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D1.8
FINAL SPECIFICATION OF COMMUNICATION SYSTEM FOR IoT ENHANCED AD

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PP	Restricted to other programme participants (including the Commission Services)	
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AUTOPILOT

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Abstract
This document presents the specification of requirements concerning communication means and the capabilities necessary for IoT and AD use case – final release

Legal Disclaimer

Abbreviations and Acronyms

Acronym	Definition
3GPP	Third Generation Partnership Project
5GAA	5G Automotive Alliance
3G, 4G, 5G	3GPP mobile technologies
6LoWPAN	IPv6 over Low-Power Wireless Personal Area Networks.
AAS	Active Antenna System
AD	Automated Driving
ADASIS	Advanced Driver Assistance System
AE	Application Entity
AIOTI	Alliance for IoT Innovation
BC	Business Case
BLE	Bluetooth LowEnergy
BTS	Base Transceiver Station
CA	Carrier Aggregation
CAM	Cooperative Awareness Message
CC	Component Carrier
CEN	European Committee for Standardization
C-ITS	Cooperative ITS
CR	Communication Requirements
CSE	Common Services Entity
CSI	Channel State Information
CSMA	Carrier sense multiple access
C-V2X	Cellular V2X
D2D	Device-to-Device
DENM	Distributed Environmental Notification Message
DITCM	Dutch Integrated Testsite Cooperative Mobility
DL	Downlink
DM RS	Demodulation Reference Signal
eMTC	enhanced Machine Type Communication
eNodeB	Evolved Node B
E2E	End-to-End
EC	European Commission
EN	European Standard
ERM	EMC and Radio Spectrum Matters
ETSI	European Telecom Standardisation Institute
EG	ETSI Guide
ES	ETSI Standard
FD-MIMO	Full-Dimension MIMO Carrier Aggregation
GN	GeoNetworking
GSM	Global System for Mobile Communications (3GPP technology)

Acronym	Definition
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IMT- Advanced	International Mobile Telecommunications-Advanced
IoT	Internet of Things
ISO	International Organization for Standardization
IP	Internet Protocol
ITS	Intelligent Transport Systems
ITU-R	International Telecommunication Union Radio Sector
KA	Knowledge Area
KPI	Key Performance indicator
LDM	Local Dynamic Map
LTE	Long Term Evolution (3GPP technology)
LTE-A	LTE-Advanced
LTN	Low Throughput Networks
LoRa	Long Range
M2M	Machine-to-Machine
MaaS	Mobility as a Service
MAP	map data
Mca, Mcc, Mcn	oneM2M standard interfaces
MCT	Machine Type Communication
MIMO	Multiple Input/Multiple Out
MQTT	Message Queuing Telemetry Transport
NB-IoT	Narrow Band Internet of Things
NFC	Near Field Communications
NGSI	Next Generation Service Interfaces
NSE	Network Services Entity
OCB	Outside the Context of a BSS
OFDM	Orthogonal frequency-division multiplexing
OMA	Open Mobile Alliance
OBU	On-Board-Unit
oneM2M	Organization to develop technical specifications for Machine-to-Machine and Internet of Things services
PC5	interface between two UEs
PDU	Packet Data Unit
PF	Platform
PS	Pilot Site
QoS	Quality of Service
RF	Radio Frequency
RFID	Radio Frequency Identification
RSU	Road Side Unit
SPAT	Signal Phase and Time

Acronym	Definition
TC	Technical Committee
TCC	Traffic Control Center
TM	Transmission Mode
TR	Technical Report
TS	Technical Specification
TTT	Transport and Traffic Telematics
TX	Transmission
UC	Use case
UE	User Equipment
UL	Uplink
Uu	UMTS Air Interface
V2X, V2E, V2I, V2V, V2N, V2C, V2G, V2P, V2H, V2D, V2M, V2U, V2O	Vehicle-to: X= Everything, E=Environment, I=Infrastructure, V= Vehicle, N=Network, C=Cloud/Edge, G=Grid, P=Pedestrian, H=Home, D= Device, M=Maintenance, U=User, O=Owner
VRU	Vulnerable Road User
WAN	Wide Area Network
WG	Working Group
WP	Working Package

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Executive Summary

This deliverable, D1.8, identifies the final list of the requirements and the protocols concerning communication aspects necessary to implement the Internet of Things (IoT) and Automated Driving (AD) use cases tested in AUTOPILOT. It must be delivered in M33 and it has been produced based on WP2 and WP4 data and information.

The main target of the AUTOPILOT project is leveraging IoT to have progress in AD. This document is an outcome of T1.4 activities and it consists of inputs received by all participant organizations of the task. As various participants span a wide range of technical domains, the document reflects this in the sense that it covers various communication domains in the field of AD and IoT.

IoT is a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols. Physical and virtual things have identities, physical attributes, virtual personalities, use intelligent interfaces and are seamlessly integrated into the information network. The IoT brings a new paradigm where the devices are things that are connected and communicating with other things. The interaction will be with a heterogeneous continuum of users, things and real physical events and the Internet is the common convergence connectivity capability, replacing the previously independent systems.
The concept of Internet of Vehicles (IoV), or Vehicle-to-Everything (V2X) communications applied for autonomous transportation and mobility applications, requires creating mobile ecosystems. Those are based on trust, security, convenience to connectivity services and transportation applications in order to ensure security, mobility and convenience to consumer-centric transactions/services. In this context for autonomous vehicle applications, five communication domains are defined covering the communications of vehicle to everything (V2X) that includes vehicle to infrastructure (V2I), vehicle to pedestrian (V2P), vehicle to device (V2D) vehicle to grid (V2G) and vehicle to vehicle (V2V) as important communication building blocks of the IoT ecosystems.

The specification described in this document was carried out following a process that included several meetings amongst task partners.
In the first phase, the group addressed an information collection activity focusing on a general overview of the communication infrastructures really deployed within the various pilot sites.
In the second phase, starting with the results of D1.7 [1] and considering the tests and test results of the pilot sites, the following was carried out:

- An assessment of the communication requirements and related KPIs actually implemented in the various use cases, in order to identify the relevant ones
- An overview of all communication protocols required to implement advanced IoT Active Directory use cases.

On the base of all the above considerations, the Communication Requirements identified in [1] have been implemented in PS and verified in compliance with the forecasted KPIs. Only CRs 34, 38 and 39 should be considered as not relevant.

Relating communications protocol, a complete survey has been provided focusing on all the levels of architecture. For standard protocols, a reference to the standard document has been provided.
The description of protocol (if not available on other sources) or a reference to a description document has been provided for non-standard protocols.

1 Introduction

1.2 Purpose of document

This document represents the Deliverable D1.8 “Final specification of Communication System for IoT enhanced AD”, second output carried out within Task 1.4 “Communication Specification” of project AUTOPILOT. According to project Technical Annex, the D1.8 purpose is to present the “Specification of requirements concerning communications means and in particular the capabilities necessary for IoT and AD use cases. Final Release on the basis of pilot site experience”.
The information presented in D1.8 on communication requirements, technology and standards are related to what has been implemented in each pilot site; the document has been distributed to and checked by PSs leaders.

1.3 Intended Audience

This deliverable D1.8 is a Public document and therefore the intended audience for this document is considered to be anyone that is interested in Communication System requirements and capabilities applied in automated driving progressed by IoT.
Within the AUTOPILOT project, the main intended audience for this deliverable is considered to be all the AUTOPILOT participants and in particular, the AUTOPILOT participants involved in WP4 “Evaluation” and in WP5 “Communication, Dissemination and Exploitation”.

1.4 Process

The specification described in this document was carried out following a process that included several meetings amongst task partners.
In the first phase, the group addressed an information collection activity focusing on a general overview of the communication infrastructures really deployed within the various pilot sites. In a second phase, starting from the results of D1.7 [1] and considering the tests and the outcomes of the pilot sites trials, the following was carried out:

- An assessment of the communication requirements and related KPIs actually implemented in the various use cases, in order to identify the relevant ones
- An overview of all communication protocols required to implement advanced IoT Active Directory use cases.

1.5 Outline of the document

The deliverable has been organized into four chapters:

- Chapter 1 “Introduction” defines the scope of the document and the followed approach
- Chapter 2 “Pilot Sites telecommunications infrastructure” aims to provide a complete representation of the communication infrastructure really implemented in the various pilot sites to run the AUTOPILOT trials. This was done on the base of the general description provided in D1.7 section 2 “AUTOPILOT Project ecosystem”, the communication technologies review and description provided in D1.7 section 3 and a reference framework based on a pre-configured format designed to collect homogeneous information amongst pilot sites
- Chapter 3 reports the final release of the communication specifications. The goals of this section are:

- to freeze the final list of the relevant communication requirements for the IoT AD use cases, basing on the experience gained by the tests carried out within AUTOPILOT Pilot Sites
- to identify a list of the protocols to use, in order to support AD IoT based Use Cases implementation considering Pilot Sites experiences. For standard protocols, a reference to the standard document will be provided (in co-ordination with task 5.5 activities). The description of protocol (if not available on other sources) or a reference to a description document will be provided for non-standard protocols. Since D1.8 is public no confidential data will be provided

- Finally, Chapter 4 reports the conclusions for all the work done.

2 Pilot Sites telecommunications infrastructure

On the base of both the general description provided in D1.7 section 2 “AUTOPILOT Project ecosystem” and the communication technologies review and description provided in D1.7 section 3 “Communication technologies review and description”, D1.8 provides for each pilot site a complete representation of the communication infrastructure really implemented.
In order to collect homogeneous information amongst the pilot sites, a reference framework based on tables and a pre-configured format to distribute to pilot sites leaders was designed.

This section aims to provide a complete representation of the communication infrastructures really implemented in each pilot site during AUTOPILOT project.

2.1 Information gathering process description

In order to collect complete information amongst the various pilot sites, a reference framework, based on both: the general description provided in D1.7 section 2 “AUTOPILOT Project ecosystem” and the communication technologies review and description provided in D1.7 section 3 “Communication technologies review and description”, has been designed (please refer to [1]).
The framework is represented by the following table:

Table 1 Pilot Site Communication Infrastructure

Technology Name	USE CASE #1	USE CASE #2	USE CASE #n
Long Range Wireless Communication Networks			
3GPP 4G (LTE)			
3GPP 4.5G (LTE advanced)			
IoT Wireless communication Technologies			
IEEE 802.15.4			
IEEE 802.11			
3GPP eMTC			
3GPP Extended Coverage GSM			
3GPP NB-IoT			
ETSI Low Throughput Networks (LTN)			
IETF 6LoWPAN/LP-WAN			
Weightless-W/N/P			
LoRaWAN			
Bluetooth Low Energy			
DASH7			
Intelligent Transport Systems wireless technologies			
ETSI ITS G5			
IEEE 802.11-OCB			
LTE Cellular-V2X-Release14			
IP Communication			

Technology Name	USE CASE #1	USE CASE #2	USE CASE #n
IP-V4 TCP/UDP			
IP-V6 TCP/UDP			
IoT Protocols			
DDS			
MQTT			
oneM2M standard			
Facilities, Transport and Application Protocols			
ETSI CAM			
ETSI DENM			
ETSI SPaT			
ETSI MAP			
CEN/TS 16157 DATEX II (?)			
Specific application protocol #1			
Specific application protocol #2			
Specific application protocol #n			

The information reported in this document has been collected by AUTOPILOT Pilot Site Leaders, and it is therefore related to what has been implemented in each pilot site as reported in [2].

2.2 Pilot site Finland - Tampere

In Tampere Pilot site the following use cases were tested.

1. **Urban Driving**
   The Urban Driving use case requires automated driving vehicles to identify, predict and react in an array of complex situations. Fully automated vehicles were tested driving from point A to B, without any action from the driver. However, the driver will be able to override and get back to manual driving at any time.
   IoT Application→ VRU detection

2. **Automated valet parking**
   In the Automated Valet Parking (AVP) use case, the driver is able to reserve a parking space and to leave the car at some predefined drop-off location. The operations of parking and maneuvering the car in the parking area (inside or outside) were managed by the parking management system.
   IoT Application → Parking management; Parking reservation

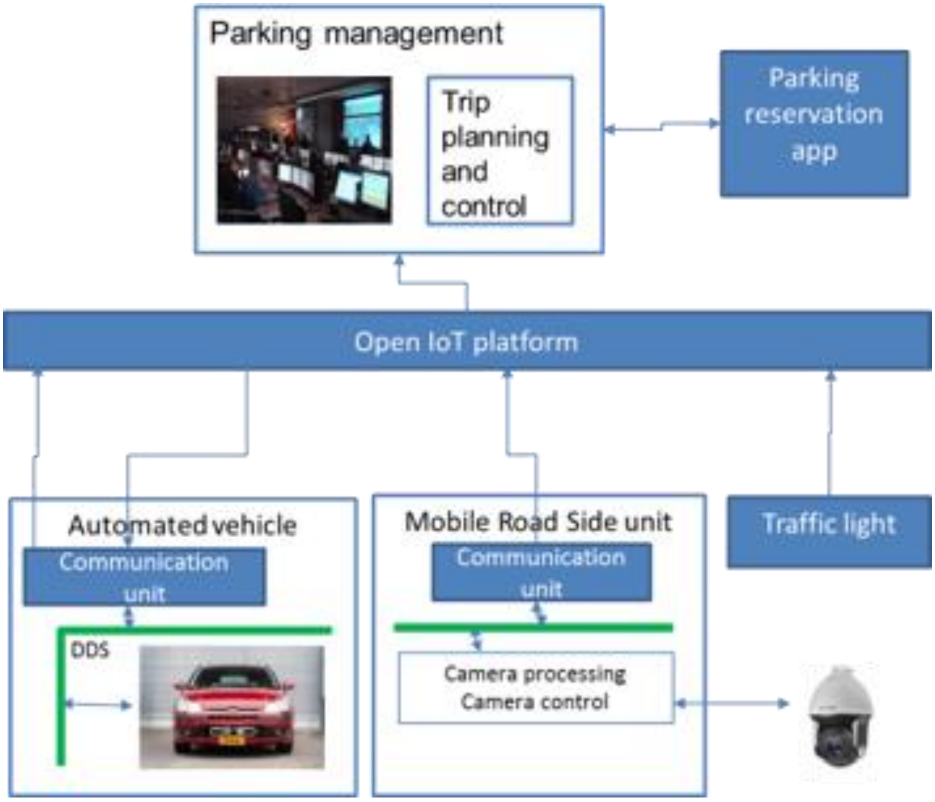

Figure 1 - Architecture Overview for all use cases (Finland)

Table 2 - Pilot Site Communication Infrastructure (Finland)

Technology Name	Urban Driving	Automated Valet Parking
Long Range Wireless Communication Networks		
3GPP 4G (LTE)	X	X
3GPP 4.5G (LTE advanced)		
IoT Wireless communication Technologies		
IEEE 802.15.4		
IEEE 802.11	X	X
3GPP eMTC		
3GPP Extended Coverage GSM		
3GPP NB-IoT		
ETSI Low Throughput Networks (LTN)		
IETF 6LoWPAN/LP-WAN		
Weightless-W/N/P		
LoRaWAN		
Bluetooth Low Energy		
DASH7		
Intelligent Transport Systems wireless technologies		

Technology Name	Urban Driving	Automated Valet Parking
ETSI ITS G5		
IEEE 802.11-OCB		
LTE Cellular-V2X-Release14		
IP Communication		
IP-V4 TCP/UDP	X	X
IP-V6 TCP/UDP		
IoT Protocols		
DDS	X	X
MQTT	X	X
oneM2M standard	X	X
Facilities, Transport and Application Protocols		
ETSI CAM		
ETSI DENM		
ETSI SPaT		
ETSI MAP		
CEN/TS 16157 DATEX II (?)		

2.3 Pilot site France - Versailles

In Versailles Pilot site the following use cases were tested

1. **Urban Driving**
   The Urban Driving use case requires automated driving vehicles to identify, predict and react in an array of complex situations. Fully automated vehicles were tested driving from point A to B, without any action from the driver. However, the driver was able to override and get back to manual driving at any time
   IoT Application → Connected and automated driving with point of interest notifications (audio/video) and VRU detection (collaborative perception).

2. **Platooning**
   The Platooning Use Case is part of the car rebalancing business case. It is closely linked to the fleet management system that indicates which vehicles have to be transferred from one station to another. The mission planning includes choosing the leading vehicle and the follower vehicles. The traffic light assist suggests reference speed in order to minimize the waiting time.
   IoT Application → Mission planning; Traffic light assist; VRU detection/management

3. **Real-Time Car Sharing**
   The real-time car-sharing use case is offering a car-sharing service for tourists. It also supports urban driving and platooning use cases. The use of IoT is expected to assist in responding to the demand of having a sufficient number of vehicles in different stations. The objective is, on one hand, to increase the quality of service for the users and, on the other

hand, to reduce the exploitation costs.

IoT Application → Touristic applications; Localization; Battery level; Charging points; Car rebalancing

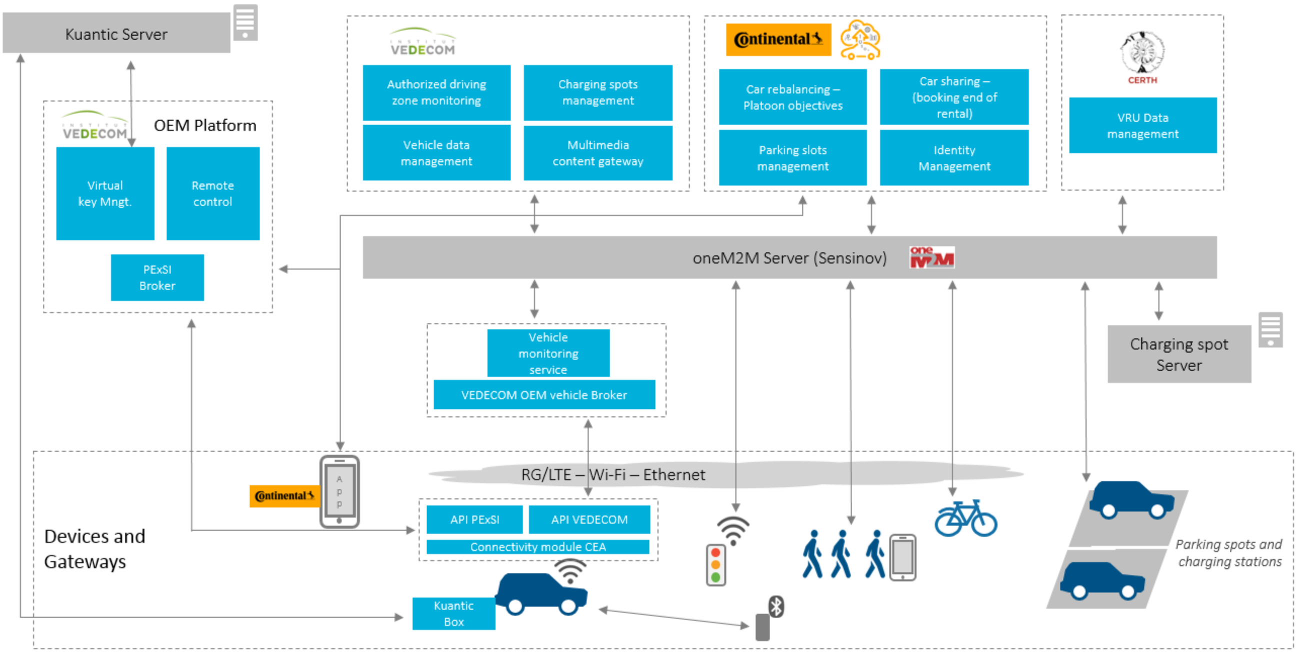

Figure 2 - Architecture Overview for all use cases (France)

Table 3 - Pilot Site Communication Infrastructure (France)

Technology Name	Urban Driving	Platooning	Real Time Car Sharing
Long Range Wireless Communication Networks			
3GPP 4G (LTE)	X	X	X
3GPP 4.5G (LTE advanced)	X	X	X
IoT Wireless communication Technologies			
IEEE 802.15.4			
IEEE 802.11	X	X	X
3GPP eMTC			
3GPP Extended Coverage GSM			
3GPP NB-IoT			
ETSI Low Throughput Networks (LTN)			
IETF 6LoWPAN/LP-WAN			
Weightless-W/N/P			
LoRaWAN	X	X	X
Bluetooth	X	X	X
DASH7			

Technology Name	Urban Driving	Platooning	Real Time Car Sharing
RFID	X	X	X
Intelligent Transport Systems wireless technologies			
ETSI ITS G5			
IEEE 802.11-OCB	X	X	X
LTE Cellular-V2X-Release14			
IP Communication			
IP-V4 TCP/UDP	X	X	X
IP-V6 TCP/UDP	X	X	
IoT Protocols			
DSS			
MQTT	X	X	X
oneM2M standard	X	X	X
Facilities, Transport and Application Protocols			
ETSI CAM	X	X	X
ETSI DENM			
ETSI SPaT			
ETSI MAP			
CEN/TS 16157 DATEX II (?)			
DIASER NF P 99-071-1 G3		X	

2.4 Pilot site Italy - Livorno

In Livorno Pilot site the following use cases were tested

1. **Urban Driving**
   The Urban Driving use case requires automated driving vehicles to identify, predict and react in an array of complex situations. Fully automated vehicles were tested approaching an intersection with a “smart” traffic light, without any action from the driver. However, the driver could override and get back to manual driving at any time.
   IoT Application→ Pedestrian detection; Fallen bicycle detection; Pothole detection; Car behavior

2. **Highway Pilot**
   In the Highway Pilot use case, a cloud service merges the sensors' measurements from different IoT devices in order to locate and characterize road hazards. The goal was then to provide the following vehicles with meaningful warnings and adequate driving recommendations to manage the hazards in a safer or more pleasant way.
   IoT Application → Puddle detection; Pothole detection; Road works notification; Car behavior

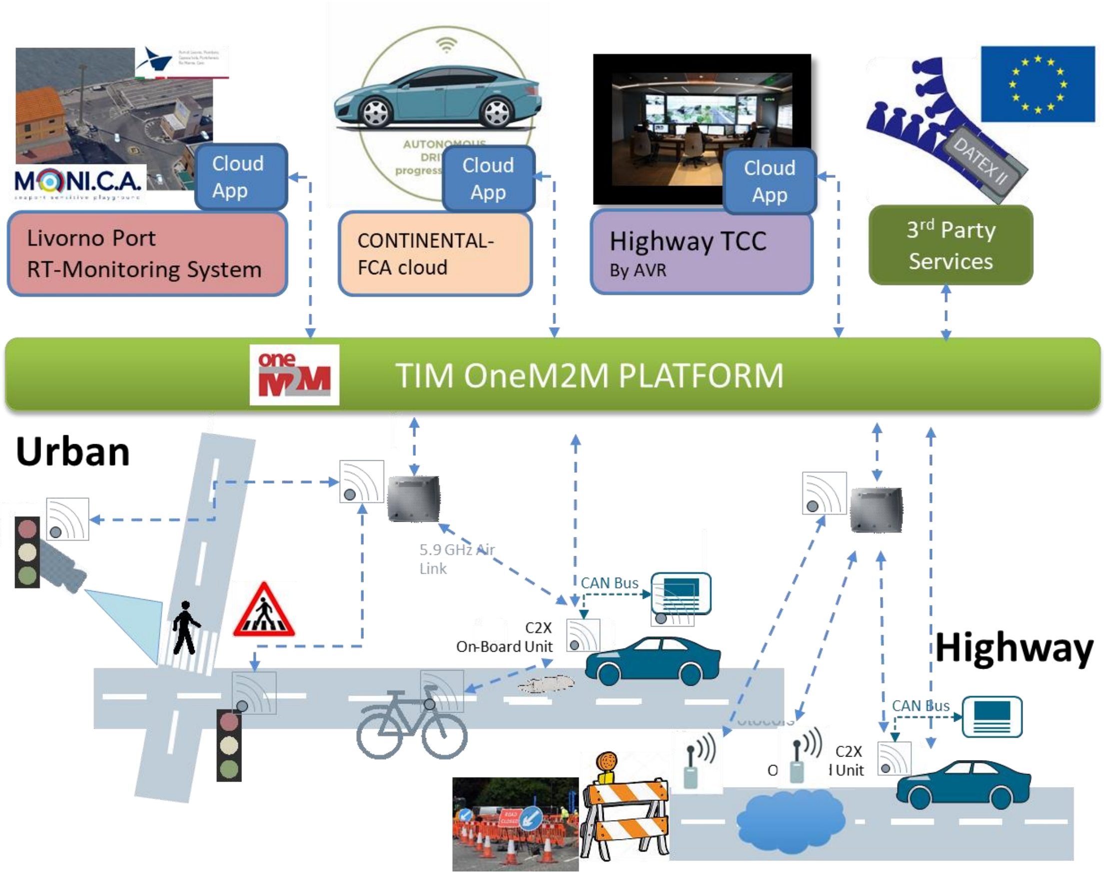

Figure 3 - Architecture Overview for all use cases (Italy)

Table 4 - Pilot Site Communication Infrastructure (Italy)

Technology Name	Urban Driving	Highway Pilot
Long Range Wireless Communication Networks		
3GPP 4G (LTE)	X	X
3GPP 4.5G (LTE advanced)		
IoT Wireless communication Technologies		
IEEE 802.15.4	X	X
IEEE 802.11	X	
3GPP eMTC		
3GPP Extended Coverage GSM		
3GPP NB-IoT		X
ETSI Low Throughput Networks (LTN)		
IETF 6LoWPAN/LP-WAN	X	X
Weightless-W/N/P		
LoRaWAN		
Bluetooth Low Energy		
DASH7		

Technology Name	Urban Driving	Highway Pilot
Intelligent Transport Systems wireless technologies		
ETSI ITS G5	X	X
IEEE 802.11-OCB	X	X
LTE Cellular-V2X-Release14	X	X
IP Communication		
IP-V4 TCP/UDP	X	X
IP-V6 TCP/UDP		
IoT Protocols		
DSS		
MQTT	X	X
oneM2M standard	X	X
Facilities, Transport and Application Protocols		
ETSI CAM	X	X
ETSI DENM	X	X
ETSI SPaT	X	
ETSI MAP	X	
CEN/TS 16157 DATEX II		X

2.5 Pilot site Netherlands – Brainport

In Brainport Pilot site the following use cases were tested.

1. **Urban Driving**
   The main scope is to show how automated driving with vulnerable road users (VRUs) detection can be realized using only mobile sensors in 3 different modalities: Crowd Estimation & Mobility Analytics using Wi-Fi based measurements, VRU with IoT connected smartphone (2-way: warning VRU and info to vehicle) & mobile ITS-G5 units.
   IoT Application → Crowd estimation & Mobility analytics; GeoFetching; Rebalancing; VRU detection; AD vehicle warning service

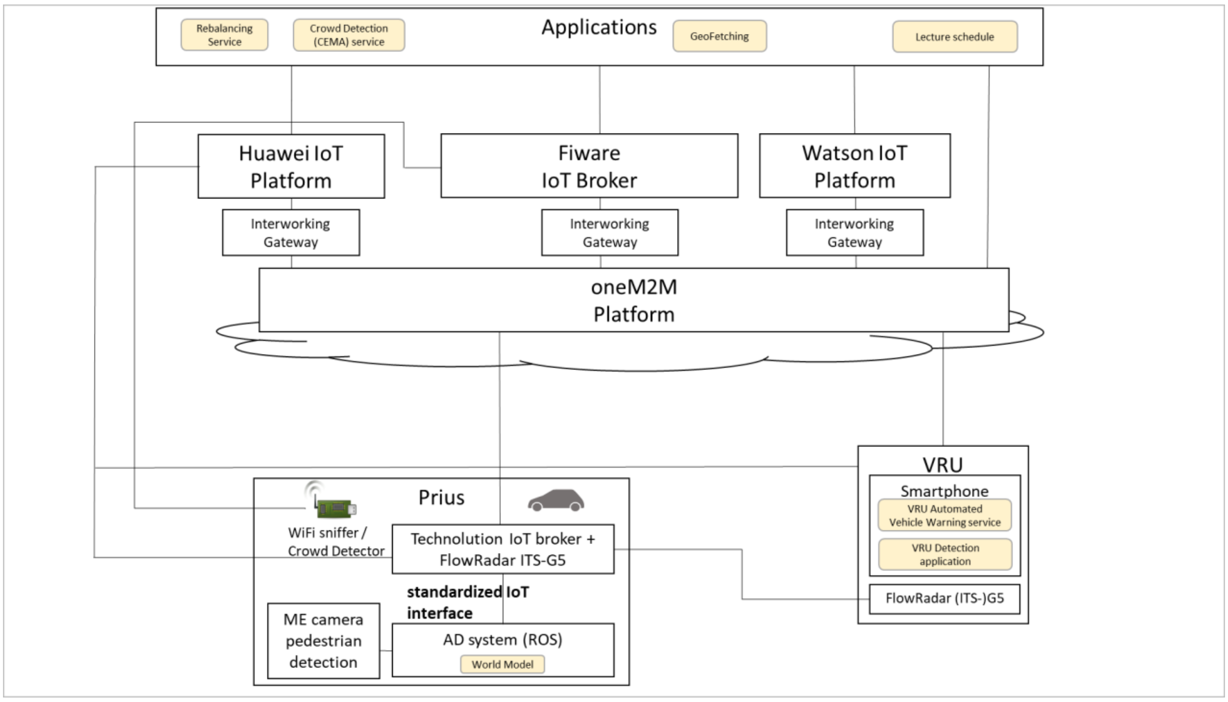

Figure 4 - Architecture Overview for Urban Driving (NED)

2. **Automated Valet Parking**

   In the Automated Valet Parking (AVP) use case, the driver is able to leave the car at some predefined drop-off location and is able to retrieve it once he/she needs it back. The operations of parking and maneuvering the car in the parking area (inside or outside) and retrieving it are managed by the parking management system and supported by a Micro Air Vehicle (MAV).

   IoT Application → crowd detector; object detection; Free parking slot detection

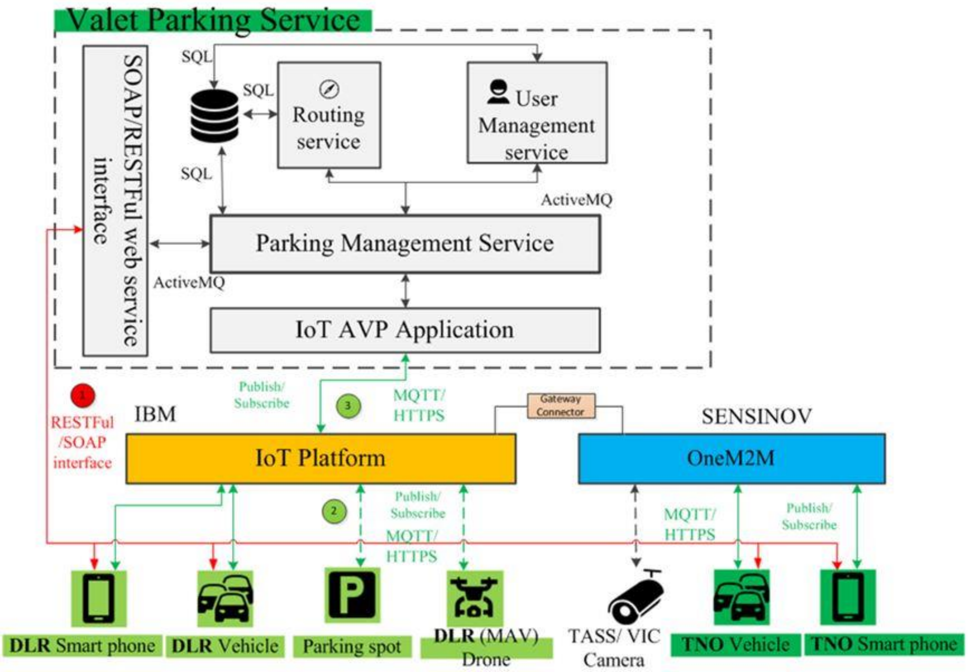

Figure 5 - Architecture Overview for Automated Valet Parking (NED)

3. **Highway Pilot**
   A cloud service merges the sensors' measurements from different IoT devices in order to locate and characterize road hazards. The goal is then to provide the following vehicles with meaningful warnings and adequate driving recommendations to manage the hazards in a safer or more pleasant way.
   IoT Application → Detection of Road Surface Hazards and Obstacles

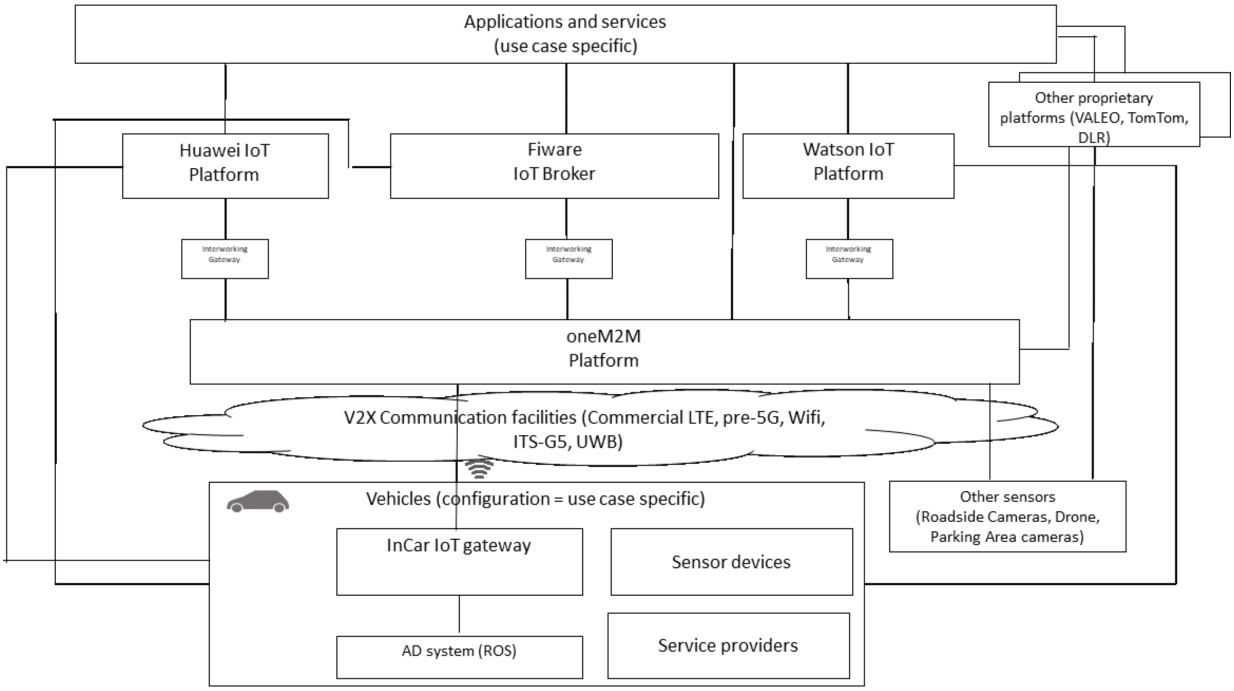

Figure 6 - Architecture Overview for Highway Pilot (NED)

4. **Platooning**
   The main scope is to show how increased flexibility in platoon maneuvering capabilities can be realized, and how it can benefit from the use of IoT technology. Additional achievements are the use of IoT data on hard shoulder authorization and availability for platooning, traffic light status and request handling, occupancy of bus lanes, etc.
   IoT Application → Crowd detector

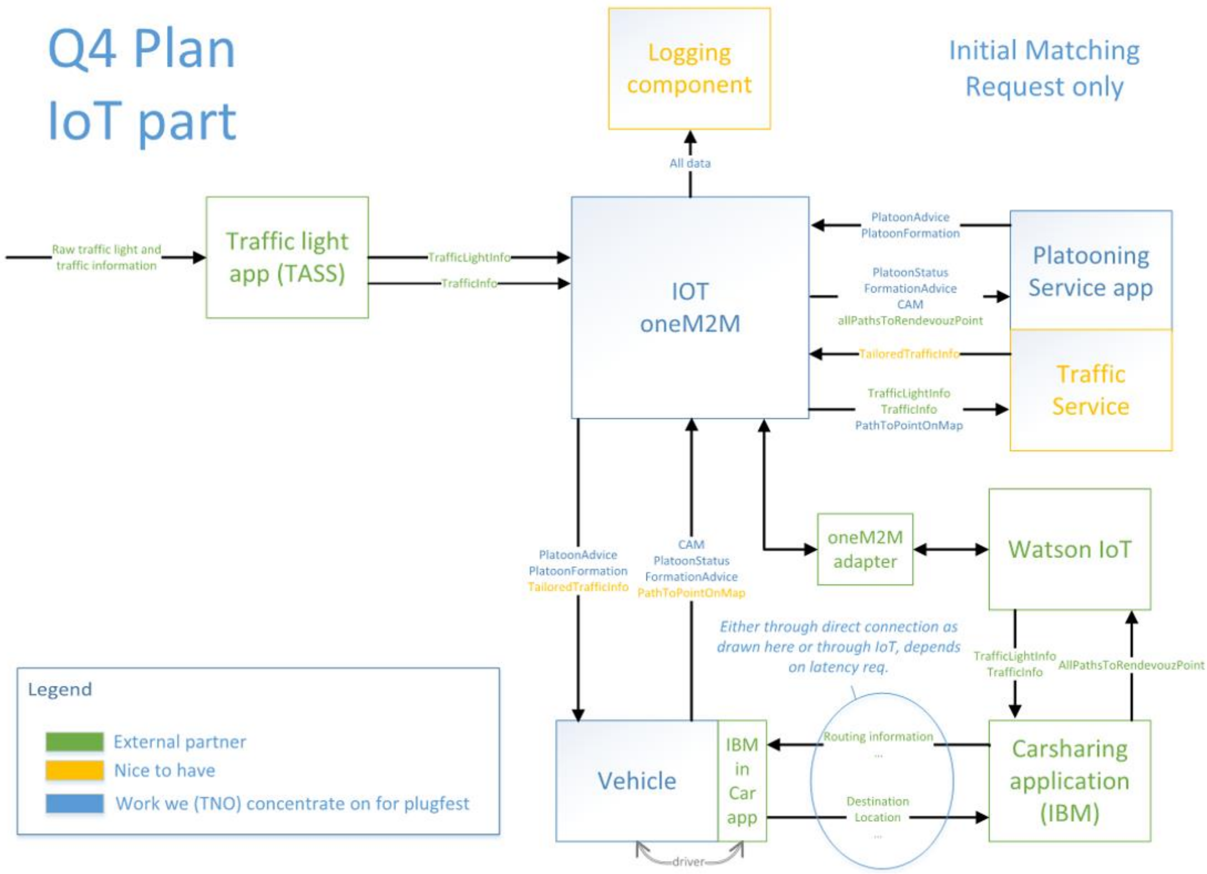

Figure 7 - Architecture Overview for Platooning (NED)

5. **Real-time Car sharing**
   Three levels of car-sharing services: (i) service that finds the closest available car and assigns it to a single customer; (ii) ride-sharing, when multiple customers that possibly have different origins and destinations share a part of the ride on a common car; (iii) allow customers to specify pick-up and drop-off time-windows to increase flexibility and planning.
   IoT Application → Vehicle routing; Trip cost estimation

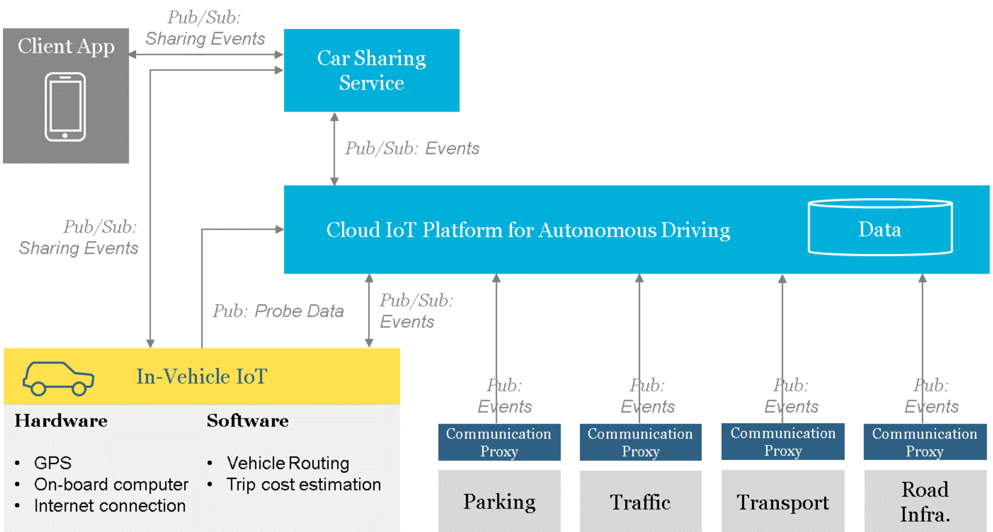

Figure 8 - Architecture Overview for real-time car sharing (NED)

Table 5 - Pilot Site Communication Infrastructure (NED)

Technology Name	Urban Driving	Automated Valet Parking	Highway Pilot	Platooning	Car sharing
Long Range Wireless Communication Networks					
3GPP 4G (LTE)	X	X	X	X	X
3GPP 4.5G (LTE advanced)					
IoT Wireless communication Technologies					
IEEE 802.15.4					
IEEE 802.11	X	X		X	X
3GPP eMTC					
3GPP Extended Coverage GSM					
3GPP NB-IoT					
ETSI Low Throughput Networks (LTN)					
IETF 6LoWPAN/LP-WAN	X			X	X
Weightless-W/N/P					
LoRaWAN					
Bluetooth Low Energy	X	X		X	X
DASH7					
Intelligent Transport Systems wireless technologies					
ETSI ITS G5	X	X		X	X
IEEE 802.11-OCB					
LTE Cellular-V2X-Release14					
IP Communication					
IP-V4 TCP/UDP	X	X	X	X	X
IP-V6 TCP/UDP					
IoT Protocols					
DSS					
MQTT			X		
oneM2M standard	X	X	X	X	X
Facilities, Transport and Application Protocols					
ETSI CAM	X	X		X	X
ETSI DENM	X	X		X	X
ETSI SPaT					
ETSI MAP					
CEN/TS 16157 DATEX II (?)					

2.6 Pilot site Spain – Vigo

In Vigo Pilot site the following use cases were tested.

1. **Urban Driving**
   The Urban Driving use case requires automated driving vehicles to identify, predict and react in an array of complex situations. Fully automated vehicles were tested driving from point A

to B, without any action from the driver. However, the driver was able to override and get back to manual driving at any time.
IoT Application → Urban service (Traffic light monitoring/notification); VRU (object/pedestrian) detection; Hazard warning

2. **Automated Valet Parking**
In the Automated Valet Parking (AVP) use case, the driver is able to leave the car at some predefined drop-off location and is able to retrieve it once he/she needs it back. The operations of parking and maneuvering the car in the parking area (inside or outside), retrieving it, and possibly other additional services, will be managed by the parking management system.
IoT Application → Parking management system; VRU (object/pedestrian) detection; Spot detection

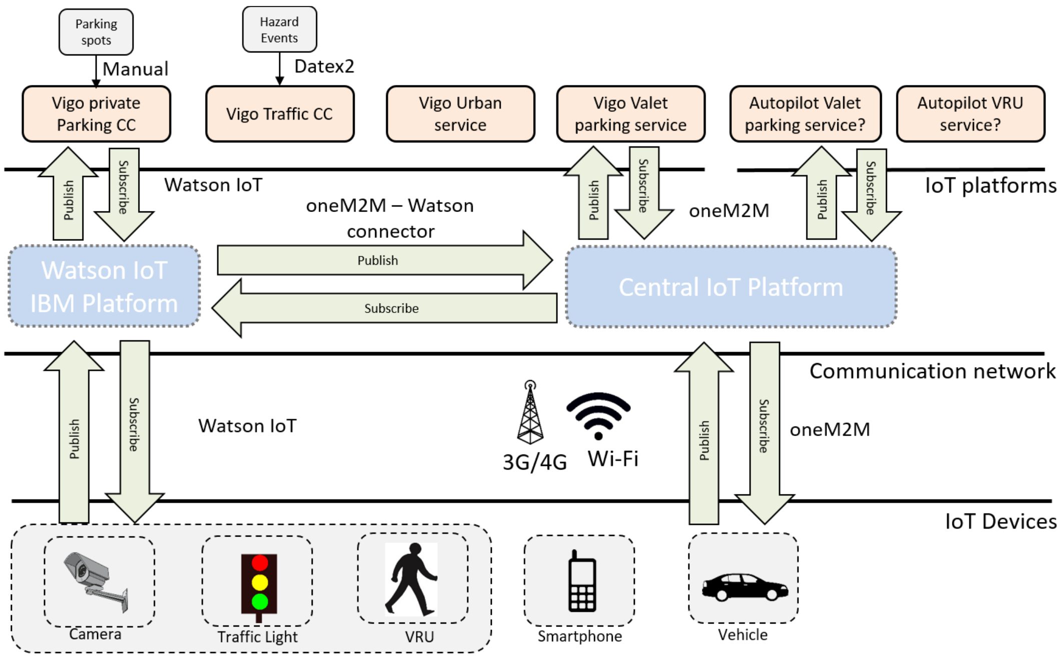

Figure 9 - Architecture Overview for all use cases (Spain)

Table 6 - Pilot Site Communication Infrastructure (Spain)

Technology Name	Urban Driving	Automated Valet Parking
Long Range Wireless Communication Networks		
3GPP 4G (LTE)	X	
3GPP 4.5G (LTE advanced)		
IoT Wireless communication Technologies		
IEEE 802.15.4		
IEEE 802.11	X	X

Technology Name	Urban Driving	Automated Valet Parking
3GPP eMTC		
3GPP Extended Coverage GSM		
3GPP NB-IoT		
ETSI Low Throughput Networks (LTN)		
IETF 6LoWPAN/LP-WAN		
Weightless-W/N/P		
LoRaWAN		
Bluetooth Low Energy		
DASH7		
Intelligent Transport Systems wireless technologies		
ETSI ITS G5	X	
IEEE 802.11-OCB		
LTE Cellular-V2X-Release14		
IP Communication		
IP-V4 TCP/UDP		
IP-V6 TCP/UDP		
IoT Protocols		
DSS		
MQTT		
oneM2M standard	X	X
Facilities, Transport and Application Protocols		
ETSI CAM	X	X
ETSI DENM	X	X
ETSI SPaT	X	X
ETSI MAP		
CEN/TS 16157 DATEX II (?)		

2.7 Pilot site South Korea

No information available

2.8 Communication infrastructure summarised

Based on the information reported in the previous sections, an overview of the various European Pilot Sites is summarised in the table below. The figures in bold indicate the number of technologies reported per use case, and the bracket abbreviations give Pilot Site country information.

Table 7 – Communication Infrastructure per Use Case (European Pilot Sites)

Technology Name	**Urban Driving** *(FI, FR, IT, NL, ES)*	**Automated Valet Parking** *(FI, NL, ES)*	**Highway Pilot** *(IT, NL)*	**Platooning** *(FR, NL)*	**Car sharing** *(FR, NL)*	SUM

Long Range Wireless Communication Networks:						
3GPP 4G (LTE)	**5** *(FI, FR, IT, NL, ES)*	**2** *(FI, NL)*	**2** *(IT, NL)*	**2** *(FR, NL)*	**2** *(FR, NL)*	13
3GPP 4.5G (LTE advanced)	**1** *(FR)*	-	-	**1** *(FR)*	**1** *(FR)*	3
IoT Wireless communication Technologies:						
IEEE 802.15.4	**1** *(IT)*	-	**1** *(IT)*	-	-	2
IEEE 802.11	**4** *(FI, FR, IT, NL)*	**2** *(FI, NL)*	-	**2** *(FR, NL)*	**2** *(FR, NL)*	10
IETF 6LoWPAN/ LP-WAN	**2** *(IT, NL)*	-	**1** *(IT)*	**1** *(NL)*	**1** *(NL)*	5
LoRaWAN	**1** *(FR)*	-	-	**1** *(FR)*	**1** *(FR)*	3
Bluetooth/BLE	**2** *(FR, NL)*	**1** *(NL)*	-	**2** *(FR, NL)*	**2** *(FR, NL)*	7
RFID	**1** *(FR)*	-	-	**1** *(FR)*	**1** *(FR)*	3
3GPP NB-IoT	-	-	**1** *(IT)*	-	-	1
Intelligent Transport Systems wireless technologies:						
ETSI ITS G5	**3** *(IT, NL, ES)*	**1** *(NL)*	**1** *(IT)*	**1** *(NL)*	**1** *(NL)*	7
IEEE 802.11-OCB	**3** *(FR, IT, ES)*	-	**1** *(IT)*	**1** *(FR)*	**1** *(FR)*	6
LTE Cellular-V2X-Release14	**1** *(IT)*	-	**1** *(IT)*	-	-	2
IP Communication:						
IP-V4 TCP/UDP	**3** *(FI, FR, IT)*	**1** *(FI)*	**1** *(IT)*	**1** *(FR)*	**1** *(FR)*	7
IP-V6 TCP/UDP	**1** *(FR)*	-	-	**1** (FR)	-	2
IoT Protocols:						
DDS	**1** *(FI)*	**1** *(FI)*	-	-	-	2
MQTT	**2** *(FI, FR)*	**1** *(FI)*	**1** *(NL)*	**1** *(FR)*	**1** *(FR)*	6
oneM2M standard	**5** *(FI, FR, IT, NL, ES)*	**3** *(FI, NL, ES)*	**2** *(IT, NL)*	**2** *(FR, NL)*	**2** *(FR, NL)*	14
Facilities, Transport and Application Protocols:						
ETSI CAM	**4** *(FR, IT, NL, ES)*	**2** *(NL, ES)*	**1** *(IT)*	**2** *(FR, NL)*	**2** *(FR, NL)*	11
ETSI DENM	**3** *(IT, NL, ES)*	**2** *(NL, ES)*	**1** *(IT)*	**1** *(NL)*	**1** *(NL)*	8
ETSI SPaT	**2** *(IT, ES)*	**1** *(ES)*	-	-	-	3
ETSI MAP	**1** *(IT)*	-	-	-	-	1
CEN/TS 16157 DATEX II	-	-	**1** *(IT)*	-	-	1
DIASER NF P 99-071-1 G3	-	-	-	**1** *(FR)*	-	1
SUM	46	18	15	22	20	121

3 Communication specification – final release

3.1 Communication requirements

The goal of this section is to freeze the final list of the relevant communication requirements for the IoT AD use cases (UC) basing on the experience gained by the tests carried out within AUTOPILOT Pilot Sites (PS).
In order to get this result, on the base of the communication requirements (CR) with related KPIs already identified in [1] section 5 "Communication requirements identification", an overall analysis has been carried out through:

- Final mapping of the requirements for Use Cases/Pilot sites
- Communication requirements overall analysis aimed to identify per each Use Case of the projects which are the significant ones and to quantify the basic KPIs that have been respected.

This activity has been carried out considering the activities and the results of Tasks: 2.5, 2.6 and 4.2.

3.1.1 Communication requirements mapping

In [1], 44 communications requirements were identified (for the complete list and description please refer to [1] - Annex 3 "Communication requirements"). In that deliverable, an initial CR mapping per UC was proposed as reported in the following table:

Table 8 – Deliverable D1.7's CR mapping per UC

Use Case	Communication requirements (#CR)
Automated Valet Parking	19, 24, 25, 26, 27, 36, 38, 39, 40
Highway Pilot	29, 30
Platooning	30, 31, 32, 33, 34
Urban Driving	18, 20, 21, 22, 23, 41, 42, 43
Car sharing	28, 35
Hazard on the roadway	1, 2, 3, 4, 5, 6, 7, 8, 44
Traffic Services	8, 12, 41, 42, 43
Traffic Light	11, 17, 18, 42
Connected bicycle	9
General requirements	10, 13, 14, 15, 16

Since this initial mapping was not so aligned with the official list of AUTOPILOT Use Cases, a new one is proposed in Table 9, where:

- Category "General Requirement" has been maintained since it refers to general communication capabilities common to all use cases.
- Categories "Traffic Light" and "Connected bicycle" has been included in "Urban driving" use case

- Categories “Traffic Services” and “Hazard on the roadway” have been included in both “Urban driving” and “Highway Pilot” use cases.

Table 9 – New CR mapping per UC

Use Case	Communication requirements (#CR)
General requirements	10, 13, 14, 15, 16
Automated Valet Parking	19, 24, 25, 26, 27, 36, 38, 39, 40
Highway Pilot	1, 2, 3, 4, 5, 6, 7, 8, 12, 29, 30, 41, 42, 43, 44
Platooning	30, 31, 32, 33, 34
Urban Driving	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 17, 18, 20, 21, 22, 23, 41, 42, 43, 44
Car sharing	28, 35

3.1.2 Communication requirements identification final release

3.1.2.1 Communication requirements global analysis

AUTOPILOT CRs overall analysis has been carried out evaluating data and information made available by WP2 and WP4; a particular focus has been posed on documents [7], [8], [9] and [10].
This activity was focused on identifying which CRs had been really implemented in AUTOPILOT PS with the related KPIs really achieved during on-field tests and trials.

In order to get this result, WP2.5 test cases [9] have been classified to highlight the ones connected to communication requirements evaluation. The result of this activity is represented by the xls file [11].
Basing on the evaluation of the field data available for all the tests above mentioned, it has been possible both to identify the CRs really implemented and to work out a picture about their performance relating to the KPI forecasted.

All the relevant information has been reported in section 5.2 “Communication Requirements global analysis reference table”.

The analysis of information available in section 5.2 generates the following considerations:

- For all the communication requirements, it has been possible to identify specific tests and measures evaluating the real application of the requirements and the related KPI performances. For only 3 CRs 34, 38 and 39, this operation failed. These requirements are related to: the “Platooning” UC to be implemented in Brainport (the 34) and the “Automated Valet Parking” UC to be implemented in Vigo PS (the 38 and 39). They were identified during AUTOPILOT starting phase but not implemented during the trial phase.
- The tests related to the majority of CRs have been carried out and have been classified as “PASSED”; only CR27 has to be considered, at the time of D1.8 drafting, as “Partly PASS”.
- At the time of D1.8 drafting, data related tests connected to CRs: 21, 22, 23 and 43 were not available.
- Considering the performances measured, all the tests classified as “PASSED” should be

considered verified in compliance with the forecasted KPIs. For some of them, it is possible to evaluate the specific values of the measure worked out (please refer to CRs: 2, 9, 10, 11, 30, 31 and 32).

- The Security features have not been considered since they will be better focused on Task 1.5 deliverables. No significant evaluations have been worked out for “Network Density” KPI (i.e. Maximum number of vehicles per unit area under which the specified reliability should be achieved.). As already reported in [12]: “Realising stress test in harsh conditions (high density, limited bandwidth …) requires involving dedicated and expensive radio simulators and measurement equipment as well as testing expertise going far beyond the current expertise of the consortium”, tests have been worked out using few vehicles.

On the base of all the above considerations, the Communication Requirements identified in [1] have been implemented in PS and verified in compliance with the forecasted KPIs. Only CRs 34 related Platooning UC, 38 and 39, related the “Automated Valet Parking” UC, should be considered as not relevant.

3.1.2.2 Final list of Communication Requirements per Use Cases

This section will present the final list of Communication Requirements grouped per Use Cases.

Table 10 – General Requirements

ID	Requirement description
CR10	Vehicles must geocast their position, speed, orientation to other vehicles on the road
CR13	Vehicles must be able to receive CAM/DENM contents from received ITS-G5 messages
CR14	Vehicles must be able to receive SPAT/MAP contents from received ITS-G5 messages
CR15	Vehicle must be able to receive data from communication system, related with contents received from IoT external services.
CR16	Vehicles must be enabled to provide /communicate elaborated data to IoT external services, through communication system.

Table 11 – Automated Valet Parking UC Requirements

ID	Requirement description
CR19	Communication between vehicle and cloud/camera management centre
CR24	Communication between Vehicle and AVP application
CR25	Communication between AVP application and cloud
CR26	Communication between Drone and cloud
CR27	Communication static camera and cloud
CR36	Communication between the application hosted on the user device and the cloud-based parking control system
CR38	The vehicle must receive exchange information (e.g. a detailed layout of the parking place, the location of dynamic objects, pedestrian location, vehicle position) with the parking control system
CR39	The vehicle must be able to provide its identification to be authorized at the parking place
CR40	Communication between parking infrastructure and cloud

Table 12 – Highway Pilot UC Requirements

ID	Requirement description

ID	Requirement description
CR1	The vehicle must receive the geocasted notifications of hazard events (e.g. potholes, roadway works, pedestrians, VRUs, puddles, etc.) from RSU
CR2	The WSN on the road must notify the presence of puddles on the road whenever they are detected
CR3	The traffic control system must receive geolocalized notifications of hazard events from RSU (e.g. potholes, roadway works, pedestrians, VRUs, puddles, etc.)
CR4	Geolocalized notifications of hazard events (e.g. potholes, roadway works, puddles, etc.) from RSU may be stored by the data management service of the IoT platform
CR5	The detection event of pedestrians on the roadway must be notified to the RSU from the camera
CR6	The number of detected pedestrians on the roadway detected by the camera may be stored by the data management service of the IoT platform
CR7	Every time the vehicle detects a hazard, it must be geocasted to other vehicles
CR8	The traffic control system must receive geolocalized notifications of hazard events (e.g. potholes, roadway works, pedestrians, VRUs, puddles, etc.) from vehicles
CR12	The traffic control system must receive information about traffic conditions
CR29	V2X Communication between vehicles and
CR30	The vehicle may send and receive information to/from the cloud
CR41	Communication between vehicle and cloud/traffic control system
CR42	Communication between infrastructure (traffic lights) and cloud/traffic control system
CR43	Communication between traffic alert system and cloud/traffic control system
CR44	The In-vehicle PF can be able to receive information related with VRU presence, generated by IoT infrastructure PF (alternative to CAM/DENM from ITS-G5 channel, for long range).

Table 13 – Platooning UC Requirements

ID	Requirement description
CR30	The vehicle may send and receive information to/from the cloud
CR31	V2X Communication between Vehicle and RSU
CR32	Communication between vehicles and cloud
CR33	V2V Communication between Vehicles

Table 14 – Urban Driving UC Requirements

ID	Requirement description
CR1	The vehicle must receive the geocasted notifications of hazard events (e.g. potholes, roadway works, pedestrians, VRUs, puddles, etc.) from RSU
CR2	The WSN on the road must notify the presence of puddles on the road whenever they are detected
CR3	The traffic control system must receive geolocalized notifications of hazard events from RSU (e.g. potholes, roadway works, pedestrians, VRUs, puddles, etc.)
CR4	Geolocalized notifications of hazard events (e.g. potholes, roadway works, puddles, etc.) from RSU may be stored by the data management service of the IoT platform

ID	Requirement description
CR5	The detection event of pedestrians on the roadway must be notified to the RSU from the camera
CR6	The number of detected pedestrians on the roadway detected by the camera may be stored by the data management service of the IoT platform
CR7	Every time the vehicle detects a hazard, it must be geocasted to other vehicles
CR8	The traffic control system must receive geolocalized notifications of hazard events (e.g. potholes, roadway works, pedestrians, VRUs, puddles, etc.) from vehicles
CR9	Bicycles must geocast their position, speed, orientation to other vehicles on the road
CR11	Traffic light must continuously geocast its light phase and the topology of the crossroad to vehicles on the road
CR12	The traffic control system must receive information about traffic conditions
CR17	The vehicle should be able to receive Signal Phase information, coming from IoT infrastructure platform (alternative to SPAT/MAP from ITS-G5 channel, for long range)
CR18	Communication between vehicle and cloud/traffic light control system
CR20	The vehicle must receive information about VRU presence and localization by a smartphone application
CR21	Communication between lecture schedule webserver of TU/e and AD vehicle
CR22	The vehicle must receive weather information by a cloud-based web server
CR23	The vehicle and the service center must communicate each other information for managing relocation requests of vehicles
CR41	Communication between vehicle and cloud/traffic control system
CR42	Communication between infrastructure (traffic lights) and cloud/traffic control system
CR43	Communication between traffic alert system and cloud/traffic control system
CR44	The In-vehicle PF can be able to receive information related with VRU presence, generated by IoT infrastructure PF (alternative to CAM/DENM from ITS-G5 channel, for long range).

Table 15 – Car Sharing UC Requirements

ID	Requirement description
CR28	Communication between the application hosted on the user device and the service center cloud
CR35	Communication between vehicle and Service center cloud

3.1.2.3 Gap analysis

IoT and ITS communication coexistence testing are imperative for stable and reliable communication. The objective is to accurately evaluate the autonomous vehicle devices' ability to maintain the performance in the presence of alternate radio protocols, networks/devices density and different weather and field environment conditions. It is critical to understand the details of coexistence testing and how to perform it both accurately and efficiently. The project recommends that further funding be dedicated in the future to address this work at scale in different environments and countries across Europe.

3.2 Communication Protocols

On the base of the information collected in section 2, this section provides a list of the protocols to be used in order to support AD IoT based Use Cases implementation. The information presented in Section 3.2 is related to what has been implemented in the various Pilot Sites.

For standard protocols, a reference to the standard document is provided. This activity has been carried out in coordination with task 5.5 activities.
For non-standard protocols, the description of protocol (if not available on other sources) or a reference to a description document is provided. Since D1.8 is public no confidential data is provided.

3.2.1 CFIO and CFOI communication protocol (CAM over “empty BTP” over “empty GeoNetworking” over 802.11-OCB or CAM over UDP over IPv6 over Ethernet)

The Versailles Pilot Site experience has been chosen as an example to describe how V2X communication and the IoT approach could be used to aid the automated driving functions.

Before going through the details, let us define some concepts that will be used in the following sub-sections.

CFIO: CAM From Inside to Outside.

CFOI: CAM From Outside to Inside.

CfioApp and cfoiApp are programs developed by CEA, on basis of ASN1C compiler open-source software package and ETSI CAM specification, to handle ETSI ITS-G5 CAM features.

VFLEX: Renault TWIZY robotized to perform Autonomous Driving (AD) capabilities. The partner VEDECOM in the Versailles PS provides three VFLEXs called VFLEX1, VFLEX2 and VFLEX3.

PC-AD: on-board computer that handles AD capabilities to each VFLEX (PC-AD1, PC-AD2 and PC-AD3).

VBOARD: Gateworks Ventana SBC (Single Board Computer) that implements connectivity capabilities. It is equipped with four kinds of interfaces that enable to handle several IoT features to enhance AD capabilities within each VFLEX (VBOARD1, VBOARD2, VBOARD3), as described below.

IP-OBU: Internet Protocol based On Board Unit, is a VBOARD.

BR0 interface is set here to simplify. It bridges:

- Wi-Fi a/b/g/n interface that provides devices inside or outside the car with Wi-Fi connectivity
- Ethernet interface that provides the VFLEX with connection to the VBOARD network. That provides both IPv4 and IPv6 connection to the VFLEX.

FRONT interface provides the VFLEX with IPv6 over IEEE 802.11-OCB (Out of Context of BSS) connection to handle V2V communication with another VFLEX ahead.

LTE (Long Term Evolution) is a MIMO interface that provides the VFLEX with 4G connection in IPv4 for communication with Cloud and the Internet.

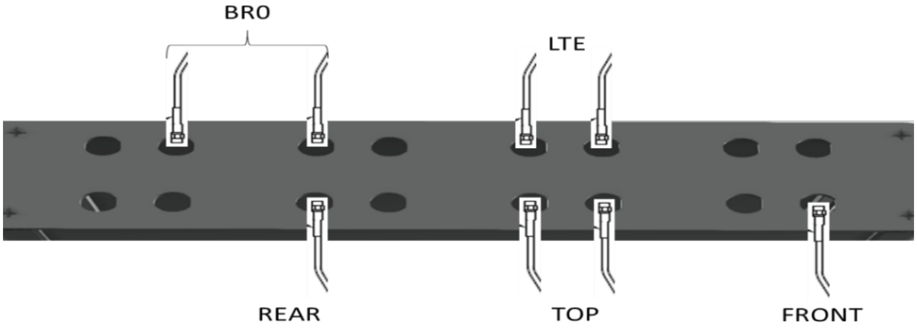

Figure 10: Gateworks Ventana SBC (VBOARD) embedded in each VFLEX

REAR interface provides the VFLEX with IPv6 over IEEE 802.11-OCB connection to handle V2V communication with another VFLEX behind.

TOP is a MIMO interface that provides the VFLEX with three features:

- CAM over IEEE 802.11-OCB connection to handle CAM (Cooperative Awareness Message) sending through the above-mentioned CFIO and CFOI communication protocols.
- IPv6 over IEEE 802.11-OCB (or IPv4 over IEEE 802.11OCB) connection to handle V2I communication between a VFLEX and an RSU (Roadside Unit) connected to a traffic light controller (TLC). The ETHERTYPE is 0x86DD.
- BTP and GeoNetworking headers are empty and we are using a specific ETHERTYPE (0x85B5).

D1.7 section 3, subsection 3.2.4.1.7 describes the concepts of IEEE 802.11-OCB.

VedeCAM is a software package developed by the partner VEDECOM to generate and read CAM messages.

XER: XML (Extensible Markup Language) Encoding Rule.

UPER: Unaligned Packed Encoding Rule.

3.2.1.1 How can CFIO and CFOI enhance the IoT and AD Capabilities?

The CFIO/CFOI communication protocol relies on both CAM over UDP over IPv6 over 802.11-OCB (over Ethernet) and CAM over IEEE 802.11-OCB. It offers capabilities necessary to Autonomous Driving (AD) car to handle ETSI ITS-G5 capabilities and to deal with other road users (other cars, bikes).

The car is seen as an IoT object that sends and consumes data. This data is used by the automated functions to manage the platooning while interacting with the other connected actors of the use case.

CFIO/CFOI also relies on IPv4 connection. That allows sending CAM messages to an IoT cloud platform. CAMs available on the IoT platform allows Vulnerable Road Users (VRU) equipped with Thing-class devices such as tablets, smartphones, smart glasses, and smartwatch to detect the presence of an AD car and to avoid accidents. In fact, these Thing-class objects are not able to generate or to receive CAMs directly. However, thanks to CFIO/CFOI, they are able to learn the content of CAMs via an IoT cloud service.

This protocol enhances the capabilities of AD cars to deal with the VRUs detection in complex road environments, such as the Urban Driving (UD) use case, where direct visibility on OCB may be impaired. In this situation, vertical visibility to base stations might help.

3.2.1.2 Topology for CFIO and CFOI

CFIO/CFOI communication protocol handles encoding and decoding of CAM messages that Thing-class devices (AD car, bicycles, smartwatch, smart glasses) send to share some ITS dynamic data. In Versailles PS, CEA implemented the following topology for CFIO/CFOI communication protocol, in partnership with VEDECOM.

On this schema, we simplified the characteristics of each VFLEX by showing only the embedded VBOARD and PC-AD.

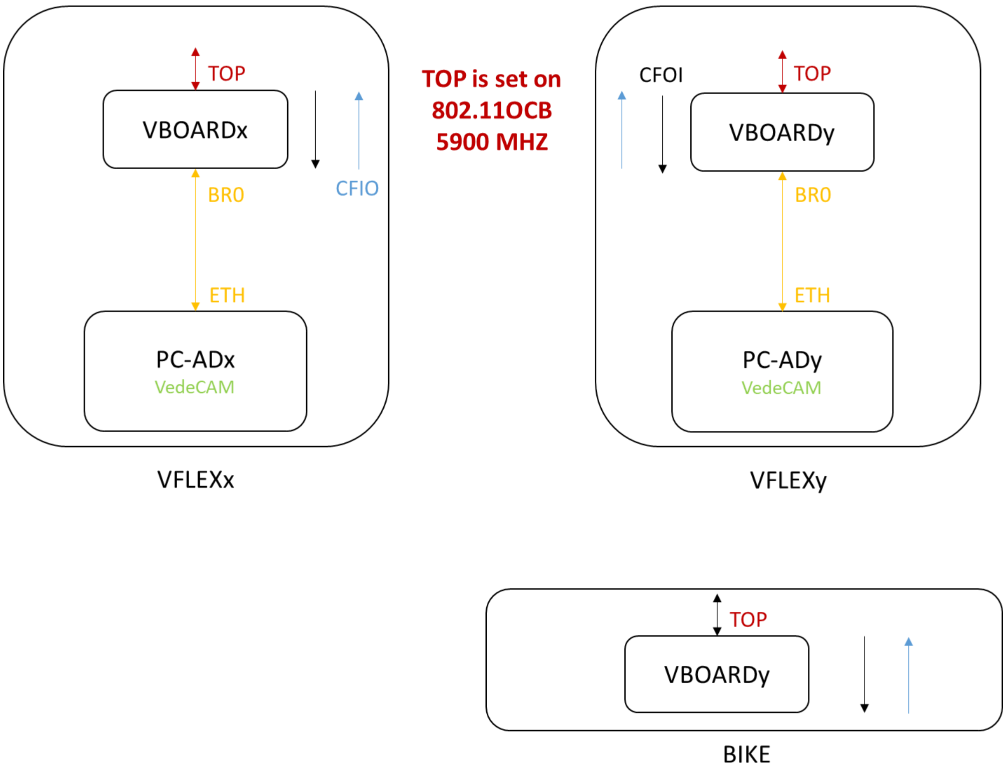

Figure 11: Topology for CFIO/CFOI communication protocol

For each VBOARD, in each VFLEX, we are using the TOP and the BR0 interfaces:

- The TOP interface is set on IEEE 802.11-OCB at the central frequency 5900MHz. It handles transmission and reception of CAM (Cooperative Awareness Messages); These CAMs contain characteristics of devices that send them such as the position, the path history, the station type (car, bike, roadside unit …), the station identification number and so on.
- The BR0 interface handles data transmission from/to each PC-AD in each VFLEX.

3.2.1.3 Message exchange for CFIO and CFOI

The CFIO/CFOI communication protocol implemented in Versailles PS is based on:

- CAM over “empty BTP” over “empty GeoNetworking” over IEEE 802.11-OCB (or over Ethernet) for the car intercommunication.
- CAM over UDP over IPv6 (over Ethernet) for the car onboard communication (between the PC-AD and the VBOARD)

CFIO handles data transmission from on-board (from the PC-AD) to off-board (toward the exterior of the VFLEX). It first decodes CAMs (XER-format) generated by the PC-AD and received through the BR0 interface to obtain an intermediary internal format. Then it encodes the result into CAM (UPER-format) and transmits it through the TOP interface.

CFOI handles data transmission from off-board (from the exterior of the VFLEX) to on-board (toward the PC-AD). It handles decoding of CAM data received from other Thing-class devices (other VLFEX, bikes) through the TOP interface and transmits it to the PC-AD through the BR0 interface.

3.2.1.4 Implementation aspects for CFIO and CFOI

In the Versailles PS, the implementation of CFIO/CFOI is compliant with ETSI CAM V1.3.2 specifications.

For that, there are a few steps to follow:

1. Get the ASN.1 specifications of ETSI CAM: these specifications are open and available in ETSI CAM documentation [19] or in “ASN.1 playground” platform [20].
   Section 6 of this document provides references to these two alternatives. For implementation in Versailles PS, we got the ASN.1 specifications directly from “ASN.1 playground” platform, which gives the complete ASN schema of ETSI CAM. For that:
   a. Go to the above-mentioned platform,
   b. Select ETSI CAM V1.3.2 schema,
   c. Click on ASN.1 specification (that will execute a download process),
   d. Save the file.asn.

   Note that the presentation of this platform changes frequently, this process small “How To” worked on April 10, 2019.
2. Generate ETSI CAM source code from ASN.1 schema got from the previous step: for that, we used the open-source “ASN1C compiler”. The goal of ASN1C compiler is to generate C or C++ source code from an ASN.1 schema given as parameter. We generate ETSI CAM C source code from the ASN.1 schema got from the first step.
3. Implementation of encoding and decoding of ETSI CAM: this consists mainly on the implementation of cfioApp and cfoiApp software packages. Both are based on UDP socket.

   The cfioApp is listening for XER-format packets (*dumpXer*) from the PC-AD. When it receives XER packets, they are decoded to get ETSI CAM message (*xerToCAM*) and then sent to outside through the IEEE 802.11-OCB TOP interface of the VBOARD (*forwardCAMToWorld*).

   The cfoiApp is listening for byte (UPER)-format packets (*byteConsumer*) from outside (of the VFLEX). Then these packets are decoded to get CAM data (*UperToCAM*). They are finally encoded into XER format (*CAMToXer*) to facilitate the processing by the PC-AD.
   The following schema gives a simplified approach of CFIO/CFOI communication approach in concordance with the previous description. It represents a function call diagram.

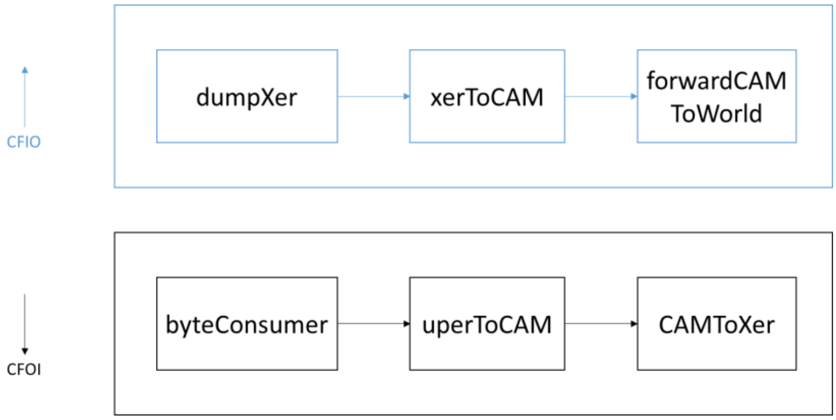

Figure 12: Implementation of ETSI CAM in Versailles PS (CFIO/CFOI communication protocol)

All the VBOARDs integrate cfioApp and cfoiApp to handle communication with the VRUs and other VFLEXs.
The following schema gives an overview of CAM types that are given as input of cfioApp and cfoiApp.

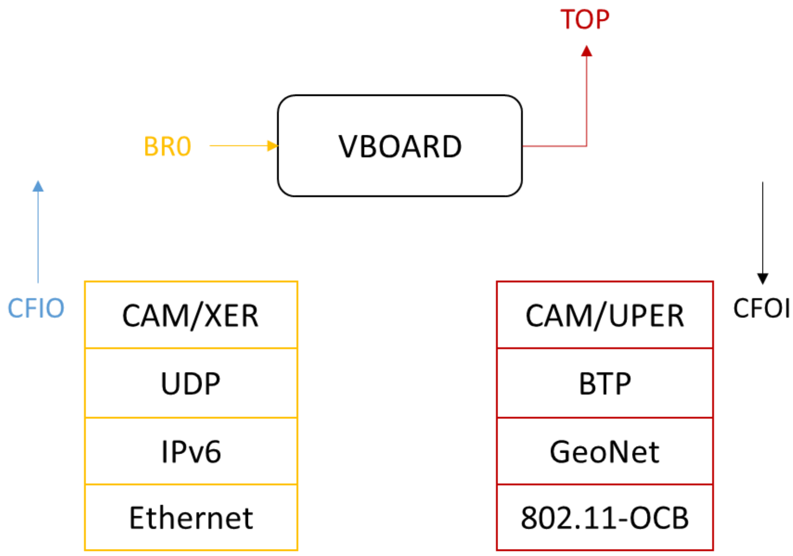

Figure 13: Input CAM for cfioApp and cfoiApp

In particular, you can observe that:

- CfioApp is waiting for XER-format CAM. This CAM is transported in UDP and transmitted on IPv6 over Ethernet. This kind of CAM is generated by a PC-AD. It cfioApp converts it to UPER-format CAM by cfioApp in order to send the message to off-board through TOP interface.
- CfoiApp is waiting for an UPER-format CAM. This is a standard CAM based on ETSI ITS G5 specification. This kind of CAM is generated by another VFLEX or a Bike in Versailles PS. Then cfoiApp converts it to XER-format CAM in order to transmit the message to PC-AD through BRO interface.
- The exchange between PC-AD and VBOARD (through cfioApp and cfoiApp) is handled in IPv6 over Ethernet, as described in the following schema where the IPv6 addresses are specified. The PC-AD is listening on port number 50001 and the VBOARD on port number 50000.

Figure 14: IPv6 configuration for handling CFIO/CFOI communication protocol

3.2.2 V2V communication protocols (RIO, Prefix Propagation, IPv6 over IEEE 802.11-OCB)

The Versailles Pilot Site experience has been chosen to describe this topic.

3.2.2.1 How can V2V communication protocol enhance IoT and AD Capabilities?

The V2V communication protocol, relying on Route Information Option (RIO), Prefix Propagation and IPv6 over 802.11-OCB, offers capabilities necessary to Autonomous Driving. This protocol is based on the Internet family of protocols and runs on Thing-class devices (IoT). The Autonomous Driving function used in the Platooning use case relies on the RTMAPS[1] [27] software and needs to exchange data directly between two or more cars. The V2V communication protocol establishes and maintains the IP communication paths between all devices (including IoT devices) of all cars in the Platooning.

3.2.2.2 Topology for V2V

Before going through the details, let us define some specific concepts that we are using in this section.

NDP [RFC 3971]: Neighbor Discovery Protocol is responsible for discovery of other network nodes on the local link, to determine the link layer addresses of the other nodes, to find available routers, and to maintain reachability information about the routes to other active neighbor nodes.

ICMPv6 [RFC 4443]: Internet Control Message Protocol version 6 is a management protocol that is very important to the running of IPv6. As such, there are many different types of messages it could transmit which is used to identify the type of message being transmitted.

RA: Router Advertisement is an ICMPv6 packet type defined in NDP. It allows routers to advertise their presence together with various link and Internet parameters either periodically, or in response to a Router Solicitation message.

PIO: Prefix Information Option is an option set to RA messages.

RIO: Route Information Option is an option set to RA messages.

LL: Link-Local

[1] - RealTime Multisensor is a solution for data acquisition, data process and data fusion.

In Versailles PS, V2V communications are intended to be used in VFLEXs in order to perform a platooning between three VFLEXs in which AD capabilities are enhanced by an IPv6 over IEEE 802.11-OCB communication protocol. For the V2V communication protocol, we focused mostly on the connections established through FRONT and REAR interfaces.

We are using the following concepts as we are handling platooning with three (3) VFLEXs:

- Leader is the leading VFLEX and is in manual mode during platooning
- First follower is the VFLEX immediately behind the Leader and is in AD mode during platooning
- Second follower is the VFLEX on the queue of the platoon of three cars and is in AD mode during platooning

The V2V communication protocol topology performed in Versailles PS is given below.

Figure 15: V2V communication for three (3) VFLEXs – Platooning

ODHCP6C and RADVD are two programs that we are using in the V2V communication protocol. We are defining and expressing them in sub-section 3.2.3.

We are using two (2) IEEE 802.11-OCB frequencies: 5880 MHz and 5890 MHz for enabling V2V communication between three VLFEXs.

To avoid interferences and loops, we managed to use only the interfaces needed depending on the role of VLFEX (Leader, First Follower or Second Follower). So, you can see in the previous schema, that:

- We always deactivate Leader's FRONT interface, as it is not useful for the communication
- We always deactivate Second follower's REAR interface, as it is not useful for the communication

Thus, from CEA side we decided to implement the following method to simplify role changing and frequency setups:

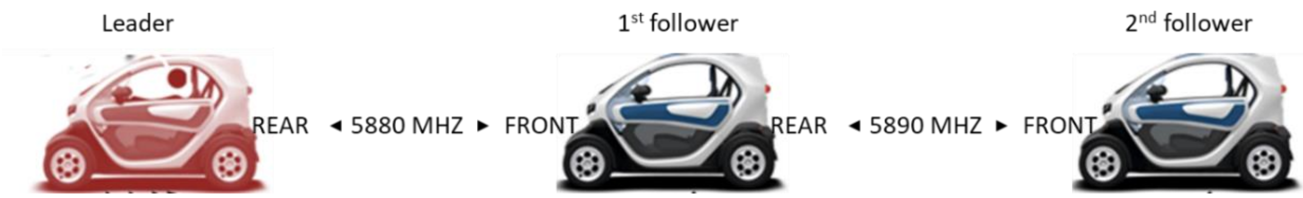

Figure 16: method chosen for frequency setup to handle Platooning

That means that whatever the VFLEX considered (VFLEX1 or VFLEX2 or VFLEX3), the frequency setup between the Leader and the First Follower and between the First Follower and the Second Follower to handle our V2V-based platooning will be the same.

We measured the latency of an ICMPv6 ping message between two (2) VFLEXs (for example, from PC-AD of Leader to PC-AD of First Follower) through REAR and FRONT interfaces. We are obtaining around 1.5ms latency, which is very promising compared to what can be performed with cellular network as 4G (around 50ms).

3.2.2.3 Message exchange for V2V

The V2V communication protocol implemented in Versailles PS is based on IPv6 over IEEE 802.11-OCB as mentioned before.

From IEEE 802.11-OCB we are exploiting frequency and wireless capabilities features.
From IPv6 we are using NDP features, in particular, Router Advertisements (RA) that are ICMP (Internet Control Message Protocol) kind of packet that is sent by equipment that implements IPv6 protocol to announce their presence to the other equipment connected through the same link. In our case, the link is established through the IEEE 802.11-OCB FRONT and REAR interfaces of each VBOARD.

Each VFLEX is equipped with one VBOARD.

We are handling three (3) "kinds" of RA:

1. RA with DefaultLifeTime set to zero (0) and a PIO containing the prefix of the BR0 interface of the VBOARD which sends the RA and the Link-Local – LL address of the interface from which it sends the RA. This kind of RA is sent from each VBOARD to its corresponding PC-AD (for example VBOARD1 to PC-AD1) through the Ethernet interface. That allows setting up IPv6 address for the PC-AD and to set the LL address of the VBOARD as the default route of the PC-AD. That enables a PC-AD to handle IPv6-based communications.

1. RA with DefaultLifeTime different from zero (0), an RIO that contains the prefix of the BR0 interface of the VBOARD that sends the RA and the LL address of the interface from which it sends the RA. The type of RA is sent from each VBOARD to another VBOARD that is connected to the same link in order to announce its prefix to the others through the IEEE 802.11-OCB FRONT/REAR interfaces. Once another VBOARD (which is in a VFLEX) receives this type of RA, it is able to add a new routing table entry to join the corresponding prefix (network). So, communication could be established between two (2) VFLEXs, if they know the prefix of each other in their routing tables.

2. RA with DefaultLifeTime different from zero (0), an RIO that contains the prefix of the BR0 of another VBOARD and the LL address of the interface of the VBOARD that sends the RA. The type of RA is sent from each VBOARD to another VBOARD that is connected to the same link in order to announce the prefix of another VBOARD that it previously learnt to the others through the IEEE 802.11-OCB FRONT/REAR interfaces. Basically, this type of RA will only be sent by the First Follower in order to announce:
    - The prefix of the Leader to the Second follower;
    - The prefix of the Second follower to the Leader.

So, communication might be established between the three cars. For example, the Leader can send

RTMAPS data to both the First follower and the Second Follower.
We measured the latency of an ICMPv6 ping6 message between Leader and Second Follower (from PC-AD of Leader to PC-AD of Second Follower). We obtained around 3ms (equivalent to the double of the latency between two VFLEXs immediately connected like Leader and First Follower and First Follower and Second Follower).
Note that the latency between two VFLEXs (PC-AD to PC-AD) represents the combination of the following latencies:

- Latency of Ethernet link between each PC-AD and its corresponding VBOARD (up to 0.3 ms);
- Latency of IEEE 802.11-OCB link between VBOARDS OCB interfaces (up to 1.2 ms).

This is an important aspect that developers should take into account for the scalability of the V2V communication protocol.

3.2.2.4 Implementation aspects for V2V

Let us define two (2) software packages that we are using to handle V2V communication protocol.

RADVD: Router Advertisement Daemon is a software package used to send RA. For that, it needs a configuration file, on which the options such as:

- the default lifetime value that the receiver has to set while handling the RA and that defines whether the receiver should consider the source of the RA as it's default route or not;
- the minimum and maximum RA intervals, which define how often the RA packets should be sent;
- the prefix or the route to announce, etc.

ODHCP6C: Openwrt Dynamic Host Configuration Protocol version 6 for Client-side is a software package that enables handling IPv6 address and routing table entries configuration once a host receives an RA.
In our case, ODHCP6C handles parsing RA and retrieving information such as:

- the source IPv6 LL address of the RA;
- the prefix or the specific route which is announced;
- the interface that receives the RA, etc.

Note that we do not specify the IPv6 LL address of the RA in the configuration file of RADVD, but it is included in the RA packets according to the design of RA.

The implemented V2V communication involved the combination of RADVD and ODHCP6C in order to send RAs and handle received RAs in a way, which is customized and adapted to what we need for enabling a vehicular inter-communication based on route and prefix exchanges.

Immediately connected neighbour: two VFLEXs are immediately connected neighbours when they are immediately following each other, without any other VFLEX between them (the REAR of the VBOARD of one is communication with the FRONT of the VBOARD of the other).

The implementation has three (3) successive steps:

1. Frequency setup: that consists on setting up the frequencies as defined in 3.2.2.2 once the VFLEX fleet Manager (human operator or cloud intelligence) has chosen the role of each VFLEX (LEADER or First Follower or Second Follower).
2. Route discovery of immediately connected neighbours: that consists of running customized RADVD and ODHCP6C software suits on the activated interface(s) of each VBOARD within

each VFLEX. So that each VFLEX is able to send and receive RAs to and from its activated interface(s) and to construct paths to join the immediately connected neighbours.

3. Route propagation: this step is necessary to make a connection between three (3) VFLEXs possible. Without this step, they can communicate only between each two of them. They have to propagate the new routes that they got from the neighbours so everyone has a routing entry for every existing VFLEX. In figure 16, without route propagation VFLEX1 (the Leader) can communicate with VFLEX2 (the First Follower) and VFLEX3 (the Second Follower) can communicate with VFLEX2. However, no communication is possible between VFLEX1 and VFLEX3. The job of route propagation is to add routing entries to the routing table of VFLEX1 for it to reach VFLEX3 through VFLEX2 and vice-versa.

In practice, in the scenario of 3-VFLEXs platooning, when the VFLEX has the role of First Follower, it propagates the routes learnt from the others to the other VFLEXs (ahead and behind) in order to make the Leader communicate with the Second Follower.

3.2.3 V2I communication protocol (DIASER over UDP over IPv4 over 4G, DIASER over UDP over IPv4 over Ethernet, DIASER over UDP over IPv4 over 802.11-OCB)

The Versailles Pilot Site experience has been chosen as an example to describe how the V2I communication and the IoT approach could be used to aid the automated driving functions in case of the crossing of a road with traffic light.

3.2.3.1 How can V2I communication protocols enhance IoT and AD Capabilities?

The V2I communication protocol relying on DIASER over UDP messages' exchange, 4G connectivity and IPv4 over 802.11-OCB offers capabilities necessary to enhance AD capabilities by transmitting safety data (traffic light information) while the AD car is approaching a semaphore.
In Versailles PS, this feature provides the AD functions used in the Platooning and the AD use cases with the capabilities to cross safely an intersection.

3.2.3.2 Topology for V2I

Let us define some concepts specific to this sub-section before going through the details.

TLC: Traffic Light Controller is a traffic regulation equipment that is able to provide traffic light status and traffic information.

RSU: Roadside Unit is a piece of equipment capable of handling communication within a vehicular network and located on roadside infrastructure. For Versailles PS, we have two kinds of RSU:

- Maestro board, which has an Ethernet interface and a 4G, interface and provides the TLC with 4G connectivity; this board is able to handle communication with a cloud server.
- VBOARD, which has BR0 LTE and TOP interfaces (as specified in sub-section 3.2.1) that will provide both 4G and IEEE 802.11-OCB connections. So that the TLC could directly communicate with the VFLEX through the RSU.

From Versailles PS point of View, **V2I** stands for Vehicle to road Infrastructure communication where the road infrastructure is a TLC connected to our RSU.

DIASER (Standard Dialog of Traffic Regulation Equipment): "DIAlogue Standard des Equipements de Régulation de trafic" (DIASER NF P 99-071-1 G3) [21] is a French closed standard which aims to normalize the exchanges of traffic light regulation equipment in a safe and secure manner. The major part of the TLC in France, in particular, the ones on which we are working on in Versailles PS, implements the DIASER specifications.

AXIMUM, **LA CROIX** and **FARECO** are the main providers of TLC in Versailles PS.

TLStatus: Traffic Light Status (colour of the traffic light).

TLRT: Traffic Light Remaining Time (time remaining before the current colour switches to another).

Versailles PS requires the transmission of TLStatus and TLRT during V2I communication.

CEA proposes the topology represented on the next figure for V2I communication protocol. It has two possible implementations according to the above-mentioned definition of the RSU.

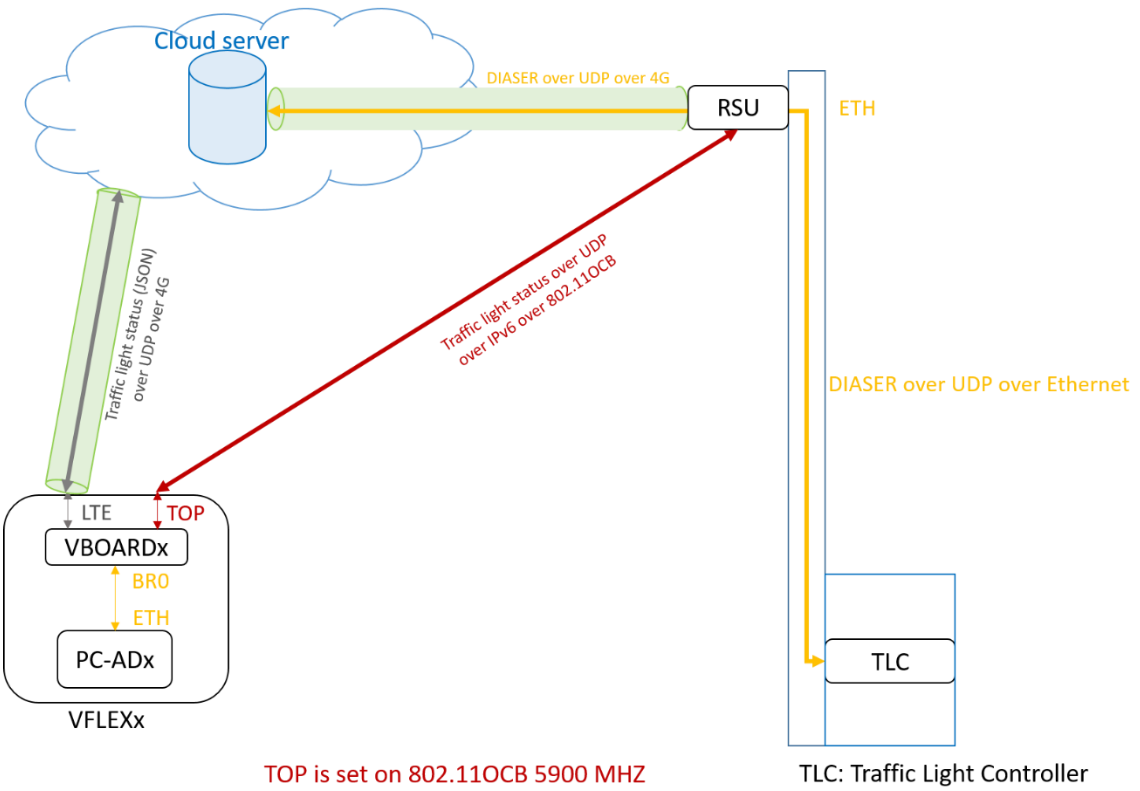

Figure 17: Topology for V2I communication in Versailles PS

The next sub-section describes the message exchange for this topology.

We are focusing on two possible topologies (the implementation is currently not done):

1. Topology 1: A cloud server requests TLStatus and TLRT to the TLC;
2. Topology 2: VLFEX requests TLStatus and TLRT to the TLC.

3.2.3.3 Message exchange for V2I

V2I communication protocols in Versailles PS includes several message exchanges depending on the topology that we consider.

For Topology 1, a cloud server generates DIASER requests to ask for TLStatus and TLRT. These DIASER requests are transported through UDP and routed through an IP over 4G connection to the IP-RSU (Maestro board). Then the IP-RSU forward (IP forwarding) the requests to the TLC.
The TLC generates corresponding DIASER responses to provide the cloud server with TLStatus and TLRT. These responses take the reverse path of the DIASER request.
Note that all the traffic through 4G connection is encapsulated into a VPN tunnel.
The recipient decodes the response according to the DIASER specifications.
Then the cloud server sends the TLStatus and the TLRT to the VFLEX through a 4G connection.

This will require approximately a 110ms latency due to 4G connection.

For Topology 2, the PC-AD of a VFLEX generates DIASER requests to ask for TLStatus and TLRT. These requests are relayed to the IP-OBU through the Ethernet connection and transported by UDP. Then the IP-OBU forwards the traffic to the OCB interface. As the TLC does not support IPv6 for now, the packets are transported by UDP over IPv4 over 802.11-OCB toward the IP-RSU. The IP-RSU forwards the request from IEEE 802.11-OCB interface to Ethernet interface. Then it transmits the requests though UDP over IP over Ethernet to the TLC.
The TLC generates the DIASER response, which takes the reverse path to reach the VLFEX.

This will require approximately a 4ms latency, which is very promising in terms of timeliness.

In addition to these two topologies, CEA developed another concept of V2I communication protocol on which the RSU (a VBOARD) is considered as a gateway to enable the VFLEX to get an internet connection. In this approach, we consider the VFLEX as a Thing-class object that is connected to Internet through an RSU.
This relies on an IPv6 over IEEE 802.11OCB connection between the VLFEX and the RSU, and an IPv6 over 4G connection to reach the internet.

3.2.3.4 Implementation aspects for V2I

Currently, these two aspects have not been completely implemented in Versailles PS.

For topology 1, CEA partner equipped itself with a simulator of TLC provided by AXIMUM. CEA implemented remote access capability in order to access to the web interface of this simulator and to enable sending DIASER requests from a host that simulates the role of a cloud server.
Once some partners (CEA, VEDECOM, AKKA, and SENSINOV) will validate this first step, a consensus should be made to decide which equipment (from one of the partner) would decode the DIASER responses in order to provide the PC-AD with the accurate TLStatus and TLRT.

For topology 2, we have to implement IPv4 IEEE 802.11-OCB, which is not yet done.

3.2.4 3GPP C-V2X protocol (3GPP Rel-14 LTE V2X)

The Third Generation Partnership Project (3GPP) published in September 2016 a standard in Release 14 for the support of V2X communications [14], which is commonly referred to as LTE-V2X or Cellular V2X (C-V2X). The standard includes two radio interfaces. The cellular Uu interface supports vehicle-to-infrastructure (V2I) communications and the PC5 interface supports vehicle-to-vehicle (V2V) communications. Figure 18 shows how the two complementary transmission modes are enabled by the Uu and the PC5 Interfaces:

- Uu operates on commercial cellular licensed spectrum; it is suitable for latency tolerant use cases, such as telematics, infotainment and informational safety (road hazard warning more than 1 km ahead).
- PC5 operates on 5.9 GHz; it enables direct communications for active safety use cases, such as: Do Not Overtake warning, Blind curve/Local Hazard warning, dynamic roadworks warning, intersection movement assist at a blind intersection, Vulnerable Road User alerts at a blind intersection, Left turn assist at intersection, collision avoidance, etc.

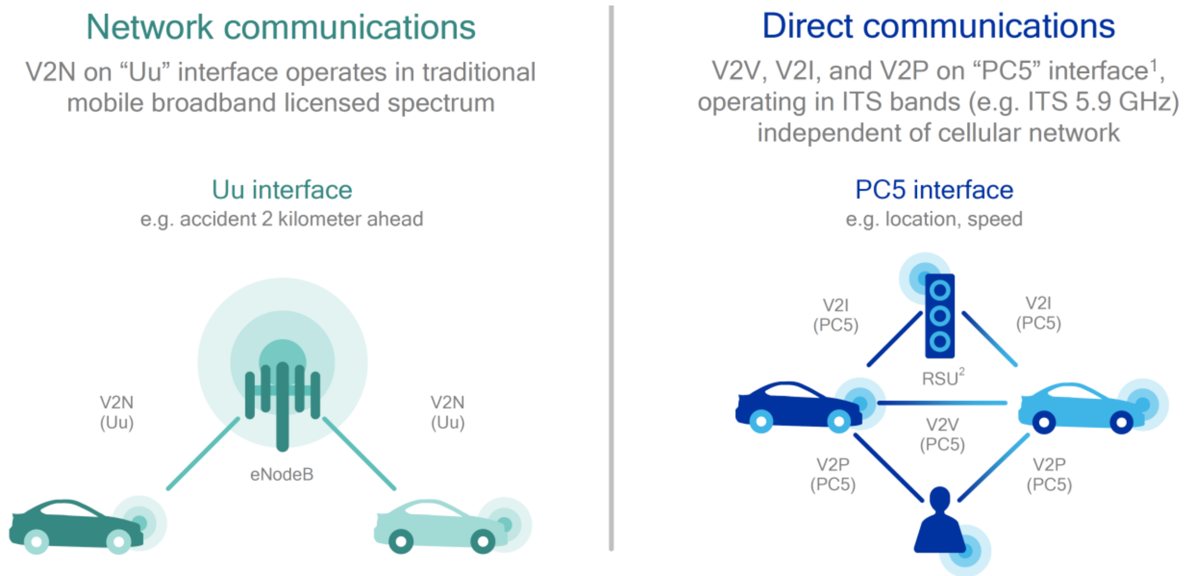

Figure 18: C-V2X complementary transmission modes

3.2.4.1 Side Link Direct communications on "PC5" interface

PC5 interface is based on direct LTE sidelink (or device-to-device communication), which was introduced in Release 12 for public safety, and enhances it for the V2V communications as follows.

Rel- 12 LTE sidelink included two modes of operation, mode 1 and mode 2, which were designed with the objective of prolonging the battery lifetime of user equipment for device-to-device communication at the cost of increasing latency. However, connected vehicles require highly reliable and low-latent communications. Because these two modes were not suitable for vehicular applications, Release 14 introduced two new communication modes, mode 3 and mode 4 (using "PC5" interface), specifically designed for vehicular communications. Whereas in transmission mode 3 the base station of the cellular network (eNodeB) controls radio resource selection, transmission mode 4 is based on autonomous radio resource selection by vehicles. In other words, mode 4 can operate without the cellular network infrastructure and is therefore considered as the baseline for safety-critical vehicular communications.

For both the transmission modes, the link design for the V2V communications is for the 5.9 GHz ITS band and fulfils challenging requirements such as high vehicle speed in the order of 250 km/h, i.e. relative speed between vehicles in the order of 500 km/h, and high frequency offset up to 0.3ppm, i.e. 1800Hz for the carrier frequency 5.9GHz. In addition, the LTE-V2V link design improves the link budget compared to other existing V2X technologies and can increase the reliability, under certain conditions, by adding a redundant transmission per packet [16].

3.2.4.1.1 Mode 4

Vehicles communicate using sidelink or V2V communications under mode 4 and autonomously select their radio resources independently of whether they are under cellular coverage or not. When the vehicles are under cellular coverage, the network decides how to configure the V2X channel and informs the vehicles through the sidelink V2X configurable parameters [14]. The message includes the carrier frequency of the V2X channel, the V2X resource pool, synchronization references, the sub-channelization scheme, the number of subchannels per subframe, and the number of RBs per subchannel, among other things. When the vehicles are not under cellular coverage, they utilize a preconfigured set of parameters to replace the sidelink V2X configurable parameters. However, the standard does not specify a concrete value for each parameter. The V2X resource pool indicates which subframes of a channel are utilized for V2X. The rest of the subframes can be utilized by other services, including cellular communications. The standard includes the option to divide the V2X resource pool based on geographical areas (referred to as zoning [14]). In this case, vehicles in an area can only utilize the pool of resources that have been assigned to such areas.

3.2.4.1.2 Mode 3

Vehicles also communicate using sidelink or V2V communications under mode 3. However, the selection of subchannels is managed by the base station or evolved NodeB (eNB), and not by each vehicle as is the case in mode 4. Mode 3 is, hence, only available when vehicles are under cellular coverage. The 3GPP has defined the necessary cellular architecture enhancements to support V2X. One of these enhancements is the V2X control function that is used by the network in mode 3 to manage radio resources and to provide vehicles (or, in general, user equipment [UE]) with the sidelink V2X configurable parameters. Mode 3 utilizes the same subchannel arrangements as defined for mode 4. As opposed to mode 4, the standards do not specify a resource management algorithm for mode 3. Each operator can implement its own algorithm that should fall under one of these two categories [15]:

- Dynamic scheduling: Vehicles request sub-channels to the eNB for each packet transmission. This increases the cellular signalling overhead and delays the packet transmission until vehicles are notified of their assigned subchannels.
- SPS: The eNB reserves sub-channels for the periodic transmissions of a vehicle like in mode 4. However, in contrast with mode 4, it is up to the eNB to decide how long the reservation should be maintained.

Vehicles operating under mode 3 can be supported by different cellular operators or by public land mobile networks (PLMNs). To enable their direct communications, the 3GPP has defined an inter-PLMN architecture, that can support the multiple scenarios (see [17]).

Technical details of C-V2X such as physical layer, medium-access control protocol and congestion control mechanisms can be found in ETSI Technical specifications, starting from [18]. In the tables below (Table 16, Table 17, Table 18) the technical parameters of C-V2X system are summarized.

Table 16 – Technical parameters of C-V2X Rel. 14 (LTE-V2X)

Parameter	Value	Comments
Maximum radiated power (e.i.r.p.)	33dBm EIRP with 6dBi antenna gain and 23dBm/MHz max PSD EIRP 14PRB: 27 dBm EIRP 20PRB: 28.5 dBm EIRP	**According to 3GPP TR 36.786 V14.0.0 (2017-03)** Table 6.2.2.2-1: Simulation assumptions: V2X communications
Antenna beam shape/gain	0 dBi or 6dBi	**According to 3GPP TR 36.786 V14.0.0 (2017-03)** Table 6.2.2.2-1: Simulation assumptions: V2X

Parameter	Value	Comments
		communications
Polarization	Omni Antenna or Recommendation ITU-R F.1336 in ECC Report 101	**According to 3GPP TR 36.786 V14.0.0 (2017-03)** Note: For coexistence scenarios such as DSRD coexistence with LTE V2X studied in 3GPP, Omni antenna is assumed. Nevertheless, the antenna pattern assumed in ECC Report 101 based on an ITU-R F.1336 model could also be used/supported.
Modulation and Coding Scheme	QPSK, target rate 1/2; QPSK, target rate 3/4; 16QAM, target rate 1/2; 16QAM, target rate 3/4.	**According to 3GPP TR 36.786 V14.0.0 (2017-03)** Section 5.3.1.1 QPSK, target rate 1/2; QPSK, target rate 3/4;16QAM, target rate 1/2; 16QAM, target rate 3/4.
Data rates	56.6kbps to 15.1Mbps	Calculated based on various modulation and coding scheme
Channel Bandwidth	10 MHz	
Communication mode	Half-duplex, broadcast	Half-duplex and broadcast are believed to be adequate for most applications considered to date.
Receiver noise power	-91 dBm	**According to 3GPP TR 36.786 V14.0.0 (2017-03)** Section 5.3.2 Where noise floor is -91dBm coming from thermal noise of -104dBm and noise figure of 13dB
Receiver sensitivity	See Table 17	**According to 3GPP TR 36.786 V14.0.0 (2017-03)** Section 5.3.1.1
TPC	TPC with range >30dB (The minimum output power is down to -40dBm)	**According to 3GPP TS 36.101 V14.7.0 (2018-03** Section 6.3.2G defines minimum output power to -40dBm
Duty Cycle	1% (worst case based on option 1) or less (based on option 2)	**According to 3GPP TR 36.786 V14.0.0 (2017-03)** Table 6.2.2.2-1: Simulation assumptions: V2X communications • Option1: 1 transmission every 100ms • Option2: Dependent traffic on UE velocity [R4-167937]
Additional Mitigation techniques	Congestion Control for C-V2X Rel. 14	**According to 3GPP TS 36.331 V14.6.2 (2018-04), 3GPP TS 36.321 V14.6.0 (2018-03) and 3GPP TS 36.213 V14.6.0 (2018-03).**
Message length	190 Bytes /300 Bytes	**According to 3GPP TR 36.786 V14.0.0 (2017-03)** Table 6.2.2.2-1: Simulation assumptions: V2X communications

Parameter	Value	Comments
Transmitter unwanted emissions	See Table 18	**According to 3GPP TS 36.101 V14.7.0 (2018-03)** section 6.6.2.2.4

Table 17 – Comparison of regulatory sensitivity and LTE V2V sensitivity (TR 36.786 V14.0.0 (2017-03) Section 5.3.1.1)

Modulation	Coding rate	Sensitivity requirement in EN 302 571 (dBm)	Sensitivity for V2V (dBm)	Margin (dB)	Sensitivity for V2V (dBm)	Margin (dB)
QPSK	½	-82	-90.01	8.01	[-89.7]	7.7
QPSK	¾	-80	-86.50	6.5	[-85.6]	5.6
16-QAM	1/2	-77	-83.85	6.85	[-83]	6
16-QAM	3/4	-73	-80.30	7.3	[-78.4]	5.4

Table 18 – Spectrum Emission limit (3GPP TS 36.101 V14.7.0 (2018-03) Section 6.6.2.2.4)

Spectrum emission limit (dBm)/ Channel bandwidth		
Δf_{OOB} (MHz)	10 MHz	Measurement bandwidth
$\pm$ 0-0.5	$[-13-12\left(^{\lvert\Delta fOOB\rvert}/_{MHz}\right)]$	100 kHz
$\pm$ 0.5-5	$[-19-\frac{16}{9}\left(^{\lvert\Delta fOOB\rvert}/_{MHz}-0.5\right)]$	100 kHz
$\pm$ 5-10	$[-27-2\left(^{\lvert\Delta fOOB\rvert}/_{MHz}-5.0\right)]$	100 kHz

3.2.4.2 C-V2X upper layers supporting the ITS-Station

Recently the ETSI TC ITS standards regarding the higher layer specifications of the C-ITS stack (i.e. CAM/DENM/BTP/GeoNetworking) have been updated in order to support the ITS-station with LTE-V2X access layer technology [26]. Generally speaking, with those new amendments of the standards, C-V2X is settled to reuse the C-ITS well-established services and application layers, including security and transport layers (see Figure 19).

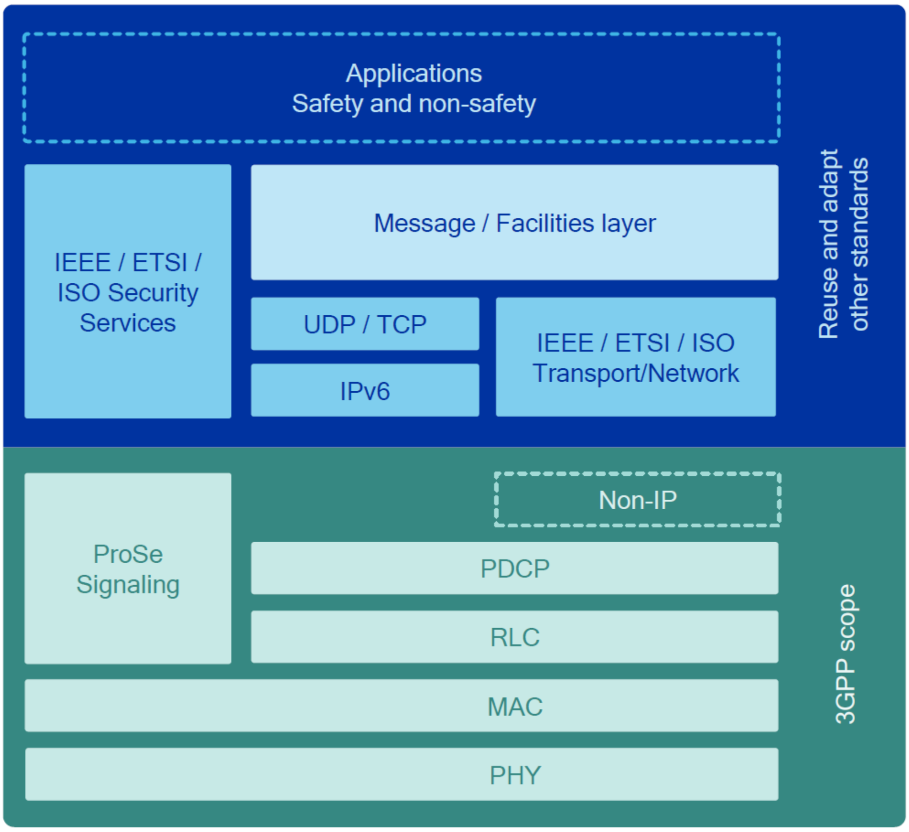

Figure 19: Full C-ITS stack for C-V2X in the ITS-Station architecture

Facilities Layer (ETSI TC ITS WG1):

- Cooperative Awareness Basic Service (aka CAM)
    - ETSI EN 302 637-2 V1.4.1 (2019-01) [19], which has been approved by ETSI TC ITS and published on ETSI website, supports both ITS-G5 and LTE-V2X.
- Decentralized Environmental Notification Basic Service (aka DENM)
    - ETSI EN 302 637-3 V1.3.0 (2018-08) [20], which has been approved by ETSI TC ITS and published on ETSI website, supports both ITS-G5 and LTE-V2X.

Transport and Network Layers (ETSI TC ITS WG3)

- Basic Transport Protocol (BTP)
    - ETSI TS 102 636-7-2 V1.1.1 (2019-01), which has been approved by ETSI TC ITS and published on ETSI website, specifies amendments for LTE-V2X to be used in conjunction with ETSI EN 302 636-5-1 (i.e., not a replacement).
    - ETSI EN 302 636-5-1 V2.2.0 (2019-02), which has been approved by ETSI TC ITS and is published on the ETSI website, is agnostic to the underlying access layer technology and thus is compatible with both ITS-G5 and LTE-V2X.
- GeoNetworking, Media-Independent Functionality (GN-MIF)
    - ETSI TS 102 636-7-1 V1.1.1 (2019-01), which has been approved by ETSI TC ITS and published on ETSI website, specifies amendments for LTE-V2X to be used in conjunction with ETSI EN 302 636-4-1 (i.e., not a replacement).
    - ETSI EN 302 636-4-1 is currently being updated under an active work item in WG3 to be truly “media-independent” in accordance with title/scope/intent of the specification.
        - Since the updated document will be agnostic to the underlying access layer technology, it will be compatible with both ITS-G5 and LTE-V2X.
        - Submitted for ETSI TC ITS approval at March 2019 meeting.

3.2.5 IoT-specific communication protocols

3.2.5.1 6lowPAN communication protocol

The 6LoWPAN standard (RFC 4944) has been defined by IETF to adapt IPv6 communication on top of IEEE 802.15.4 networks. 6LoWPAN refers to IPv6 over Low Power Wireless Personal Area Networks. It enables IPv6 packets communication over low power and low rate IEEE 802.15.4 links and assures interoperability with other IP devices. 6LowPAN devices can communicate directly with other IP-enabled devices.

The fundamental difference between 6LowPAN and Zigbee is the IP interoperability of the first. 6LowPAN devices are capable of communication with other IP-enabled devices whereas Zigbee node needs an 802.15.4/IP gateway to interact with an IP network. The decision to select one standard versus another should be determined by the target application.

3.2.5.2 Narrow-Band IoT protocol

NB-IoT (Narrow Band Internet of Things) has been introduced in Release 13 of the 3GPP specification enabling IoT services in the mobile domain. NB-IoT applications focus mainly on devices placed in locations where a substantial extension of the radio coverage is required and battery life is an extremely important factor since it is not easy or even economically convenient to replace the battery. In these cases, the life cycle of the devices corresponds de facto to the life of their battery.

At the same time, the amount of data to be transferred and received by these devices is very small (in the order of several tens of bytes per day as average or even smaller), so NB-IoT is an optimized solution for specific applications such as smart metering.

NB-IoT technology allows three different forms of deployment:

- **"stand-alone ":** it works in spectrum portions made available, for example, by re-farming one or more GSM carriers, using one or more nominal 200 kHz channels, 180 kHz effective.
- **"guard-band":** it works by using one or more 180 kHz PRB allocated in the guard(s) band of an LTE channel.
- **"in-band":** NB-IoT can be deployed on an LTE channel by using one or more 180 kHz spectrum portions, called Physical Resource Blocks (PRBs), allocated directly inside it;

The NB-IoT system is self-contained, as it provides dedicated control channels and synchronization signals, separate from LTE. It is precisely this feature that also allows NB-IoT to be deployed in "guard-band" or "stand-alone" mode since for broadcasting and synchronization purposes it does not depend on an existing legacy system.

3.2.5.3 Domain-specific IoT protocols

IoT communication facilitating enhanced automated driving (AD) covers several domains including the concept of V2X (Vehicle-to-Everything) or V2E (Vehicle-to-Environment) communications applied for autonomous transportation and mobility applications and services as illustrated in Figure 20. A vehicle with automated features must have established reliable interactions with different domains that are interlinked through IoT devices and one or multiple systems. The whole ecosystem relies on the interaction among On Board Units (OBUs), Road Side Units (RSUs), and Vulnerable Road Users (VRUs). Smart sensors and actuators in the vehicles, roads and traffic control infrastructures collect a variety of information to serve enhanced AD.

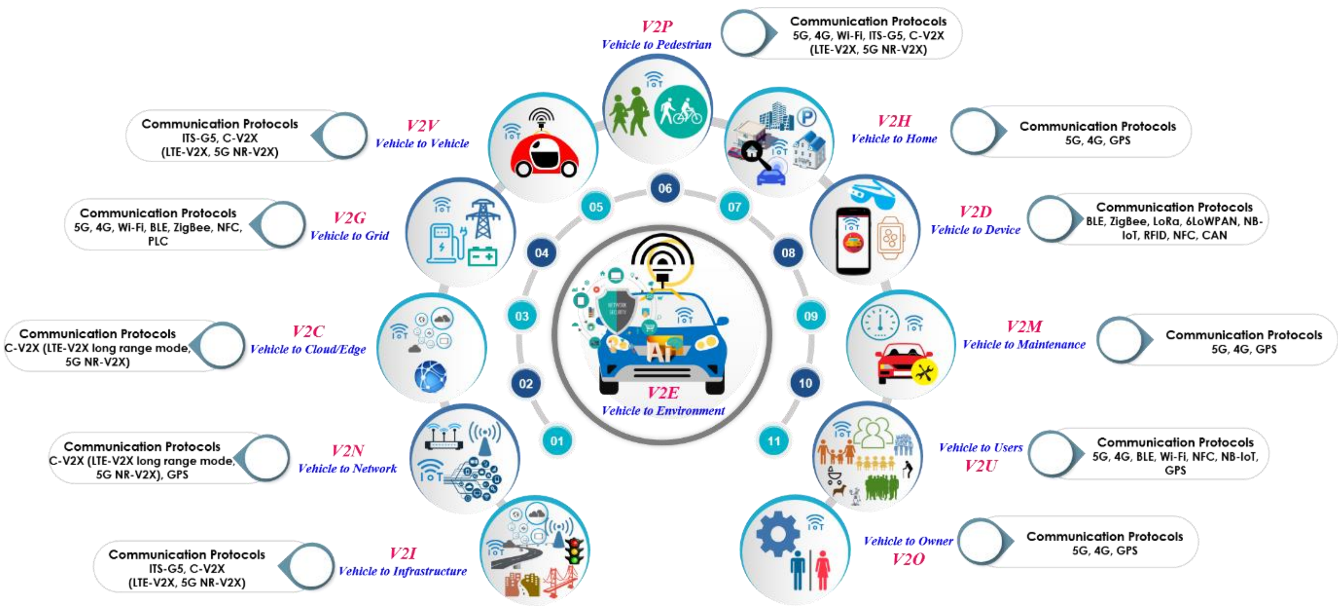

Figure 20: Autonomous vehicle domains of interaction and communication channels

The autonomous vehicles and IoT applications cover several domains of interaction, communication, exchange of information and knowledge as illustrated in Figure 20. The figure illustrates all the domains of interactions between the autonomous vehicle and the environment through communication and sensing capabilities. The overall interactions are covered under the name Vehicle to Environment (V2E) and consist of:

- Communication and sensing interactions between the autonomous vehicle and the dynamically changing environment (e.g. other terrestrial vehicles, pedestrians, cyclists, aerial and naval/maritime vehicles, different types of IoT devices, etc.)
- Communication and sensing interactions between the vehicle and its static environment (e.g. charging stations, traffic signals, tolling systems, electronic parking, roads, buildings, home, IoT devices, etc.)
- Communication and sensing interactions with different service providers (e.g. network communication providers, cloud/edge service providers, etc.)
- Communications with the owners, users, mobility service providers (e.g. vehicle owners, users, vehicles fleet owners/operators, vehicles producers, IoT service providers, maintenance providers, etc.).

The convergence of autonomous vehicles, IoT and AI applications are accelerating the implementation of Internet-of-Vehicles (IoV) concept and the move to Mobility as a Service (MaaS) and tier-one automotive companies, large technology companies and technology start-ups active involved in V2E, addressing first safety, security and privacy use cases to accelerate user acceptance and innovation.

In detail:

Vehicle-to-Infrastructure (V2I) communication is a wireless exchange of information between vehicles and the Road Side Units of the infrastructure, such as traffic, road and weather condition alerts, traffic control, upcoming traffic lights information, or parking lot information.

Vehicle-to-Network (V2N) communication is a wireless exchange of information between vehicles and cellular networks, used for value-added services such as traffic jam information and real-time routing or available charging stations for electric vehicles (EVs).

Vehicle-to-Cloud/Edge (V2C) communication is a wireless exchange of information between vehicles and the cloud or edge computing centres, for instance, used for tracking and usage-based insurance.

Vehicle-to-Grid (V2G) communication is wired/wireless exchange of information between electric vehicles and the charging station/power grid for such as battery status and correct charging and energy storage and power grid load/peak balancing.

Vehicle-to-Vehicle (V2V) communication is a wireless exchange of information between vehicles about for instance speed and position of surrounding vehicles.

Vehicle-to-Pedestrian (V2P) communication is a wireless exchange of information between vehicles and vulnerable road users (VRUs) for safety-related services.

Vehicle-to-Home (V2H) communication is a wireless exchange of information between vehicles and a fixed or temporarily home, for instance, used for real-time routing.

Vehicle-to-Device (V2D) communication is wired/wireless exchange of information between the vehicle and IoT devices either inside or outside the vehicle.

Vehicle-to-Maintenance (V2M) communication is a wireless exchange of information between the vehicle and the vehicle condition responsible (automotive manufacturer or repair shop), including vehicle condition monitoring, predictive maintenance notification or alerts.

Vehicle-to-Users (V2U) communication is wired/wireless exchange of information between the vehicle and its current user including situational information.

Vehicle-to-Owner (V2O) communication is a wireless exchange of information between vehicles and its owner. Use cases may be car rental, fleet management, freight tracking, etc.

Today, there are two key technologies considered for intelligent transportation systems (ITS), namely ITS-G5 and C-V2X, which are based on different design principles and radio interfaces [6]. However, the higher layers (above the PHY/MAC radio layers) can largely share the same protocol stack. The two technologies are primarily intended for driver assistance warnings rather than autonomous driving but contribute to extends the line-of-sight limited operation of sensors such as cameras, radars and LIDARs.

ITS-G5 is specified by ETSI and its radio air interface is based on IEEE 802.11p (DSRC in the US), which is an approved amendment of the Wi-Fi standard to add wireless access in vehicular environments (WAVE). ITS-G5 works independently of cellular networks, supports V2V and V2I low latency short-range communication in the 5.9GHz frequency band, and uses orthogonal frequency-division multiplexing (OFDM) and a carrier sense multiple access (CSMA) based protocol in the MAC layer. ITS-G5 facilitate high reliability under high vehicle speed mobility conditions. Enhancements towards more advanced services, such as autonomous driving, are addressed by the IEEE 802.11 Next Generation V2X Study Group.

C-V2X is specified by 3GPP and is realized as LTE-V2X (3GPP rel. 14/15) for short- and long-range communication. The short-range mode works independently of cellular networks, supports V2V, V2I and V2P communication, uses direct side-link communication over PC5 interface, uses orthogonal frequency-division multiplexing (OFDM) in the 5.9GHz frequency band, and its MAC layer is based on semi-persistent scheduling allowing deterministic sharing of the medium among multiple stations in a distributed manner. While the long-range mode is cellular mobile network dependent and supports V2N communication, i.e. up/down link communication between vehicles and base stations in a cellular LTE network over Uu interface. The next release 5G NR-V2X (5G New Radio V2X, rel. 16) address improvements such as lower latency, increased reliable communication and higher data rates to support autonomous driving. 5G NR-V2X will complement LTE-V2X, i.e. not replace but co-exist with LTE-V2X.

LTE-V2X short-range mode and ITS-G5 are substitutes, but LTE-V2X has been shown in recent tests to have a superior performance in range/link-budget (reliability) [6]. However, ITS-G5 G5 is not an equivalent substitute for LTE-V2X for delivering C-ITS priority services. ITS-G5 cannot match the performance of LTE-V2X in direct side-link short-range communications and does not support long-range communications. The current, ITS-G5 cannot achieve the level of implicit compatibility between LTE-V2X and 5G-V2X, due to the different technological and design principles in the specifications of IEEE 802.11p (ITS-G5) and 3GPP C-V2X (LTE-V2X/5G-V2X). LTE-V2X is the natural precursor to 5G NR-V2X from the perspectives of both design and industrial ecosystem, and the combination of these two C-V2X technologies can allow for the most cost-effective deployment of C-ITS services in EU [6].

3.2.6 Recommendations for next generation communication protocols

This sub-section stands for giving an overview of the current evolutions of the different communication protocols which are used in the scope of AUTOPILOT. The texts are mainly extracted from papers or standards. The references [22] [23] [24] are given in sections 6 of this document.

3.2.6.1 From IEEE 802.11p to IEEE 802.11NGV and 802.11BD [22]

The development of IEEE 802.11p mainly focused on vehicular communication standard that brings supports for vehicular safety, traffic management, and other applications that add value, such as parking and vehicular diagnostics. The requirements set for 802.11p were thus to support relative velocities up to 200 km/h, response times of around 100ms and communication range of up to 1 km.

The 802.11p standard derived its PHY and MAC layers from 802.11a. Since then, however, 802.11a has given way to its successors i.e., 802.11n and 802.11ac, while 802.11ax is in its final stages of standardization. The IEEE 802.11 Next Generation V2X (802.11NGV) Study Group was formed in March 2018. Its objective is to enhance 802.11p MAC and PHY capabilities. After an initial feasibility study, the IEEE 802.11bd Task Group was created in January 2019 in replacement of 802.11NGV study group.

The primary design objectives of 802.11bd include supporting the following:

- at least one mode that achieves twice the MAC throughput of 802.11p with relative velocities up to 500 km/h;
- at least one mode that achieves twice the communication range of 802.11p;
- at least one form of vehicle positioning in affiliation with V2X communications.

Additionally, 802.11bd must support the following:

- Interoperability: 802.11p devices must be able to decode (at least one mode of transmissions from 802.11bd devices, and vice-versa).
- Coexistence: 802.11bd must be able to detect 802.11p transmissions and defer channel access, and vice-versa.

- Backward compatibility: At least one mode of 802.11bd must be interoperable with 802.11p.
- Fairness: In co-channel scenarios, 802.11bd and 802.11p must get equal channel access opportunities.

The activities of the workgroup are in progress.

3.2.6.2 ITS-G5 evolutions

From ETSI side they are few evolutions in the facilities layer. Indeed, **PoTi** – Position and Time information [23] entity is one of these new evolutions. It manages the position and time referencing information for ITS application and services. It interfaces with ITS applications or with other layer entities in order to provide position and time reference information, such as CAM, DENM, and C-ACC. Furthermore, PoTi may interact with positioning or the time management functions residing in other parts of the system outside of the ITS-S (ITS-Stations) system. Such information may be received from GNSS receiver or from other ITS-Ss.
It ensures time synchronicity between the ITS-Ss in the ITS system. It also enables keeping track of the handled data’s quality (e.g. by monitoring local time deviation) and its conformity to rules (e.g. maximum values) set forth in this document. The facility also manages all (cyclic or sporadic) updates.

One can imagine improving positioning information used in the different use cases of AUTOPILOT with this new feature.
The last updates of ETSI PoTi specifications draft are from March 2019.

3.2.6.3 5G with V2X, CAM over IP over 5G (CEA)

3GPPP Release 14 brought supports for V2X service by providing data transport service for basic road safety service such as CAM, DENM, SPAT, MAP, and BSM and so on. Release 15 [24] works on top of that to provide a further set of requirements in order to enhance 3GPP supports for V2X uses cases.

There are different examples of scenarios, but let us focus on ones that are in relationship with the works done in AUTOPILOT:

- Platooning: “Vehicles platooning enables the vehicles to dynamically form a group travelling together. All the vehicles in the platoon receive periodic data from the leading vehicle, in order to carry on platoon operations. This information allows the distance between vehicles to become extremely small, i.e., the gap distance translated to time can be very low (sub-second). Platooning applications may allow the vehicles following to be autonomously driven.”
  In Versailles Pilot Site, we are using the same concept of platooning. However, instead of transmitting the data from the leading vehicle to the followers through an LTE connection, we are using IPv6 over 802.11OCB connection. One can imagine doing a comparative study between these two concepts in order to know which one provides better performances.
- Extended Sensors: “Extended Sensors enables the exchange of raw or processed data gathered through local sensors or live video data among vehicles, RSUs, devices of pedestrians and V2X application servers. The vehicles can enhance the perception of their environment beyond what their own sensors can detect and have a more holistic view of the local situation.”
  In Versailles PS, in particular, in Urban Driving use case, data from cars (position, speed, wheel angle, …), and VRU (cyclists, pedestrians) are shared in order to enhance the perception of the environment and to anticipate driving intention and or events (braking,

slowing down). That is currently done through LTE (4G) communication. One can imagine handling that through 5G communication. Thus, that would be interesting to study the enhancements.

4 Conclusions

This deliverable identifies the final list of the requirements and the protocols concerning communication aspects necessary to implement Internet of Things (IoT) and Automated Driving (AD) use cases tested in AUTOPILOT. It must be delivered in M33 and it has been produced based on WP2 and WP4 data and information.

The specification described in this document was carried out following a process that included several meetings amongst task partners.
In the first phase, the group addressed an information collection activity focusing on a general overview of the communication infrastructures really deployed within the various pilot sites.
In the second phase, starting from the results of D1.7 [1] and considering the tests and the outcomes of the pilot sites trials, the following was carried out:

- An evaluation of the communication requirements and the related KPIs really implemented within the various use cases to identify the relevant ones.
- An overview of all the communication protocols necessary to implement IoT enhanced AD use cases.

The information, presented in D1.8 on communication requirements, technology and standards, is related to what has been implemented in each pilot site; the document has been distributed to and checked by PSs leaders.

For all the communication requirements, it has been possible to identify specific tests and measures evaluating the real application of the requirements and the related KPI performances. For only 3 CRs, 34 related the “Platooning” UC to be implemented in Brainport, 38 and 39 related the “Automated Valet Parking” UC to be implemented in Vigo PS, this operation failed.

- The tests related the majority of CRs have been carried out and have been classified as “PASSED”; only CR27 has to be considered, at the moment of D1.8 drafting, as “Partly PASS”.
- At the moment of D1.8 drafting, data related tests connected to CRs: 21, 22, 23 and 43 were not available.
- Considering the performances measured, all the test classified as “PASSED” should be considered verified in compliance with the forecasted KPIs. For some of them, it is possible to evaluate the specific values of the measure worked out (please refer to CRs: 2, 9, 10, 11, 30, 31 and 32).

On the base of all the above considerations, the Communication Requirements identified in [1] have been implemented in PS and verified in compliance with the forecasted KPIs. Only CRs 34, 38 and 39 should be considered as not relevant.

Relating communications protocol, a complete survey has been provided focusing all the level of architecture. For standard protocols, a reference to the standard document has been provided.
The description of protocol (if not available on other sources) or a reference to a description document has been provided for non-standard protocols.

5 Annexes

5.1 Specific information provided by PS

5.1.1 France

The parking spots of the car-sharing stations in Versailles will be equipped with parking detectors so that the intelligent fleet management system gets the information on how many vehicles are available on each car-sharing station. These detectors are installed in the ground and work through LoRaWAN technology. Other characteristics are:

- Directive antenna Yagi 2.4 GHz
- 868 MHz antenna
- Magnetic detection
- LoRaWAN, RFID and Bluetooth connectivity

Figure 21 Parking detector (ONESITU) used on car sharing stations

5.2 Communication Requirements global analysis reference table

This section maps the communication requirements identified in deliverable D1.7 with the tests/measures carried out in WP 2.5 and related to the communication infrastructure really implemented in the Pilot Sites.
If a direct relation between a specific CR and tests was not clearly found, the approach followed aimed at identifying those tests that were better covering the functionalities required by the communication requirement.
Not always it has been possible to clearly identify the standard used for the execution of the tests even if all the additional information provided by WP2.5 docs, when available, have been integrated into the table below.

ID	Use case name / keyword	Requirement description	End-to-end latency (L)	Reliability (R)	Bandwidth (B)	Communication range (CR)	Node mobility (N)	Creator Organization	Standards/ protocols covering CR	Gap	Notes/Gap description	TEST

<table>
<tr><th>ID</th><th>Use case name / keyword</th><th>Requirement description</th><th>End-to-end latency (L)</th><th>Reliability (R)</th><th>Bandwidth (B)</th><th>Communication range (CR)</th><th>Node mobility (N)</th><th>Creator Organization</th><th>Standards/ protocols covering CR</th><th>Gap</th><th>Notes/Gap description</th><th>TEST</th></tr>
<tr><td>CR 1</td><td>Hazard on the roadway</td><td>The vehicle must receive the geocasted notifications of hazard events (e.g. potholes, roadway works, pedestrians, VRUs, puddles, etc.) from RSU</td><td>Low</td><td>High</td><td>Low</td><td>V2X HIGHWAY</td><td>Vehicular URBAN Vehicular SUBURBAN Vehicular HIGHWAY</td><td>CNIT, TIM, LINKS</td><td>covered by ITSG5 DENBS, RSUs must support GeoBroadcast forwarding</td><td>no</td><td>-</td><td>Vigo:
<table>
<tr><td>Vehicle_safety_urban_driving_7</td><td>The information sent from smart camera, the own VRU or/and in-vehicle sensors to the IoT pilot platform is received correctly
(upload)</td></tr>
<tr><td>Vehicle_safety_urban_driving_8</td><td>The in-vehicle communication platform receives VRU information filtered by vehicle position
(download)</td></tr>
</table>
Livorno:
<table>
<tr><td>ITS-G5_3</td><td>Basic GeoNetworking test</td></tr>
<tr><td>Vehicle_safety_highway_pilot_5</td><td>The Road Hazard information is shared with all stakeholders - Vehicles are properly notified
Test of the notification to AD vehicles from C-eHorizon</td></tr>
</table>
Brainport:
<table>
<tr><td>Vehicle_safety_urban_driving_8</td><td>The in-vehicle communication platform receives VRU information filtered by vehicle position
(download)</td></tr>
<tr><td>Vehicle_safety_highway_pilot_5</td><td>The Road Hazard information is shared with all stakeholders - Vehicles are properly notified</td></tr>
</table>
</td></tr>
</table>

ID	Use case name / keyword	Requirement description	End-to-end latency (L)	Reliability (R)	Bandwidth (B)	Communication range (CR)	Node mobility (N)	Creator Organization	Standards/ protocols covering CR	Gap	Notes/Gap description	TEST
CR 2	Hazard on the roadway	The WSN on the road must notify the presence of puddles on the road whenever they are detected	high	High	Low	Wireless PAN Wireless LAN Wireless WAN	No mobility	CNIT, TIM, LINKS	NB-IoT OneM2M	no	-	Livorno: IoT_device_1 — Medium: 10ms < L < 100ms End-to-end latency (L) IoT_device_2 — Medium: 10-4 < R <10-6 Reliability (R) IoT_device_3 — Medium: 100 Mb/s > B > 1 Mb/s Bandwidth (B) IoT_device_4 — Specific for NB-IoT IoT_device_5 — Specific for NB-IoT IoT_device_6 — Specific for NB-IoT Vehicle_safety_highway_pilot_2 — The in-vehicle IoT pothole detection system will be ready in December 2018
CR 3	Hazard on the roadway	The traffic control system must receive geolocalized notifications of hazard events from RSU (e.g. potholes, roadway works, pedestrians, VRUs, puddles, etc.)	High	High	Low	Wired Long Range	No mobility	CNIT, TIM, LINKS	DATEX, DENM XER	no	-	Livorno: Functionality_1 — IoT platform is able to process a new message from an IoT message Vehicle_safety_highway_pilot_5 — The Road Hazard information is shared with all stakeholders - Vehicles are properly notified Test of the notification to AD vehicles from C-eHorizon
CR 4	Hazard on the roadway	Geolocalized notifications of hazard events (e.g. potholes, roadway works, puddles, etc.) from RSU may be stored by the data management service of the IoT platform	High	Medium	Low	Long Range	No mobility	CNIT, TIM, LINKS	OneM2M	no	-	Livorno: IoT_platform_3 — The IoT-platform is capable of receiving events/messages from the devices connected HTTP and MQTTs tested Functionality_1 — The IoT platform is able to process a new message from an IoT message. Vehicle_safety_highway_pilot_3 — The information sent from the vehicle is received correctly from the IoT platform + cloud The in-vehicle IoT pothole detection system will be ready in December 2018

<table>
<tr><th>ID</th><th>Use case name / keyword</th><th>Requirement description</th><th>End-to-end latency (L)</th><th>Reliability (R)</th><th>Bandwidth (B)</th><th>Communication range (CR)</th><th>Node mobility (N)</th><th>Creator Organization</th><th>Standards/ protocols covering CR</th><th>Gap</th><th>Notes/Gap description</th><th>TEST</th></tr>
<tr><td>CR 5</td><td>Pedestrian detection</td><td>The detection event of pedestrians on the roadway must be notified to the RSU from the camera</td><td>Low</td><td>High</td><td>Low</td><td>Wired
Wireless LAN</td><td>No mobility</td><td>LINKS</td><td>ITSG5 through RSU gateway</td><td>no</td><td>-</td><td>Livorno<table><tr><td>Vehicle_safety_urban_driving_7</td><td>The information sent from smart camera to the IoT pilot platform is received correctly</td></tr></table></td></tr>
<tr><td>CR 6</td><td>Pedestrian detection</td><td>The number of detected pedestrians on the roadway detected by the camera may be stored by the data management service of the IoT platform</td><td>High</td><td>Medium</td><td>Low</td><td>Wired
Long Range</td><td>No mobility</td><td>CNIT, TIM, LINKS</td><td>OneM2M</td><td>no</td><td>-</td><td>Livorno<table><tr><td>IoT_platform_3</td><td>The IoT-platform is capable of receiving events/messages from the devices connected
HTTP and MQTTs tested</td></tr><tr><td>Functionality_1</td><td>The IoT platform is able to process a new message from an IoT message.</td></tr></table></td></tr>
<tr><td>CR 7</td><td>Hazard on the roadway</td><td>Every time the vehicle detects an hazard, it must be geocasted to other vehicles</td><td>Low</td><td>High</td><td>Low</td><td>V2X URBAN
V2X SUBURBAN
V2X HIGHWAY</td><td>Vehicular URBAN
Vehicular SUBURBAN
Vehicular HIGHWAY</td><td>CNIT, TIM, LINKS</td><td>ITSG5 - DENM</td><td>no</td><td>Vehicles must be able to geobroadcast forwarding.</td><td>Livorno:<table><tr><td>ITS-G5_1</td><td>Signal’s centre frequency correct (e.g., 5900MHz for CCH)</td></tr><tr><td>ITS-G5_2</td><td>Transmitting power is correct according to the standard</td></tr><tr><td>ITS-G5_3</td><td>Basic GeoNetworking test</td></tr><tr><td>ITS-G5_5</td><td>The device is able to generate DENMs at 1, 10 and 25 Hz Performed only at 1 Hz (not at 10 and 25 Hz) because only 1 Hz is needed by the use case</td></tr><tr><td>IOP_ITS-G5_2</td><td>The ITS-G5 device can send and receive messages such as DENM, SPAT, MAP
DENM at 1Hz in real highway traffic situation; communication range up to 900 m.</td></tr></table></td></tr>
</table>

<table>
<tr><th>ID</th><th>Use case name / keyword</th><th>Requirement description</th><th>End-to-end latency (L)</th><th>Reliability (R)</th><th>Bandwidth (B)</th><th>Communication range (CR)</th><th>Node mobility (N)</th><th>Creator Organization</th><th>Standards/ protocols covering CR</th><th>Gap</th><th>Notes/Gap description</th><th>TEST</th></tr>
<tr><td>CR 8</td><td>Hazard on the roadway with TCC in the loop</td><td>The traffic control system must receive geolocalized notifications of hazard events (e.g. potholes, roadway works, pedestrians, VRUs, puddles, etc.) from vehicles</td><td>High</td><td>Medium</td><td>Low</td><td>Long Range</td><td>Vehicular URBAN Vehicular SUBURBAN Vehicular HIGHWAY</td><td>CNIT, TIM, LINKS</td><td>ITSG5, DATEX, DENM XER</td><td>no</td><td>through a RSU gateway to TCC In addition to DATEX (used for RSU<->DATEX Node communications) also DENM XER is employed (for RSU<-> DATEX 2 C-ITS Adapter communications)</td><td>Livorno:
<table><tr><td>Functionality_1</td><td>The IoT platform is able to process a new message from an IoT message.</td></tr><tr><td>Vehicle_safety_highway_pilot_3</td><td>To verify that the information sent from the vehicle is received correctly</td></tr></table></td></tr>
<tr><td>CR 9</td><td>Connected bicycle</td><td>Bicycles must geocast their position, speed, orientation to other vehicles on the road</td><td>Low</td><td>High</td><td>Low</td><td>V2X URBAN</td><td>Pedestrian Vehicular URBAN</td><td>CNIT, TIM, LINKS</td><td>ITSG5</td><td>no</td><td>-</td><td>Livorno:
<table><tr><td>IoT_device_1</td><td>Medium: 10ms < L < 100ms
End-to-end latency (L)</td></tr><tr><td>IoT_device_2</td><td>Medium: 10-4 < R <10-6
Reliability (R)</td></tr><tr><td>IoT_device_3</td><td>Medium: 100 Mb/s > B > 1 Mb/s Bandwidth (B)</td></tr><tr><td>ITS-G5_1</td><td>Signal's centre frequency correct (e.g., 5900MHz for CCH)</td></tr><tr><td>ITS-G5_2</td><td>Transmitting power is correct according to the standard</td></tr><tr><td>ITS-G5_3</td><td>Basic GeoNetworking test</td></tr><tr><td>IOP_ITS-G5_1</td><td>the ITS-G5 device can send and receive CAM messages (CAM at 1-10Hz in real highway traffic situation; communication range up to 900 m)</td></tr></table></td></tr>
</table>

ID	Use case name / keyword	Requirement description	End-to-end latency (L)	Reliability (R)	Bandwidth (B)	Communication range (CR)	Node mobility (N)	Creator Organization	Standards/ protocols covering CR	Gap	Notes/Gap description	TEST
CR 10	V2V communication	Vehicles must geocast their position, speed, orientation to other vehicles on the road	Low	High	Low	V2X HIGHWAY	Vehicular URBAN Vehicular SUBURBAN Vehicular HIGHWAY	CNIT, TIM, LINKS CTAG	ITSG5	no	-	Livorno: IoT_device_1: Medium: 10ms < L < 100ms End-to-end latency (L) IoT_device_2: Medium: 10-4 < R <10-6 Reliability (R) IoT_device_3: Medium: 100 Mb/s > B > 1 Mb/s Bandwidth (B) ITS-G5_1: Signal's centre frequency correct (e.g., 5900MHz for CCH) ITS-G5_2: Transmitting power is correct according to the standard ITS-G5_3: Basic GeoNetworking test IOP_ITS-G5_1: the ITS-G5 device can send and receive CAM messages (CAM at 1-10Hz in real highway traffic situation; communication range up to 900 m)

ID	Use case name / keyword	Requirement description	End-to-end latency (L)	Reliability (R)	Bandwidth (B)	Communication range (CR)	Node mobility (N)	Creator Organization	Standards/ protocols covering CR	Gap	Notes/Gap description	TEST
CR 11	V2X communication	Traffic light must continuously geocast its light phase and the topology of the crossroad to vehicles on the road	Low	High	Low	V2X URBAN	Vehicular URBAN	CNIT, TIM, LINKS CTAG	ITSG5 through SPAT and MAP messages, and proprietary protocol over 802.11	no	-	Livorno IoT_device_1: Medium: 10ms < L < 100ms End-to-end latency (L) IoT_device_2: Medium: 10-4 < R <10-6 Reliability (R) IoT_device_3: Medium: 100 Mb/s > B > 1 Mb/s Bandwidth (B) IOP_ITS-G5_2: the ITS-G5 device can send and receive messages such as DENM, SPAT, MAP (DENM at 1Hz in real urban traffic situation; communication range up to 500 m.) Brainport: Vehicle_safety_platooning_5b: The messages sent by the traffic light to the Platooning service via the IoT Platform are received correctly. Vigo Vehicle_safety_urban_driving_1: The information sent from the traffic light to the IoT pilot platform is received correctly Vehicle_safety_urban_driving_4: The in-vehicle communication platform receives the traffic light status, the road network and topology filtered by vehicle position

ID	Use case name / keyword	Requirement description	End-to-end latency (L)	Reliability (R)	Bandwidth (B)	Communication range (CR)	Node mobility (N)	Creator Organization	Standards/ protocols covering CR	Gap	Notes/Gap description	TEST
CR 12	Traffic conditions	The traffic control system must receive information about traffic conditions	High	High	Low	V2X URBAN	Vehicular SUBURBAN Vehicular HIGHWAY	CTAG /Silvia Alén, LINKS		yes	GAP: requires to define the protocol that will be used to communicate to exchange traffic information. It is not defined who sends the traffic information to TCC (if vehicles directly or aggregated information through RSUs) KA: Communications and Interoperability	Livorno Vehicle_safety_urban_driving_11: The information sent from traffic sensors or TMC to the IoT pilot platform is received correctly Vigo Vehicle_safety_urban_driving_11: Planned in 2019

ID	Use case name / keyword	Requirement description	End-to-end latency (L)	Reliability (R)	Bandwidth (B)	Communication range (CR)	Node mobility (N)	Creator Organization	Standards/ protocols covering CR	Gap	Notes/Gap description	TEST
CR 13	V2X communication	Vehicles must be able to receive CAM/DENM contents from received ITS-G5 messages	Low	High	Low	V2X HIGHWAY	Vehicular URBAN Vehicular SUBURBAN Vehicular HIGHWAY	LINKS TECH, CTAG	ITSG5	no	-	Tampere Vehicle_safety_urban_driving_8 — The in-vehicle communication platform receives VRU information filtered by vehicle position Versailles Vehicle_safety_urban_driving_10 — The VRU detection service is working Livorno ITS-G5_6 — The device can receive a CAM receive at 1, 10 and 25 Hz Performed only at 1 Hz and 10 Hz, because 25 Hz is not supported by the device and not needed by the use case ITS-G5_7 — The device can receive a DENM receive at 1, 10 and 25 Hz Performed only at 1 Hz (not at 10 and 25 Hz) because only 1 Hz is needed by the use case IOP_ITS-G5_1 — ITS-G5 device can send and receive CAM messages in realistic situations CAM at 1-10Hz in real highway traffic situation; communication range up to 900 m. IOP_ITS-G5_2 — the ITS-G5 device can send and receive messages such as DENM, SPAT, MAP (DENM at 1Hz in real highway traffic situation; communication range up to 900 m) Brainport: Vehicle_safety_urban_driving_8 — The in-vehicle communication platform receives VRU information filtered by vehicle position Vigo: Vehicle_safety_urban_driving_8 — The in-vehicle communication platform receives VRU information filtered by vehicle position

ID	Use case name / keyword	Requirement description	End-to-end latency (L)	Reliability (R)	Bandwidth (B)	Communication range (CR)	Node mobility (N)	Creator Organization	Standards/ protocols covering CR	Gap	Notes/Gap description	TEST
CR 14	V2X communication	Vehicles must be able to receive SPaT/MAP contents from received ITS-G5 messages	Low	High	Low	V2X HIGHWAY	Vehicular URBAN Vehicular SUBURBAN Vehicular HIGHWAY	LINKS TECH, CTAG	ITSG5	no	-	Livorno IOP_ITS-G5_2: the ITS-G5 device can send and receive messages such as DENM, SPAT, MAP (DENM at 1Hz in real highway traffic situation; communication range up to 900 m) Brainport Vehicle_safety_platooning_5b: The messages sent by the traffic light (e.g. status, time to next status) to the Platooning service via the IoT Platform are received correctly Vigo Vehicle_safety_urban_driving_6: The traffic light service is working

ID	Use case name / keyword	Requirement description	End-to-end latency (L)	Reliability (R)	Bandwidth (B)	Communication range (CR)	Node mobility (N)	Creator Organization	Standards/ protocols covering CR	Gap	Notes/Gap description	TEST
CR 15	IoT services	Vehicle must be able to receive data from communication system, related with contents received from IoT external services.	High	Medium	Low	Long Range Communication	Vehicular URBAN	LINKS	LTE,OneM2M	no	-	Tampere Vehicle_safety_urban_driving_10 — A the VRU detection service is working -Precondition: Verification IoT communication and interoperability ready Versailles Vehicle_safety_urban_driving_10 — A the VRU detection service is working - IoT information is available on the IoT platform and received by the vehicle Livorno IoT_platform_4 — IoT-platform is capable of sending events/messages to the devices connected TIM IoT platform HTTP and MQTTs tested Brainport IoT_platform_4 — IoT-platform is capable of sending events/messages to the devices connected HUA IoT platform IoT_platform_4 — IoT-platform is capable of sending events/messages to the devices connected IBM IoT platform IoT_platform_4 — IoT-platform is capable of sending events/messages to the devices connected Sensinove IoT platform IoT_platform_4 — IoT-platform is capable of sending events/messages to the devices connected NEC IoT platform IoT PF forwards the message back to the vehicle (e.g. CEMA outputs) Vigo IoT_platform_4 — IoT-platform is capable of sending events/messages to the devices connected IBM IoT platform

<table>
<tr><th>ID</th><th>Use case name / keyword</th><th>Requirement description</th><th>End-to-end latency (L)</th><th>Reliability (R)</th><th>Bandwidth (B)</th><th>Communication range (CR)</th><th>Node mobility (N)</th><th>Creator Organization</th><th>Standards/ protocols covering CR</th><th>Gap</th><th>Notes/Gap description</th><th>TEST</th></tr>
<tr><td>CR 16</td><td>IoT services</td><td>Vehicles must be enabled to provide /communicate elaborated data to IoT external services, through communication system.</td><td>High</td><td>Medium</td><td>Low</td><td>Long Range Communication</td><td>Vehicular URBAN</td><td>LINKS</td><td>LTE,OneM2M</td><td>no</td><td>-</td><td>Tampere
<table>
<tr><td>Vehicle_safety_urban_driving_3</td><td>the information sent from the vehicle is received correctly - The information about the vehicle status is sent to the IoT platform</td></tr>
</table>
Versailles
<table>
<tr><td>IoT_platform_3</td><td>IoT-platform is capable of receiving events/messages from the devices connected
Sensinove IoT platform
AE Creation => Subscription to oneM2M AE => container creation</td></tr>
</table>
Livorno
<table>
<tr><td>IoT_platform_3</td><td>IoT-platform is capable of receiving events/messages from the devices connected
TIM IoT platform
HTTP and MQTTs tested</td></tr>
</table>
Brainport
<table>
<tr><td>IoT_platform_3</td><td>IoT-platform is capable of receiving events/messages from the devices connected
HUA IoT platform</td></tr>
<tr><td>IoT_platform_3</td><td>IoT-platform is capable of receiving events/messages from the devices connected
IBM IoT platform</td></tr>
<tr><td>IoT_platform_3</td><td>IoT-platform is capable of receiving events/messages from the devices connected
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AE Creation => Subscription to oneM2M AE => container creation</td></tr>
<tr><td>IoT_platform_3</td><td>IoT-platform is capable of receiving events/messages from the devices connected
NEC IoT platform
IoT PF received messages & events (e.g. WiFi probe events) from the connected device (e.g. WiFi sniffer).
IoT PF can also store the messages in persistent storage (NoSQL DB)</td></tr>
</table>
Vigo</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>CR 17</td><td>Traffic Light handling</td><td>The vehicle should be able to receive Signal Phase information, coming from IoT infrastructure platform (alternative to SPaT/MAP from ITS-G5 channel, for long range)</td><td>High</td><td>High</td><td>Low</td><td>Long Range Communication</td><td>Vehicular HIGHWAY</td><td>LINKS</td><td>oneM2M</td><td>no</td><td>-</td><td>
Tampere
<table>
<tr><td>Vehicle_safety_urban_driving_10</td><td>A the VRU detection service is working -Precondition: Verification IoT communication and interoperability ready</td></tr>
</table>
Versailles
<table>
<tr><td>Vehicle_safety_urban_driving_10</td><td>A the VRU detection service is working - IoT information is available on the IoT platform and received by the vehicle</td></tr>
<tr><td>IoT_platform_4</td><td>IoT-platform is capable of sending events/messages to the devices connected
Sensinove IoT platform</td></tr>
</table>
Livorno
<table>
<tr><td>IoT_platform_4</td><td>IoT-platform is capable of sending events/messages to the devices connected
TIM IoT platform
HTTP and MQTTs tested</td></tr>
<tr><td>Vehicle_safety_urban_driving_4b</td><td>The in-vehicle communication platform receives the traffic light status</td></tr>
</table>
Brainport
<table>
<tr><td>IoT_platform_4</td><td>IoT-platform is capable of sending events/messages to the devices connected
HUA IoT platform</td></tr>
<tr><td>IoT_platform_4</td><td>IoT-platform is capable of sending events/messages to the devices connected
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<tr><td>IoT_platform_4</td><td>IoT-platform is capable of sending events/messages to the devices connected
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IoT PF forwards the message back to the vehicle (e.g. CEMA outputs)</td></tr>
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Vigo
<table>
<tr><td>IoT_platform_4</td><td>IoT-platform is capable of sending events/messages to</td></tr>
</table>
</td></tr>
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ID	Use case name / keyword	Requirement description	End-to-end latency (L)	Reliability (R)	Bandwidth (B)	Communication range (CR)	Node mobility (N)	Creator Organization	Standards/ protocols covering CR	Gap	Notes/Gap description	TEST
CR 18	Urban Driving Intersection support	Communication between vehicle and cloud/traffic light control system	High	High	Medium	Long Range	Vehicular Suburban	VTT	TCP/IP	no	-	Tampere Vehicle_safety_urban_driving_3: The information sent from the vehicle is received correctly Vehicle_safety_urban_driving_4: The in-vehicle communication platform receives the traffic light status… (tested in November 2018)
CR 19	Automated Valet Parking	Communication between vehicle and cloud/camera management centre	High	High	Medium	Wireless LAN Long Range	Pedestrian	VTT	TCP/IP	no	-	Tampere Vehicle_safety_valet_parking_1: Verify the availability of the Parking Management Function at Drop off phase Brainport Vehicle_safety_valet_parking_1: Verify the availability of the Parking Management Function at Drop off phase
CR 20	Urban Driving (relocation TU/e)	The vehicle must receive information about VRU presence and localization by a smartphone application	Low	High	Medium	Wireless LAN Long Range	Vehicular URBAN	TU/e	ITSG5	no	-	Brainport Vehicle_safety_urban_driving_8: The in-vehicle communication platform receives VRU information..

ID	Use case name / keyword	Requirement description	End-to-end latency (L)	Reliability (R)	Bandwidth (B)	Communication range (CR)	Node mobility (N)	Creator Organization	Standards/ protocols covering CR	Gap	Notes/Gap description	TEST	
CR 21	Urban Driving (relocation TU/e)	Communication between lecture schedule webserver of TU/e and AD vehicle	Mdium	Medium	Low	SUBURBAN	Vehicular URBAN	TU/e	HTTP	yes	GAP: There seems not to be a standard to cover this communication over HTTP, application level must implement the protocol. KA: Communication /connectivity	Brainport	
												vehicle_safety_car_rebalancing_18	Feature not yet implemented. CEMA functionality was tested instead and covers the same functionality. The lecture schedule is planned to be implemented Q1 – 2019 as additional information but is not required to have the use case function.
CR 22	Urban Driving (relocation TU/e)	The vehicle must receive weather information by a cloud-based web server	High	Medium	Low	SUBURBAN	Vehicular URBAN	TU/e	HTTP	no	-	Brainport	
												Vehicle_safety_car_rebalancing_3	Not yet tested (not in the test list)
												Vehicle_safety_car_rebalancing_4	Not yet tested (not in the test list)
CR 23	Urban Driving (relocation TU/e)	The vehicle and the service center must communicate each other information for managing relocation requests of vehicles	High	Medium	Low	SUBURBAN	Vehicular URBAN	TU/e	HTTP	no	-	Brainport	
												Vehicle_safety_car_rebalancing_11b	Not yet tested (not in the test list)
												Vehicle_safety_car_rebalancing_11	Not yet tested (not in the test list)
												Vehicle_safety_car_rebalancing_12	Not yet tested (not in the test list)
												Vehicle_safety_car_rebalancing_13	Not yet tested (not in the test list)

ID	Use case name / keyword	Requirement description	End-to-end latency (L)	Reliability (R)	Bandwidth (B)	Communication range (CR)	Node mobility (N)	Creator Organization	Standards/ protocols covering CR	Gap	Notes/Gap description	TEST	
CR 24	Automated Valet Parking	Communication between Vehicle and AVP application	Medium	Medium	Low	Short range and long range	URBAN	DLR	-	yes	GAP: At the time of the writing of this document, no standard protocol was specified for this communication and no access technology, since it specifies long and short range. KA: communication /connectivity	Brainport	
												Vehicle_safety_valet_parking_1	Verify the availability of the Parking Management Function at Drop off phase
CR 25	Automated Valet Parking	Communication between AVP application and cloud	High	Medium	Low	Long Range Communication	URBAN	DLR	TCP/IP	no	-	Brainport	
												Vehicle_safety_valet_parking_1	Verify the availability of the Parking Management Function at Drop off phase
CR 26	Automated Valet Parking	Communication between Drone and cloud	Medium	Low	Medium / High	Short range and long range	URBAN	DLR	TCP/IP.	yes	GAP: not specified which Higher layer protocol will be used, standard application-layer protocols does not seem to be available. KA: Communications/connectivity	Brainport	
												MAV_autonomous_1	Autonomous Take-off of Micro Air Vehicle (MAV) Successfully tested outdoors as well as indoors

ID	Use case name / keyword	Requirement description	End-to-end latency (L)	Reliability (R)	Bandwidth (B)	Communication range (CR)	Node mobility (N)	Creator Organization	Standards/ protocols covering CR	Gap	Notes/Gap description	TEST
CR 27	Automated Valet Parking	Communication static camera and cloud	Medium	Low	Medium / High	Short range and long range	URBAN	DLR	TCP/IP	-	GAP: not specified which standard Higher-layer protocols will be used. KA: Communications/Connectivity	**Brainport** Vehicle_safety_valet_parking_1: Availability of the Parking Management Function - Correct identification of free parking space (e.g. by cameras) Partly PASS
CR 28	Car sharing service	Communication between the application hosted on the user device and the service center cloud	High	High	Medium	Long Range	Pedestrian	IBME	TCP/IP/HTTP	no	-	**Brainport** Interoperability_1: IoT device (e.g. vehicle) is able to connect successfully to the IoT platform Car_Sharing_1: The service can process customer requests sent from a mobile or web application to the service
CR 29	Highway Pilot	V2X Communication between vehicles and infrastructure	Low/Medium	High	Low	V2X Highway	Vehicular Highway	TECH /Jan Bosma	ITSG5, LTE	no	same as CR31 but with Higher reliability and distance	**Brainport** Vehicle_safety_highway_pilot_3: The information sent from the vehicle is received correctly
CR 30	Highway Pilot, Platooning	The vehicle may send and receive information to/from the cloud	High	High	Medium	Long Range	Vehicular Highway	TECH, TNO	LTE	no	GAP: it depends from the type of information	**Brainport** IoT_device_1b: Latency is verified (KPI: High: L > 100 ms) at application level between Vehicle (IoT device) and cloud service via LTE connection and cloud IoT platform. IoT_device_2: Packet loss is verified (High: R > 10-4) for LTE connected devices (= vehicle IoT platform) IoT_device_3b: Maximum requests per second are verified to be > 20 Hz per vehicle between a vehicle IoT device and the cloud IoT platform.

ID	Use case name / keyword	Requirement description	End-to-end latency (L)	Reliability (R)	Bandwidth (B)	Communication range (CR)	Node mobility (N)	Creator Organization	Standards/ protocols covering CR	Gap	Notes/Gap description	TEST
CR 31	Platooning	V2X Communication between Vehicle and RSU	Low / Medium	Low	Low	Short <300m	URBAN SUBURBAN HIGHWAY	TNO	ITSG5, LTE	no	-	**Brainport** Vehicle_safety_platooning_5b: the messages sent by the traffic light (e.g. status, time to next status) to the lead vehicle are received. Basic implementation passed with real-time data from traffic light controllers, light information was received on the OneM2M IoT platform and Platooning service
CR 32	Platooning	Communication between vehicles and cloud	Medium / High	Medium	Low	Long > 300m	URBAN SUBURBAN HIGHWAY	TNO, DLR	same as CR30	yes	-	**Brainport** IoT_device_1b: Latency is verified (KPI: High: L > 100 ms) at application level between Vehicle (IoT device) and cloud service via LTE connection and cloud IoT platform. IoT_device_2: Packet loss is verified (High: R > 10-4) for LTE connected devices (= vehicle IoT platform) IoT_device_3b: Maximum requests per second are verified to be > 20 Hz per vehicle between a vehicle IoT device and the cloud IoT platform.

ID	Use case name / keyword	Requirement description	End-to-end latency (L)	Reliability (R)	Bandwidth (B)	Communication range (CR)	Node mobility (N)	Creator Organization	Standards/ protocols covering CR	Gap	Notes/Gap description	TEST
CR 33	Platooning	V2V Communication between Vehicles	Low	Medium	Low	V2X URBAN V2X SUBURBAN V2X HIGHWAY	URBAN SUBURBAN HIGHWAY	TNO	ITSG5, 3GPP LTE	no	shouldn't it be High reliability?	Brainport Vehicle_safety_platooning_1: The required lead vehicle DATA (e.g. position, velocity, acceleration, orientation, etc.) sent to follower vehicles correspond to expected values Verified with real-time data over ITS-G5 and UWB Vehicle_safety_platooning_2: The contents of all messages sent by the lead vehicle (e.g. emergency stop, activation, etc.) to the follower vehicles are received correctly Verified with real-time data over ITS-G5 and UWB Vehicle_safety_platooning_3: the DATA sent by the follower vehicle (e.g. position, velocity, acceleration, orientation, etc.) to the other vehicles in the platoon are received correctly Verified with real-time data over ITS-G5 and UWB
CR 34	Platooning	Cellular Communication between Vehicles	Medium / High	Medium	Medium / High	Long > 300m	URBAN SUBURBAN HIGHWAY	TNO	LTE	no	-	Brainport - : -
CR 35	Car sharing service	Communication between vehicle and Service center cloud	High	High	Medium	Long Range	Vehicular SUBURBAN	IBME	LTE?	yes	GAP: standard application protocols are undefined for this communication , the LTE was assumed due to the range of communication . KA: Communication /connectivity	Brainport Interoperability_1: IoT device (e.g. vehicle) is able to connect successfully to the IoT platform Car_Sharing_2: The car-sharing service computes riding costs The test used virtual machine

ID	Use case name / keyword	Requirement description	End-to-end latency (L)	Reliability (R)	Bandwidth (B)	Communication range (CR)	Node mobility (N)	Creator Organization	Standards/ protocols covering CR	Gap	Notes/Gap description	TEST
CR 36	Automated Valet Parking	Communication between the application hosted on the user device and the cloud-based parking control system	High	High	Low	Long Range	Pedestrian	CTAG	LTE, HTTP	no	-	Vigo Parking_3: The parking spot service receives a predefined number of user queries Publically available parking service API was used to run the test case
CR 38	Automated Valet Parking	The vehicle must receive exchange information (e.g. a detailed layout of the parking place, the location of dynamic objects, pedestrian location, vehicle position) with the parking control system	Medium	High	Medium	Short Range Communication	Pedestrian	CTAG	ITSG5 MAP	no	-	Vigo - | -
CR 39	Automated Valet Parking	The vehicle must be able to provide its identification to be authorized at the parking place	Low	High	Low	Short Range Communication	Pedestrian	CTAG	ITSG5 TS 102 731 (security)	no	-	Vigo - | -

<table>
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<tr><td>CR 40</td><td>Automated Valet Parking</td><td>Communication between parking infrastructure and cloud</td><td>Medium</td><td>High</td><td>Medium</td><td>Long Range Communication</td><td>No mobility</td><td>CTAG</td><td>TCP/IP/HTTP?</td><td>no</td><td>-</td><td>All the tests use publicly available parking service API. Communication uses Iot Platform

Vigo
<table><tr><td>Parking_1</td><td>The IoT device can be identified as a data provider for the parking spot detection service</td></tr><tr><td>Parking_2</td><td>The parking spot service has a correct number of active providers and receives data packages</td></tr><tr><td>Parking_4</td><td>The parking spot status is set correctly</td></tr><tr><td>Parking_5</td><td>The parking spot service receives a correct data package containing information about the availability of a parking spot</td></tr></table></td></tr>
<tr><td>CR 41</td><td>Urban Driving</td><td>Communication between vehicle and cloud/traffic control system</td><td>Medium</td><td>High</td><td>Medium</td><td>Long Range Communication</td><td>Vehicular Suburban</td><td>CTAG</td><td>LTE, TCP/IP ?</td><td>no</td><td>-</td><td>Vigo
<table><tr><td>Vehicle_safety_urban_driving_3</td><td>The information sent from the vehicle is received correctly
Planned for December 2018</td></tr><tr><td>Vehicle_safety_urban_driving_4</td><td>The in-vehicle communication platform receives the traffic light status, the road network and topology filtered by vehicle position
Executed in CTAG proving ground</td></tr></table></td></tr>
<tr><td>CR 42</td><td>Urban Driving</td><td>Communication between infrastructure (traffic lights) and cloud/traffic control system</td><td>Medium</td><td>High</td><td>Low</td><td>Long Range Communication</td><td>Vehicular Suburban</td><td>CTAG</td><td>TCP/IP, DATEX?</td><td>no</td><td>-</td><td>Vigo
<table><tr><td>Vehicle_safety_urban_driving_1</td><td>The information sent from the traffic light to the IoT pilot platform is received correctly</td></tr></table></td></tr>
</table>

ID	Use case name / keyword	Requirement description	End-to-end latency (L)	Reliability (R)	Bandwidth (B)	Communication range (CR)	Node mobility (N)	Creator Organization	Standards/ protocols covering CR	Gap	Notes/Gap description	TEST
CR 43	Urban Driving	Communication between traffic alert system and cloud/traffic control system	High	High	Low	Long Range Communication	Vehicular Suburban	CTAG	TCP/IP/DATEX?	no	-	Vigo Vehicle_safety_urban_driving_2: Planned Vehicle_safety_urban_driving_7: Planned Vehicle_safety_urban_driving_11: Planned
CR 44	Obstacle or VRU detection	The In-vehicle PF can be able to receive information related with VRU presence, generated by IoT infrastructure PF (alternative to CAM/DENM from ITS-G5 channel, for long range).	High	High	Low	Long Range Communication	Vehicular HIGHWAY	LINKS	OneM2M	no	-	Livorno Vehicle_safety_urban_driving_12b: The in-vehicle communication platform receives road event information IoT_platform_4: IoT-platform is capable of sending events/messages to the devices connected TIM IoT platform HTTP and MQTT tested Vigo Vehicle_safety_urban_driving_12: Planned IoT_platform_4: IoT-platform is capable of sending events/messages to the devices connected IBM IoT platform

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