Information & Communication Technologies
for the Internet-of-Things

Vehicular Networking:

Technologies and Standards

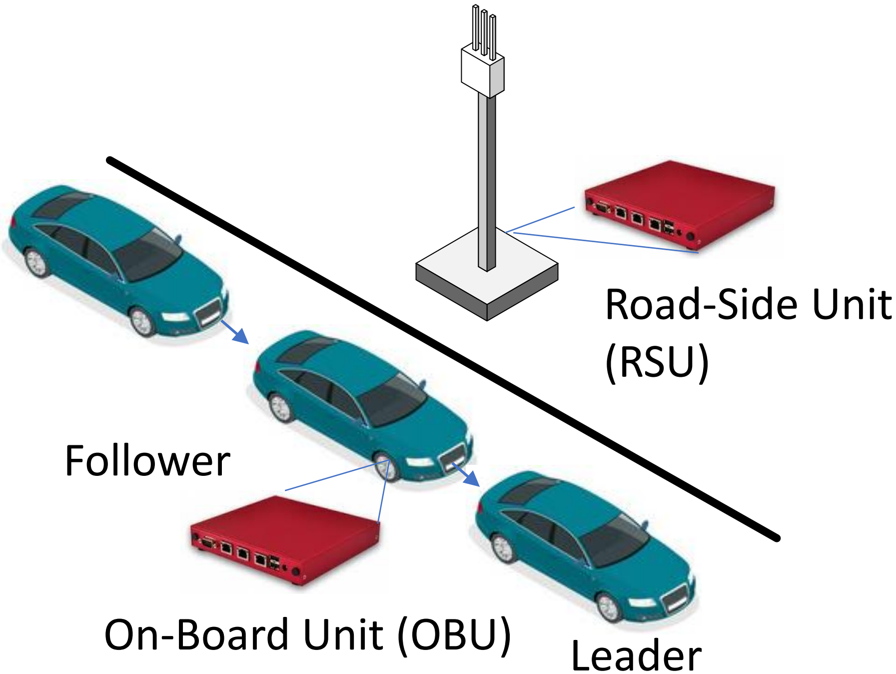
Pedro Santos

Original content.

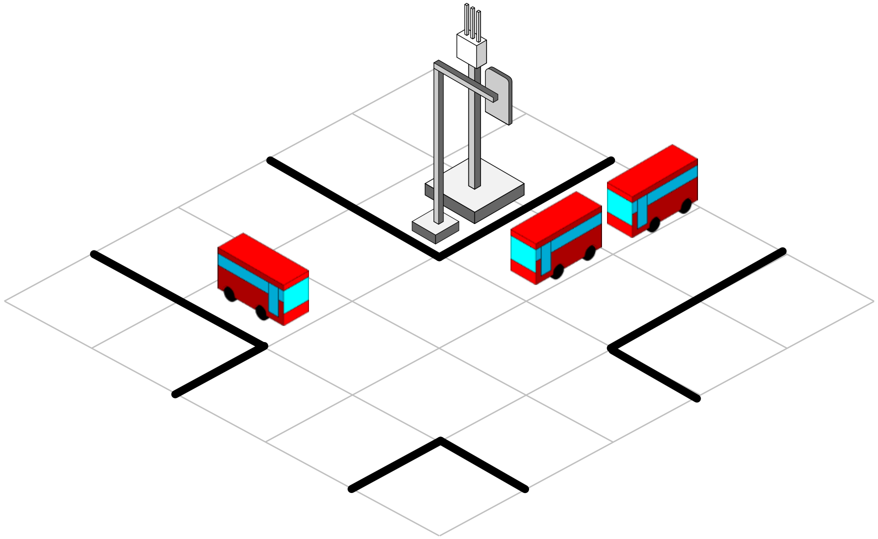
Slides under preparation.

Vehicular Applications

Platooning Application



Intersection Scenario



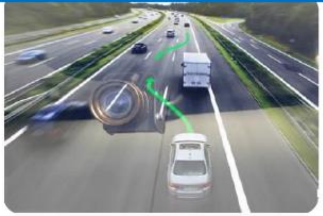
Vehicular Applications

Classes of Scenarios
Cooperative Maneuveurs Cooperative Lane Merge Coordinated, Cooperative Driving Manoeuvre Cooperative Traffic Gap Vehicles Platooning in Steady State Platoon Merging and Dissociation Platoon Security (e.g., member mis-behaviour)
Safety/Emergency Obstructed View Assist / Vehicle Decision Assist Infrastructure Assisted Environment Perception Vehicles Collects Hazard and Road Event for AV Cooperative Manoeuvres of Autonomous Vehicles for Emergency Situations
Intersection Continuous Traffic Flow via Green Lights Coordination Automated Timing Intersection Crossing Group Start (ad hoc platoon to cross intersection)
Lane/Area Management Tunnel Coordination Cooperative Curbside Management Cooperative Lateral Parking (?) Bus Lane Sharing Request Bus Lane Sharing Revocation
Infotainment and Situational Awareness Adjustment to road conditions High-Definition Map Collecting and Sharing Awareness Confirmation Autonomous Vehicle Disengagement Report (Release of disengagement report)
Tele-Operation Tele-Operated Driving Tele-Operated Driving Support Tele-Operated Driving for Automated Parking Remote Automated Driving Cancellation (RADC) Infrastructure-Based Tele-Operated Driving

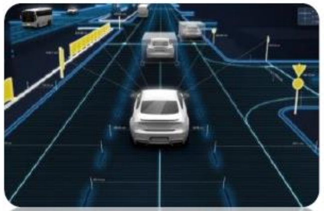
Requirements of Vehicular Networking

Uses cases for autonomous driving applications (SA1 TR22.886)

Vehicle Platooning


Cooperative Operation, Sensor sharing


Remote Driving


Advanced Driving

NR-V2X requirements for autonomous driving (SA1 TS22.186)

Use Cases	E2E latency (ms)	Reliability (%)	Data rate (Mbps)
Vehicle Platooning	10	99.99	65
Advanced Driving	3	99.999	53
Extended Sensors	3	99.999	1000
Remote Driving	5	99.999	UL:25, DL:1

	Lateral (m)	Longitudinal (m)
Positioning Accuracy	0.1	0.5

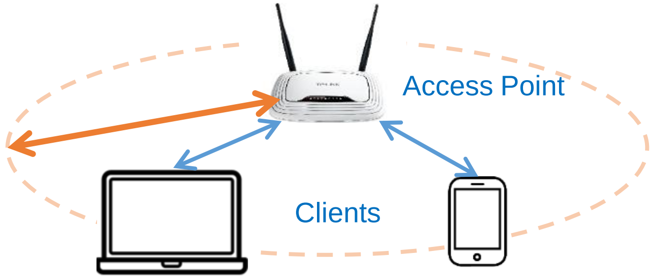
Note: 5GAA may adjust the above requirements according to inputs from car OEMs.

Maxime Flament (CTO 5GAA). Path towards 5G for the automotive sector. 17 Oct 2018.

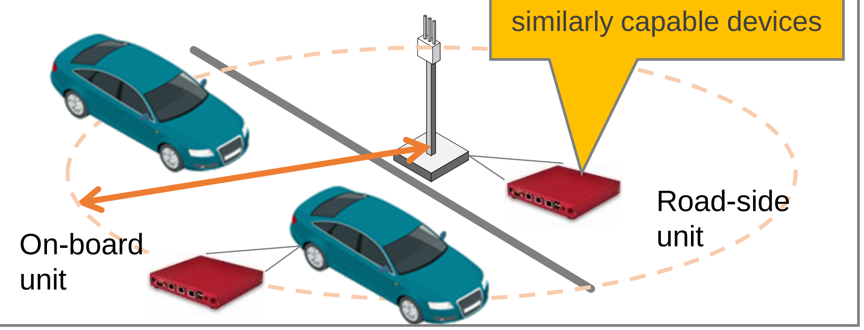
Technologies of LAN and WAN

LAN

IEEE 802.11n/ac/ax network
Range: between 1m to 300m

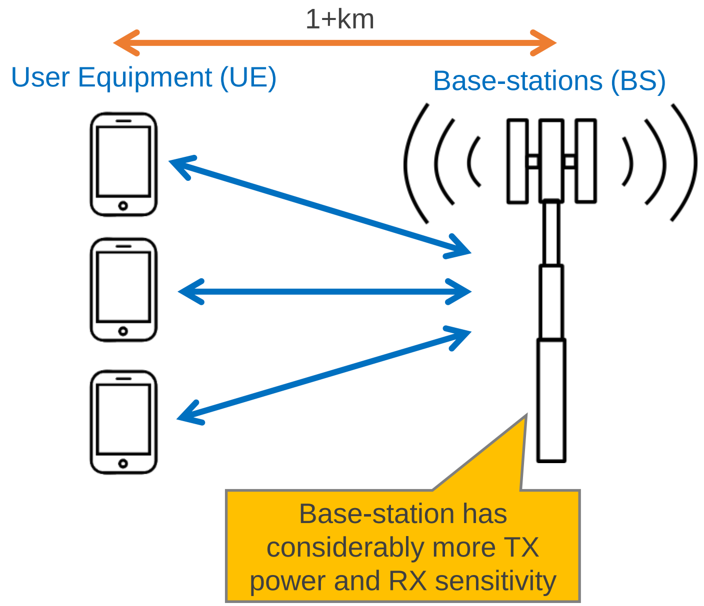


IEEE 802.11p network
Range: between 100m to 1km



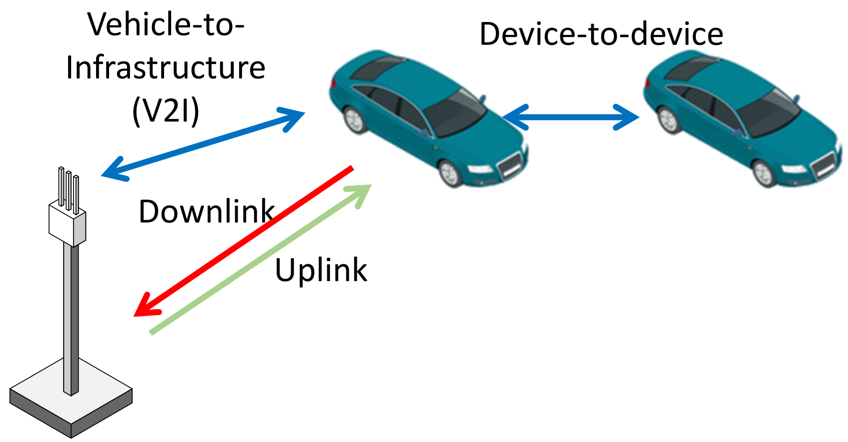
WAN

- **Cellular Technologies:** 2G/GSM, 3G/UMTS, 4G/LTE, 5G/NR, NB-IoT, LoRa, SigFox
- **WiMax** (IEEE 802.16)

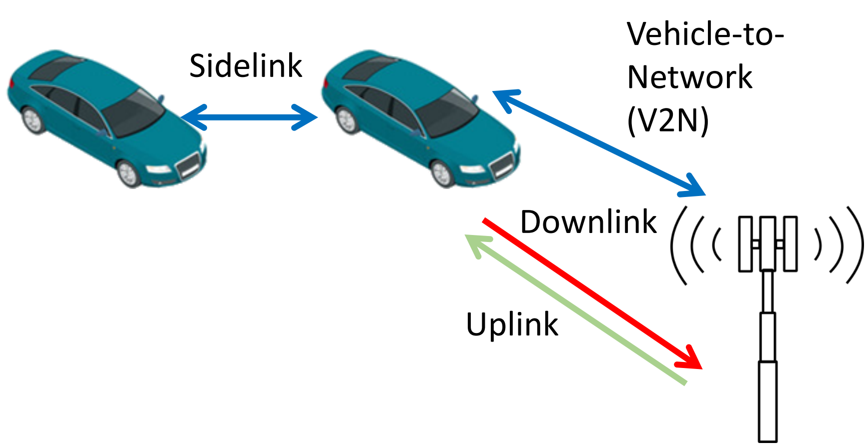


Terminology in Different Contexts

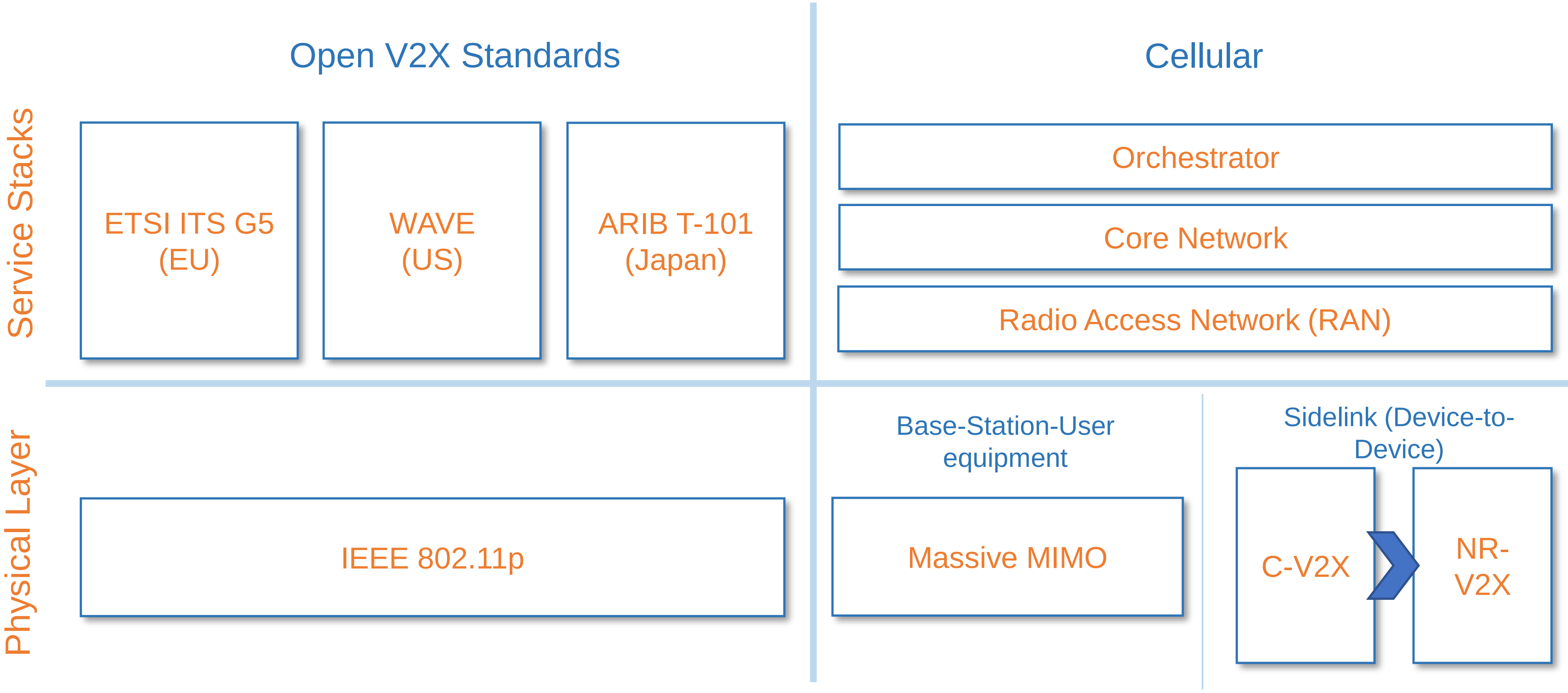
Open Standards
(prevalent in Local Area Networks)



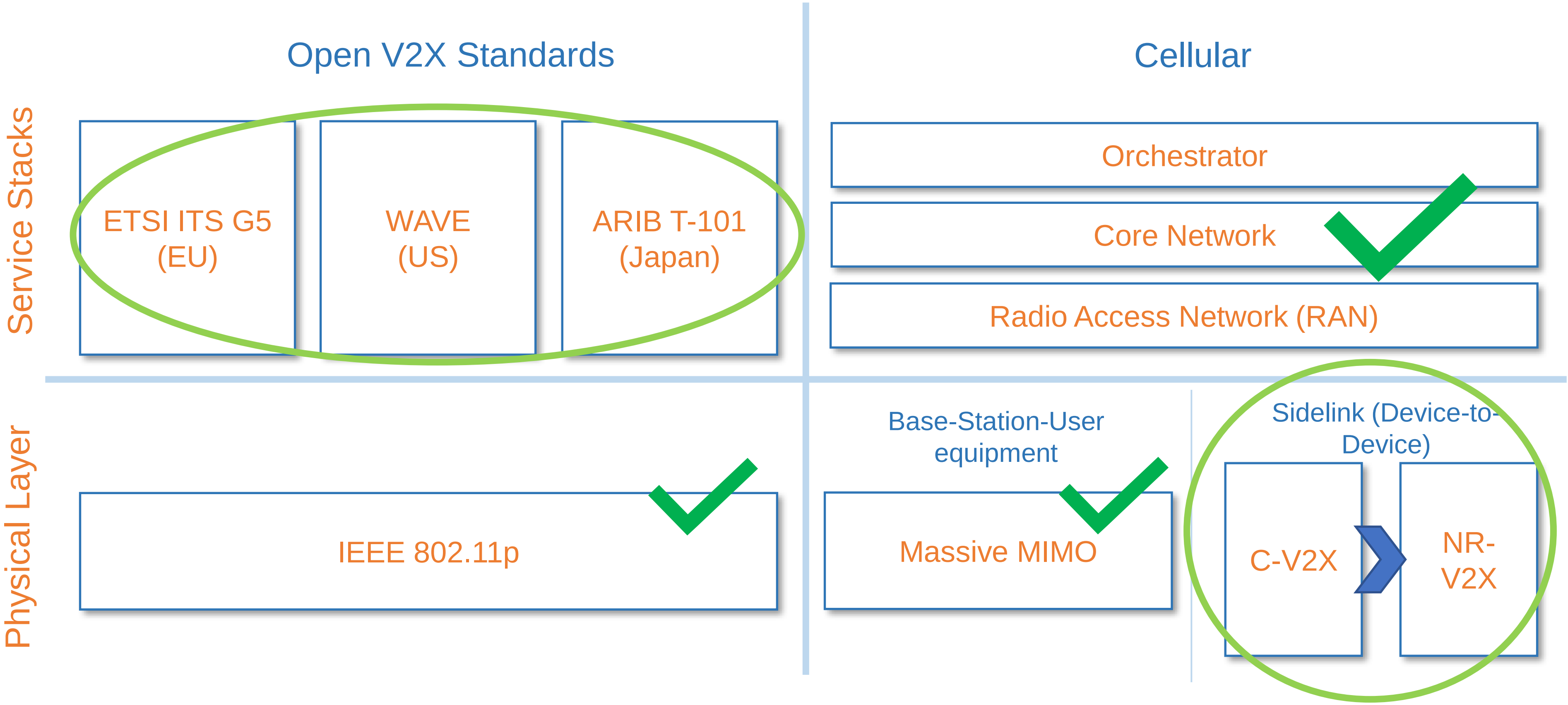
Cellular
(Prevalent in Wide Area Networks)



Technological landscape on vehicular communications



Technological landscape on vehicular communications

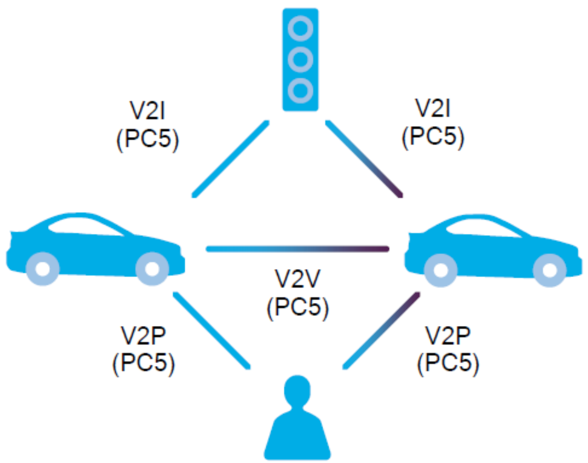


C-V2X

C-V2X has two complementary communication modes

Direct (= Sidelink)

V2V, **V2I**, and **V2P** operating in ITS bands (e.g. ITS 5.9 GHz) independent of cellular network

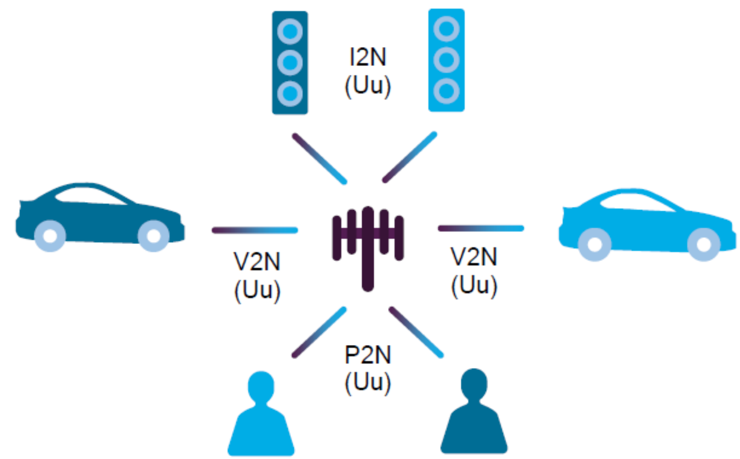


Short range (<1 kilometer), location, speed

Implemented over "PC5 interface"

Network (= Up/Downlink)

V2N operates in traditional mobile broadband licensed spectrum



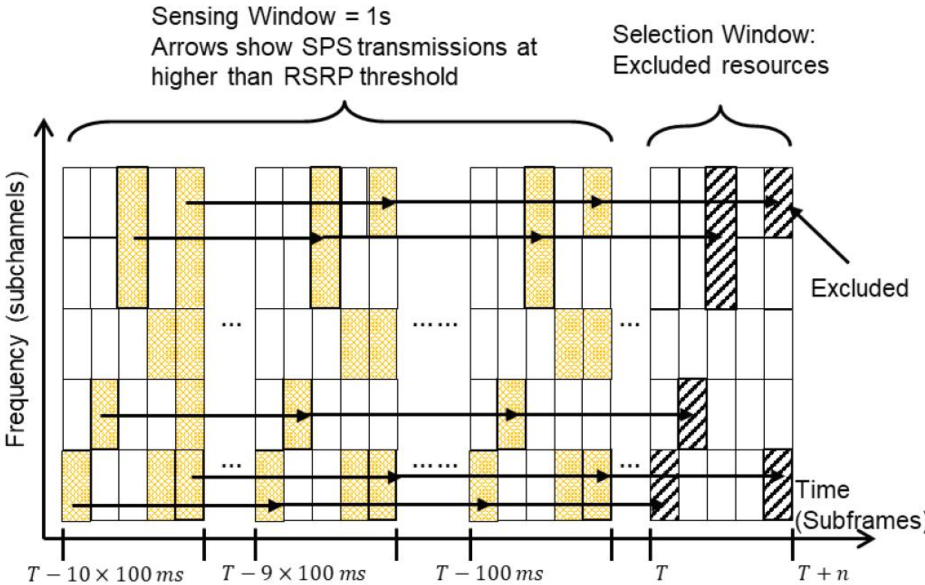
Long range (>1 kilometers). e.g. accident ahead

Implemented over "Uu interface"

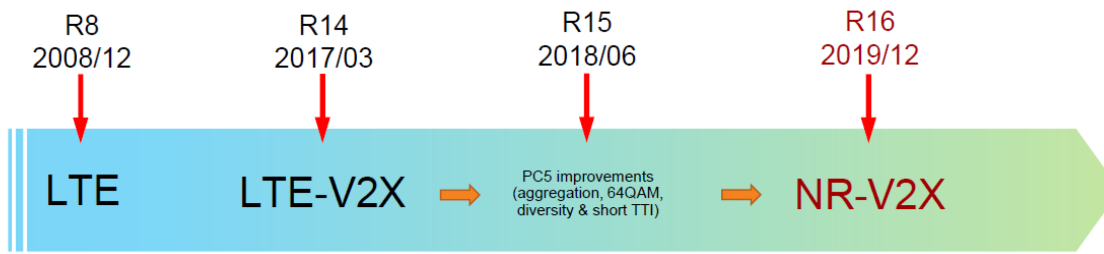
Maxime Flament (CTO, 5GAA), "**Path towards 5G for the automotive sector (slides)",** 17 Oct 2018.

C-V2X Mode 4

- As specified in the 3GPP Release 14, C-V2X (or LTEV2X) is based on the PC5 or sidelink LTE radio interface to allow direct broadcast communication between vehicles.
- CV2X can operate in either 10 MHz or 20 channels, versus IEEE 802.11p-based DS only operates in a channel of 10 MHz bar
- C-V2X employs a time-frequency resourc shown in Figure 1, where the time is divid sub-frames and the channel is divided int wide Resource Blocks (RBs).
- The RBs within the same sub-frame are t into sub-channels.
- C-V2X supports two main modes of opera mode 3 and mode 4. In mode 3, the resou and scheduling is controlled and managed by the cellular base station (eNB), whereas in mode 4, vehicles autonomously select their own sidelink resources based on a standardized reservation algorithm described below.



C-V2X/NR-V2X



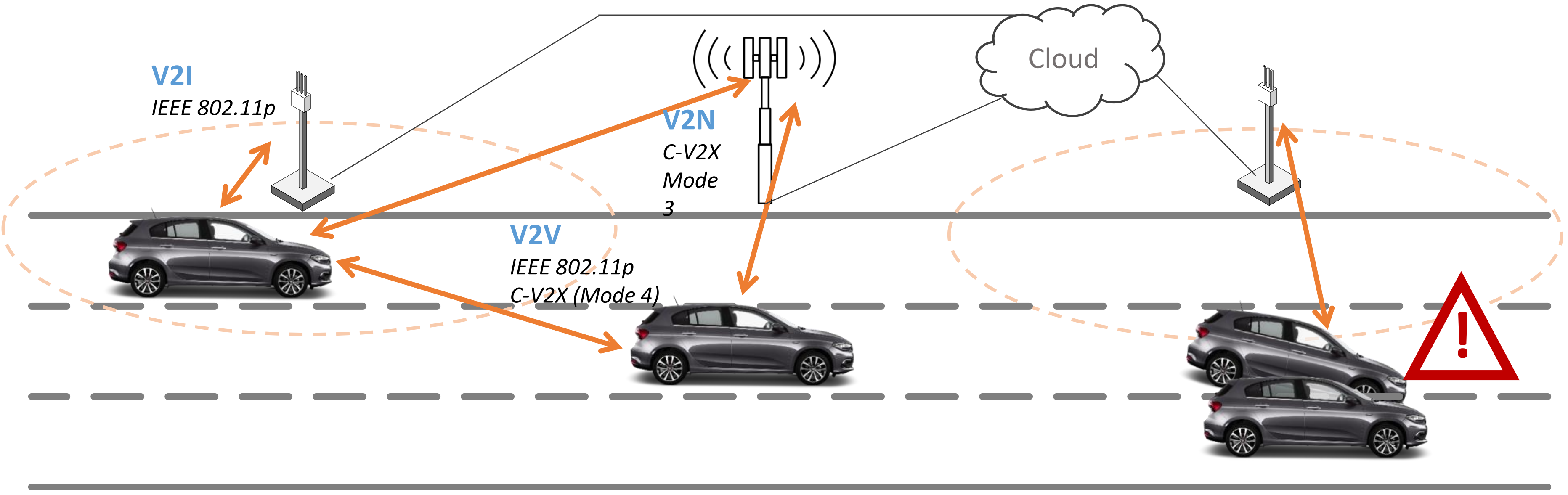
- NR-V2X study item started in June 2018.
- Subsequent NR-V2X work item by December 2019.

Commercial brand	Name of technical specification	Stand. Body	Time-frame
1G	N/A	N/A	1980
2G	Global System for Mobile Communications **(GSM)**	ETSI	1990
3G	Universal Media Telecom-munications System **(UMTS)**	3GPP	2000
4G	Long-Term Evolution **(LTE)**	3GPP	2010
5G	New Radio **(NR)**	3GPP	2020

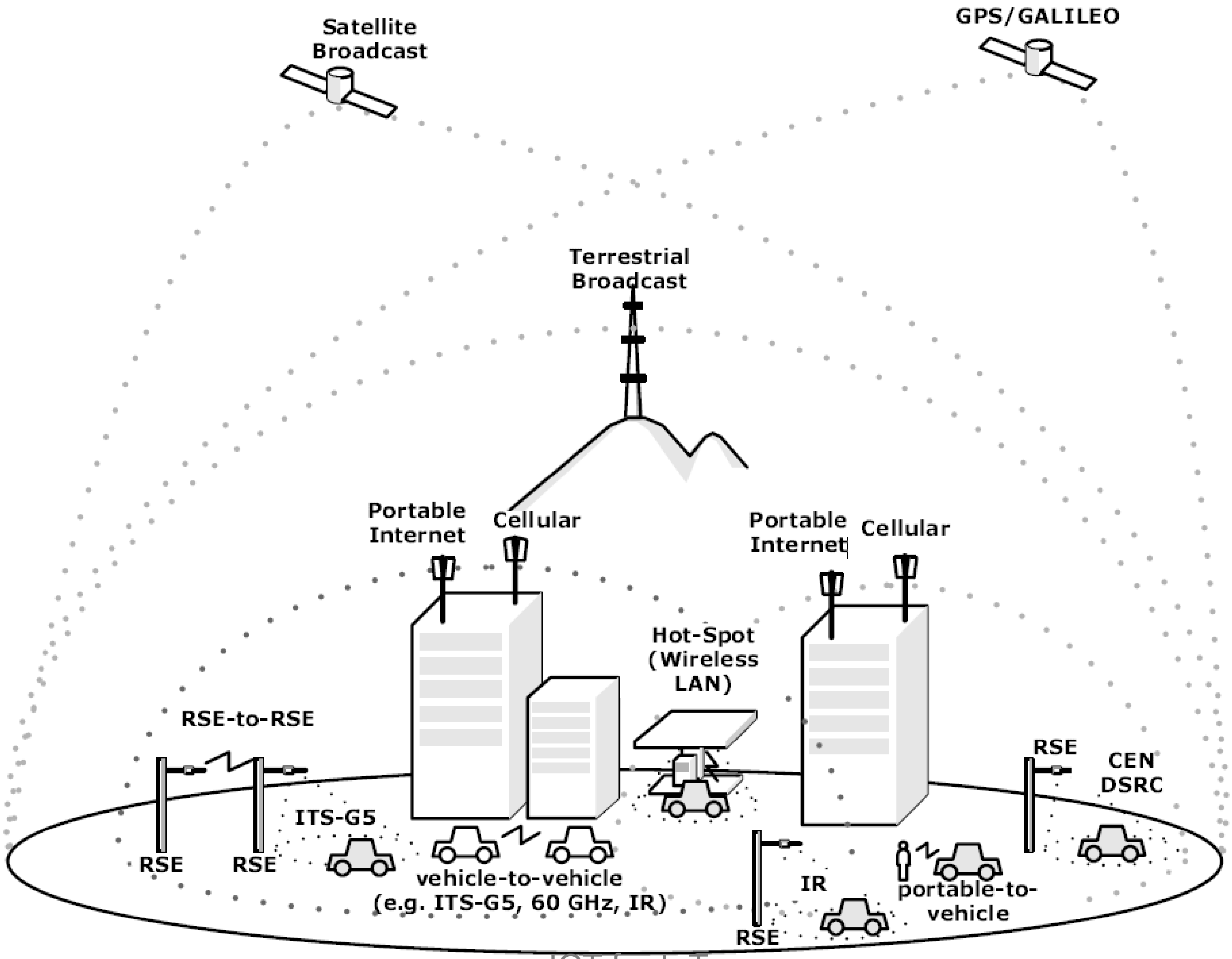
Maxime Flament (CTO, 5GAA), "**Path towards 5G for the automotive sector (slides)",** 17 Oct 2018.

Co-existence of 3GPP and IEEE 802.11p

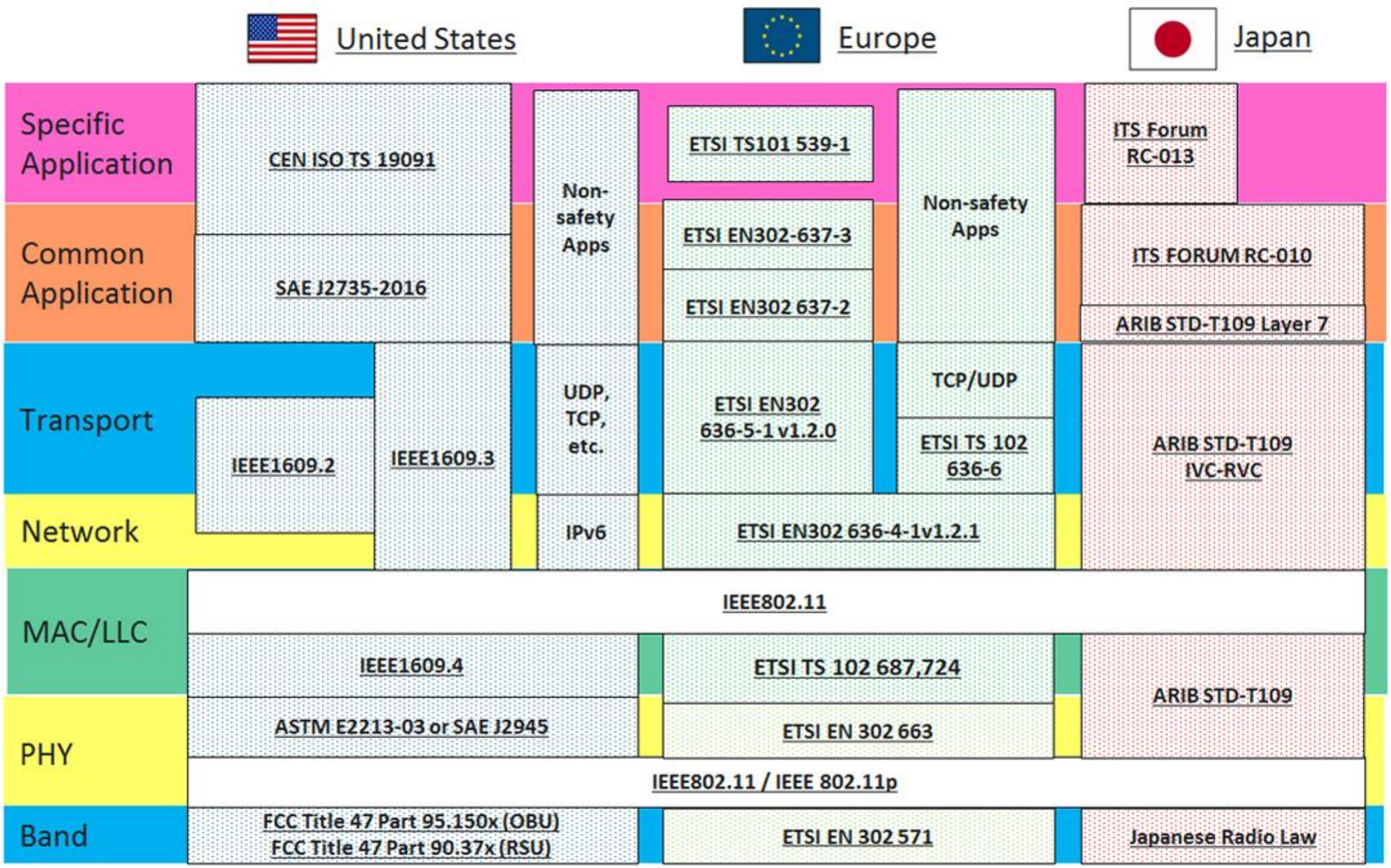
- Cellular and IEEE 802.11 technologies can be complementary
  - IEEE 802.11p operates as a local area network, being mostly useful for V2I and V2V low-latency messages
  - Cellular can complement with long-distance V2N links in areas where infrastructure coverage is limited
  - C-V2X can compete with IEEE 802.11p for V2V links, but there is no concept of Road-Side Unit (RSU)



Service Stacks – ETSI ITS G5

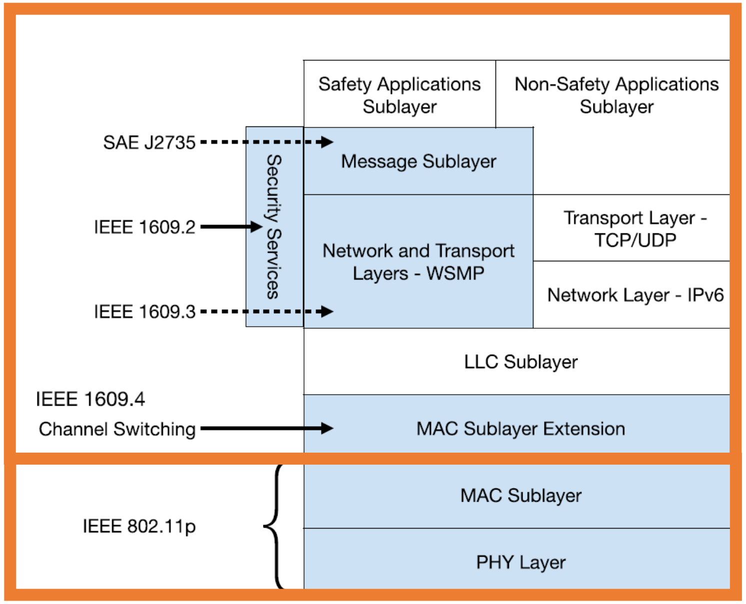


Service Stacks – ETSI ITS G5



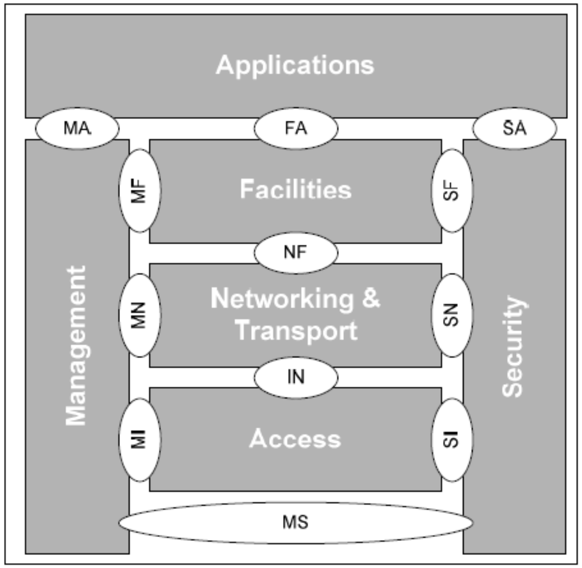
Service Stacks

- **ETSI ITS G5:** A service stack devised at Europe that builds on top of IEEE 802.11p
  - Periodic messages: Cooperative Awareness Messages (CAM)
- **WAVE Wireless Access in Vehicular Environments (USA):** U.S. service stack the U.S. that builds on top of 802.11p
  - Periodic messages: Basic Safety Messages (BSM)
- **ARIB T-101 (Japan):** Japanese service stack; operates on 700MHz

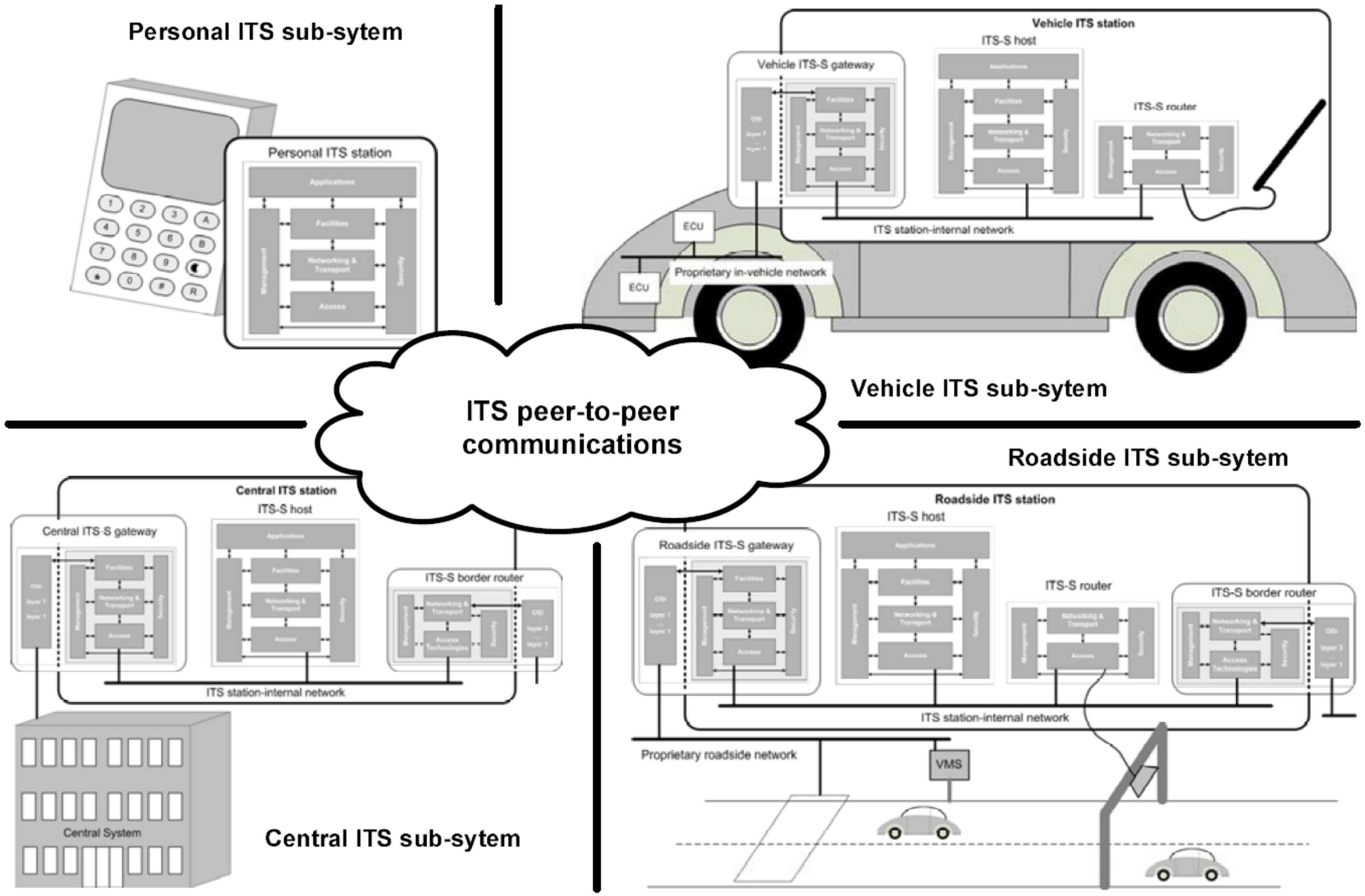


S. Gao, A. Lim, and D. Bevly, "An empirical study of DSRC V2V performance in truck platooning scenarios," *Digital Communications and Networks*, vol. 2, no. 4, pp. 233–244, Nov. 2016, doi: 10.1016/j.dcan.2016.10.003.

Service Stacks – ETSI ITS G5



ITS-G5



Personal ITS sub-sytem
Personal ITS station
Vehicle ITS station
ITS-S host
Vehicle ITS-S gateway
ITS-S router
ITS station-internal network
ECU
ECU
Proprietary in-vehicle network
Vehicle ITS sub-sytem
ITS peer-to-peer communications
Roadside ITS sub-sytem
Central ITS station
ITS-S host
Central ITS-S gateway
ITS-S border router
ITS station-internal network
Central System
Central ITS sub-sytem
Roadside ITS station
ITS-S host
Roadside ITS-S gateway
ITS-S router
ITS-S border router
ITS station-internal network
Proprietary roadside network
VMS

Service Stacks – ETSI ITS G5

II. ITS-G5 IVC STANDARDIZATION

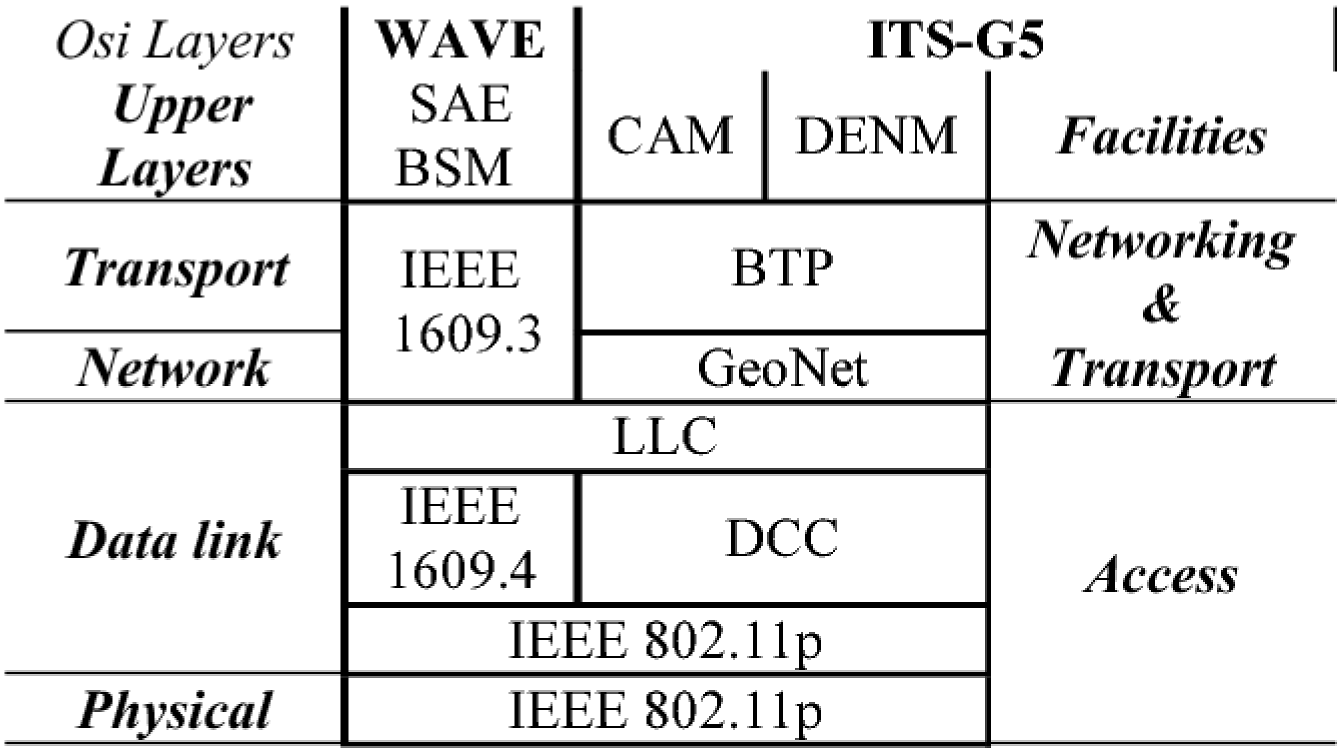


Figure 1. The US WAVE protocol stack versus EU ITS-G5 approach

- 0_ETSI_en_302663v010301p_ITS G5 Access Layer Specification
- 1_ETSI_en_302665v010101p_ITS Communications Architecture
- 1_ETSI_en_30263702v010301v_ITS Vehicular Comms Basic Set Apps P2 Specs Cooperative Awareness Basic Service
- 1_ETSI_en_30263703v010201v_ITS Vehicular Comms Basic Set Apps P3 Specs Decentralized Environmental Notification
- 1_ETSI_tr_102638v010101p_ITS Vehicular Communications Basic Set of Applications Definitions
- 1_ETSI_ts_10263701v010101p_ITS Vehicular Comms Basic Set Apps P1 Functional Requirements
- 1_ETSI_ts_1026360403v010101p_ITS Vehicular Comms Basic Set Apps GeoNetworking P4 Geographical addressing and forwarding

Thank you