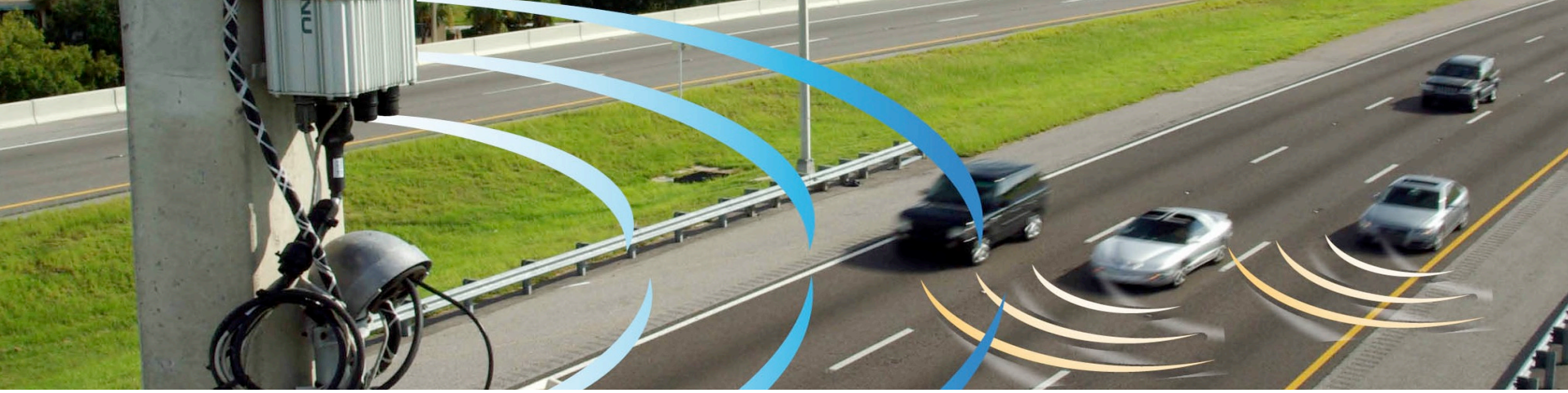


V2X Connectivity Roadmap

Prof. Javier Gozalvez, j.gozalvez@umh.es

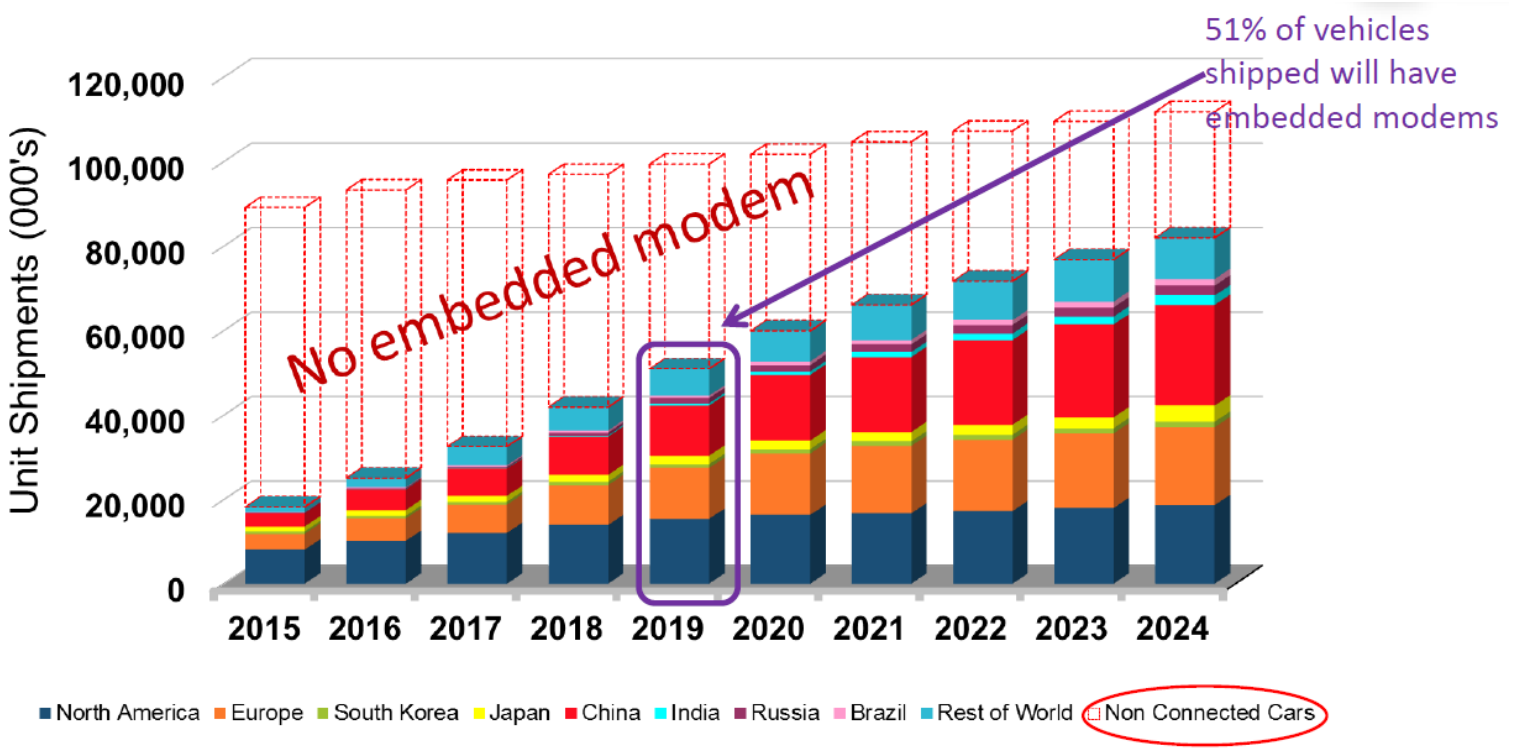
Universidad Miguel Hernández de Elche, Spain

Past President (2016-2017), IEEE Vehicular Technology Society
Editor in Chief, IEEE Vehicular Technology Magazine

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Connected vehicles: a reality

- AT&T: 14.6 millions of connected vehicles in 2Q 2017
- 50% of new mobile connections in 1Q 2017 in USA were for connected vehicles (Chetan Sharma Consulting)

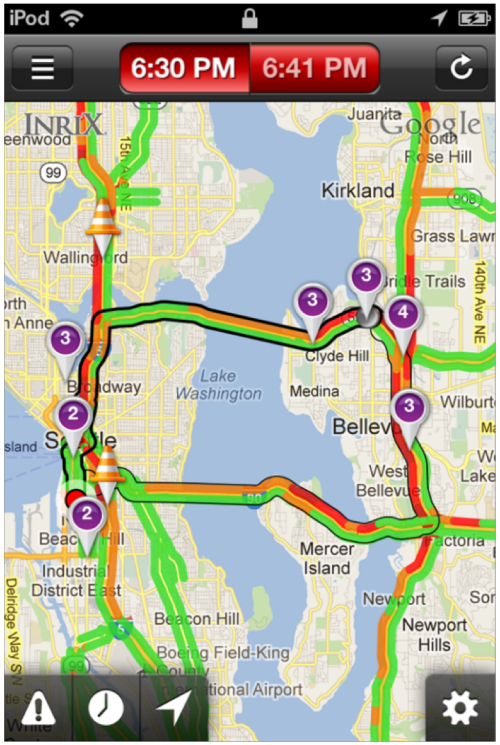


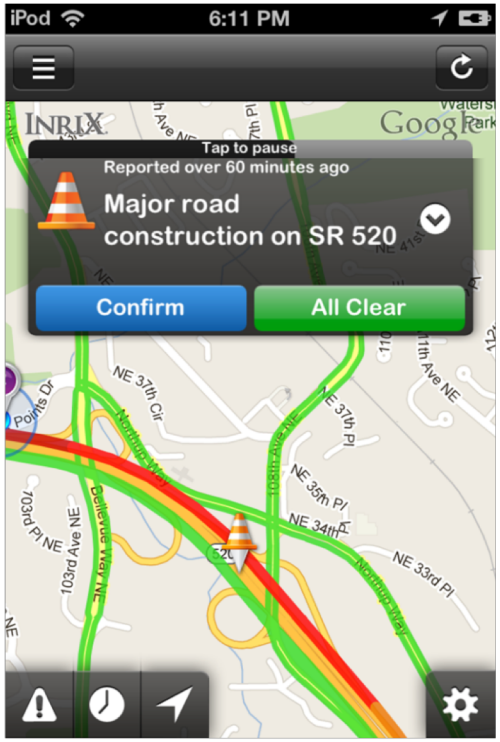
Source: A 5G Perspective on Connecting Cars, Roger C. Lanctot, Strategy Analytics

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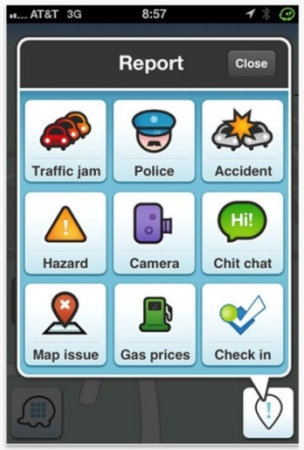
Connected vehicles: a mobile sensor

- Connectivity transforms vehicles into mobile sensors
- Automotive/transportation: 2nd industry in terms of data generation
  - Data will generate more revenues than selling a car (KPMG)









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Software Over The Air updates

- New business opportunities



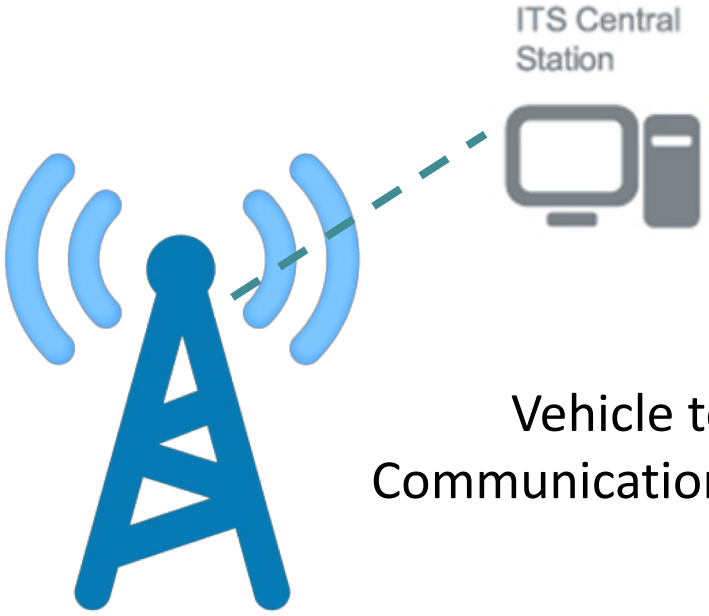
- Vehicles: between 100 and 200 million lines of code
  - Software reliability is a major concern
  - 15% of vehicle recalls in 2015 were software related (SRS)
- Software recalls: Over The Air (OTA) updates

Connected Vehicles 2.0

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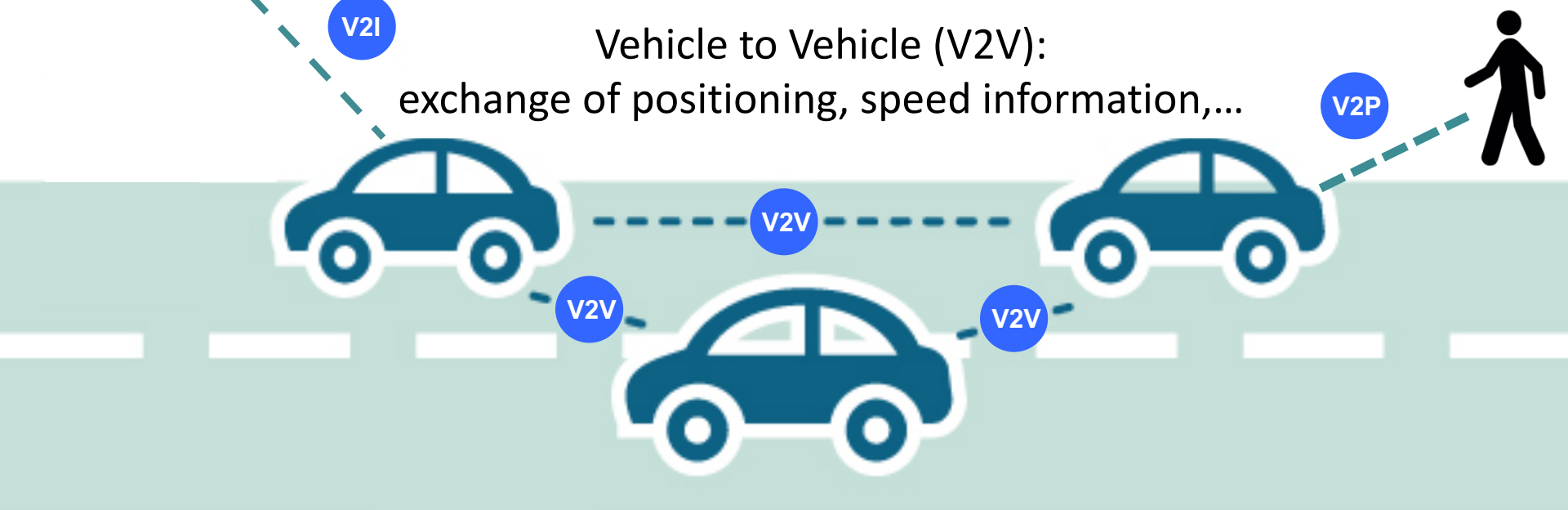
Vehicle to everything communications



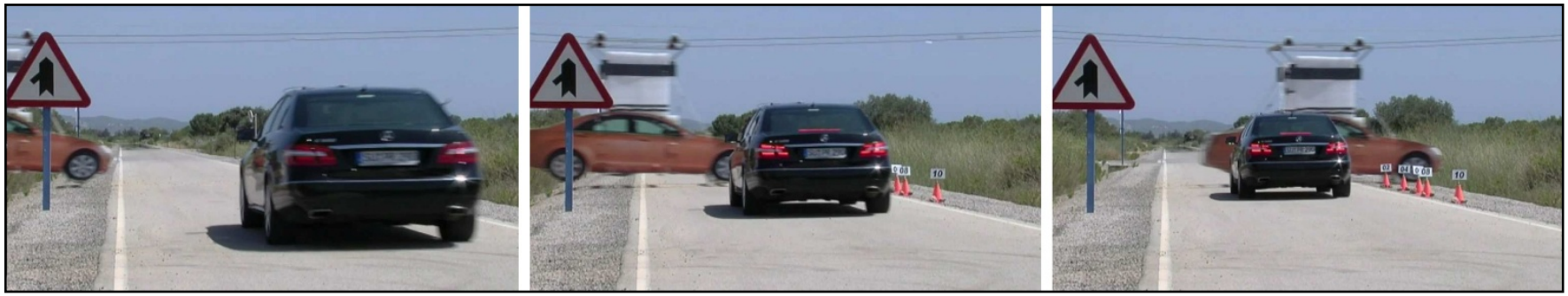
Cooperative C-ITS systems
V2X communications

Vehicle to Infrastructure (V2I)
Communication with infrastructure nodes

Vehicle to Vehicle (V2V):
exchange of positioning, speed information,…

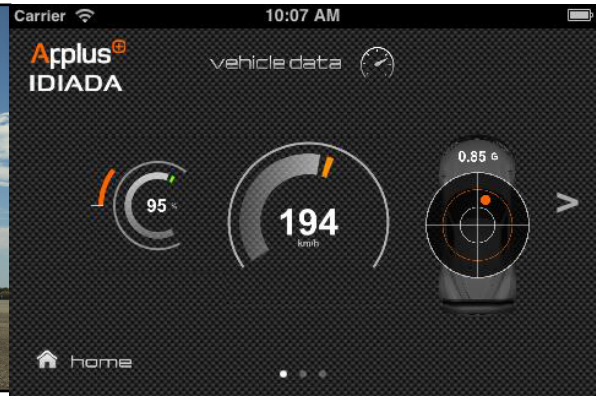


V2X Day 1 Applications









M. Sepulcre, J. Gozalvez, and J. Hernandez, "Cooperative vehicle-to-vehicle active safety testing under challenging conditions", *Transportation Research Part C: Emerging Technologies*, vol. 26, pp. 233-255, Jan. 2013.

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V2X Day 1 Applications



GLOSA – Green Light Optimal Speed Advisory

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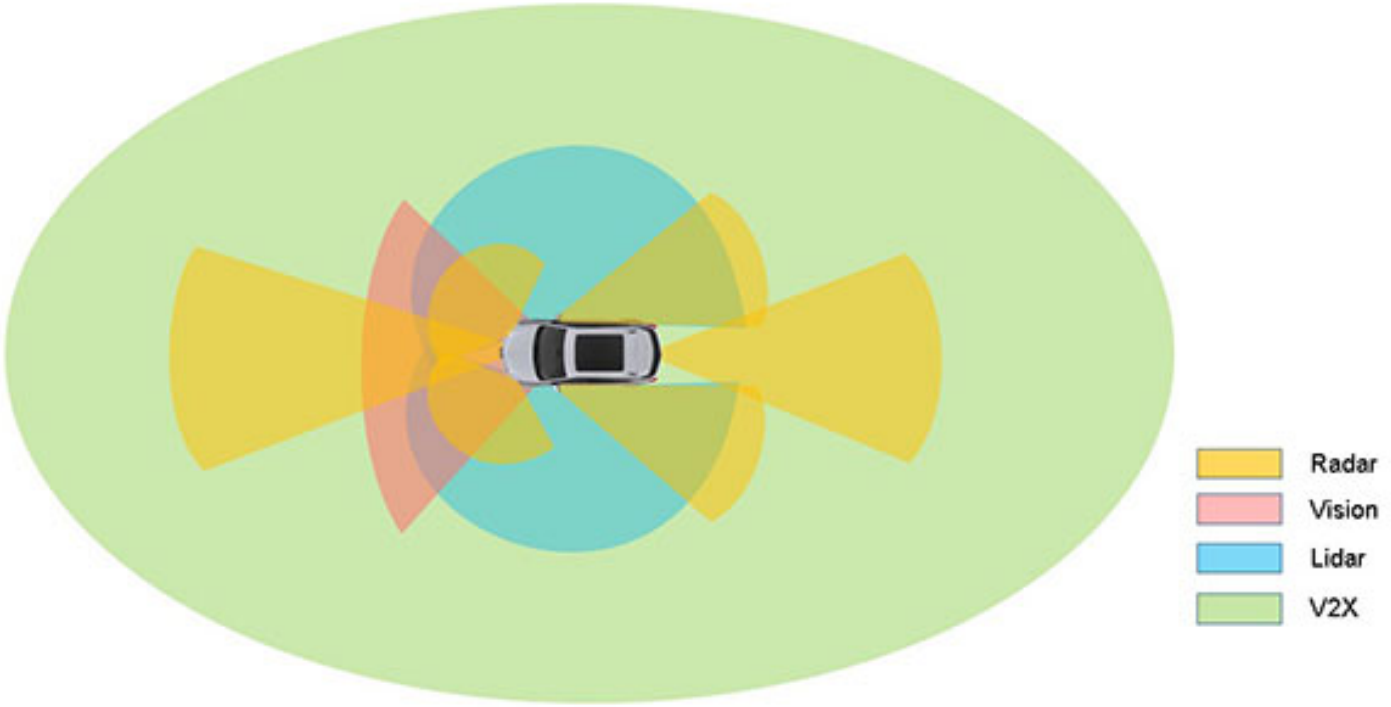
Connected Automated Vehicles

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V2X = ADAS

- V2X will complement existing sensors
  - V2X: part of a vehicle Active Safety Driver Assistance System

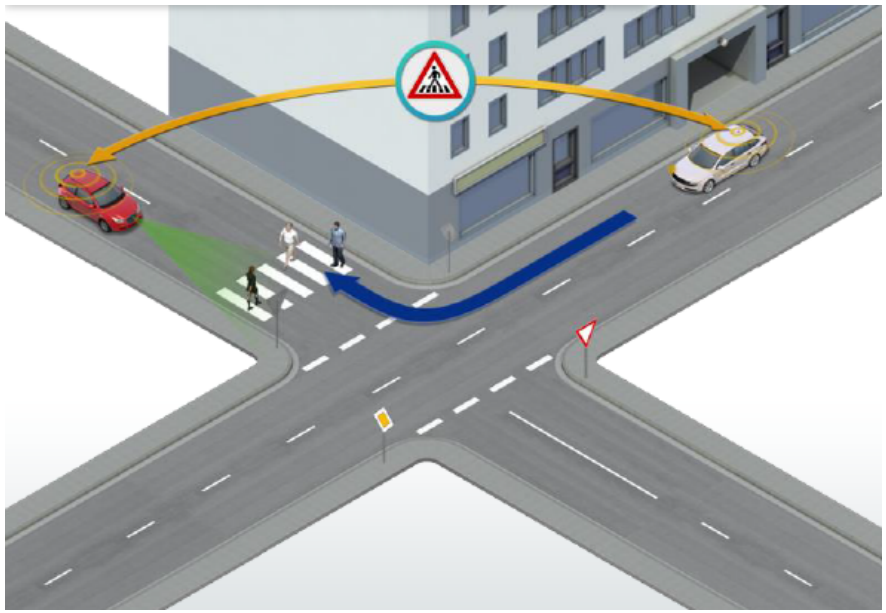


Source: RENESAS Electronics America Inc.

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Cooperative perception

- V2X allows vehicles exchanging data about detected objects
  - V2X provides additional information beyond what can be sensed directly by onboard sensors



Vulnerable Road Users warning

Cooperative driving

- V2X facilitates communicating planned maneuvers
  - Rather than having to infer them indirectly from observed actions
  - Reduces misunderstandings about intended maneuvers





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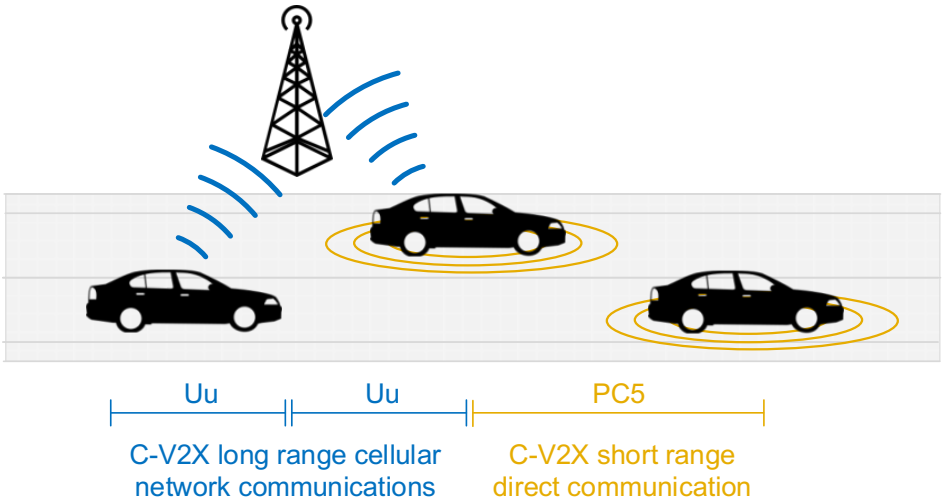
V2X Connectivity Today

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V2X Standards

- 1st international standard for V2X communications
  - Adaptation of WiFi to vehicular environments
    - IEEE 802.11p: evolution of IEEE 802.11a
  - ETSI ITS-G5 (EU), DSRC/IEEE WAVE (US), ARIB T109 (Japan)
- 1st cellular-based C-V2X standard: 3GPP Release 14



- Network communications (V2I): uu interface
- Sidelink or direct communications (V2V): PC5 interface

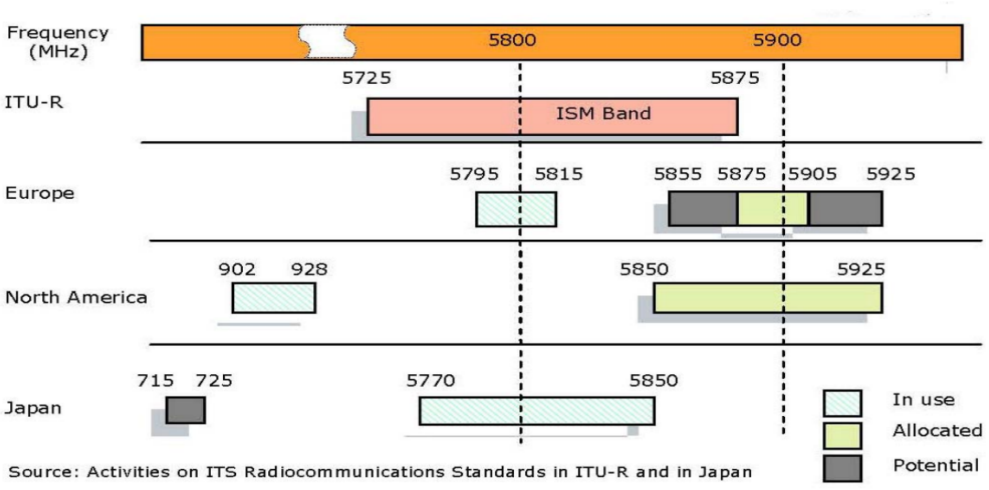
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802.11p vs C-V2X

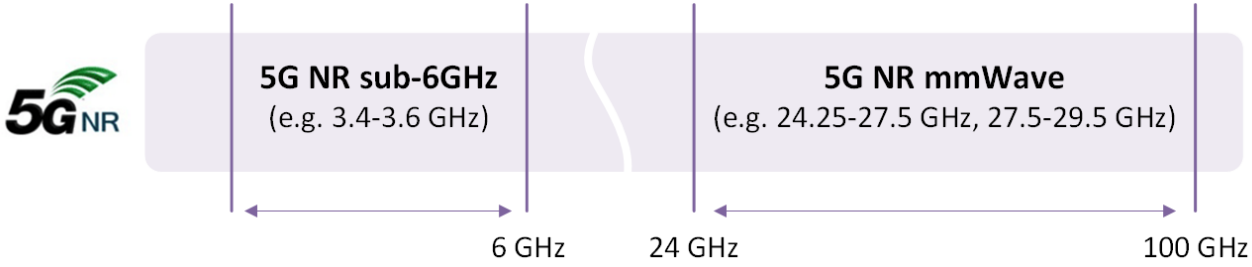
- Worldwide deployment plans
  - 802.11p a reality: ~120,000 units sold as of May 2018 (IHS Markit)
    - 1st Toyota cars since end of 2015 (Japan)
    - GM Cadillac CTS units from 2017
    - Scheduled in Europe in 2019
  - C-V2X chipsets available since 2018
    - In-vehicle commercial deployment from 2020 (source 5GAA)

V2X Standards

- Multi-channel operation at the 5.9GHz band



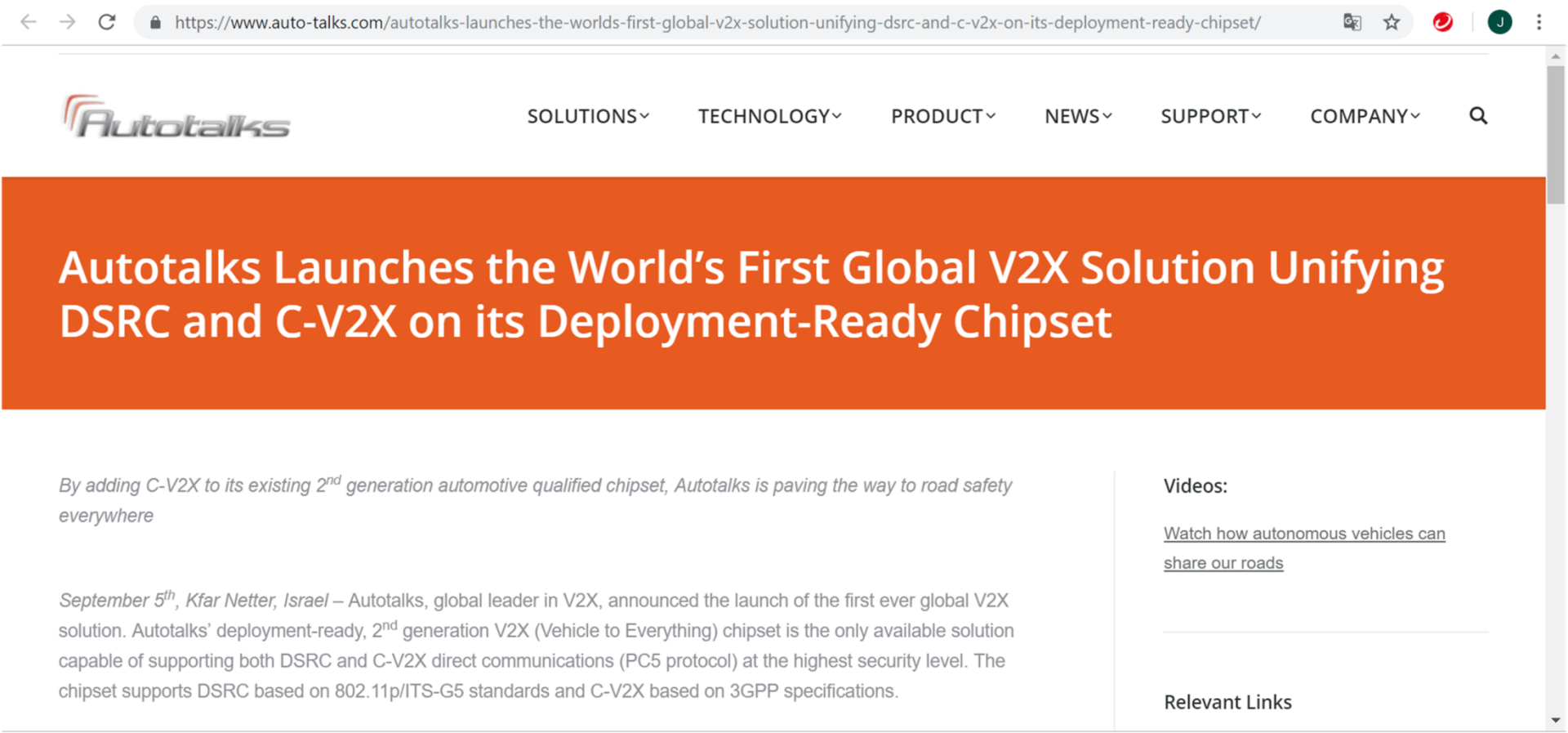
  - FCC in USA: unlicensed devices sharing DSRC (ITS) spectrum
  - Spectrum neutrality in Europe: how can they co-exist?



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802.11p vs C-V2X

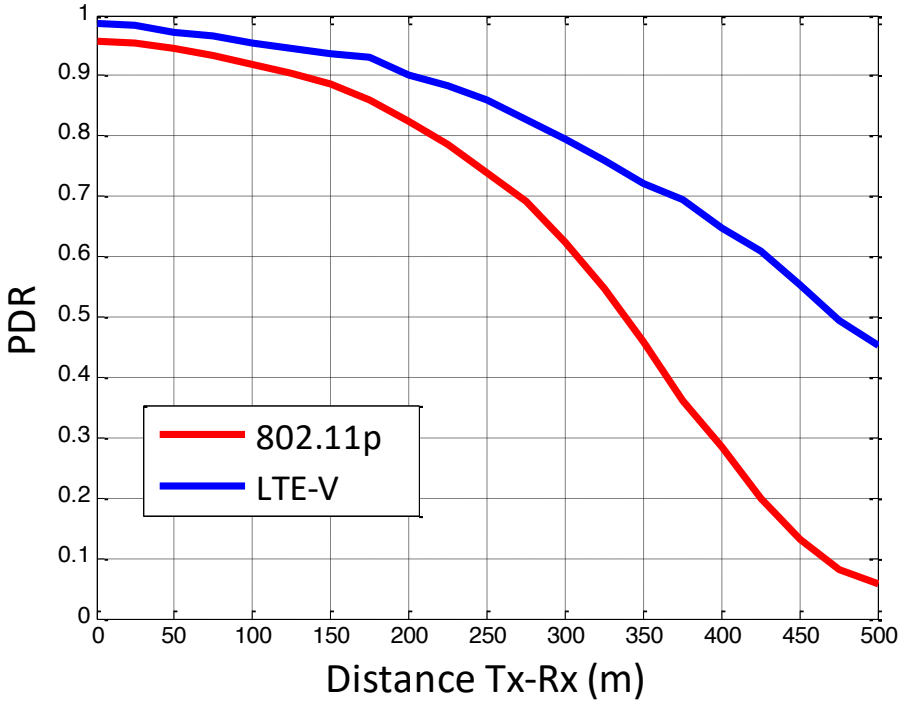


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802.11p vs C-V2X

- C-V2X vs 802.11p at system/network level
  - Highway scenario with 6 lanes & 120 vehicles/km
    - Beacon packets every 100ms, 6Mbps data rate, 23dBm tx power



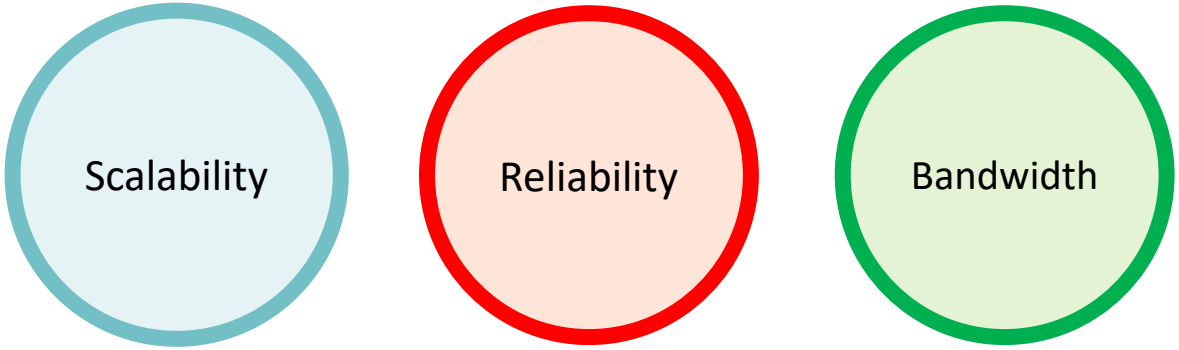
R. Molina-Masegosa, J. Gozalvez, "LTE-V for Sidelink 5G V2X Vehicular Communications: A New 5G Technology for Short-Range Vehicle-to-Everything Communications", IEEE Vehicular Technology Magazine, vol. 12, no. 4, pp. 30-39, Dec. 2017.

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802.11p vs C-V2X

- eV2X and connected automated driving
  - Cooperative perception/sensing, cooperative driving

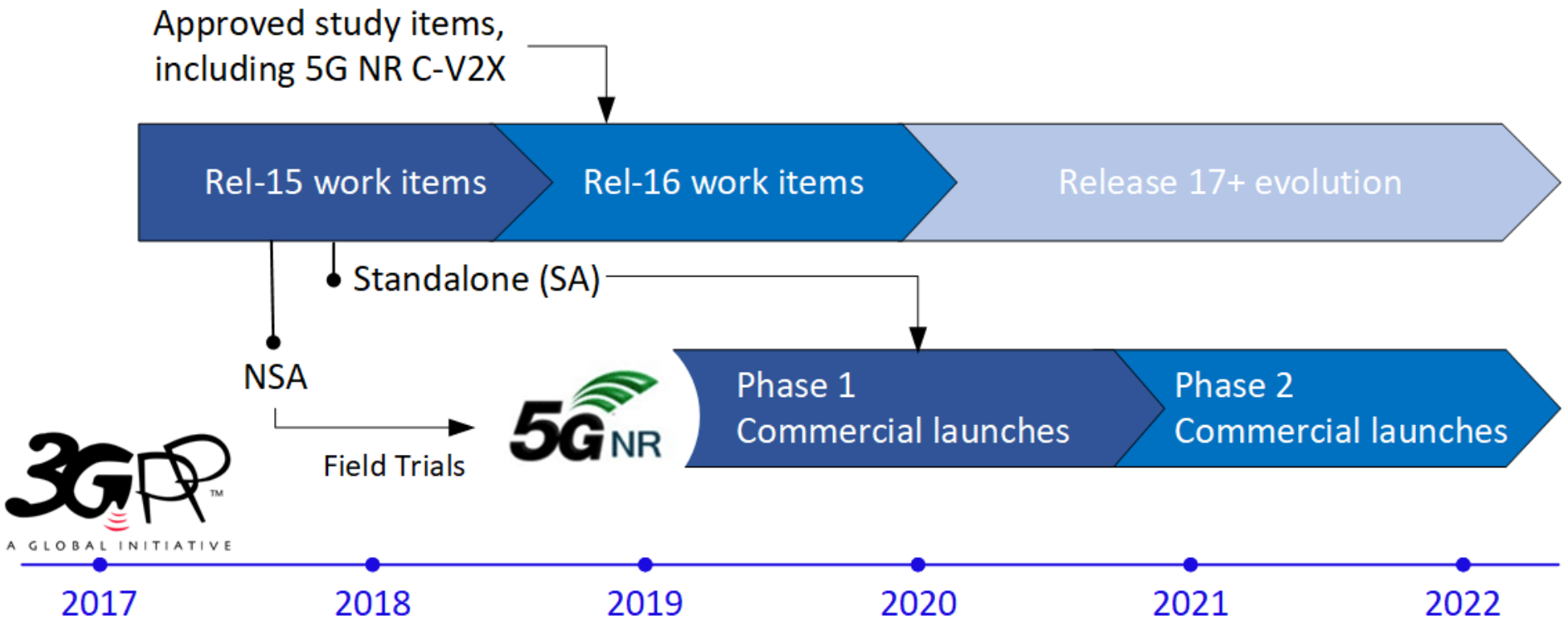


V2X Connectivity Roadmap

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5G NR V2X



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IEEE 802.11 NGV

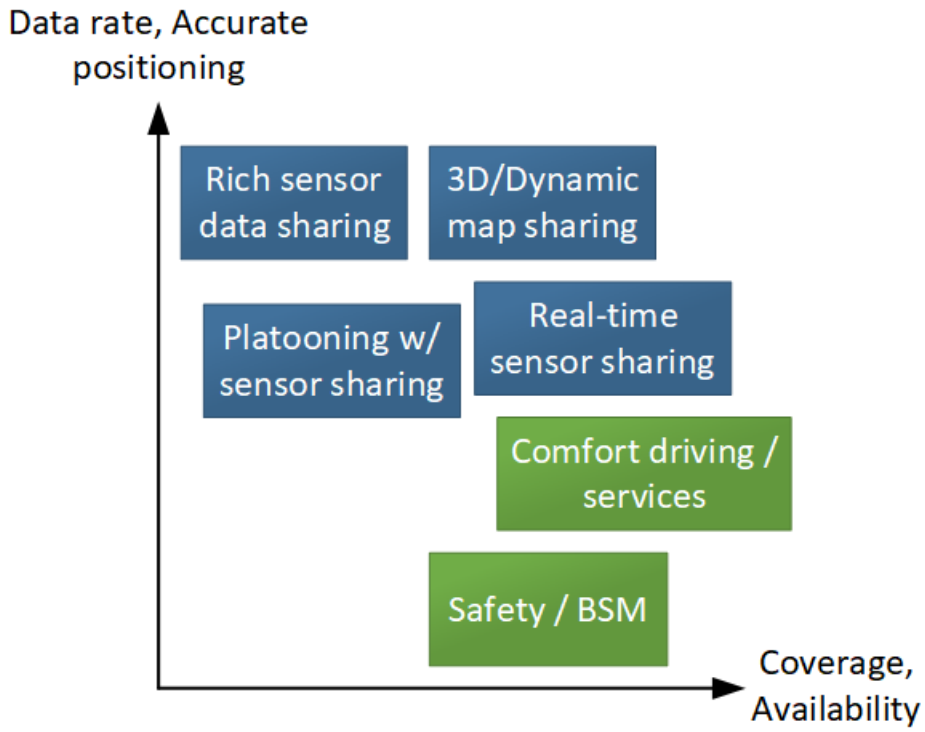
- IEEE 802.11 Next Generation V2X Study Group Project Authorization Request
  - "This amendment shall provide **interoperability**, **coexistence**, backward compatibility, and fairness with deployed OCB (Outside the Context of a BSS) devices."
  - "This amendment defines **modifications** to both the IEEE 802.11 Medium Access Control layer (**MAC**) and Physical Layers (**PHY**) for vehicle to everything (V2X) communications for **5.9 GHz band** as defined in clauses E.2.3 and E.2.4 of IEEE Std 802.11™-2016; and, **optionally**, in the **60 GHz frequency band** (57 GHz to 71 GHz) as defined in clause E.1 of IEEE Std 802.11™-2016."

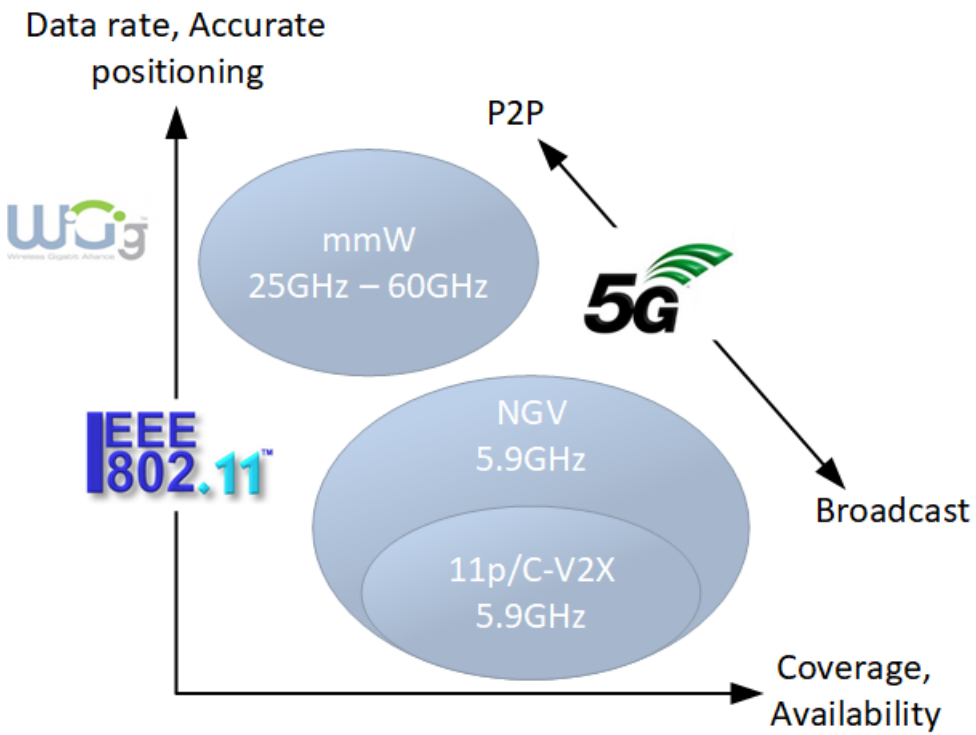
802.11 NGV Proposed PAR, IEEE P802.11 Wireless LANs, doc.: IEEE 802.11-18/0861r8, Sept 2018

mmWave for V2X

- mmWave (>30GHz): support enhanced V2X (eV2X) services demanding higher data rates
- mmWave is widely used for automotive RADAR
  - EU: 63-64 GHz allocated for ITS applications
  - Proposals for joint radar/communication system at 60GHz
- mmWave: candidate technologies
  - 5G mmWave cellular (New Radio)
  - IEEE 802.11ad

V2X Roadmap


Data rate, Accurate positioning
Rich sensor data sharing
3D/Dynamic map sharing
Platooning w/ sensor sharing
Real-time sensor sharing
Comfort driving / services
Safety / BSM
Coverage, Availability


Data rate, Accurate positioning
P2P
mmW
25GHz – 60GHz
5G
NGV
5.9GHz
11p/C-V2X
5.9GHz
Broadcast
Coverage, Availability

Vehicle as a Smartphone



Thank you for your attention!

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Horizon 2020 Programme

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