C-V2x
Intelligent Transportation Systems

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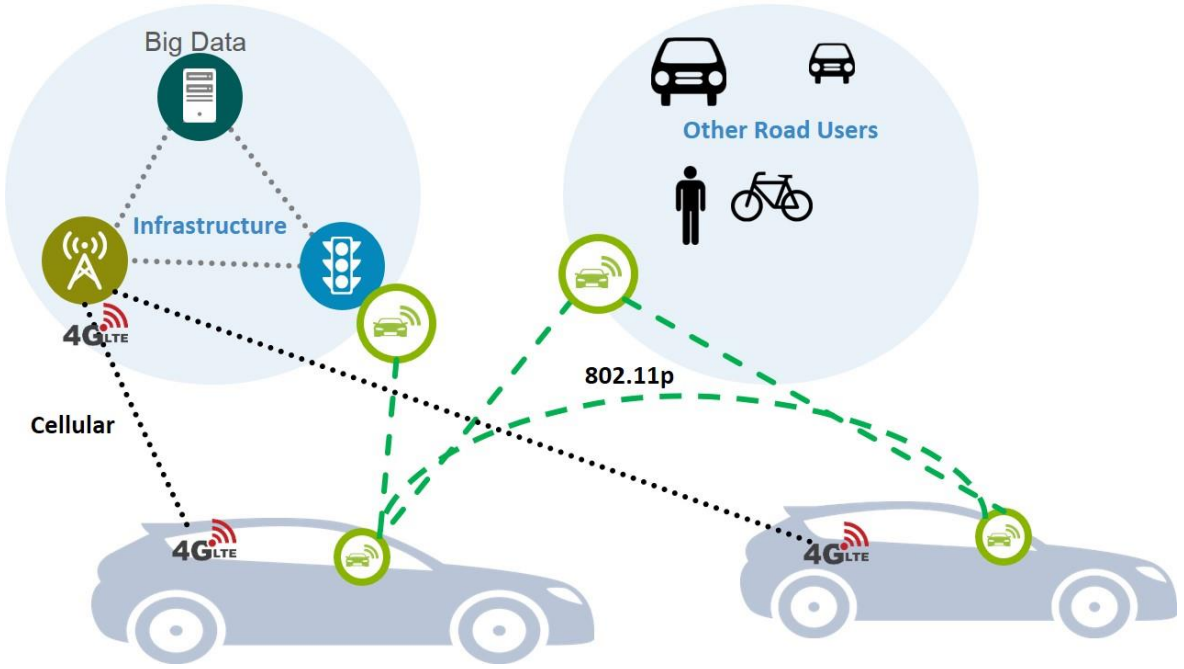
802.11p or C-V2x?

- Requirements for Cooperative ITS systems
  - High relative speeds between transmitters and receivers
  - Extremely low latency in safety-related applications (<50 ms)
  - Tolerate high load generated by periodic transmission of multiple messages, and high vehicle density
  - V2x messages are mostly local in nature, are important for nearby receivers

C-V2x: Cellular Vehicle to Everything

Cellular and IEEE 802.11p for C-ITS



802.11p or C-V2x

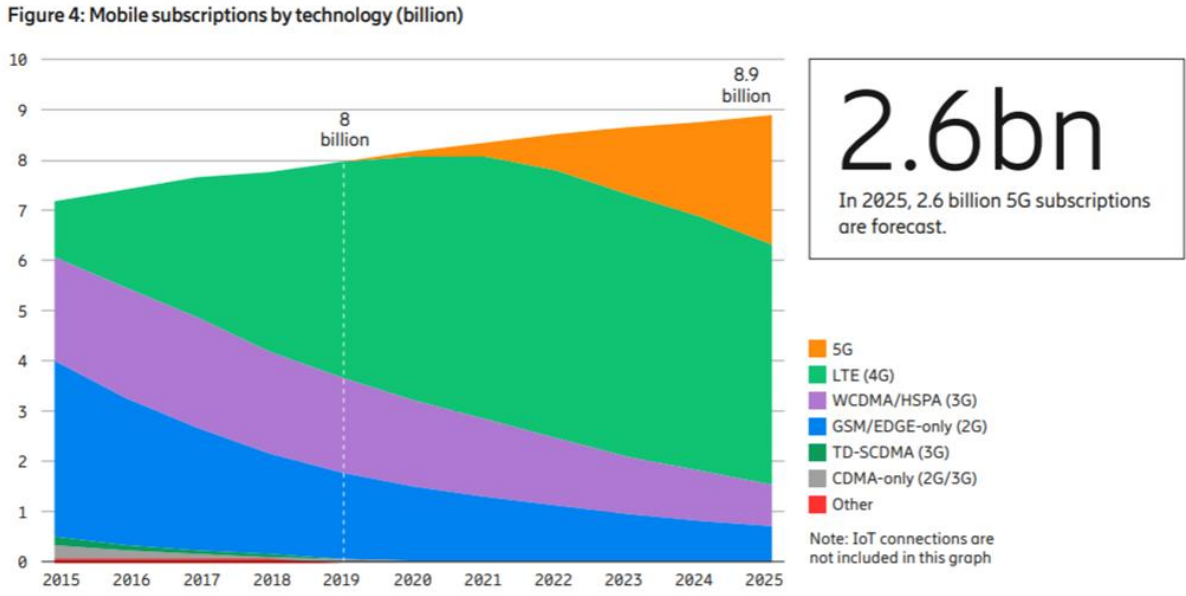
- **802.11p is here today**
  - Standard approved in 2009
  - Several ETSI ITS plug-test events
  - Extensive field trials
    - Safety Pilot, Drive C2X, Score@F, simTD, etc.

- Significant efforts in the last 10 years to validate 802.11p
  - This should be re-done for any other alternative technology

802.11p or C-V2x

- **Some argue that Cellular-V2x is still far out**
- Cellular technology is by far the most successful wireless standard
  - 5.5 billion mobile broadband subscriptions in Q2 2018
- LTE (Rel. 8) dates back to 2009, 5G unde deployment in 2020
  - Extensive cellular infrastructure, it takes time to upgrade
  - ~ 5 billion LTE subscribers still in 2025, next to 2.6 billion 5G subscribers
- LTE Rel. 8. can only address basic ITS use cases
  - No support for low latency and high mobility use cases
  - 3GPP V2x study group established in 2015

Mobile subscriptions worldwide.
Source: Ericsson Mobility Report, November 2019



State of LTE in 2018

- LTE coverage still far from 100%
  - Not geographic coverage, but percentage of time when LTE signal available to users
  - Around 65-68% in Germany, France
  - Extensive 3G infrastructure

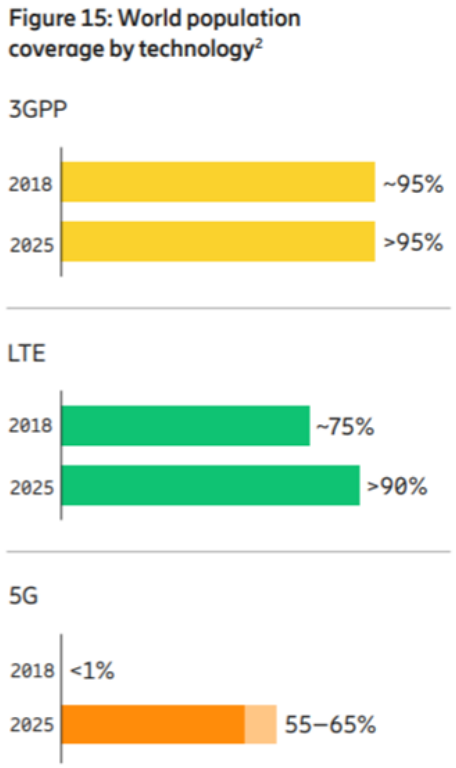
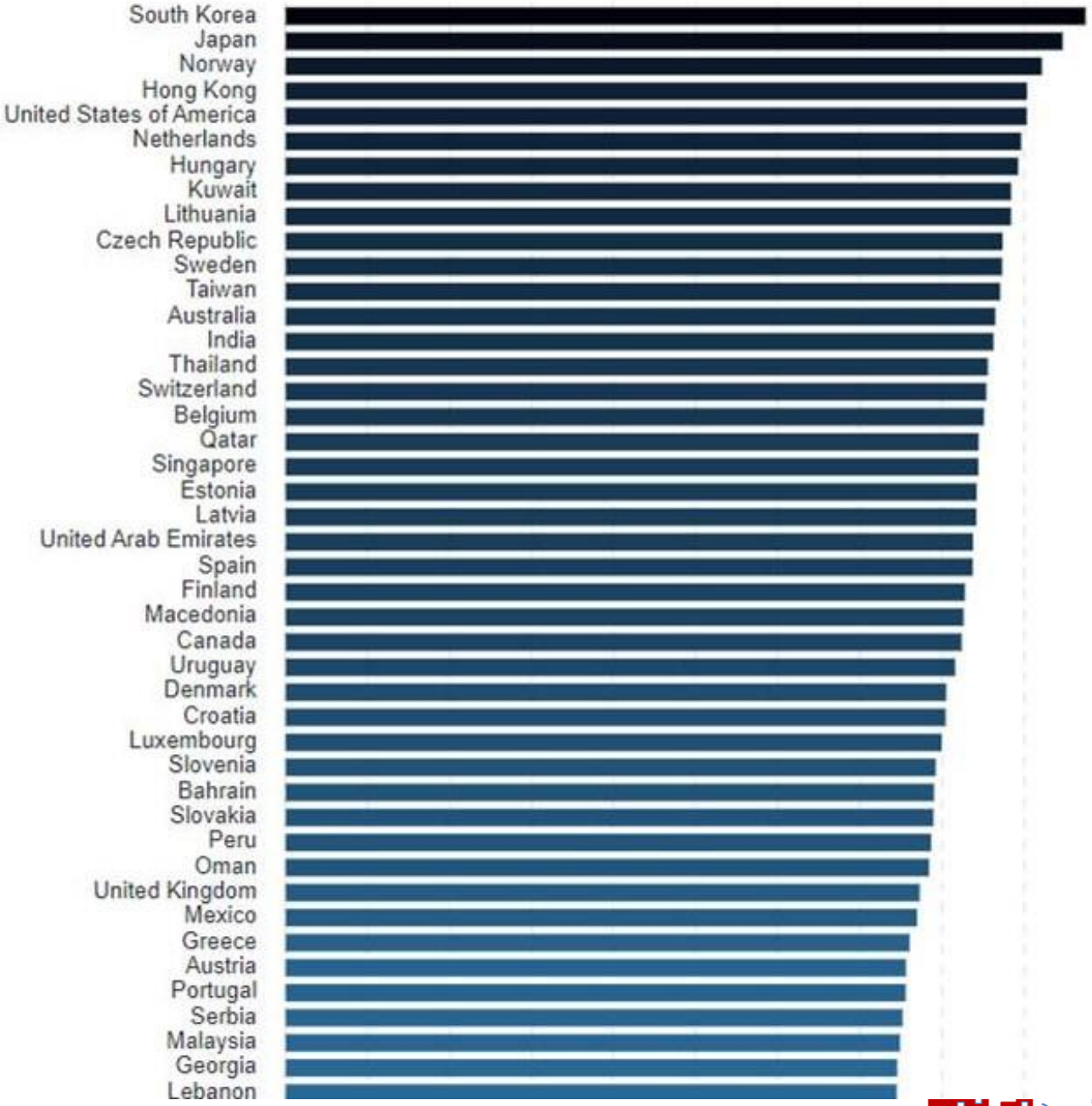


Figure 15: World population coverage by technology[2]



LTE support for V2x applications

- LTE Release 8 can cover most of the V2I – I2V non-safety use cases

- Problem with very congested scenarios
  - evolved Multimedia Broadcast/Multicast Service (eMBMS) in LTE-A (Rel. 9)
    - Designed to support static scenarios – crowds in football stadiums
    - Not efficient when a large number of incoming and outgoing vehicles

- Problems with handovers between MNOs (mobile network operators) and cooperation between application service providers

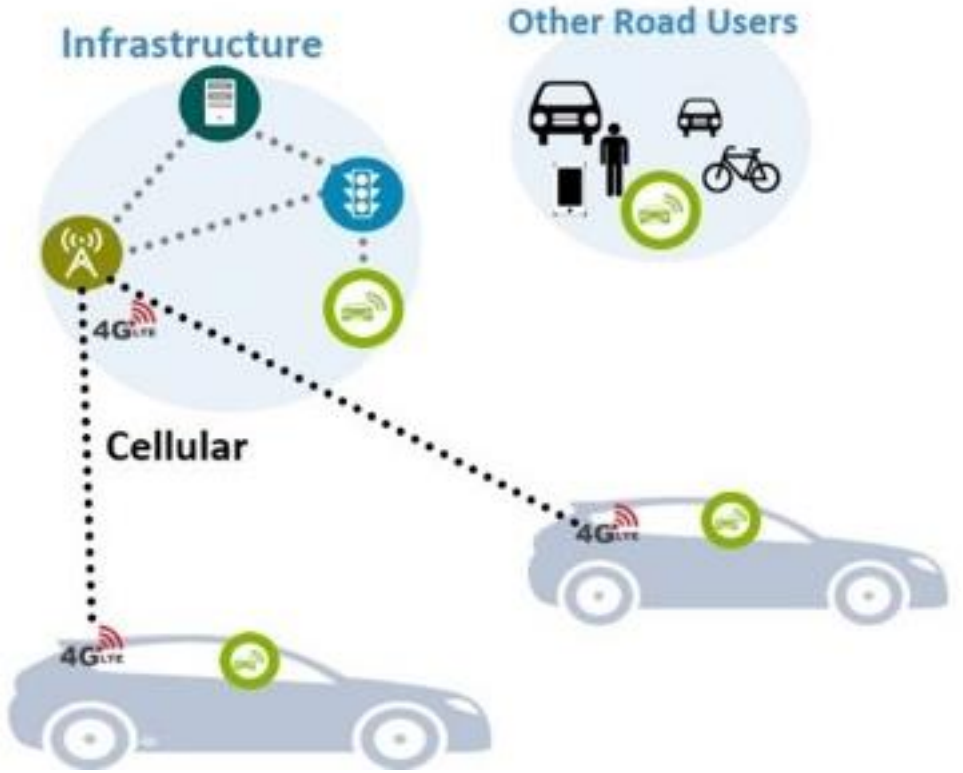
LTE support for V2x applications

- Safety-related use cases represent the real challenge
  - Need complete coverage along the roads (which is not yet the case)
  - Need to handle high bandwidth with very low latency
- Some V2V use-cases require **continuous information exchange** (1 – 20 Hz)
  - **Cooperative Awareness Messages (CAM) - autonomous cars**
  - Too much data for LTE networks to handle
    - **Example: 256 bytes/message, 10 Hz, 2 hours of driving/day = 0.5 Gbyte per month per car**
    - **At the receiver side, assuming 30 cars in the area of interest, roughly 15 Gbytes per month**
    - 1 autonomous car in 2020 – **4 Tbyte per day (generated inside the car, not transmitted entirely)**
- MNOs typically bill based on resources used ($ / bit / s), but V2V traffic should be free
  - Alternative business model to be developed to justify investments

THE COMING FLOOD OF DATA IN AUTONOMOUS VEHICLES

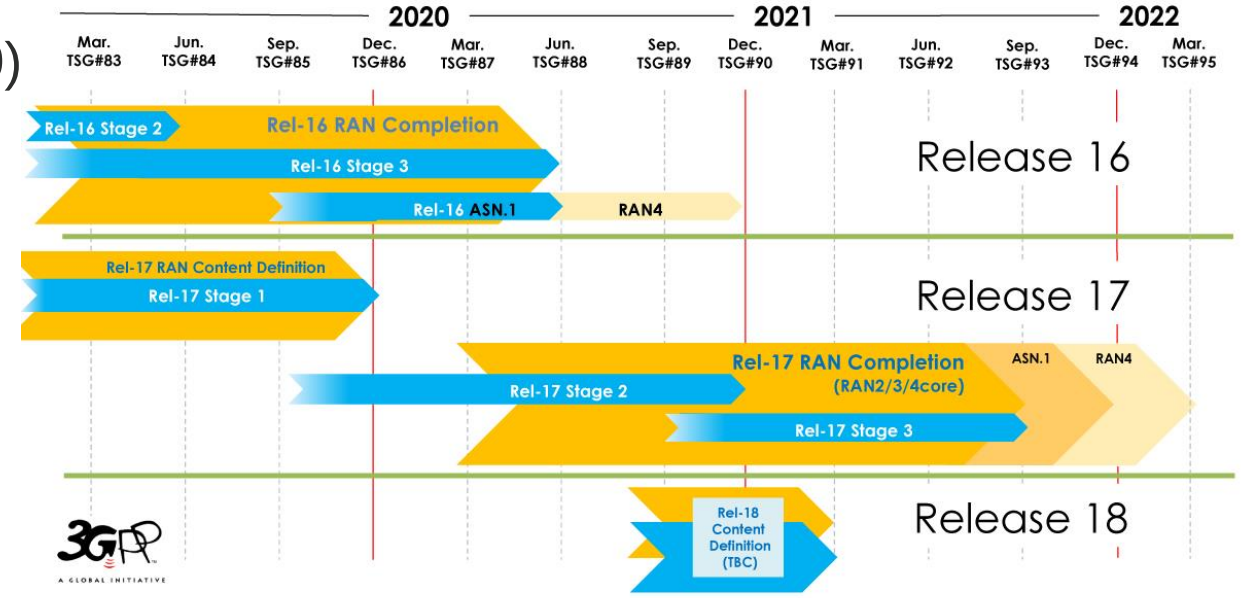
LTE support for V2x applications

- Some V2V use cases do not require high bandwidth, but **very low latency**
  - event-based broadcasting of Decentralized Environmental Notification messages (DENM) – e.g. fast braking
- Could work in the cellular network, but not always
  - Across multiple MNOs, across borders, across cells
- **Another solution: develop direct communication technology, as part of the cellular system**
  - **Device-to-Device** communication, part of Release 12, but not suitable for V2V
    - If two devices want to communicate directly, the network allocates the time / frequency resources
    - The network manages the interference generated by the D2D communication
    - Signalling/control via the eNodeB
    - Direct data sending between the UEs
  - D2D will not work if no continuous network coverage



C-V2x evolution

- LTE-D2D – Release 12 (2012)
- C-V2x Phase I– Release 14 (started in 2014, published in 2016)
  - V2V, V2I, V2N support
- C-V2x Phase II – Release 15 (published in 2018)
  - 5G support (called also 5G-V2x)
- C-V2x Phase III – Release 16 (expected for 2020)
  - Enhanced 5G support



Source: 3GPP TSG SA#87e, 17-20 March 2020, e-meeting document SP-200222

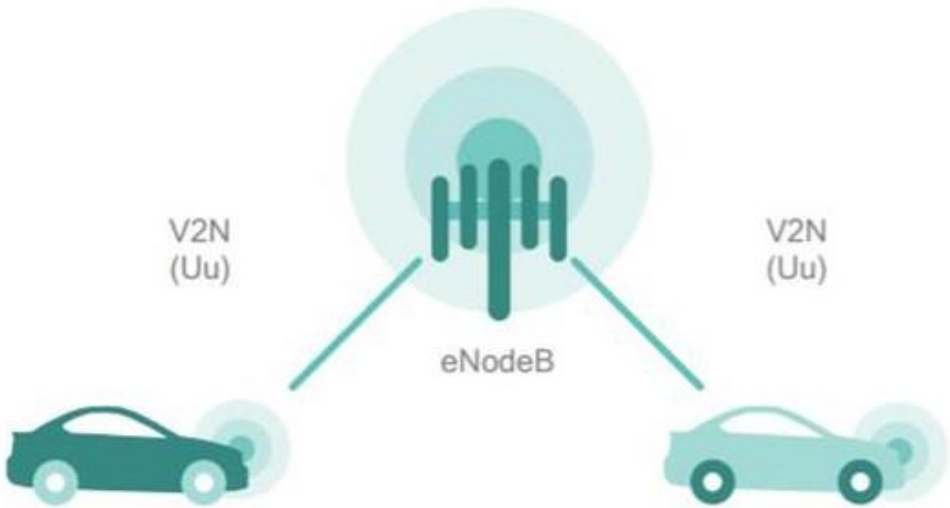
C-V2X defines two complementary transmission modes

Network communications

V2N on “Uu” interface operates in traditional mobile broadband licensed spectrum

Uu interface

e.g. accident 2 kilometer ahead



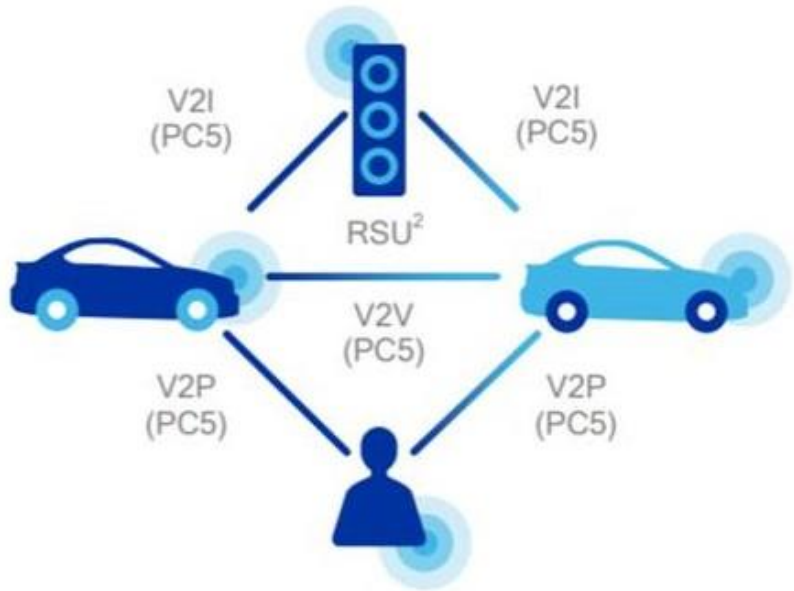
On the traditional cellular spectrum

Direct communications

V2V, V2I, and V2P on “PC5” interface[1], operating in ITS bands (e.g. ITS 5.9 GHz) independent of cellular network

PC5 interface

e.g. location, speed



On 5,9 GHz

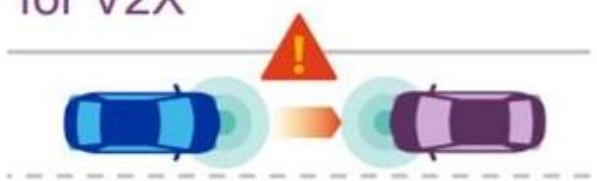
Continuous V2X technology evolution required

And careful spectrum planning to support this evolution

Evolution to 5G,
while maintaining backward compatibility

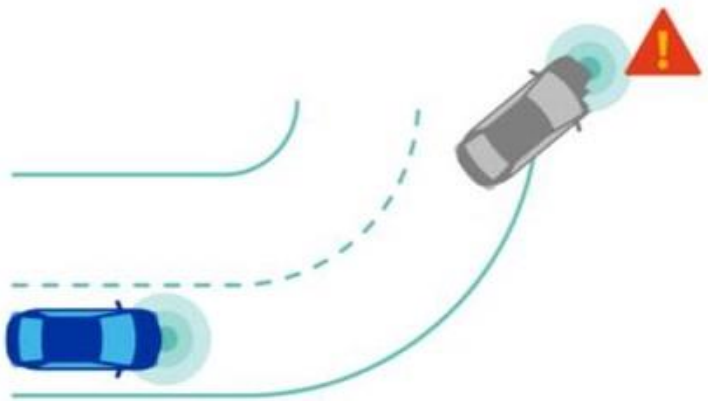
Basic safety
802.11p or C-V2X R14

Established foundation for V2X



Enhanced safety
C-V2X R14/15

Enhanced range and reliability



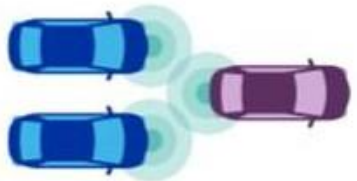
Advanced safety
C-V2X R16 (building upon R14)

Higher throughput

Higher reliability

Wideband ranging and positioning

Lower latency



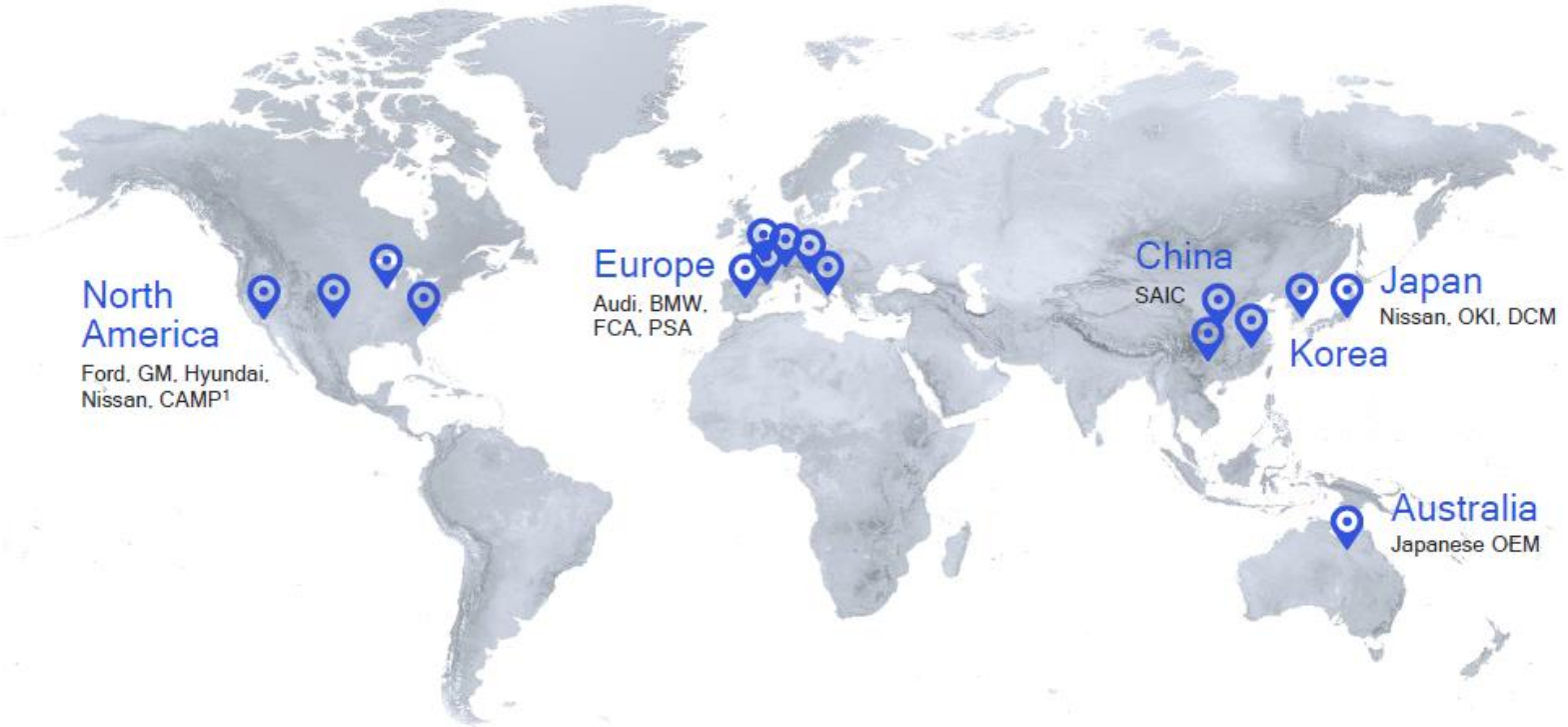
C-V2X

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

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