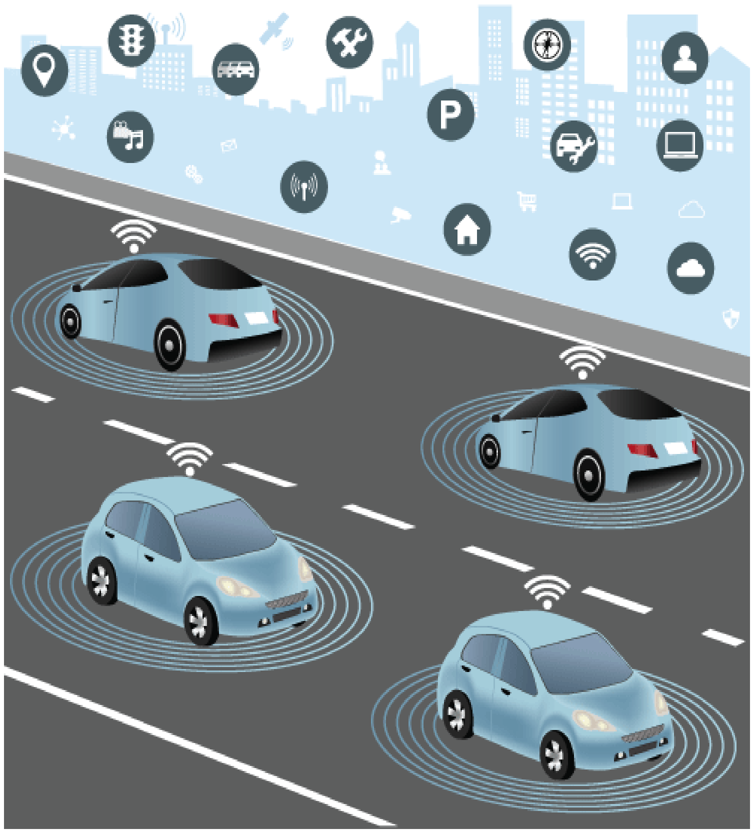

Connected Vehicles: A Component in the Transformation to Smart Cities

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Introduction

- Era of explosive growth of multimedia applications and services
- Onset of autonomous vehicular technology
- Limited spectrum resources demand smart spectrum management
- Communication establishment among autonomous vehicles for sustained long periods with very little delay poses a formidable challenge.
- The talk introduces the audience to:
  - An overview of the standards for connected vehicles and their evolution
  - Security mechanisms, trust management, privacy management
  - A view of the ongoing academic research
  - Advanced use cases

Problem Identification

- Limited navigation system, especially in remote places
- Loss of cellular coverage
- Traffic congestions
  - Cost U.S. Drivers ~ $300 Billion in 2016
  - $1,400 per driver on average
  - Drivers spend, on the average 42 Hours a year in traffic during peak hours

Problem Identification

- In 2010, Traffic accidents in the U.S. cost $871 billion a year (Source: The Economic and Societal Impact Of Motor Vehicle Crashes, 2010 (Revised), US DOT NHSTA, DOT HS 812 013, May 2015)
  - 33,000 deaths
  - 3.9 million injured
  - 24 million vehicles damaged
  - 20% increase in cost over that in 2000
- In 2020, Estimated cost is $1 Trillion, assuming 20% increase in cost over that in 2010

Outline

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- Introduction
- C-V2X – Status, Impact, Use Cases
- Spectrum Issues
- Security and Privacy in Connected Vehicles
- Cyber Security Issues Relevant to Connected Vehicles
- Current Research Relevant to Connected Vehicles
- Conclusions

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Objectives

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- WWRF VIP CV White Paper
  - OULOOK 25, OCT. 2019, Distributed during WWRF Meeting ‘43 in London, UK
  - Assembles contributions from twelve authors
- Objectives are to:
  - Create a better understanding in the automotive industries of the potential and capabilities of future wireless technologies
  - Enable the telecom and automotive industries to jointly discuss the vision, usage scenarios, requirements and enabling technologies to achieve the targets of future vertical industry communications in 5G and beyond
  - Assemble current research in academia relevant to connected vehicles
  - Illustrate use cases that will provide insight into the gaps that exist in the evolving standards
  - Contribute to the evolution towards autonomous and connected vehicles

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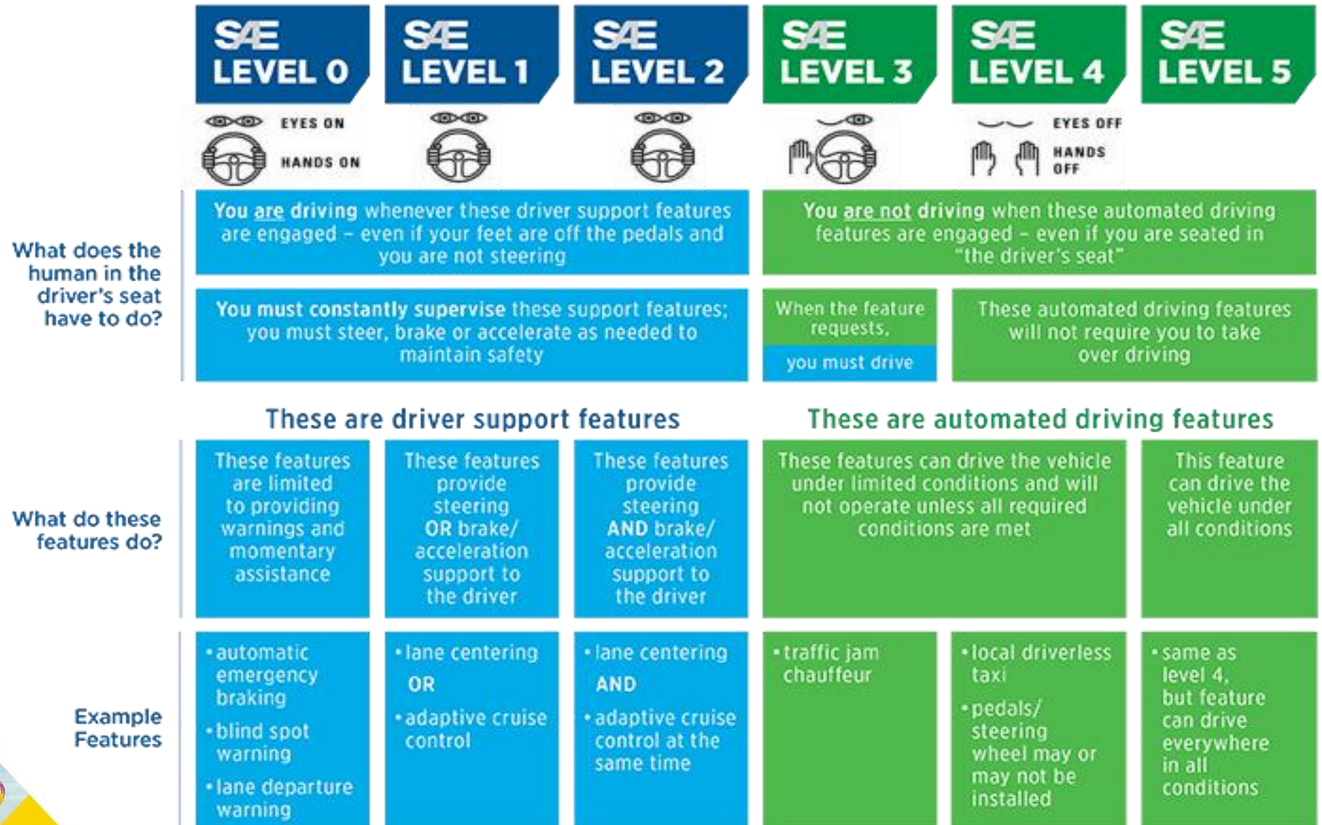
SAE Levels 0-5: Evolving to Automated Driving



Source: SAE International Release update (11.12.2018)

Dedicated Short Range Communications (DSRC), IEEE 802.11p, WAVE

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- DSRC based on IEEE 802.11p
- 75 MHz band at 5.9 GHz
- Provides low latency
  - 2 ms delay
- Range - 1000 m
- Limited interference
  - Due to the short range, DSRC is quite robust against interference from distant sources
- Strong performance under adverse conditions

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C-V2X Standard

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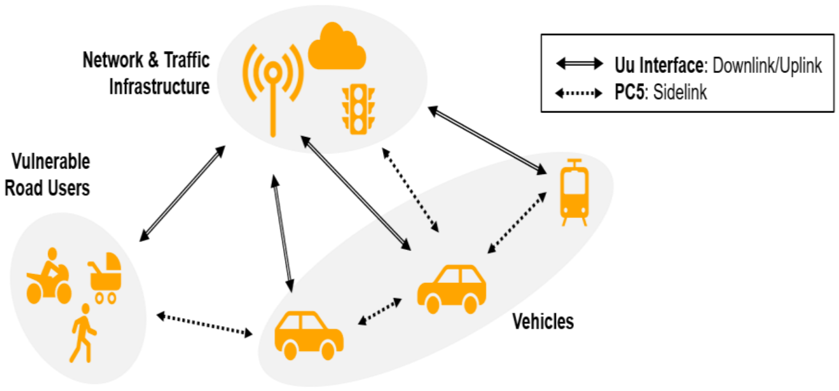
- Formulated in 3GPP REL. 14, 15, and 16.
  - REL. 14 and 15 address LTE C-V2X
  - REL. 16 Addresses 5G C-V2X
- LTE C-V2X Utilizes Two Interfaces
  - Uu (cellular), and
    - Caters to communications between vehicles and the (static) network infrastructure.
  - PC5 (direct peer-to-peer communication)
    - Caters to direct communications among vehicles, road side units, and vulnerable road users without using cellular network infrastructure



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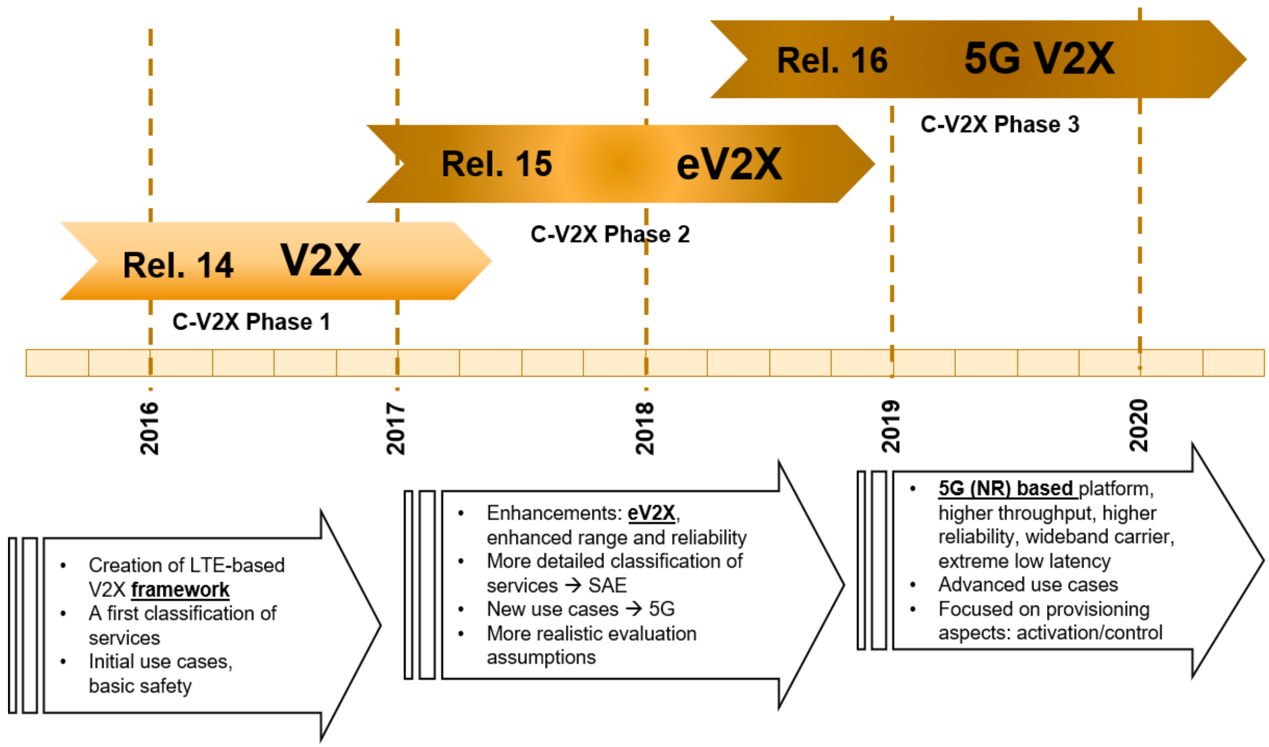
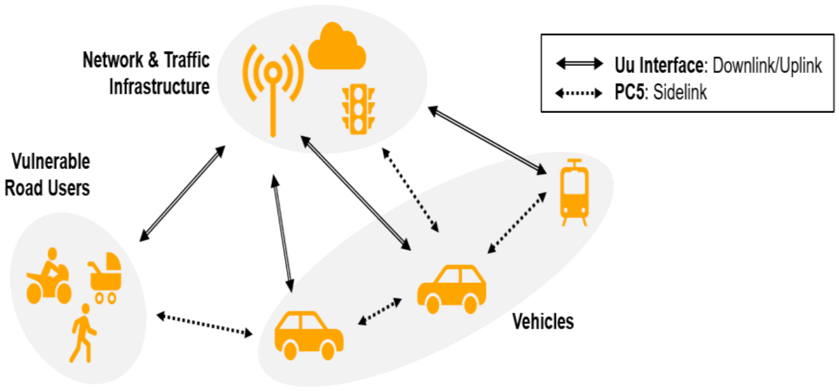
C-V2X Timeline



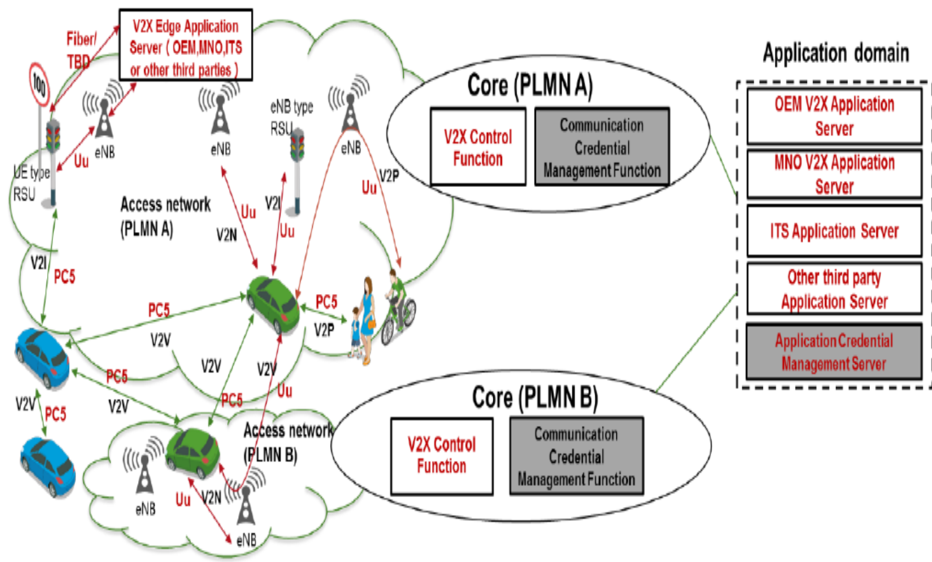
LTE C-V2X: With and Without LTE Coverage

- Support for critical services
  – PC5-based USIM-less communication allows C-V2X to support critical safety services when LTE coverage is unavailable or if the vehicle does not have an active cellular subscription.
- Radio Resource Allocation
  – Uu requires cellular coverage and the base station allocates the radio resources
  – Without cellular coverage, a UE selects resources autonomously from a preconfigured set of resources



LTE C-V2X: Core Network Perspective

- Core Network Architecture
  - Two new functions added
    - V2X Control Function (CF)
    - V2X Application Server (AS)
  - V2X CF and AS Work with other core network functions and UE to provide:
    - authorization/configuration to V2X services, and
    - timely establishment, modification, and termination of existing connections through standardized interfaces and procedures at different levels of the protocol stack



5G C-V2X: RAN Perspective

- Based on New Radio (NR)
- Features discussed include:
  - Evolving Uu interface to support advanced V2X use cases
  - Supporting three different services on the side-link: unicast, groupcast, and broadcast.
  - Enhancing channel feedback, channel state information acquisition, power control schemes, link adaptation, and MIMO transmission schemes.
  - Accomodating the bandwidth part concept introduced for NR.
  - Flexible time-frequency multiplexing of data and control channels.
  - Accommodating a variety of Uu-based resource allocation approaches, including dynamic resource allocation, activation/deactivation (e.g., semi-persistent scheduling), and
  - (pre-)configured.
  - Potential use of different subcarrier spacings and cyclic prefix, but only one at a time.
  - In Rel. 16, at least CP-OFDM will be supported for the side-link.
  - A more accurate, and perhaps proactive, QoS management for C-V2X, based on the framework defined for NR, could be adopted.

LTE C-V2X: Services Perspective

- C-V2X focused on:
  - defining (basic safety/non-safety) use-cases
  - requirements (latency, reliability, message size, message frequency, range, speed)
  - the need to sustain operation in and out of network coverage
  - interworking between UEs of different network operators
  - flexibility (prioritization, range, distribution area, etc.), capacity (high density of UE), energy efficiency, and positioning accuracy.

- Rel. 15 details use cases
  - vehicle platooning
  - advanced driving, extended sensors, remote driving
  - more stringent performance requirements
    - E.g., improved positioning accuracy (0.1m), very high density (4k+ cars/km^2), and UE-enabled relaying for access and discovery.