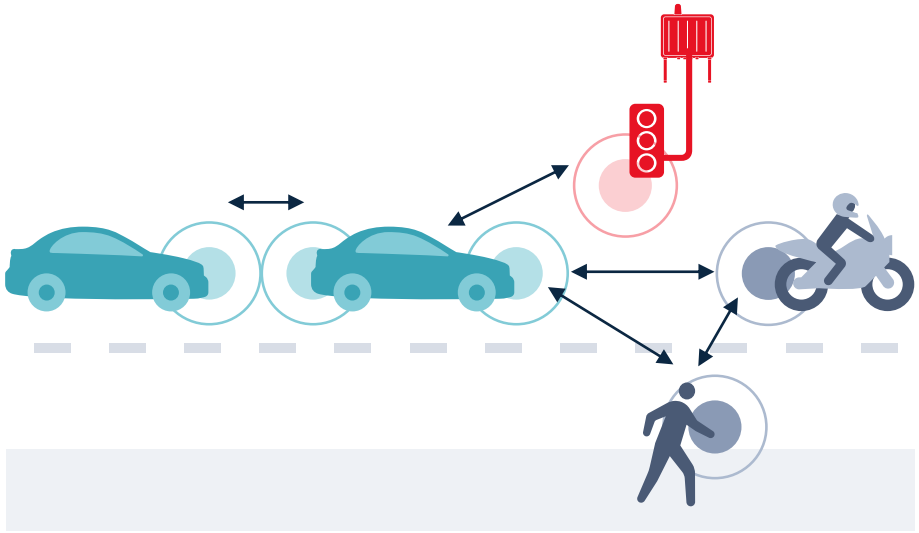
e.g. collision avoidance safety systems

Vehicle-to-pedestrian (V2P)

e.g. safety alerts to pedestrians, bicyclists

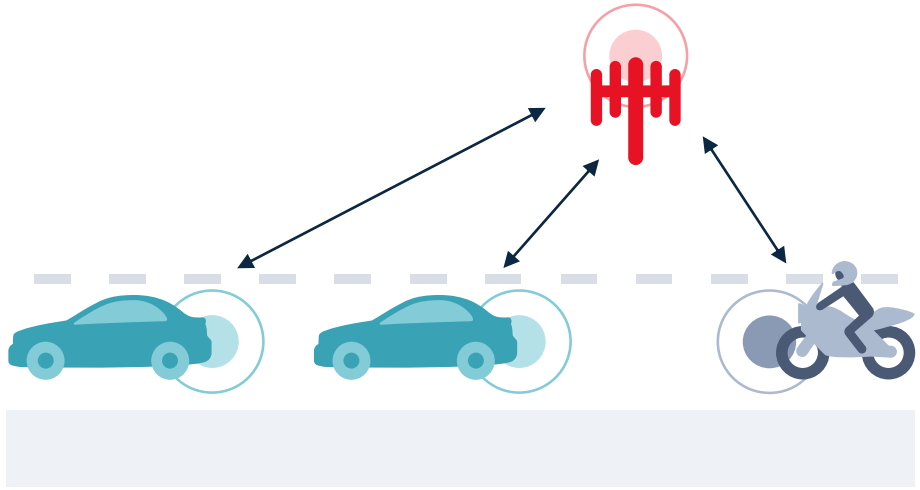
Designed specifically for transportation, C-V2X informs safety critical and mobility-benefiting applications

1 Direct communication independent of cellular network



- Direct V2V, V2I, and V2P communications designed to operate in 5.9GHz spectrum dedicated to surface transportation
- Reliable, low latency message exchange for safety use cases, e.g., collision avoidance, protecting VRUs

2 Network communication



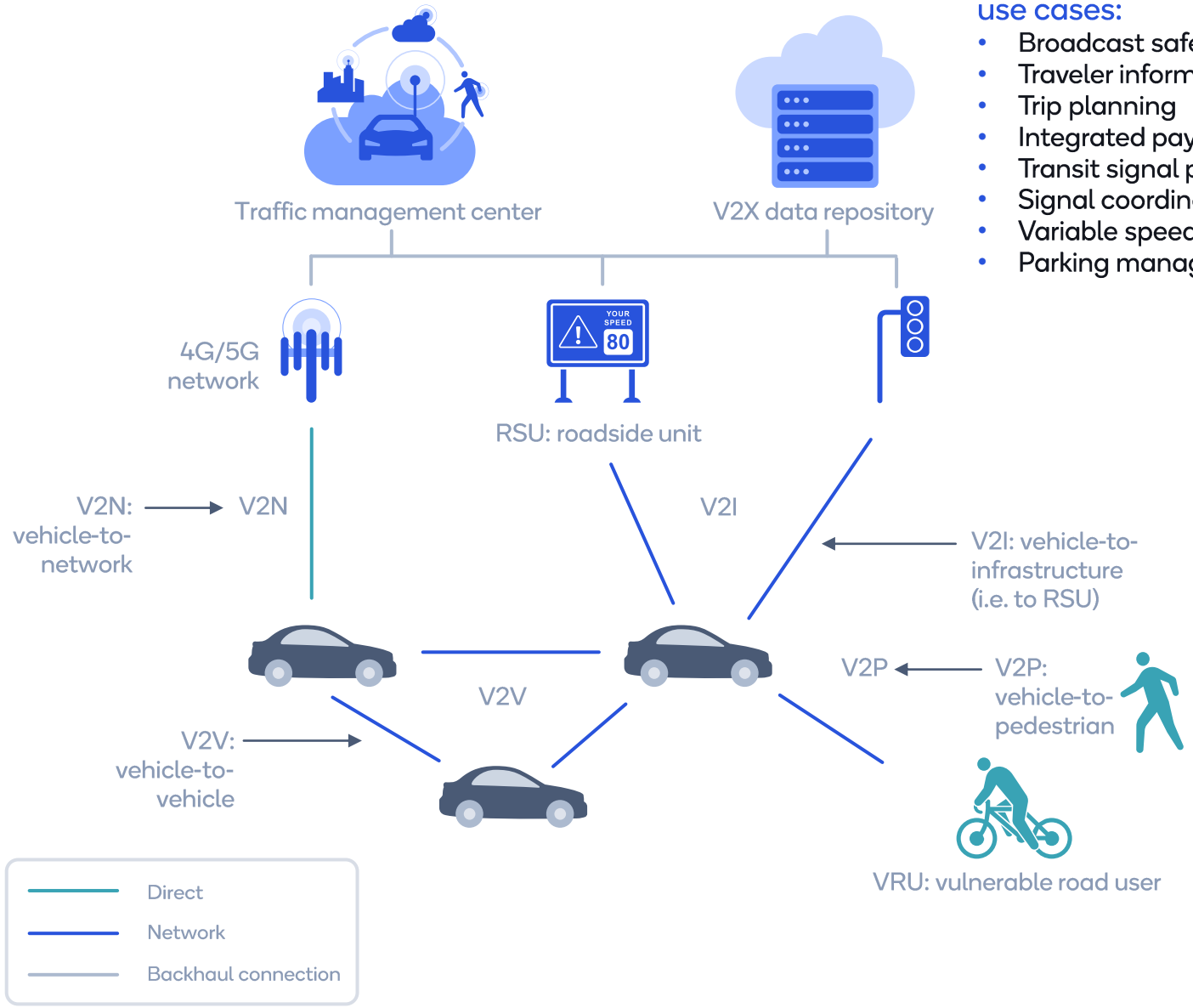
- V2N operates in a mobile operator's licensed spectrum
- Cloud access informs active traffic management and demand management services, while maximizing operational efficiency

C-V2X technology

Complementary transmission modes working together to enhance safety and efficiency

C-V2X Architecture

C-V2X allows vehicles to communicate directly with each other, roadside infrastructure and other road users



Potential data driven use cases:

- Broadcast safety alerts
- Traveler information
- Trip planning
- Integrated payment
- Transit signal priority
- Signal coordination
- Variable speed limit signs
- Parking management

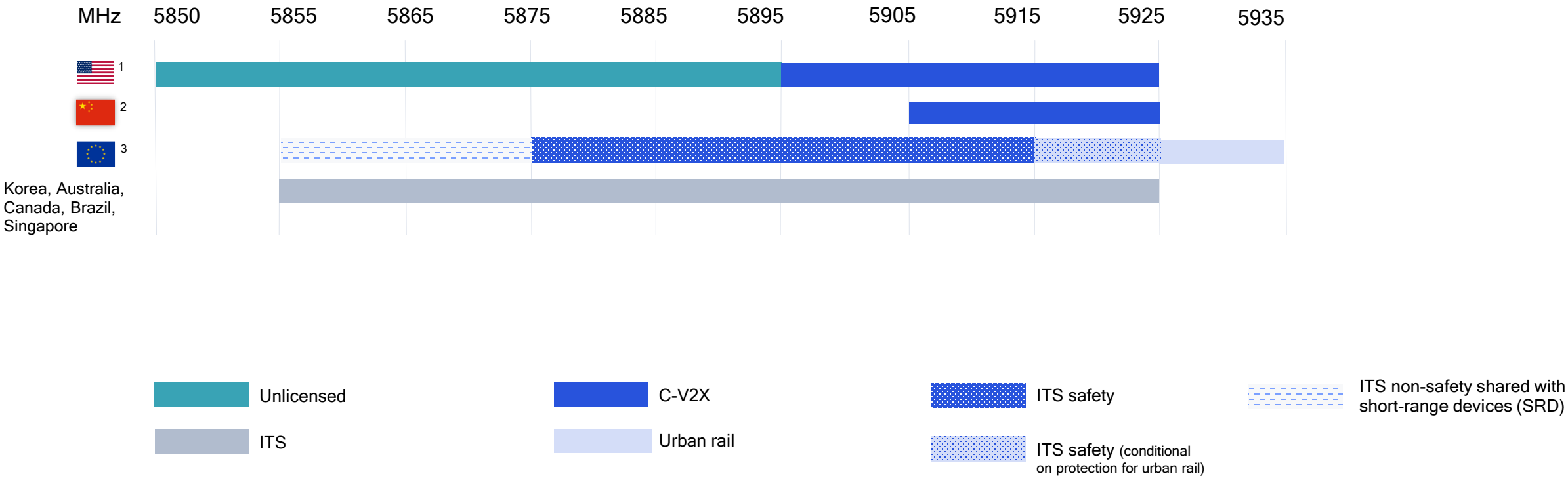
Enhanced intersection safety

Robust connectivity in dense urban environments

More than 2X range even when blocked

More reliable safety warnings for receiving vehicles

Global snapshot of allocated/targeted ITS spectrum



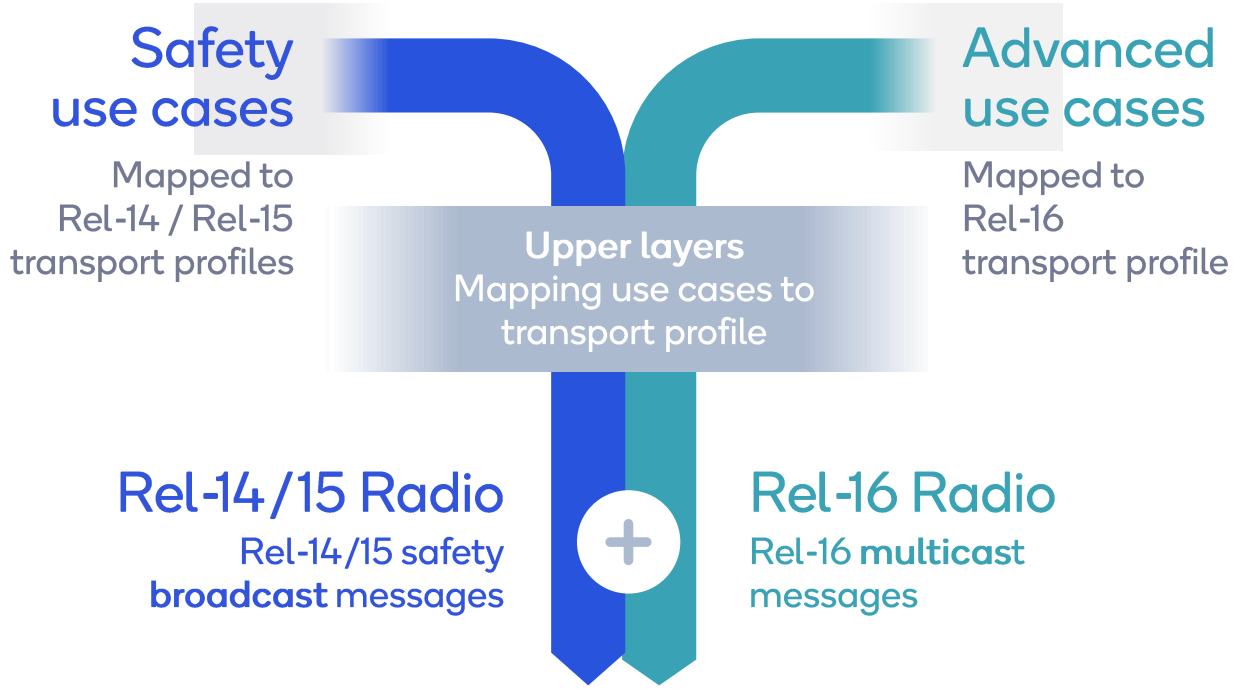
1 FCC assigned upper 30 MHz of ITS band (5.895-5.925 GHz, B47). 2 MIIT officially regulated the upper 20 MHz (5.905-5.925 GHz). 3 ITS spectrum allocation in Europe is still pending. The EU has adopted technology neutrality in spectrum allocation.

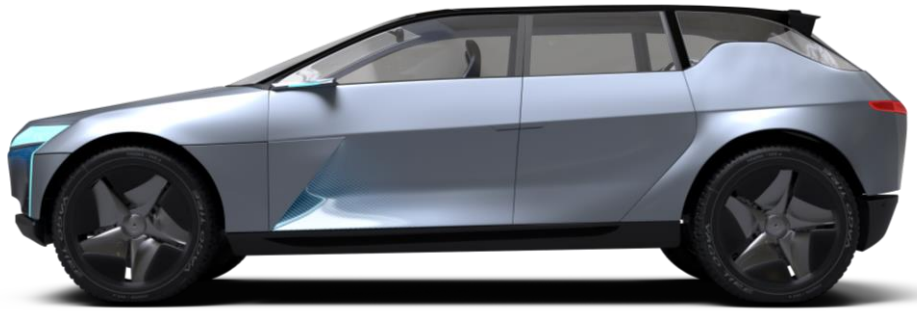
ITS spectrum

Best scenario for current (basic safety) and future (advanced safety) use cases is as much spectrum as possible – 5GAA and C2C-CC have conducted studies that show 40 MHz is needed

5G NR C-V2X was envisioned to be backward compatible at upper layers

By enabling coexistence of Rel-16 with previous releases



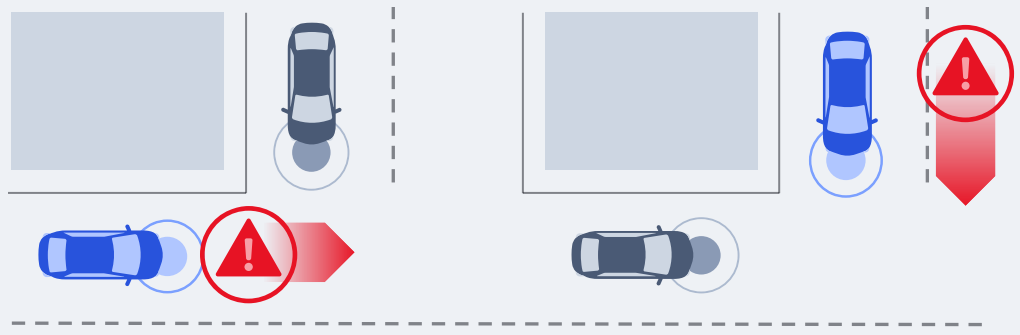


Rel-16 C-V2X vehicles would be designed to support Rel-14/Rel-15 for safety

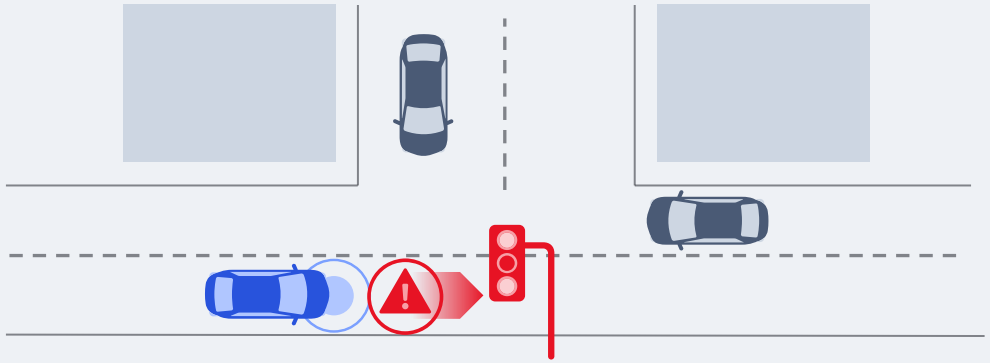
China NCAP in 2025 is a driver for V2X Basic Safety

Euro NCAP – 2029? NHTSA NCAP?

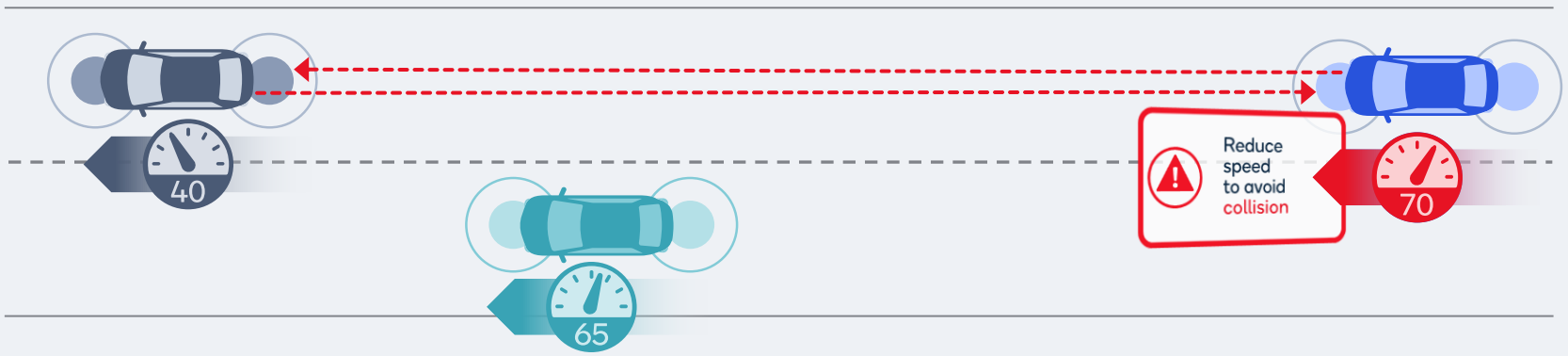
Use Case 1 - V2V: Intersection movement assist (IMA)



Use Case 3 - I2V: Red light violation warning (RLVW)



Use Case 2 - V2V: Send collision warning at high closing speeds and long ranges



Timeline:

March 2022 (done):
Roadmap final release

June 2023:
Test guide public comments

Q1 2024:
Test guide final publication

Day 1 (North America): Single 20 MHz channel operation

- Prioritization of different traffic classes
- Applications won't all run at the same time and place — segregating by category and location can support a broad range of applications
- Critical safety applications often share the same messages (BSM, SPaT, MAP) — additional applications do not add to message traffic
- 5GAA and other industry organizations are defining a Day 1 Deployment Guide to profile use of standards

C-V2X direct can support V2V and V2I basic safety applications in a single channel

Single channel operation is effective for Day 1 safety applications

V2V and V2I simulation

concluded that V2I applications do not adversely affect V2V safety messages

Traffic prioritization

higher priority to safety messages restrict low priority traffic under congestion

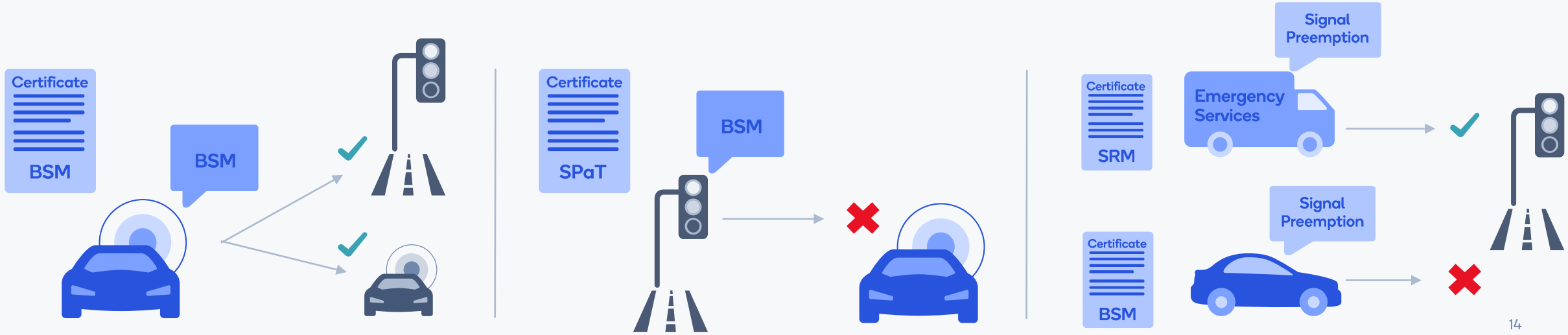
V2X Communications Security with IEEE 1609.2

Different sender types can send different message types

- Ordinary car **can** send BSM, RSU **cannot**
- Public safety (police) car **can** send signal preemption, ordinary car **cannot**

Send permissions are indicated by a certificate

- Cryptographically bound to the sender and the message
- Issued by a Certificate Authority (CA)
- CA ensures that certificate holder (a) is of the right type (b) is **correctly implemented** and **meets performance requirements**



IEEE 1609.2 certificate issuance

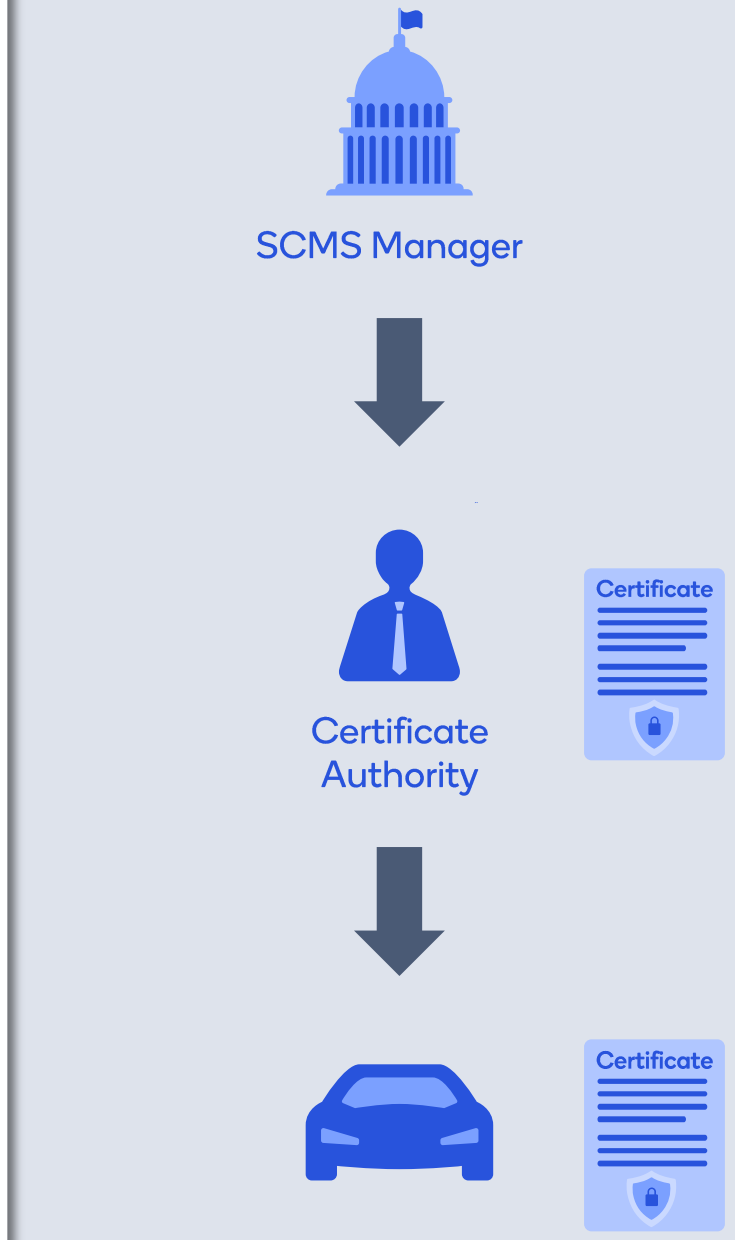
SCMS Manager sets policy

- Requirements for end entities (EEs)
  - Performance and reliability (application / use-case specific)
  - Secure design
  - Secure operation
  - How the EE demonstrates it meets these requirements – certification, self-assertion, …
- Requirements for operation of Certificate Authorities (CAs)
  - Processes, audit, record keeping, …
- System robustness
  - How to handle bad actors in the system, e.g. EEs that send incorrect / malicious messages

Certificate Authority ensures that EE meets requirements set for that application and issues certificates

- Certificate means receivers can trust that sender is authorized and is behaving correctly

EE uses certificates to sign messages and communicate with other EEs (V2X)



Where want to be:

Cooperative Maneuvers with Advanced Safety Communications

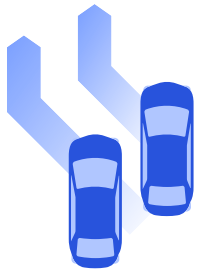
Aspiration: Cooperative Perception and Coordinated Maneuvers

Increased situational awareness

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

Sensor sharing

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



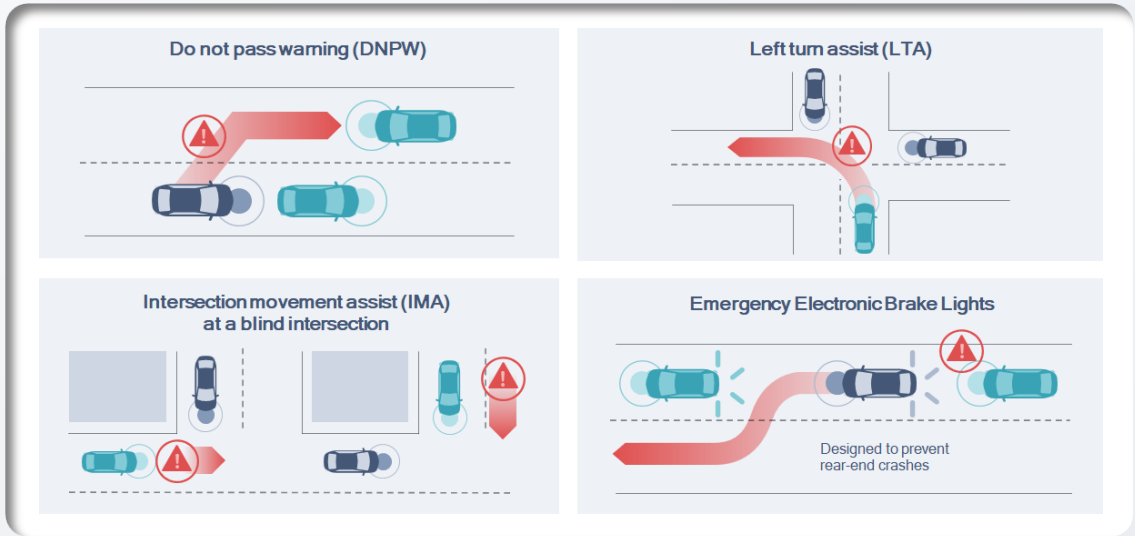
Coordinated driving / intention sharing

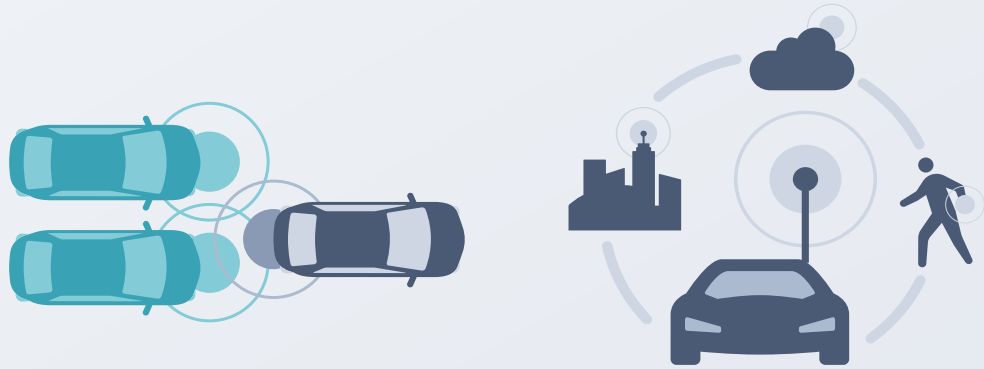
Exchanging intention and sensor data for more predictable, coordinated autonomous driving

Real-time infrastructure updates

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

C-V2X Direct Communication important to connected and automated vehicles (CAVs)

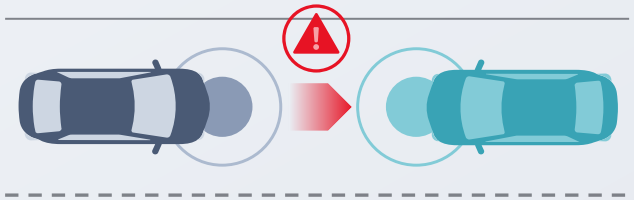




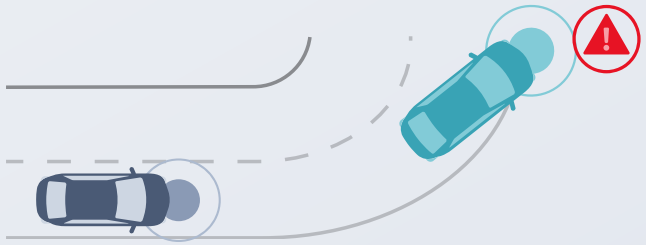
Assist autonomous driving use cases

Basic and enhanced safety

Established foundation for V2X



Enhanced range and reliability

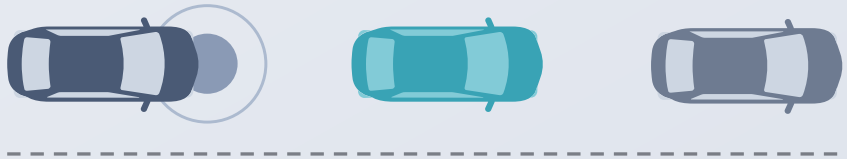


Real-time local updates

Coordinated driving

Intention/trajectory sharing

Sensor sharing



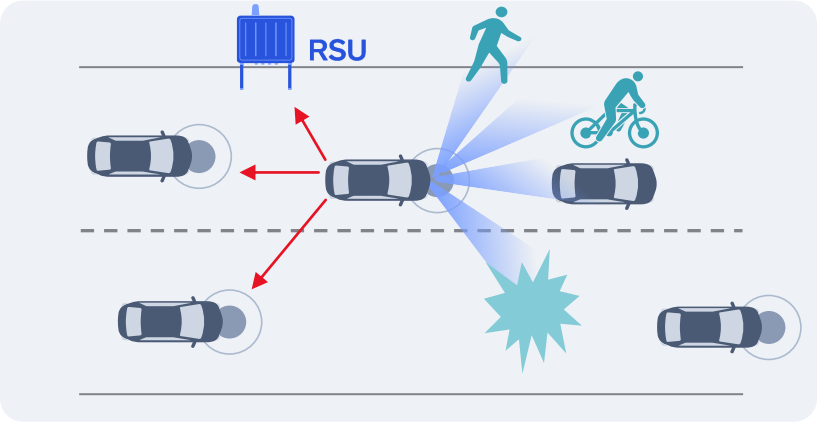
SAE J3224 Sensor Data Sharing Message (SDSM) Overview

Goal: Message standard for situational awareness for RSUs, vehicles, VRUs

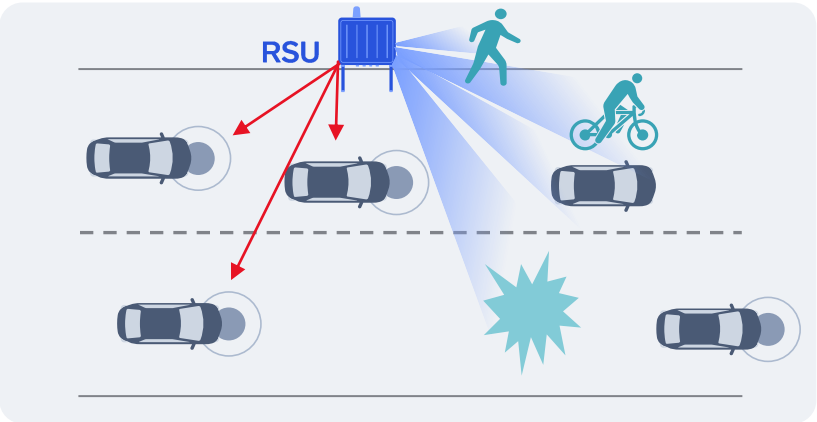
- Disseminate detected road users, obstacles, road impairments to enhance cooperative and automated driving
- Developed by the SAE Advanced Applications Technical Committee

Example scenarios: Vehicle / RSU-based detection of non-V2X vehicles, obstacles, VRUs

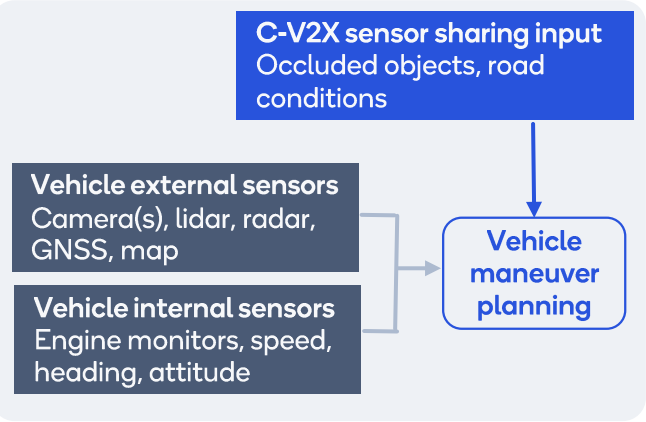
V2V, V2I: VRU, vehicle, obstacle detection
V2X vehicle transmits sensor-sharing message to other V2X vehicles, RSUs



I2V sensor sharing: VRU, vehicle, obstacle detection
RSU transmits sensor-sharing message to other V2X vehicles, RSUs



Sensor Sharing:
vehicle maneuver planning input

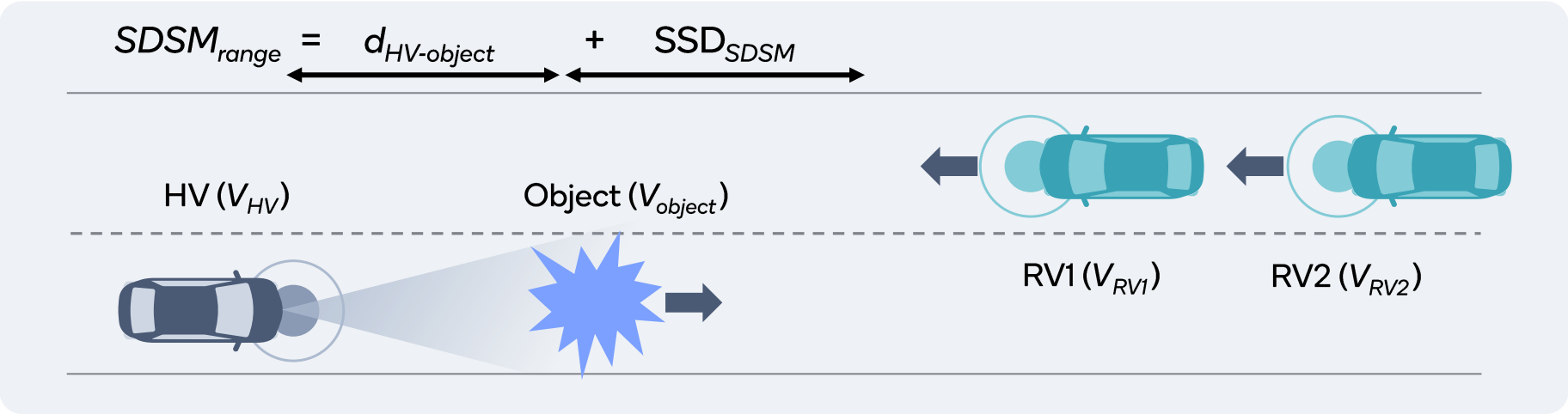


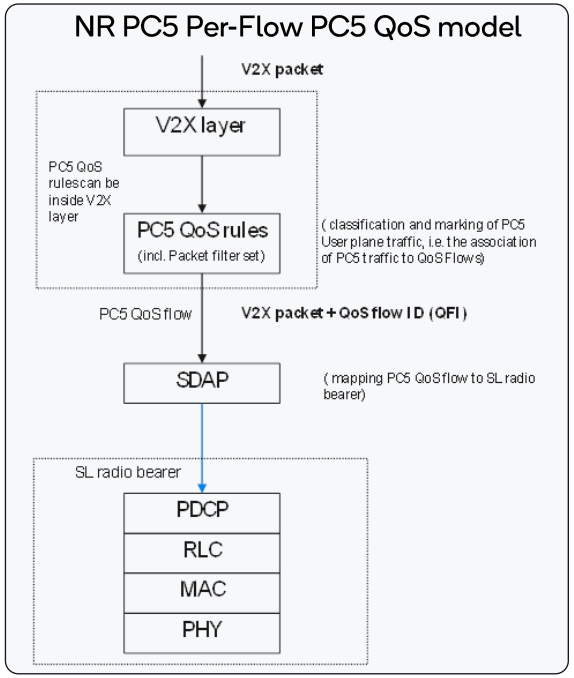
SDSM design principles:

- Message originates from OBUs, RSUs; received by OBUs, RSUs or VRUs
- Message can include one or more detected objects
- Detected objects include vehicles, VRUs, road impairments, objects and obstacles
- Physical-layer independent messaging standard

SDSM QOS Parameter: Range

For maximum benefit, sensor sharing data should be received with sufficient distance for the receiver to react – this distance may be situationally-dependent.





NR V2X QoS enables applications to provide range as QoS input to the lower layer

- Applications may dynamically determine a range based on service and/or application QoS requirements
- J3224 devices may determine a range based on detected object characteristics and detected road/weather conditions

Conclusion: V2X will some day enhance AVs to be CAVs

Thank you

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