

C-Mobile

Accelerating C-ITS Mobility Innovation and deployment in Europe

D4.7: Standardisation and interoperability for Global harmonisation

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Abbreviations

Systems, Technologies and Organisations

Abbreviation	Definition
4G	4 th Generation of mobile telecommunications technology
ARC-IT	Architecture Reference for Cooperative and Intelligent Transportation
CA	Certificate Authority
CAM	Cooperative Awareness Message
CAN	Controller Area Network
CPBO	Communication Provider Back Office, implemented in C-MoBiLE as a GeoMessaging platform and server
CEN	Comité européen de normalisation (European Committee for Standardisation)
C-ITS	Cooperative ITS
CVRIA	Connected Vehicle Implementation Architecture
DCC	Decentralised Congestion Control
DENM	Decentralized Environmental Notification Message
DS	Deployment Site
EIF	European Interoperability Framework
ETSI	European Telecom Standards Institute
HMI	Human Machine Interface
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
IETF	Internet Engineering Task Force
ISO	International Organisation for Standardisation
ITF	Interoperability Task Force
ITS	Intelligent Transport Systems
ITSC	(IEEE) Intelligent Transportation Systems Conference
ITU	International Telecommunications Union
IVI	Infrastructure to Vehicle Information
IVIM	IVI Message
LDM	Local Dynamic Map
MAPEM	MapData Messages
MIB	Management Information Base
MOST	Media Oriented Systems Transport
MQTT	Message Queuing Telemetry Transport, a standard publish-subscribe-based messaging protocol.
OBD	On-board diagnostics
OBU	On-Board Unit in a vehicle, specifically capable of ITS-G5 communication
OSI	Open Systems Interconnection
PID	Personal Information Device, specifically capable of 4G/LTE communication to a CPBO
PKI	Public Key Infrastructure
RSU	Road Side Unit, specifically capable of ITS-G5 communication
SAE	Society of Automotive Engineers
SDO	Standardisation Developing Organisations
SPATEM	Signal Phase And Timing Messages

SSRM	Signal Request Extended Message
SSEM	Signal request Status Extended Message
TC	Technical Committee
US DOT	US Department of Transportation
V2I	Vehicle-to- Infrastructure
V2V	Vehicle-to-Vehicle
VRU	Vulnerable Road User
WG	Work Group
WP	Work Package

C-ITS Services

Abbreviation	Definition
RTM	Rest Time Management
MPA	Motorway Parking Availability
UPA	Urban Parking Availability
RWW	Road Works Warning
RHW	Road Hazard Warning
SVW	Signal Violation Warning
WSP	Warning System for Pedestrians
GP	Green Priority
GLOSA	Green Light Optimised Speed Advisory
CTLV	Cooperative Traffic Light for Vulnerable road users
FI	Flexible Infrastructure
IVS	In-Vehicle Signage
MTTA	Mode & Trip Time Advice
PVD	Probe Vehicle Data
EBL	Emergency Brake Light
CACC	Cooperative Adaptive Cruise Control
SSVW	Slow and Stationary Vehicle Warning
MAI	Motorcycle Approaching Indication
BSD	Blind Spot Detection
EVW	Emergency Vehicle Warning

Executive Summary

In the past years, there has been tremendous progress in the field of cooperative intelligent transport systems (C-ITS); several successful cooperative mobility experiments have proven potential benefits of cooperative systems in increasing both energy efficiency and safety for specific transport modes. However, the large variety of cooperative applications have been designed for different goals, stakeholders or specific settings / environments and have been developed on a silo-based approach and deployed independently from each other, still serving, at higher level, similar goals and functionalities for the end-user. Scalability, IT-security, decentralisation and operator openness are some of the most important properties that a technical and commercial successful solution must provide.

C-MoBiLE aims to stimulate / push existing and new pilot sites towards large-scale, real-life C-ITS deployments interoperable across Europe. Well-defined operational procedures will lead to decentralised and dynamic coupling of systems, services and stakeholders across national and organisational borders in an open, but secure C-ITS ecosystem, based on different access technologies, the usage of which is transparent for service providers and seamless and continuous for the end-users across different transport modes, environments and countries.

The present document describes the activities and the results of task 4.4 Standardisation and Interoperability. The main objective of this task is to ensure the alignment between the C-MoBiLE C-ITS implementations and the latest applicable C-ITS standards, being the primary condition to ensure interoperability of the deployed platforms.

This objective has been addressed by the following activities:

- Monitoring the standardisation process relating to the applicable C-ITS standards:
 - Ensure the global use of the most appropriate latest version of the standards for all deployed services,
 - Liaison with European and international Standards Developing Organisations (e.g., ETSI, CEN/ISO or IEEE) to raise issues/gaps encountered with the C-ITS standards.
- Ensuring interoperability of C-MoBiLE deployments:
 - Installation of the Interoperability Task Force (ITF) to monitor and control the progress of interoperability effort at all deployment sites in weekly conference calls,
 - Constant reporting on ongoing testing activities between the deployment sites with the maintenance of the test outcomes in interoperability sheets documenting the cross functionality for all deployed services in all deployment sites,
 - Maintenance of an interoperability tracker website for easy follow-up on open/ongoing/closed issues,
 - Verification that C-MoBiLE implementations are interoperable with already deployed C-ITS equipment and services in two evaluation events in September 2019,
 - Organisation of a dedicated C-MoBiLE TESTFEST event in December 2019 to check the actual interoperability of all C-MoBiLE devices intended to be used in the project and the conformance of deployments to all relevant international standards.

1. Introduction

1.1. C-MoBiLE at a glance

The C-MoBiLE (Accelerating C-ITS Mobility Innovation and deployment in Europe) vision is a fully safe & efficient road transport without casualties and serious injuries on European roads, in particular in complex urban areas and for Vulnerable Road Users. We envision a congestion-free, sustainable and economically viable mobility, minimizing the environmental impact of road transport. C-MoBiLE will set the basis for large scale deployment in Europe, elevating research pilot sites to deployment locations of sustainable services that are supported by local authorities, using a common approach that ensures interoperability and seamless availability of services towards acceptable end user cost and positive business case for parties in the supply chain.

1.2. Objective

The objective of task 4.4 is to ensure the alignment between the C-MoBiLE C-ITS architecture and devices, and the latest applicable C-ITS standards, being the primary condition to ensure interoperability of the deployed platforms.

This objective has been addressed by the following activities:

- Monitoring the standardisation process relating to the applicable C-ITS standards:
 - Follow the version of standards used in C-MoBiLE implementation and ensure the global use of the most appropriate latest version of the standards
 - Actively liaise with European and international Standards Developing Organisations (e.g., ETSI, CEN/ISO or IEEE) to raise issues encountered with the C-ITS standards and contribute to the necessary revision procedures (e.g., compatibility issues between standard versions)
- Ensuring interoperability of C-MoBiLE deployments:
 - Set-up of the Interoperability Task Force (ITF) to monitor and control the progress of interoperability effort at all deployment sites in weekly conference calls,
 - Constant reporting on ongoing testing activities between the deployment sites with the maintenance of the test outcomes in interoperability sheets documenting the cross functionality for all deployed services in all deployment sites,
 - Maintenance of an interoperability tracker website for easy follow-up on open/ongoing/closed issues,
 - Verification that C-MoBiLE implementations are interoperable with already deployed C-ITS equipment and services in two evaluation events in September 2019,
 - Organisation of a dedicated C-MoBiLE TESTFEST event in December 2019 to check the actual interoperability of all C-MoBiLE devices intended to be used in the project and also the conformance of deployments to all relevant international standards.

1.3. Intended audience

The document is public and is addressed to professionals interested in standardisation activities on C-ITS services and in testing activities to demonstrate interoperability of complex solutions at deployment sites on an international level.

1.4. Approach

The present document intends to report on the task 4.4 activities related to compliancy of C-MoBiLE standards with global applicable C-ITS standards. The concepts of interoperability and interoperability testing in the context of large-scale C-ITS deployments are elaborated based on the ideas developed in deliverable D5.4: Verification of largescale C-ITS Interoperability [5]. The focus is on the interoperability challenges faced and resolved by the deployment sites during the service rollout and operation, i.e. reporting on test results achieved through the execution of tests between peer deployment sites.

A comprehensive report is given on the TESTFEST event that was held in December 2019 which gathered representatives and equipment from all deployment sites (and invited external partner) in the city of Vigo to perform three days of on-the-road testing with the objective of proofing the interoperability of the deployed/implemented C-ITS solutions.

The relevant standardisation groups within the major Standardisation Developing Organisations (SDO) and their relevance to the C-MoBiLE work are described including the twinning activities with the US. C-MoBiLE

identified a number of shortcomings in the existing specifications during the implementation and deployment of the C-ITS services which led to a list of recommendations to the SDOs.

1.5. Document structure

The present document is organised in the following chapters:

Chapter 2 reflects on standardisation and interoperability in a general way and at different abstraction levels (architecture, service, application).

Chapter 3 reports on the core activities for achieving interoperability between the eight deployment sites.

Chapter 4 provides a report on the organisation and the results of the TESTFEST.

Chapter 5 summarises standardisation activities and lists recommendations to Standardisation Development Organisations.

Chapter 6 concludes with recommendations for the future interoperability and rollout of C-ITS services in Europe.

2. Interoperability and Standards

2.1. Interoperability and Standards in the context of the C-Mobile project

2.1.1. Interoperability

Interoperability can be defined generally as the characteristic of a product or system, whose interfaces are completely understood, to work with other products or systems, at present or in the future, in either implementation or access, without any restrictions. On a higher level, different layers of interoperability have been defined taking also into account the non-technical aspects of interoperability. Figure 1 shows the different layers at which interoperability can be achieved (Source: EC New European Interoperability Framework 2017 [24]).



Figure 1: Layers of interoperability

Figure 2 depicts the elements that should be considered in regard to interoperability in each of the layers.

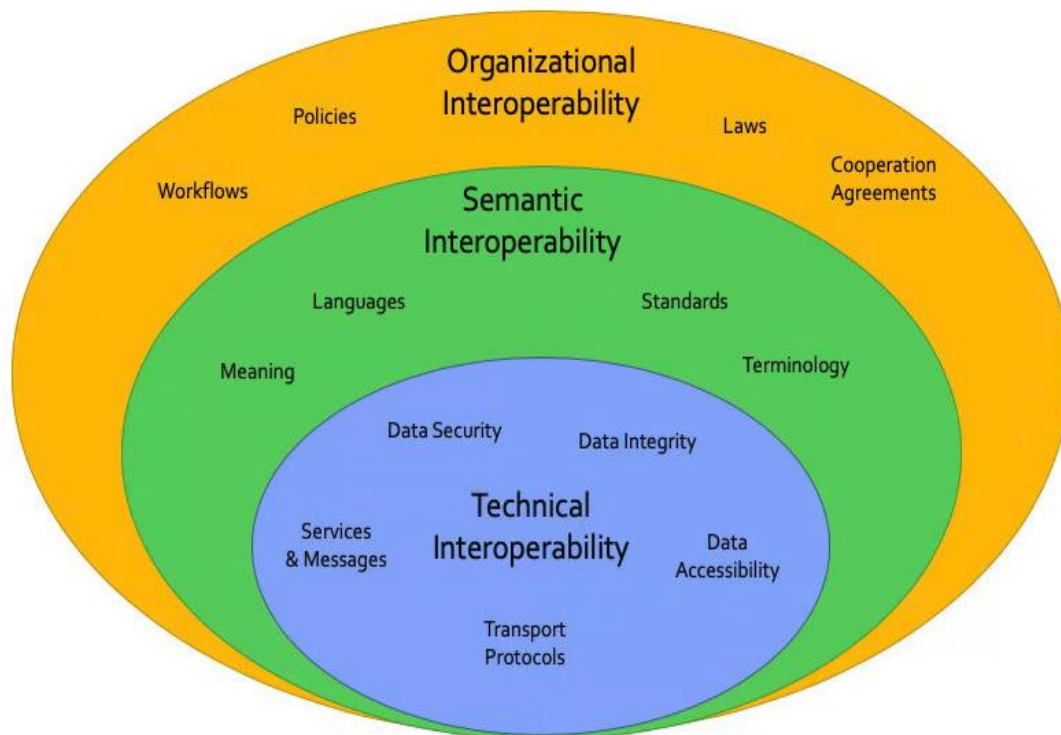


Figure 2: Elements of interoperability

In the context of the C-MoBiLE project, interoperability is mainly considered on the layer of technical interoperability and partly on the semantic interoperability layer for the interpretation of message at a Human Machine Interface (HMI) as defined by the HMI design guidelines. The deployment sites need to verify the interoperability of their host systems; i.e. that the HMI and Personal Information Devices (PID) from one service provider is interoperable with their own Communication Provider Back Office (CPBO, also known as GeoMessaging Server), and the HMI and On-Board Unit (OBU) is interoperable with the Road Side Units (RSU) of the host deployment site. This is essential for large-scale deployments.

C-ITS services are based on the exchange of data between vehicles of different category (cars, trucks, buses, motorcycles, emergency and specialised vehicles, etc.), the roadside and urban infrastructure (traffic lights, road tolls, variable message signs, etc.), control and services centres in the cloud (traffic control centre, service providers, map providers, etc.), and other road users (pedestrians, cyclists, etc.). To support interoperability, C-ITS specifications are developed to exchange and share information between ITS applications of a given application domain, and even between application domains.

The final interoperability objective of C-MoBiLE can be summarised as: Services build for one city shall also work in another city, cross region, cross border in a seamless and continuous manner.

2.1.2. Standards

Standards are fundamental to interoperability as they help in enabling the meaningful information exchange among EU deployment sites. To standardise the definitions and address the interoperability, C-MoBiLE partners liaised with ETSI, CEN/ISO, and IEEE with an aim of developing a methodology and tool to check the standards compliancy. GDPR is also considered and applied due to different level of privacy from service providers in terms of interoperability and standards.

Interoperability in the context of the C-MoBiLE project relies on the exchange of C-ITS messages that are using the same specification. Therefore, it was agreed that the messages used shall conform to the standards (as per ETSI Plugtests™ 2016) as summarised in the table below.

Subject	Standard	Version	Comment
CAM	ETSI EN 302 637-2 [2]	V1.3.2 (V1.4.1 in Vigo)	Cooperative Awareness Message
DENM	ETSI EN 302 637-3 [11]	V1.2.2 (V1.3.1 in Vigo)	Decentralised Environmental Notification
CDD	ETSI TS 102 894-2 [16]	V1.2.1 (V1.3.1 in Vigo)	Common Data Dictionary for all messages
Geonetworking	ETSI EN 302 636-4-1	V1.2.1	For 802.11p networks

Subject	Standard	Version	Comment
	[8]		
BTP	ETSI EN 302 636-5-1 [9]	V1.2.1	For 802.11p networks
MAP, SPaT, SRM, SSM	ETSI TS 103 301 [12]	V1.1.1	ETSI header incl. version for TS 19091 [15]
MAP, SPaT, SRM, SSM	ISO TS 19091 [15]	V0910	Based on SAE J2735 [25]
IVI	CEN ISO TS 19321 [15]	Version of 2015-04	In Vehicle Information
Road Sign codes	ISO/DIS 14823-2 [21]	Version of 2016-07-29	Road sign codes for IVI
Security	ETSI TS 103 097 [17]	V1.3.1	Security envelope and certificate format

Table 1: Message standards

2.2. Architecture Overview

The C-MobILE architecture framework defined in WP3 follows the international standard ISO/IEC/IEEE 42010:2011 [21]. It establishes a common practise for creating, interpreting, analysing and using architecture descriptions within a particular domain of application or stakeholder community. This helped to put architecture framework and architecture description concepts in context. Extending this international standard enabled a systematic architecture description of C-ITS specific stakeholders, their concerns, viewpoints, model kinds, and correspondence rules. Architecture perspectives which are based on the international standard ISO/IEC 25010 [23] are used to define the tactics for interoperability, security, performance, usability, reliability, availability, and adaptability.

The communication architecture for C-MobILE conforms to the general communications reference architecture defined in ETSI EN 302 665 and is illustrated in Figure 3. The same detailed descriptions can be found under C-MobILE deliverable D3.1 [2].

The ETSI communication reference architecture defines six generic entities:

- Applications (re)present the ITS-S applications making use of the ITS-S services to connect to one or more other ITS-S applications. An association of two or more complementary ITS-S applications constitutes an ITS application which provides an ITS service to a user of ITS.
- Facilities represents ITSC's communication specifications at OSI layers 5, 6 and 7, e.g. cooperative awareness basic service (for CAM, ETSI EN 302 637-2 [2]), decentralised environmental notification basic service (for DENM, ETSI EN 302 637-3 [11]) and location dynamic map (LDM, ETSI EN 302 895 [13]).
- Networking & transport represents ITSC's communication specifications at OSI layers 3 and 4, e.g. GeoNetworking, IPv6 over GeoNetworking and IPv6 with mobility extensions. To connect to systems via other protocols (e.g. IPv4) a gateway is needed.
- Access represents ITSC's communication specifications at OSI layers 1 and 2, e.g. on 5.9 GHz spectrum usage, Decentralised Congestion Control (DCC) and coexistence of ITS and EFC (CEN DSRC) services in the 5.8 GHz and 5.9 GHz bands.
- Management responsible for managing communications in the ITS station. This entity grants access to the Management Information Base (MIB).
- Security provides security services to the OSI communication protocol stack, to the security entity and to the management entity. "Security" can also be considered as a specific part of the management entity.

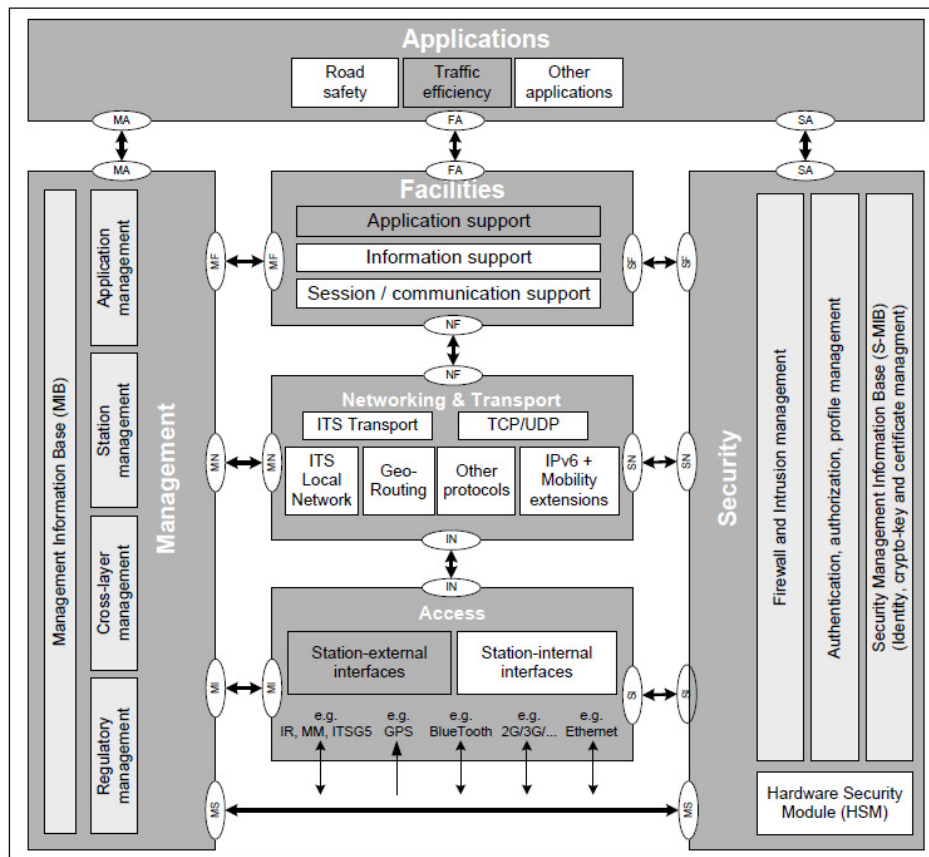


Figure 3: The reference communication architecture ETSI EN 302 665 [12]

2.3. Interoperability and Standards at the Communication Layer

The communication layer corresponds to the Communication viewpoint of the architecture framework defined in C-Mobile deliverable D3.1 [2]. The communication viewpoint can be mapped to the ISO's Open System Interconnection model and is shown in Figure 4. The communication viewpoint addresses the mode of communication between systems and sub systems, specification of the network interfaces and protocols and adequate functionalities to host communication functionalities. This enables the understanding of communication networks between systems as well as between layers among the involved stakeholders and deployment site leaders. The communication network is categorised based on their functionalities such as Cooperative ad-hoc networks, In-Vehicle networks, public mobile data networks. These are described in detailed in the deliverable D3.1 [2] specifying some of them in this report.

- Car-specific networks: The type of networks needed can be based on CAN, MOST or FlexRay. CAN is mostly preferred and is standardised at the lower layers (physical, data link, transfer layer). EOBD is another EU standard providing diagnostic and reporting capabilities based on OBD-II.
- VRU-specific networks such as mopeds and eBikes do not have any standardised interfaces yet. Some vendors have their own proprietary implementation of an OBD-II.

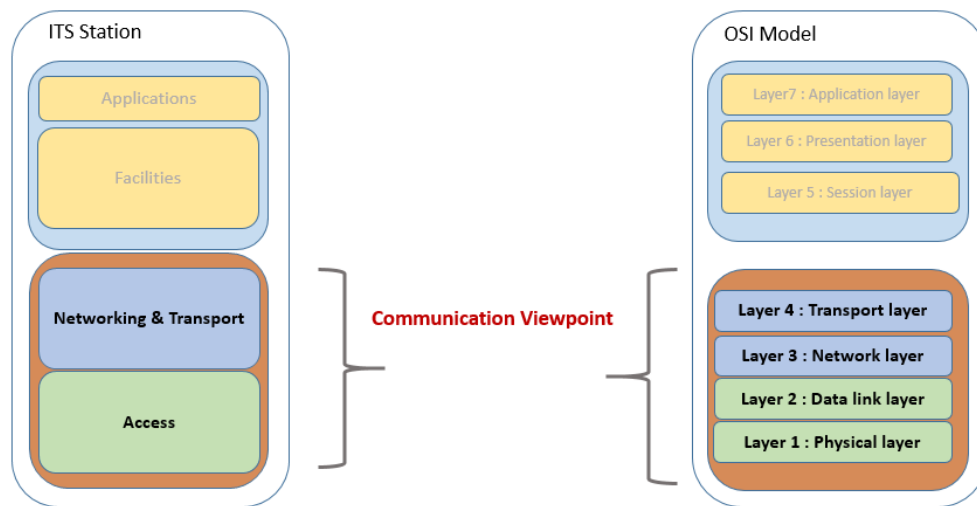


Figure 4: Communication viewpoint mapping of ITS station and OSI model

2.3.1. Standards and Specifications by Service

The standard and specifications by each service has been explained in deliverables D2.3 [1] and D3.3 [2]. It can be referred under communication viewpoint of C-MobILE services. It describes per service which components are involved, how they are related and which protocols should be used between entities. However, the realisation of the usage of protocols in deployment sites will be explained in later section. The protocol layers mentioned here are the layers as defined by ETSI. See ETSI EN 302 665 [12] for details. We assembled the communication protocols that were specified for C-MobILE project in Table 2. However, the deployment sites or involved partners are subjected to have their own proprietary protocols implementation which is mentioned in later sections.

Service	Protocol layer	Profiles
Rest-Time Management	TCP, IPv4, IPv6, ETSI ITS CAM, ETSI ITS G5	Not specified
Motorway Parking Availability	ETSI ITS MAPEM, MQTT, AMQP, ETSI ITS-G5, IPv4, IPv6	[32]
Urban Parking Availability	ETSI ITS BSA, ETSI ITS-G5, SPDP, TTI (TPEG2)	[32]
Road Works Warning	ETSI ITS CAM, DATEX 2, ETSI ITS DENM, Geonetworking, IPv4, IPv6, TCP	DENM [26], chapter 4.2.1
Road Hazard Warning	ETSI ITS DENM, MQTT, GeoNetworking, AMQP, IPv4, IPv6	DENM [26], chapter 4.2.1
Emergency Vehicle Warning	ETSI ITS BSA, ETS ITS CAM, ETSI ITS DENM, MQTT, GeoNetworking	Custom profile, see [1]
Signal Violation Warning	SAE J2735 [25], CEN ISO 19091 [15], ETSI 102 894-2 [16], ETSI 102 638 [18], DATEX, ETSI ITS SPATEM, ETSI ITS DENM, MQTT, GeoNetworking	MAPEM [29], SPATEM [30]
Warning System for Pedestrians	ETSI ITS DENM, ETSI ITS SPAT, ETSI ITS CAM, GeoNetworking, ETSI ITS-G5	Custom profile, see [1]
Green Priority	ETSI ITS SSM, ETSI ITS SPAT, MQTT, GeoNetworking	SRM [27], SSM [28]
GLOSA	ETSI ITS DENM, MQTT, ETSI ITS SPATEM/MAPEM, GeoNetworking, ETSI ITS-G5	MAPEM [29], SPATEM [30]
Cooperative Traffic Light for Pedestrian	DATEX, MQTT, AMQP, GeoNetworking	CAM [31]

Service	Protocol layer	Profiles
Flexible Infrastructure	ETSI ITS MAPEM, ETSI ITS CAM, MQTT, GeoNetworking	DENM [26], chapter 4.2.1 IVI [26], chapter 4.3
In Vehicle Signage	ETSI ITS BSA, ETSI ITS IVIM, MQTT, DATEX, GeoNetworking	IVI [26], chapter 4.3
Mode & Trip Time Advice	ETSI ITS-G5, ETSI ITS DENM, MQTT	IVI [26], chapter 4.3
Probe Vehicle Data	ETSI ITS BSA, SAE J2735 [25], ETSI ITS CAM	CAM [31]
Emergency Brake Light	CAN, propriety vehicle interface, ETSI ITS CAM, GeoNetworking	Not specified
Cooperative Adaptive Cruise Control	CAN, ETSI ITS CAM, SRM, MQTT, GeoNetworking	See [1]
Slow or Stationary Vehicle Warning	ETSI ITS CAM, ETSI ITS DENM, GeoNetworking	Custom profile, see [1], [26]
Motorcycle Approaching Indication	ETSI ITS CAM, ETSI ITS DENM, MQTT, GeoNetworking, ETSI ITS-G5	Custom profile, see [1]
Blind Spot Detection	ETSI ITS DENM, MQTT, ETSI ITS CAM, ETSI ITS-G5, GeoNetworking	Custom profile (DENM with cause code 97)

Table 2: Communication Protocols and Profiles

2.4. Interoperability and Standards at the Application Layer

The application layer corresponds to the Information view of the architecture framework defined in C-MoBiLE deliverable D3.1 [2]. The information viewpoint can be mapped to the ISO's Open System Interconnection model described in D3.1 [2] and is shown in Figure 5. Information viewpoint describes how the architecture stores, manages, and distributes data and information. The information view provides high-level view of static data structure and information flow to users, developers, testers, and maintainers.

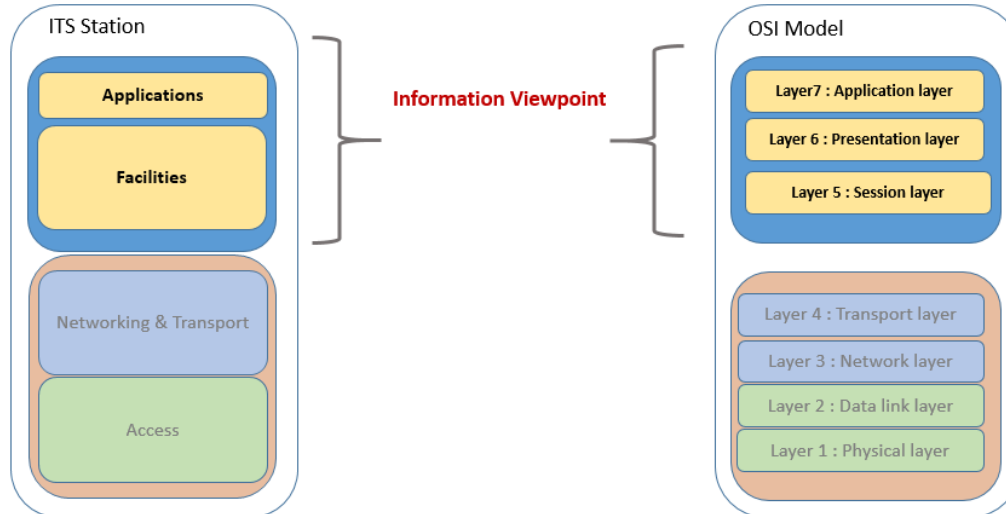


Figure 5: Information viewpoint mapping between ITS station and OSI model

2.4.1. Standards and Specifications by Service

In order to ensure the interoperability between different deployment sites, the InterCor project approach was recommended to be followed for the application layer (See D3.3 [2]). Only the specification of communication protocols was mentioned, but not the exact data format that will be applied at this layer. The results for this layer shall be included by each service implementation at deployment sites in the later section.

The requirements and specifications were defined to ensure interoperability of twenty services between eight C-MoBiLE Deployment sites (See D2.3 [1]). The C-MoBiLE requirements are categorised into Technical (Architecture, Deployment, Operational/Communications, Evaluation and Security) and Non-Technical (App interface and configuration, Human behaviour/reaction, Socio-Cultural, Legal/Privacy, Economical/Marketing,

and Environmental) requirements. The main technical requirements related to interoperability are the compliance with the latest ITS communication standards (R/G01-AR-11); defining standardised interface (R/G01-AR-13); seamless, multimodal and cross-border provision of new and existing interoperable C-ITS services (R/G02-DE-01); guaranteeing data flow to enable verification of interoperability (R/G02-DE-07); monitoring and guaranteeing interoperability among services (R/G02-DE-09).

To ensure interoperability of devices at all C-MobILE deployment sites, ETSI/SAE/ISO standards related to C-ITS type of messages are referred in D2.3 [1], MAPEM and SPATEM messages defined in ETSI EN 103 301 [12] to be used to ensure interoperability between deployment sites (R/S09-GP-11, R/S10-GLOSA-01); DENM messages defined in ETSI EN 302 637-3 [11] to be used for the notification of the Emergency Brake Light (R/S16-EBL-14), while notification of the CACC should use MAPEM and SPATEM messages defined in ETSI EN 103 301 [12] (R/S17-CACC-02).

Specifications for the message sets, including mandatory and optional data elements are set in the C-MobILE project in D2.3 [1] as:

- Cooperative Awareness Messages (CAM) in ETSI EN 302 637-2 [2].
- Decentralised Environmental Notification Messages (DENM) in ETSI EN 302 637-3 [11].
- European message sets for MAPEM, SPATEM, SREM, SSEM in ETSI TS 103 301 [12].
- In-Vehicle Information (IVI) in ISO TS 19321 [15].

Apart from identifying these interoperable messages, it is necessary to put focus on connectivity at the application layer between deployment sites. Given the diversity of back-end environments at the deployment sites, it is necessary to verify the interoperability of the shared interfaces mentioned in C-MobILE architecture (See D3.3 [2]). The detailed verification of local and shared interfaces between C-ITS systems and components for each of the services are described in D5.4 [5]. This document verifies and reports the interfaces of systems and components from different deployment sites within in C-MobILE. In particular, the following interfaces are verified:

- Interface between the Communication Provider Back Office (CPBO, also called GeoMessaging Server) and the Personal Information Devices (PID). This interface typically uses 4G/LTE cellular network communication.
- ITS-G5 communication interface between Road Side Units (RSU) and On-Board Units (OBU).
- Human Machine Interface (HMI) of the in-vehicle devices (PID, OBU).

The requirements for interoperability at application and facility layers compliance to ETSI and ISO specification are described in the C-MobILE deliverable D5.4 [5].

3. Interoperability Issues and Solutions

3.1. Interoperability Task Force and workshops

The starting point of the C-MoBILE interoperability work was the organisation of two workshops to kick-off the activity. Those workshops took place on 23 May 2018 in Brussels and during the ITS World Congress on 18 September 2018 in Copenhagen.

Furthermore, the Interoperability Task Force (ITF) was installed to continuously follow up on the interoperability achievements at the deployment sites. The ITF had its first conference call on 5 December 2018 and continues its work up to the present day.

3.1.1. Interoperability workshop 1

The main goal of this first workshop was to identify the need for cross-border service interoperability. The targeted audience was comprised of expert representatives from C-MoBILE and of eight EU-funded projects (InterCor, NeMo, AEOLIX, Concorda, SAFE STRIP, and MOBiNET) and platforms (eMI3 and MaaS Alliance). In particular, a close cooperation was established with the InterCor project, enabling C-MoBILE to align with the C-Roads platform, under whose umbrella several national C-ITS implementations were (and are still being) carried out, also by C-MoBILE partners and at some C-MoBILE deployment sites.

At that time, the first real ITS and C-ITS services were being deployed on a pan-European level. Many C-ITS projects defined and implemented services which run on huge amounts of data provided by all kind of sensors, built into vehicles, roadside infrastructure but also data produced all kinds of other data sources. These services were mainly developed to serve only a local public. Furthermore, services are deployed in many cases as smartphone applications which access the backend data over proprietary interfaces. It was understood that to really get the market of C-ITS services going these interfaces must be specified more rigorously and where necessary standardised. Cross-border interoperability and pan-European harmonisation of application program interfaces is an absolute necessity to really start the C-ITS services market. It must be possible to use a C-ITS application in Barcelona, and without any changes, except some minor configuration settings, use the same application in Bordeaux or another city/region.

During this first workshop each of the participating projects presented their status and current results. The main objective of the envisaged series of workshops was to prevent inventing the wheel repeatedly and to increase the efficiency of running European C-ITS projects, platforms and alliances. The idea behind the workshop was to use a bottom-up, technical approach in identifying overlaps and gaps in technology and data needs.

Consensus was that common data needs are translated to existing standards and specifications. Where they exist, they are proposed as mandatory interfaces between service and back-end system, where they are missing necessary information proposals are made to extend these existing standards. Finally, where standards and specifications do not exist, a proposal for a new standardisation is made.

To that end the following standardisation workflow was defined.

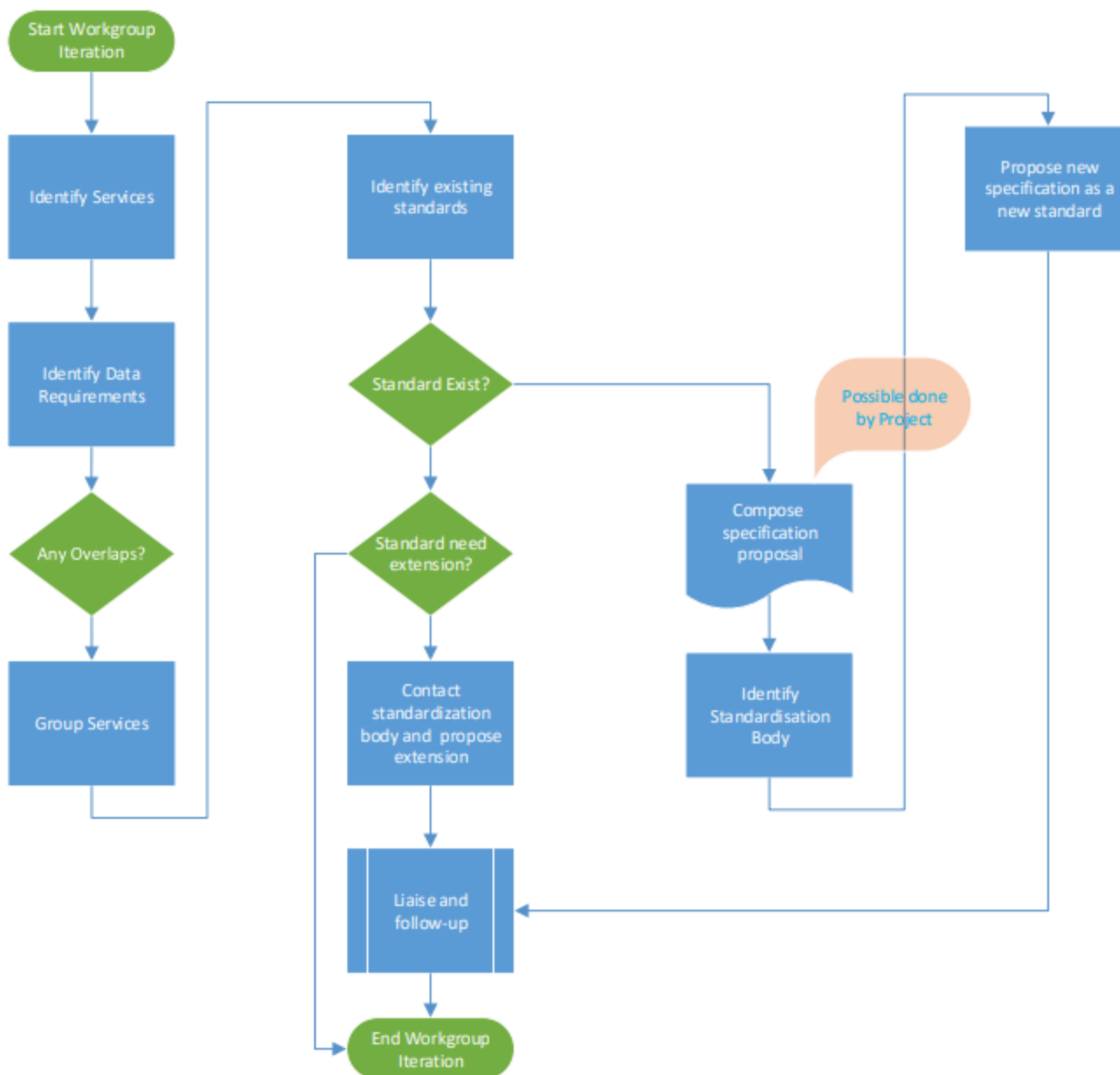


Figure 6: Standardisation workflow

The participants clearly flagged a need for a follow-up workshop which would take the work one step further by identifying the concrete data needs of the different projects and platforms. This second consultation workshop on services interoperability was foreseen during the ITS World Congress in Copenhagen in September 2018.

3.1.2. Interoperability workshop 2

The goal of the second workshop was continue on the identification of common functionality and data needs by the different services developed and deployed by the participating projects, i.e. a further completion of the already identified services and the common data sets and functionality they need to operate with the intention to lead to the identification of standards, any extensions to existing standards or creation of proposals for new standards.

Unfortunately, this second workshop drew a much smaller audience. However, the work on the service table continued and delivered the following (incomplete) snapshot:

Service Packages	DATA Need	Protocol or Standard	Draft Standard	Project	Related Project
Green light optimal speed advice (GLOSA)	Optimal Speed	SPaT, MAP, TSI, TPEG TEC to announce optimal speed and	TSI	C-MobILE, SAFARI	Concorda, InterCor, MOBiNet,

Service Packages	DATA Need	Protocol or Standard	Draft Standard	Project	Related Project
		service presence			AutoPilot, Compass4D
Road work warning (Health warning)		DATEX, TPEG, Alert-C, ETSI		C-MobILE	InterCor, Concorda, SAFE STRIP
Emergency vehicle warning		DENM, TPEG TEC		C-MobILE	Concorda
Warning system for pedestrians		DENM		C-MobILE	SAFE STRIP
Green Priority		SPaT MAP, TPEG TEC for service advertisement		C-MobILE	Freilot
Booking & Payment of journey		MaaS alliance Booking API	MSP/TSP API	MaaS Alliance	NeMo, C-MobILE, InterCor (truck)
Dispatching			TSP API	MaaS Alliance	NeMo
Aggregating Transport Providers			MSP/TSP API	MaaS Alliance	MOBiNET
Search & Find of charging stations		DATEX II, TPEG EMI	(Working on draft deliverable)	NeMo	eMI3, MaaS Alliance
Smart navigation and journey planning		TPEG TEC, TPEG RMA (Road and multi-modal routes)	MSP/TSP API	NeMo	eMI3, MaaS Alliance, C-MobILE, Aeolix
Multimodal Journey planning		TPEG RMA (Road and multi-modal routes)	MSP/TSP API		MaaS Alliance
Authentication and Authorisation			(Working on draft deliverable)	NeMo	eMI3, MaaS Alliance, MOBiNET, C-MobILE
Smart Charging		ISO-15118, OCCP, TPEG-EMI		Emi3	NeMo
Lane level crossing detection		DENM, DATEX, TPEG?		SAFE STRIP	Concorda, C-Roads (CZ)
Road Wear Level & Predictive road maintenance		BLE, CAM, DATEX, TPEG		SAFE STRIP	
Merging and intersection support: e2Call		TPEG? (Ask SAFE STRIP)		SAFE STRIP	Concorda
Personalised VMS/VDS and traffic centre information		TPEG?		SAFE STRIP	
Autonomous vehicles support		Too abstract?		SAFE STRIP	Concorda, MaaS Alliance
Toll collection		Too abstract?		SAFE STRIP	
Parking Booking and charging		TPEG-PKI (advertisement)		SAFE STRIP	eMI3, MaaS Alliance, C-MobILE
Ad -hoc priority route				MOBiNET	
Multi Modal Travel Assistance		TPEG for information		MOBiNET	
Parking Services		TPEG-PKI (advertisement)		MOBiNET	
Weight In Motion (WIM)		TPEG?		MOBiNET	
Demand Responsive Transit				MOBiNET	

Table 3: Services, standards project overview

The results developed during the two workshops were considered useful inputs to the C-MobILE project. However, to proceed the interoperability of C-MobILE deployments, it was considered to continue in a smaller, project internal group, to put the focus on the actual issues identified at the deployment sites. This led to the installation of the ITF; the following chapter gives details on its work.

3.1.3. Interoperability Task Force

Interoperability assessment has already been described in D5.4: Verification of largescale C-ITS Interoperability [5] developed by task T5.3 Verification of Interoperability. However, the scope and objective for Task 5.3 has been set to verify the interoperability of deployed systems rather than on verification of the integration of systems.

The main goal of the present document is to report on the cross-border service interoperability between deployment sites. This interoperability can be achieved by testing the services deployed in one site using equipment coming from another site. This approach follows the demand from the first interoperability workshop that requested explicitly: “It must be possible to use a C-ITS application in Barcelona, and without any changes, except some minor configuration settings, use the same application in Bordeaux”.

The Interoperability Task Force (ITF) was installed in late 2018 with the following objectives:

- Bring together representatives from all deployment sites including the developers of backend and frontend solutions.
- Test services across deployment sites, i.e. use an application developed in one deployment site at another deployment site and receive information relevant in time and location of the visited site.
- Report issues that restrict interoperability.
- Resolve those issues.
- Finally, achieve full cross-deployment site interoperability.

The meetings of the ITF have been held as telephone conferences with the first call taking place on 5 December 2018 followed in 2019 by a set of 10 additional ones. In 2020, with the increasing availability of the services at the deployment sites the frequency of the ITF calls went from monthly to bi-weekly and finally to weekly, resulting in a total number of about 35 calls. Typically, at least one representative per deployment site was present in the call; additionally, (application, system, service) developers from the companies providing solutions to the deployment sites joined the calls to fill in further technical inputs to the resolution of detected interoperability issues.

The outputs from the technical discussions at the calls and the results from the interoperability have been reported in two ways:

- Issues have been recorded in the web-based ITF issue tracker. The 18 recorded issues are described in the following chapter 3.2. At the time of writing the present report, all issues have been resolved meaning that no technical problem is restricting interoperability.
- The status of the inter deployment site interoperability has been reported in the interoperability tracker sheets. Basically an Excel workbook containing one tab per deployment site, those sheets summarise the interoperability on a per-services base for each peer-to-peer deployment site pairing. The status at the date of submission of the present deliverable is shown in full detail in chapter 3.3.

3.2. Issues reported by the Deployment Sites

During the conference calls of the Interoperability Task Force it happened that issues were reported that were of global significance to all deployment sites and that blocked interoperability or the testing to achieve it. Whenever such an issue could not be resolved directly in the call, an item in the web-based ITF tracker tool was opened.

Typical reasons for opening an item were:

- Exchange with and feedback from other tasks of C-MobILE required,
- Intervention of technology provider necessary, e.g. implementation and installation of new software versions,
- Interpretation of ambiguous standard statement needed.

Per item, a number of fields exist that carry the following information:

- Title Short descriptive,
- Assignee Individual responsible to resolve the issue or to supervise the resolution,
- Status Possible values:
 - o Active: Issue open, value not applicable at the time of writing the present deliverable.
 - o Resolved: The issue was caused by different interpretations of base standards/profiles. Once these contradicting interpretations have been clarified, the issue was resolved
 - o Closed: The issue was caused by technical implementation problems between deployment sites. Once the problem was fixed, the issue was closed.
- Priority High, Normal, Low,

- Description What is the problem,
- Deployment site All or individual site(s),
- Suggested solution If available at the time of entering the issue.

The complete list of all tracked items is given below. At the time of writing the present report, all issues have been resolved and closed.

Note: Issues #1 and #2 had been mere test issues and are excluded from the listing.

Message Profiles (GeoMessaging Server Messages)	
Assignee	C-MobILE Members
Status	Resolved
Priority	High
Description	ITS Stations communicate by means of message formats as listed by D5.3 chapter 2.7 (page 15). These messages are sent over an MQTT publish/subscribe message broker. Profiles determine how these message specifications should be interpreted. C-Roads adopted the InterCor profiles and these profiles as a consequence were applied by C-MobILE. However, since C-MobILE has a focus on inter-city and roaming interoperability, some of these interpretations aka profiles lead to misunderstandings and implementation deviations. This is a serious issue. This MUST be a main topic for the TESTFEST and a common profile must be defined which realises true cross-deployment site interoperability. A concrete problem has been raised by Technolution and the Copenhagen deployment site.
Deployment site	All
Suggested solution	It was decided to use the Dutch profile for MAP messages. This does not exclude the fact that there are still doubts and maybe issues which one may have but using the Dutch profile is the base line. For DENM and IVI messages the InterCor profiles will be used.

Table 4: ITF issue tracker item #3

Ambiguous CPBO registration specifications in deliverable D5.3 regarding fields of returned responses	
Assignee	C-MobILE Members
Status	Resolved
Priority	Normal
Description	CPBO registration specifications in deliverable D5.3 are ambiguous on the signing, encoding and fields of requests and returned responses. Solutions are proposed for decision in the Interoperability Task Force. All CPBOs and PIDs need to be adapted. Some CPBOs and PIDs have already been adapted to the proposed solutions, while the DYNNIQ SDK in the IDIADA PID and the CERTH PID may need more development time. The issues also prevented cross-deployment verifications of some of the PID and OBU HMIs.
Deployment site	All
Suggested solution	Discuss during future ITF calls and propose agreement regarding solution. See D5.4 for additional information.

Table 5: ITF issue tracker item #4

Ambiguous CPBO registration specification regarding fields of returned Token requests	
Assignee	C-MobILE Members
Status	Resolved
Priority	Normal
Description	CPBO communication specifications in deliverable D5.3 are ambiguous also on the signing, encoding and fields of requests and returned token responses. Solutions are proposed for decision in the Interoperability Task Force. All CPBOs and PIDs need to be adapted. Some CPBOs and PIDs have already been adapted to the proposed solutions, while the DYNNIQ SDK in the IDIADA PID and the CERTH PID may need more development time. The issues also prevented cross-deployment verifications of some of the PID and OBU HMIs.
Deployment site	All
Suggested solution	Discuss during future ITF calls and propose agreement regarding solution. See D5.4 for additional information.

Table 6: ITF issue tracker item #5

Interpretation of C-ITS messages (MAP, SPAT, DENM and IVI)

Assignee	C-MobILE Members
Status	Resolved
Priority	Normal
Description	The specified profile for using C-ITS messages for the services still leaves room for different interpretations, many of which are caused by different member state profiles. Consequently, many HMIs of PIDs and OBUs are not interoperable in one or more deployment site.
Deployment site	All
Suggested solution	Discuss during future ITF calls and propose agreement regarding solution. See D5.4 for additional information

Table 7: ITF issue tracker item #6

CERTH's GeoMessaging does not support PUBLISH operations from clients (PIDs)	
Assignee	CERTH
Status	Closed
Priority	Normal
Description	Communication with Geomessaging platform fails. See PID-CPBO.COM.1 of deliverable D5.4.
Deployment site	All
Suggested solution	Not available at the time of opening this issue.

Table 8: ITF issue tracker item #7

CPBO, PID and OBU not finalised for Newcastle deployment site	
Assignee	Newcastle DS
Status	Closed
Priority	Normal
Description	The CPBO, PID and OBU must be finalised by Siemens, Zircon and NeoGLS.
Deployment site	Newcastle
Suggested solution	Not available at the time of opening this issue.

Table 9: ITF issue tracker item #8

RSU (Dutch interpretation) and OBU not finalised for Copenhagen	
Assignee	Copenhagen DS
Status	Closed
Priority	Normal
Description	The CPBO and PID must be integrated by Technolution and Dynniq.
Deployment site	Copenhagen
Suggested solution	Not available at the time of opening this issue.

Table 10: ITF issue tracker item #9

Failing Barcelona CPBO - Bilbao PID test	
Assignee	Bilbao DS
Status	Closed
Priority	Normal
Description	Test PID-CPBO.COM.2 -The connection cannot be established because of PahoMqttClient return error code 4. <i>Error#58; Failure Bad user name or password (4)</i>
Deployment site	Barcelona
Suggested solution	This is because Dynniq is using "JWTAuthentication" as username instead of using client-id. Dynniq should change this.

Table 11: ITF issue tracker item #10

PID-CPBO.REG.2 - 3 Uncertainty about passing test	
Assignee	Dynniq
Status	Closed
Priority	Normal
Description	Barcelona app uses Dynniq's SDK for the registration process. The SDK deals server's responses to invalid requests internally, not allowing the developers to force those tests/cases. This test is considered as passed as the definition of the specifications for this interface has been led by Dynniq (Deliverable D5.3).

Deployment site	Barcelona
Suggested solution	To be fixed by Dynniq! Check with Dynniq.

Table 12: ITF issue tracker item #11

PID-CPBO.REG.2 Thessaloniki could not be tested	
Assignee	Thessaloniki DS
Status	Closed
Priority	Normal
Description	This second test could not be tested. The expected result (400 Bad Request) depends on the implementation of CERTH's platform.
Deployment site	Thessaloniki I
Suggested solution	Check with Dynniq about response code (500 instead of 400).

Table 13: ITF issue tracker item #12

Barcelona CPBO - Bilbao PID PID-CPBO.REG.3	
Assignee	Dynniq
Status	Closed
Priority	Low
Description	Third test could not be tested. The expected result (500 Internal Error) depends on the implementation of Dynniq's platform.
Deployment site	Barcelona
Suggested solution	Like issue 10: This is because Dynniq is using "JWTAuthentication" as username instead of using client-id. Dynniq should change this.

Table 14: ITF issue tracker item #13

Development of a profile for IVI messages	
Assignee	ERTICO
Status	Resolved
Priority	High
Description	The specified profile for using C-ITS message for the services still leaves room for different interpretations, many of which are caused by different member state profiles. Consequently, many HMIs of PIDs and OBUs are not interoperable in one or more deployment sites. Agreement: IVI detection and relevant zones and DENM following InterCor profile.
Deployment site	All
Suggested solution	For IVI messages the InterCor profile is adopted.

Table 15: ITF issue tracker item #14

Development of a profile for DENM messages	
Assignee	ERTICO
Status	Resolved
Priority	High
Description	The specified profile for using C-ITS message for the services still leaves room for different interpretations, many of which are caused by different member state profiles. Consequently, many HMIs of PIDs and OBUs are not interoperable in one or more deployment sites.
Deployment site	All
Suggested solution	For DENM messages the InterCor profile is adopted.

Table 16: ITF issue tracker item #15

Development of a profile for SPATEM and MAPEM messages	
Assignee	ERTICO
Status	Resolved
Priority	High
Description	The specified profile for using C-ITS message for the services still leaves room for different interpretations, many of which are caused by different member state profiles. Consequently, many HMIs of PIDs and OBUs are not interoperable in one or more deployment sites.
Deployment site	All
Suggested solution	Dutch profile will be used as a baseline.

Table 17: ITF issue tracker item #16

Registration Server Roaming Issue	
Assignee	ERTICO, later also Dynniq
Status	Closed
Priority	Normal
Description	When testing cross border roaming it seems that some registration servers do not implement URL forwarding to the services' home server. Seamless reconnection from one country to another when travelling from one DS to another without closing the app is the aim.
Deployment site	All
Suggested solution	The ITF decided to use the Home Server strategy to solve this issue.

Table 18: ITF issue tracker item #17

Same service does not use same message types	
Assignee	IDIADA
Status	Resolved
Priority	Normal
Description	When reviewing D2.3 it looks like the same service implemented by different deployment sites does not use the same message types. One DS uses DENM while the other uses IVI message types. FI; DENM in Barcelona and IVI in Thessaloniki WSP; DENM in Barcelona/NBR, none in Vigo No agreement but BDX, NEW and BCN are using IVI messages. Only THE is using DENM.
Deployment site	All
Suggested solution	No specifications exist to solve this problem. D4.7 should document this issue and propose a message type for each service. This will be input for future projects and standardisation bodies.

Table 19: ITF issue tracker item #18

Tile management interpretation is different among DSs	
Assignee	IDIADA
Status	Resolved
Priority	Normal
Description	Some DSs (e.g. Vigo) publish events to tile 18 in the event tile and adjacent 18-zoom tile. This is fine if the apps subscribe to tile 16-zoom and obtain those "from the distance". But if the app only subscribes to tile 18-zoom (like Dynniq's SDK), it will receive the event in the tile adjacent to the event's tile, so too late. The user experience is totally ruined. We need to define a way on how the events are published in which tiles. OPTION 1 (Dynniq); - Publishing in traces' tiles (zoom 18) OPTION 2 (Vigo and Bordeaux); - Publish in event's tile and adjacent tiles (zoom 18). Also able to receive in at less zoom. Agreement: OPTION 1
Deployment site	All
Suggested solution	Agreed during the last ITF conference call to use zoom level 18. All deployment sites to tile zoom 18. All events need to be published in tiles with zoom level 18. Traces about the events need to be covered by zoom level 18.

Table 20: ITF issue tracker item #19

Difference Base64 (BOR) and Base64URL (CPH) coding	
Assignee	NeoGLS and Dynniq
Status	Closed
Priority	Normal
Description	It seems that the Registration server of BOR uses Base64 and CPH uses

	Base64URL (i.e. replacing '+' with '-' and '/' with '_' in Base64) to encode the token. Decoders should be able to handle both as there is no difference in other common characters.
Deployment site	Barcelona, Bordeaux
Suggested solution	Align codings.

Table 21: ITF issue tracker item #20

3.3. Status of interoperability per Deployment Site

3.3.1. Introduction

The main objective of the ITF was to continuously follow up on the interoperability achievements at and between the deployment sites. To monitor that progress, a web based interoperability tracker was installed. This tracker was created as an Excel workbook with one sheet per deployment site. Each of these sheets lists in a matrix all C-MobLE services and gives the interoperability status in relation to all peer deployment sites. Obviously, as not all deployment sites offer the totality of services, peer-to-peer interoperability can only be achieved for services deployed in both host and foreign sites and using the same communication technology.

A number of values have been agreed per service/deployment matrix entry to achieve a homogenous value representation, consequently allowing a harmonised view on the interoperability status of all deployment sites.

Those values are:

- **Interoperable**
The app connects to the server, receives the expected messages and shows the corresponding info to the user.
- **Conn(ection) pass**
The app connects to the server, receives the expected messages, but does not fully understand them.
- **G5 interop(erable)**
The OBU receives the expected messages from the RSU and the corresponding info is shown to the user.
- **G5 Conn(ection) pass**
The OBU receives the expected messages from the RSU but does not fully understand them.
- **Pending**
Tests still to be executed or fixes yet to be done.
- **N/A** (Not applicable)
Foreign city use case not applicable for this host city. Typically, this value is assigned when a service uses a different communication means (cellular versus ITS G5) or a different message type between two deployment sites, e.g. CAM instead of DENM.
- **■** (No value)
Service not developed in the PID/OBU or not available at the foreign site.

As an additional convention, it was made mandatory to add an explanatory comment to all fields carrying the value **G5 Conn(ection) pass**, **Pending** or **N/A**.

During the calls of the ITF, each deployment site reported on the current interoperability status based on the interoperability tracker matrix and identified issues that prevented interoperability for any of the matrix (i.e. service/peer-site combinations) entries. The resulting discussions and the subsequent testing activities led over time to an improved interoperability level. Currently, in November 2020, interoperability has been achieved at a satisfactory level with only a small number of non-critical points remaining still open.

In the following sub-chapters, the interoperability status per deployment site as reported in the interoperability tracker sheets is provided. This gives a snapshot of the status at the time of writing the present report. It is expected that all remaining **Pending** values will vanish from the sheets before the end of the project as all remaining service deployments will have been completed by then and all open technical issues should have been closed. Furthermore, additional explanations are given for matrix entries that do not show interoperability.

3.3.2. Interoperability status of Barcelona deployment site

Service \ Host City	Bilbao	Bordeaux	Copenhagen	Newcastle	North Brabant	Thessaloniki	Vigo
BSD	-	-	-	-	-	-	-
CACC	-	-	-	-	-	-	-
CTLV	-	-	-	-	-	-	-
EBL	-	-	-	-	-	-	-
EVW	-	N/A	-	-	N/A	N/A	N/A
FI	-	Interop	-	N/A	-	Interop	-
GLOSA	-	Interop	Interop	Interop	Interop	Interop	Conn pass
GP	-	-	-	-	-	-	-
IVS	-	Interop	-	Interop	-	Interop	Interop
MAI	-	N/A	-	-	-	-	N/A
MPA	-	-	-	-	-	-	-
MTTA	-	-	-	-	-	-	-
PVD	-	Interop	-	Interop	-	N/A	Conn pass
RHW	Interop	Interop	Interop	Interop	Interop	Interop	Conn pass
RTM	-	-	-	-	-	-	-
RWW	Interop	Interop	Interop	Interop	Interop	Interop	Conn pass
SSVW	-	-	-	-	-	-	-
SVW	-	Interop	-	Interop	Interop	Interop	Conn pass
UPA	-	-	-	-	-	-	-
WSP	-	N/A	N/A	-	N/A	N/A	Conn pass

Table 22: Interoperability status of Barcelona deployment site

Additional information per peer deployment site:

- **N/A** values in Bordeaux column
EVW, MAI and WSP are delivered in CAM messages. The C-MOBILE deployment in Barcelona is using DENM for those services.
- **N/A** value in Copenhagen column
WSP service incompatible in Copenhagen as it is based on a warning about pedestrians, while the Barcelona service is a warning about cyclists.
- **N/A** value in Newcastle column
FI delivered in an incompatible format.

- **N/A** values in North Brabant column
EVW and WSP implemented only over ITS-G5, no cellular communication.
- **N/A** values in Thessaloniki column
EVW is delivered in CAM and WSP is delivered in IVI messages. The C-MoBILE deployment in Barcelona is using DENM for those services.
PVD: Barcelona app is able to send CAM messages, but the Thessaloniki publication permissions (available in the authentication JWT token) do not allow it.
- **N/A** values in Vigo column
EVW and MAI are delivered in CAM messages. The C-MoBILE deployment in Barcelona is using DENM for those services.
- **Conn pass** value in Vigo column
GLOSA, PVD, RHW, RWW, SVW and WSP are delivered in a different version of the standard. The C-MoBILE deployment in Barcelona is using the agreed upon 2016 version.

3.3.3. Interoperability status of Bilbao deployment site

Service \ Host City	Barcelona	Bordeaux	Copenhagen	Newcastle	North Brabant	Thessaloniki	Vigo
BSD	-	Interop	-	-	N/A	-	-
CACC	-	-	-	-	-	-	-
CTLV	-	-	-	-	-	-	-
EBL	-	-	-	-	-	-	-
EVW	-	-	-	-	-	-	-
FI	-	-	-	-	-	-	-
GLOSA	-	-	-	-	-	-	-
GP	-	-	-	-	-	-	-
IVS	-	-	-	-	-	-	-
MAI	-	-	-	-	-	-	-
MPA	-	N/A	-	-	N/A	-	-
MTTA	-	-	-	-	-	-	-
PVD	-	-	-	-	-	-	-
RHW	Interop	Interop	Interop	Interop	Interop	Interop	Interop
RTM	-	-	-	-	-	-	-
RWW	Interop	Interop	Interop	Interop	Interop	Interop	Interop
SSVW	-	-	-	-	-	-	-
SVW	-	-	-	-	-	-	-
UPA	-	Interop	-	-	-	-	-
WSP	-	-	-	-	-	-	-

Table 23: Interoperability status of Bilbao deployment site

Additional information per peer deployment site:

- **N/A** value in Bordeaux column
MPA service is specific for Bilbao. A common implementation with other deployment sites has been followed, but additional functionalities requested by local parking provider restrict the interoperability.
- **N/A** values in North Brabant column
BSD implemented only over ITS-G5, no cellular communication.
MPA service not available.

3.3.4. Interoperability status of Bordeaux deployment site

Service \ Host City	Barcelona	Bilbao	Copenhagen	Newcastle	North Brabant	Thessaloniki	Vigo
BSD	-	Interop	-	-	Pending	-	-
CACC	-	-	-	-	-	-	N/A
CTLV	-	-	Interop	-	N/A	N/A	-
EBL	-	-	-	-	-	-	Interop
EVW	Interop	-	-	-	G5 Interop	N/A	Interop
FI	Interop	-	-	Interop	-	Interop	-
GLOSA	Interop	-	Interop	Interop	Interop	Interop	Interop
GP	-	-	G5 Interop	-	G5 Interop	-	G5 Interop
IVS	Interop	-	-	Interop	-	Interop	Interop
MAI	Interop	-	-	-	-	-	N/A
MPA	-	Interop	-	-	N/A	-	-
MTTA	-	-	-	-	-	Interop	-
PVD	Interop	-	-	Interop	-	N/A	N/A
RHW	Interop	Interop	Interop	Interop	Interop	Interop	Interop
RTM	-	-	-	-	-	-	-
RWW	Interop	Interop	Interop	Interop	Interop	Interop	Interop
SSVW	-	-	-	-	-	-	Interop
SVW	Interop	-	Interop	Interop	Interop	Interop	Interop
UPA	-	Interop	-	-	-	-	-
WSP	Interop	-	Interop	-	Pending	N/A	Interop

Table 24: Interoperability status of Bordeaux deployment site

- N/A values in North Brabant column
CTLV not provided as traditional C-ITS service, but rather as a communication from camera to RSU.
MPA service not available.
- Pending values in North Brabant column
BSD and WSP currently not implemented.
- N/A values in Thessaloniki column
CTLV and EVW not available for testing.
PVD: CAMs currently not possible for Thessaloniki system.
WSP is delivered in IVI messages. The C-MoBiLE deployment in Bordeaux is using DENM for those services.

- N/A values in Vigo column
A different use case is deployed for CACC.
PID is publishing CAM messages for MAI and PVD services using ETSI 1.2.1, while Vigo understands only the new standard (ETSI 1.3.1).

3.3.5. Interoperability status of Copenhagen deployment site

Service \ Host City	Barcelona	Bilbao	Bordeaux	Newcastle	North Brabant	Thessaloniki	Vigo
BSD	-	-	-	-	-	-	-
CACC	-	-	-	-	-	-	-
CTLV	-	-	N/A	-	Interop	N/A	-
EBL	-	-	-	-	-	-	-
EVW	-	-	-	-	-	-	-
FI	-	-	-	-	-	-	-
GLOSA	Interop	-	Interop	Interop	Interop	Interop	Interop
GP	-	-	-	-	-	-	-
IVS	-	-	-	-	-	-	-
MAI	-	-	-	-	-	-	-
MPA	-	-	-	-	-	-	-
MTTA	-	-	-	-	-	-	-
PVD	-	-	-	-	-	-	-
RHW	N/A	N/A	N/A	N/A	N/A	Interop	N/A
RTM	-	-	-	-	-	-	-
RWW	Interop	Interop	Interop	Interop	Interop	Interop	Interop
SSVW	-	-	-	-	-	-	-
SVW	-	-	-	-	-	-	-
UPA	-	-	-	-	-	-	-
WSP	N/A	-	N/A	N/A	N/A	Interop	Interop

Table 25: Interoperability status of Copenhagen deployment site

- **N/A** values for service CTLV
The service is deployed using the Dutch profile. It can only be interoperable if cyclist specific signal groups are used.
- **N/A** values for service RHW
CPH only processes the warning “Icy roads” which is not deployed in all sites.
- **N/A** values for service WSP
PoC deployment, only THE and VIGO deploy the WSP service in the same way.

3.3.6. Interoperability status of Newcastle deployment site

Service \ Host City	Barcelona	Bilbao	Copenhagen	Bordeaux	North Brabant	Thessaloniki	Vigo
BSD	-	Interop	-	Interop	Pending	-	-
CACC	-	-	-	Interop	-	-	N/A
CTLV	-	-	Interop	Interop	N/A	N/A	-
EBL	-	-	-	Interop	-	-	Interop
EVW	Interop	-	-	Interop	G5 Interop	N/A	Interop
FI	Interop	-	-	Interop	-	Interop	-
GLOSA	Interop	-	Interop	Interop	Interop	Interop	Interop
GP	-	-	G5 Interop	Interop	G5 Interop	-	G5 Interop
IVS	Interop	-	-	Interop	-	Interop	Interop
MAI	Interop	-	-	Interop	-	-	N/A
MPA	-	Interop	-	Interop	N/A	-	-
MTTA	-	-	-	Interop	-	Interop	-
PVD	Interop	-	-	Interop	-	N/A	N/A
RHW	Interop	Interop	Interop	Interop	Interop	Interop	Interop
RTM	-	-	-	-	-	-	-
RWW	Interop	Interop	Interop	Interop	Interop	Interop	Interop
SSVW	-	-	-	Interop	-	-	Interop
SVW	Interop	-	Interop	Interop	Interop	Interop	Interop
UPA	-	Interop	-	Interop	-	-	-
WSP	Interop	-	Interop	Interop	Pending	N/A	Interop

Table 26: Interoperability status of Newcastle deployment site

- N/A values in North Brabant column
CTLV not provided as traditional C-ITS service, rather a communication from camera to RSU.
MPA service not available.
- Pending values in North Brabant column
BSD and WSP currently not implemented.
- N/A values in Thessaloniki column
CTLV and EVW not available for testing.
PVD: CAMs currently not possible for Thessaloniki system.
WSP is delivered in IVI messages. The C-MOBILE deployment in Newcastle is using DENM for those services.

- N/A values in Vigo column
A different use case is deployed for CACC.
PID is publishing CAM messages for MAI and PVD services using ETSI 1.2.1, while Vigo understands only the new standard (ETSI 1.3.1).

3.3.7. Interoperability status of North Brabant deployment site

Service \ Host City	Barcelona	Bilbao	Bordeaux	Copenhagen	Newcastle	Thessaloniki	Vigo
BSD (ITS-G5)	-	Conn pass	Conn pass	-	Pending	-	-
CACC (ITS-G5)	-	-	Conn pass	Conn pass	N/A	-	N/A
CTLV (none)	-	-	N/A	N/A	N/A	-	-
EBL	-	-	-	-	-	-	-
EVW (ITS-G5)	N/A	-	Interop	-	Interop	N/A	N/A
FI	-	-	-	-	-	-	-
GLOSA (4G)	Interop	-	Interop	Interop	Interop	Interop	Conn pass
GP (ITS-G5)	-	-	Conn pass	Interop	N/A	N/A	Conn pass
IVS	-	-	-	-	-	-	-
MAI	-	-	-	-	-	-	-
MPA (4G)	-	Pending	Pending	-	Pending	-	-
MTTA	-	-	-	-	-	-	-
PVD	-	-	-	-	-	-	-
RHW (4G)	Interop	Interop	Interop	Interop	Interop	Interop	Conn pass
RTM	-	-	-	-	-	-	-
RWW (4G)	Interop	Interop	Interop	Interop	Interop	Interop	Conn pass
SSVW	-	-	-	-	-	-	-
SVW (4G)	Interop	-	Interop	Interop	Interop	Interop	Conn pass
UPA	-	-	-	-	-	-	-
WSP (ITS-G5)	-	-	Pending	N/A	Pending	N/A	N/A

Table 27: Interoperability status of North Brabant deployment site

- **Conn pass** values for BSD
Bilbao and Bordeaux use the same communication protocol as North Brabant. Since BSD is delayed in North Brabant the full interoperability has not been assessed yet.
- **Pending** values for BSD
Connection test has not been done with Newcastle.
- **Conn pass** values for CACC
The CACC function in North Brabant concerns one vehicle connecting to the GLOSA service using the ITS-G5 unit that is also used for platooning. It exploits GLOSA information provided via ITS-G5. The ITS-G5 unit that has been tested for GLOSA in Bordeaux and Copenhagen uses the same

communication protocol for GLOSA as North Brabant. The testing of CACC in North Brabant is planned at a later time, and the full interoperability with the CACC vehicle could not be physically executed.

- **N/A** values for CACC
Newcastle uses 4G for GLOSA and Vigo is not compatible with the C-MoBiLE standard for this ITS-G5 service.
- **N/A** values for CTLV
The implementation of CLTV does not use communication between users and road-side unit.
- **N/A** values for EVW
Barcelona, Thessaloniki and Vigo use 4G for this service while North Brabant uses ITS-G5.
- **Conn pass** values for GLOSA, RHW, RWW and SVW in the Vigo column
Vigo delivers these services in a different version of the message set standard (MSS). North-Brabant deployment is using the IDIADA app which adopts the 2016 version of the MSS.
- **Conn pass** values for GP
Bordeaux and Vigo use the same communication standard, no test executed with the service for assessment of the full interoperability test, only at communication level.
- **N/A** values for GP
Thessaloniki uses 4G for this service while North Brabant uses ITS-G5. Newcastle has an implementation of this service without service requests, in contrast to North Brabant.
- **Pending** values for MPA
The developed MPA technology was planned to be implemented in North Brabant together with an associate partner, but no agreement could be made. The technology may be added to the service in Bilbao and Bordeaux. At that time interoperability can be assessed.
- **Pending** values for WSP
WSP is deployed together with BSD and is delayed. Interoperability can be checked with Bordeaux and Newcastle once the communication protocol is defined.
- **N/A** values for WSP
Copenhagen, Thessaloniki and Vigo use either 4G (instead of ITS-G5) or have a different communication protocol.

3.3.8. Interoperability status of Thessaloniki deployment site

Service \ Host City	Barcelona	Bilbao	Bordeaux	Copenhagen	Newcastle	North Brabant	Vigo
BSD	-	-	-	-	-	-	-
CACC	-	-	-	-	-	-	-
CTLV	-	-	-	-	-	N/A	-
EBL	-	-	-	-	-	-	-
EVW	Conn pass	-	Conn pass	-	-	N/A	Conn pass
FI	Conn pass	-	Interop	-	-	-	-
GLOSA	Conn pass	-	Conn pass	Conn pass	Conn pass	Conn pass	N/A
GP	-	-	N/A	N/A	N/A	N/A	N/A
IVS	Conn pass	-	Interop	-	Conn pass	-	Interop
MAI	-	-	-	-	-	-	-
MPA	-	-	-	-	-	-	-
MTTA	-	-	Conn pass	-	-	-	-
PVD	Interop	-	Interop	-	Interop	-	Interop
RHW	Interop	Interop	Interop	Conn pass	Conn pass	Conn pass	Interop
RTM	-	-	-	-	-	-	-
RWW	Interop	Interop	Interop	Conn pass	Conn pass	Conn pass	Interop
SSVW	-	-	-	-	-	-	-
SVW	Conn pass	-	Conn pass	-	-	N/A	Conn pass
UPA	-	-	-	-	-	-	-
WSP	Conn pass	-	N/A	Conn pass	-	N/A	Conn pass

Table 28: Interoperability status of Thessaloniki deployment site

- All **Conn pass** values
The CERTH app was connected to the brokers of the other DSs through the proxy registration server implemented by CERTH, but it was not capable of showing any messages in the HMI. This is an issue which is planned to be resolved in the next upgrade of the CERTH app.
- All **N/A** values
ITS-G5 only in host city; with cellular deployment, the goal is to test the service locally in small scale as PoC.

3.3.9. Interoperability status of Vigo deployment site

Service \ Host City	Barcelona	Bilbao	Bordeaux	Copenhagen	Newcastle	North Brabant	Thessaloniki
BSD	-	-	-	-	-	-	-
CACC	-	-	Conn pass	-	-	Conn pass	-
CTLV	-	-	-	-	-	-	-
EBL	-	-	Conn pass	-	-	-	-
EVW	Conn pass	-	Conn pass	-	-	Conn pass	Conn pass
FI	-	-	-	-	-	-	-
GLOSA	Interop	-	Interop	Interop	Interop	Interop	Interop
GP	-	-	Conn pass	Conn pass	Conn pass	Conn pass	Conn pass
IVS	Interop	-	Interop	-	Interop	-	Interop
MAI	Conn pass	-	Conn pass	N/A	-	-	-
MPA	-	-	-	-	-	-	-
MTTA	-	-	-	-	-	-	-
PVD	Conn pass	-	Conn pass	-	Conn pass	-	Conn pass
RHW	Conn pass	Conn pass	Conn pass	Conn pass	Conn pass	Conn pass	Conn pass
RTM	-	-	-	-	-	-	-
RWW	Conn pass	Conn pass	Conn pass	Conn pass	Conn pass	Conn pass	Conn pass
SSVW	-	-	Conn pass	-	-	-	-
SVW	Interop	-	Interop	-	-	Interop	Interop
UPA	-	-	-	-	-	-	-
WSP	Conn pass	-	Conn pass	Conn pass	Conn pass	Conn pass	Conn pass

Table 29: Interoperability status of Vigo deployment site

Additional information per peer deployment site:

Conn pass value in all columns

The latest versions of ETSI standards are currently deployed (2019). Until the update in December 2019, VIGO was using the same version of the CAM and DENM standards (2016) as the rest of the deployment sites, the operational interoperability has been demonstrated in the interoperability tests of Thessaloniki, Bordeaux and Vigo (TESTFEST December 2019).

- ETSI messages are profiled according to C-ROADS release 1.5 both for C-Mobile and C-ROADS pilots.

3.4. Evaluation events to solve interoperability issues on a project scale

3.4.1. Introduction

As stated above, one of the objectives of the ITF was to test services across deployment sites. Obviously, this did not necessarily mean that project partners had to travel with their equipment to the remote deployment site to do the testing there. This especially applies when evaluating services deployed using mobile 4G technology, i.e. applications installed on a personal device.

However, two physical test weeks were organised in September 2019 at different C-MobILE deployment sites to achieve a comprehensive view on the state of interoperability, especially for deployments delivering messages via ITS-G5.

Interoperability between deployment sites was tested by physically testing in-vehicle systems from one deployment site in the physical environment of another deployment site. To organise this efficiently, and to avoid exhaustive cross-testing, the two deployment sites of Bordeaux and Thessaloniki were selected as test locations with the following intention and pre-requisites:

- At least one site supports ITS-G5 services with Road Side Units, and at least one site supports a CPBO with cellular services and GeoMessaging server.
- All C-MobILE in-vehicle systems, OBUs and PIDs, from all other deployment sites can be tested simultaneously at the same deployment site.
- Focus on the services that are most common to all deployment sites: RWW, RHW, GLOSA, IVS, and any other service that is operational at the test locations.
- Test scenarios are derived from the test examples that are also used for C-MobILE tasks T5.3 and T6.2.
- Tests were organised to support both Interoperability Verifications and Technical Validations.
- In general, the in-vehicle systems and HMIs of the host or test DS were the measure for 'interoperability' and 'compliance' for the local service implementations and events.
- In general, the in-vehicle systems and HMIs of the guest deployment sites were verified and validated against the test systems of the host deployment sites.

The first evaluation event took place in week 38/2019 (16-19 September) at the deployment site Bordeaux. This event was followed one week later (week 39/2020, 24-27 September) by the second event organised at the Thessaloniki deployment site. The following chapters give a brief overview of the two testing events that also contributed to the preparation of the TESTFEST event described in chapter 4. More detailed in-depth analysis of the two events and their results can be found in the C-MobILE deliverables of WP6.

In addition to the technical results achieved during the test sessions, the two events offered also the opportunity for discussions on interpretation issues in the C-ITS specifications, e.g. interpretation and use of optional data elements in MAPEM messages used at an evaluation deployment site. Such issues are potentially leading to diverging interpretations during the C-ITS service deployment and consequently may hinder interoperability. Where applicable, the result of the discussions may lead to feedback to the standardisation organisations (see chapter 6 of the present deliverable).

3.4.2. Evaluation event at Bordeaux Deployment Site

3.4.2.1. Objective and Test Location

The objective of the first evaluation event was the verification and validation of the interoperability of OBUs and PIDs from all deployment sites in an on-site testing event at the Bordeaux deployment site. The services under test were RWW, RHW, IVS and GLOSA. A number of virtual events were made available around the premises of NeoGLS. Furthermore, real-time IVS and GLOSA events were observable at the deployments on the ring road and in the city centre of Bordeaux. GeoMessaging Service (CPBO) for cellular-based services and RSUs for ITS-G5 based services were operational for the test runs.



Figure 7: Bordeaux test site and (virtual) events

3.4.2.2. Test Scenarios

Test examples of events were provided in advance to the test week to enable remote testing by participants from other deployment sites. The test examples were derived from the scenarios that are also used for the Interoperability Verification Tests (see C-MobILE deliverable D5.4 [5]). The ITS-G5 services were executed without the provision of PKI security certificates.

A test scenario is a predefined route passing event locations for one or more services, and may include predefined and predictable virtual events as well as real-life (unpredictable) events. The figure above shows examples of such events.

3.4.2.3. Summary of results

At the deployment site in Bordeaux the C-ITS services under test are implemented using both the ITS-G5 and the cellular communication channels. Therefore, it was possible to test ITS-G5 interoperability in combination with the cellular services to the PIDs. The figure below shows from left to right the PIDs and OBUs that were present and under test during the evaluation event:

- PID from Bordeaux DS (also used in Bilbao DS)
- PID from Barcelona DS (also used in North Brabant DS)
- OBU from North Brabant DS
- PID from Vigo DS

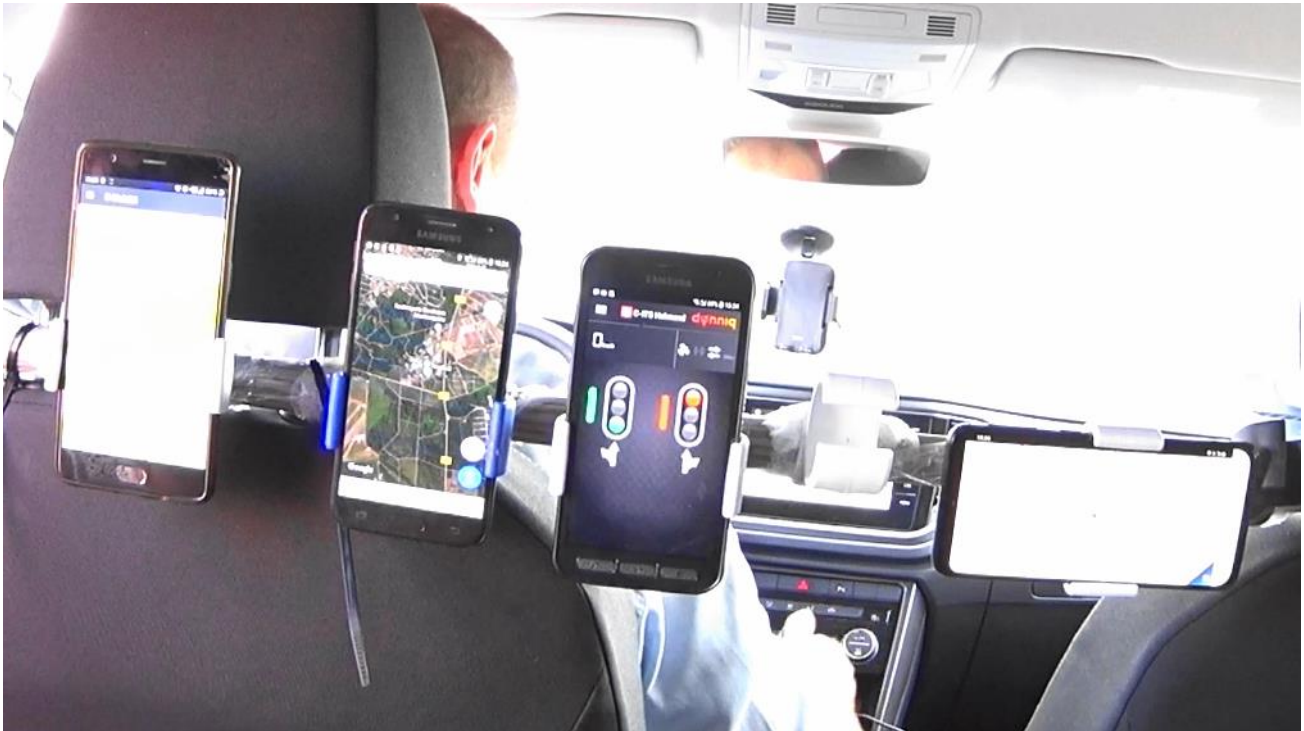


Figure 8: OBU and PID devices tested in Bordeaux

OBUs from the deployment sites of Bordeaux and Newcastle and PIDs from the deployment sites of Copenhagen and Thessaloniki were not available on site for verification and validation testing.

During the 4-day testing session in Bordeaux, the following results were achieved:

- Connection of Vigo, Barcelona and Bordeaux PIDs to Bordeaux GeoMessaging server.
- Successful interoperability achieved using cellular communication for services RWW, RHW and IVS with all present PIDs.
- Successful interoperability achieved using cellular communication for service GLOSA with Vigo PID. The Barcelona PID showed some problems to solve with GLOSA. Those were reported to the technical provider.
- Successful interoperability achieved using ITS-G5 communication for service GLOSA with Dynniq OBU.
- Performance of all tests (as defined in C-Mobile deliverables D5.4 [5] and D6.2 [6]) applicable for the available C-ITS services in Bordeaux.
- Generation of baseline and treatment logs, upload to test CTAG's CTS, and verification / validation of the data quality of the logging. This was a valuable test of this procedure in regard to the TESTFEST event and even more so for the evaluation tasks for all deployment site operations as performed in WP6.
- Generation of a video recording of all applications at the same time enjoying different services.

3.4.3. Evaluation event at Thessaloniki Deployment Site

3.4.3.1. Objective and Test Location

The objective of the second evaluation event was the verification and validation of the interoperability of PIDs from all deployment sites in an on-site testing event at the Thessaloniki deployment site. The services under test were RWW, RHW, and IVS with mostly virtual events deployed on the track around the CERTH offices, which is the same track that is also used for training for professional drivers within C-Mobile. GLOSA was available in the city centre of Thessaloniki. The CPBO for cellular-based services was operational for the test runs. ITS-G5 communication is not deployed in Thessaloniki, consequently no OBUs were tested.

3.4.3.2. Test Scenarios

Also for the second event, samples of test events have been provided in advance to enable remote testing by participants from the other deployment sites. The actual test scenarios were defined directly at the event, and presented and explained during the briefing meetings at the beginning of each test day.

3.4.3.3. Summary of results

At the deployment site in Thessaloniki the C-ITS services under test are implemented using exclusively the cellular communication channel. Therefore, OBU devices were not tested during this second evaluation event. The figure below shows the PIDs that were present and under test during this evaluation event:

- PID from Bordeaux DS (also used in Bilbao DS)
- PID from Barcelona DS (also used in North Brabant DS)
- PID from Thessaloniki DS
- PID from Vigo DS



Figure 9: PID devices tested in Thessaloniki

During the 4-day testing session in Thessaloniki, the following results were achieved:

- Connection of Vigo, Barcelona and Bordeaux PIDs to Thessaloniki GeoMessaging server.
- Successful interoperability achieved using cellular communication for services RWW, RHW, IVS and GLOSA with present Bordeaux and Vigo PIDs.
- Performance of all tests (as defined in C-Mobile deliverables D5.4 [5] and D6.2 [6]) applicable for the available C-ITS services in Thessaloniki.
- Generation of a video recording of all applications at the same time enjoying different services.

4. Report on the interoperability TESTFEST

4.1. Introduction to the TESTFEST and the TESTFEST concept

This chapter presents the C-MoBiLE TESTFEST held in December 2019 at the Vigo deployment site in and around the city of Vigo in Spain, where CTAG provided the infrastructure for the TESTFEST. The objective of this TESTFEST was to validate the interoperability of C-ITS service implementations from all C-MoBiLE deployment sites and also from external technology providers. Both ITS-G5 and cellular communication were used to provide the services for Road Works Warning (RWW), Road Hazard Warning (RHW), In-Vehicle Signage (IVS), Green Light Optimised Speed Advice (GLOSA) and Slow or Stationary Vehicle Warning (SSVW).

A number of test scenarios were executed repeatedly in 5 sessions of 2-3 hours over a period of 2.5 days from the morning of 2 December until noon of 4 December 2019. One scenario was run on the CTAG test site as a lab test to verify and debug participant systems safely. All other test scenarios were run on the public road in normal, real-life traffic conditions.

The objective of any TESTFEST event is obviously to check that implementations from different vendors are interoperable, in the case of the C-MoBiLE TESTFEST, that OBUs and PIDs from all deployment sites are interoperable with the deployments in Vigo. However, a TESTFEST serves also as a forum for developers to exchange experiences from their implementation and testing activities and is also an excellent opportunity for networking. The following bullet list illustrates the complete role of a TESTFEST in general and in particular to the C-MoBiLE event.

- TESTFEST = Proof of interoperability
 - Connecting C-MoBiLE components / systems from different partners
 - OBU and PID from all C-MoBiLE deployment sites
 - OBU and PID from all external participants
 - Deployments in Vigo (RSU, CPBO)
 - Verify and test correct interworking/interoperability, e.g.
 - OBU / PID receives Vigo DS messages
 - Messages are correctly interpreted
 - Information is provided to the user (driver)
- TESTFEST = Developer's playground
 - Proof-of-concept for new technologies
 - Testing in real-life traffic conditions
 - Review validity of chosen development concepts
 - Testing results feed back into development process
 - Testing and validating common log data for verification, data management and evaluation
- TESTFEST = Exchange of ideas
 - Opportunity for networking between
 - Partners
 - Competitors
 - Other experts
 - Observers of the TESTFEST
 - Showcasing the state-of-the-art of the C-MoBiLE developments

4.2. TESTFEST preparation phase

The TESTFEST preparations started in June 2019 with the establishment of a core TESTFEST group comprised of participants from all deployment sites. This group gathered in 11 dedicated conference calls between 5 July and 25 November 2019 for the technical and also the organisational aspects in the preparation of the event. In the beginning, the major decisions were taken, i.e.

- Choice of TESTFEST venue: Vigo deployment site with CTAG as on-site technology provider and event organiser.
- Choice of services to test:
 - Road Works Warning,
 - Road Hazard Warning,
 - Slow or Stationary Vehicle Warning,
 - Green Light Optimised Speed Advice – Time to green / Time to red,
 - In-Vehicle Information.

- Event type: Open event, organisations external to the C-MoBILE consortium welcome to participate in the TESTFEST.
- Objective of the TESTFEST:
 - Validate the interoperability of all C-MoBILE devices intended to be used in the context of the large-scale deployments,
 - Ensure the interoperability of devices from participants external to the C-MoBILE consortium,
 - Prove the correct access to service information through ITS-G5 and cellular channels,
 - Gather data samples as input to the evaluation activities of task T6.4.
- Expected results of the TESTFEST
 - Transmitted C-MoBILE service information is received and correctly interpreted by all participating devices,
 - Information from the Vigo servers is correctly understood by applications of other deployment sites.

In the next step, the TESTFEST was announced in late September with a save-the-date mailing to a wide audience using the mailing lists of ERTICO and the C-MoBILE partners, echoed by other partner organisations / projects (e.g. InterCor, C-Roads Spain, etc.). At the same time, the online event registration was opened. To further promote the event, the group decided to hold two preparatory webinars. The first webinar targeted all potential participants and contained general presentations on the C-MoBILE project, the TESTFEST concepts and objectives, and the TESTFEST venue. The objective of this first webinar which took place on 14 October 2019 was to attract potential TESTFEST participants and to transport the benefits of a TESTFEST participation. The second webinar was held on 4 November 2019 and was aimed at companies that had already (or were about to be) registered for the TESTFEST. It covered technical details on the test scenarios, the service deployments at the test sites in Vigo and connection and access details to the CTAG servers. Both webinars were well attended and saw lively exchanges between the organisation team and the TESTFEST participants.

In parallel, the on-site team of CTAG made an excellent job in preparing the infrastructures of the test sites at the CTAG premises and in the city of Vigo. Test site and test scenarios are found in the following chapter.

4.3. Test site and test scenario overview

4.3.1. Introduction

The VIGO deployment site has been chosen as venue for the C-MoBILE TESTFEST event with CTAG (Centro Tecnológico de Automoción de Galicia - Automotive Technology Centre of Galicia) hosting the event. The CTAG premises are located in the A Granxa Industrial Estate (Porriño, Pontevedra), the largest industrial area of the Euro-region Galicia-North of Portugal close to the city of Vigo.

The CTAG site in Porriño acted as base for the TESTFEST event. The daily briefing and debriefing sessions took place on site in a meeting room which was also used as work space for all participating test teams to prepare and configure their equipment. A dedicated parking area was also reserved for the participants.



Figure 10: TESTFEST briefing and preparation area

4.3.2. Testing areas

The VIGO TESTFEST offered three testing areas, one at the test track within the CTAG premises and two real-traffic test areas in interurban (roads / motorways) and urban (city of Vigo) environments. Details of each testing are found in the following chapters.



Figure 11: TESTFEST testing areas overview

It is worth mentioning here that in this TESTFEST event, as depicted in the table below, it was possible to test interoperability with different ETSI standard versions.

Communication Technology	CTAG Test Track & Test Circuit	Vigo City
ETSI ITS-G5	DENM-->ETSI EN 302 637-3 v1.2.1 CAM --> ETSI EN 302 637-2 v1.3.1 MAPEM/SPATEM/IVIM --> ETSI 103 301 v1.1.1	DENM-->ETSI EN 302 637-3 v1.3.1 CAM --> ETSI EN 302 637-2 v1.4.1 MAPEM/SPATEM/IVIM --> ETSI 103 301 v1.2.1 Security based on ETSI TS 102 941 1.3.1 and ETSI 103 097 1.3.1
Cellular	DENM-->ETSI EN 302 637-3 v1.2.1 CAM --> ETSI EN 302 637-2 v1.3.1 MAPEM/SPATEM/IVIM --> ETSI 103 301 v1.1.1 Security based on Authentication and Authorizacion by JWT (JSON Web Token)	DENM-->ETSI EN 302 637-3 v1.3.1 CAM --> ETSI EN 302 637-2 v1.4.1 MAPEM/SPATEM/IVIM --> ETSI 103 301 v1.2.1 Security based on Authentication and Authorizacion by JWT (JSON Web Token)
Message Profiling according to C-Roads release release 1.3		

Table 30: Standard version deployed at the test sites

With this variety came the possibility to test not only according to the set of standards available in the initial stage of C-MoBILE (as done in the previous interoperability tests in Bordeaux and Thessaloniki, see section 3.4) but also with the latest version of the same standards (published during the project process) for participants able to do this.

This was possible as the city of Vigo, following a C-ITS policy aiming at making services available according to the latest standard versions, had already started to provide services according to latest available C-Roads specifications (release 1.5) for pilot operations at the time of the TESTFEST.

By doing this, C-MoBILE was fulfilling two of the commitments described in the grant agreement: i.e. liaising with the C-Roads platform to harmonise approaches towards large-scale deployment and using the latest standard versions available.

4.3.2.1. Testing area CTAG test track

The on-site CTAG test track offered to participants a controlled test environment with simulated and real events for the following three services.

- GLOSA: One cooperative traffic light with real events in the controlled test environment,
- RHW and RWW with simulated warnings.



Figure 12: TESTFEST testing area - CTAG test track

4.3.2.2. Testing area CTAG surroundings

The surroundings of CTAG acted as a real-life traffic test area where interurban roads (N-550) and motorways (A-55) are equipped with the services RHW, RWW, SSVW and IVS. All service deployments offered simulated events as depicted in the figure below.



Figure 13: TESTFEST testing area - CTAG surroundings

4.3.2.3. Testing area Vigo city

The test area in the city of Vigo used a part of the overall Vigo DS C-ITS deployments. On the test route (Avenida de Madrid – Plaza America- Avenida de Madrid), the services GLOSA, RHW and RWW were available with real traffic events being announced.

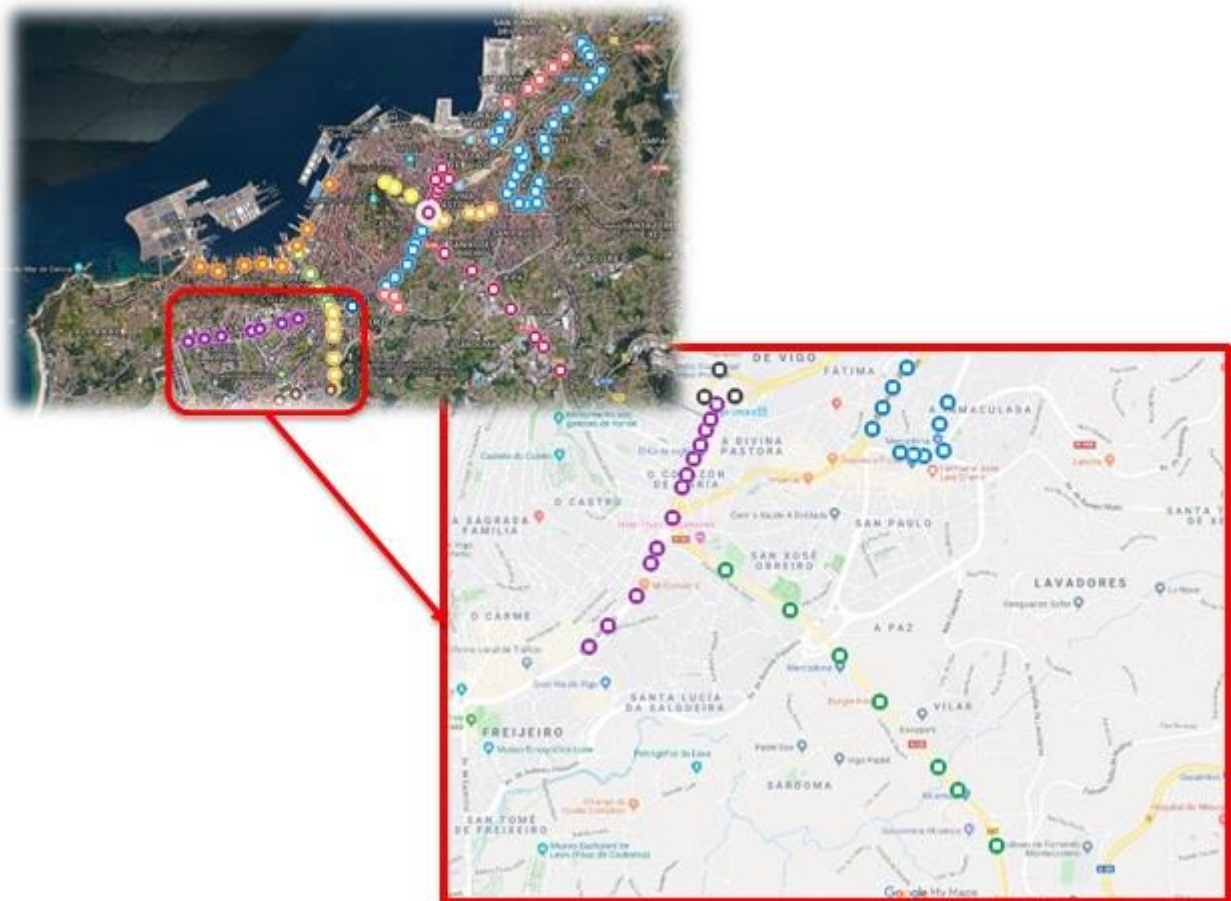


Figure 14: TESTFEST testing area - Vigo city

4.3.3. Testing scenarios

4.3.3.1. Road Hazard Warning (RHW)

The Road Hazard Warning (RHW) service provides to road users information related to potentially hazardous events on the road. An approaching road user receives this information and is thereby warned about the location and the type of hazard that lies ahead. The main objective is to get a more attentive driving while approaching and passing a hazardous location by providing in-car information about those hazards, including location and type of hazard, remaining distance to hazard location, duration of the events creating the hazard and lane and speed advice. This helps minimizing the risk of collisions/accidents and enhances the overall road safety resulting in less incidents / injuries / fatalities amongst road users.

This service was deployed at the test areas CTAG surroundings and city of Vigo using the ITS-G5 and/or cellular communications.

Road Hazard Warning (RHW)



Figure 15: TESTFEST service - RHW

4.3.3.2. Road Works Warning (RWW)

The Road Works Warning (RWW) service provides to road users information about a zone on the road that contains, at some point, the neutralisation of part of a lane or a lane closure (but without road closure) due to a planned mobile road work site. The main objective is to get a more attentive driving while approaching and passing a work zone or road operator vehicles in operation by providing in-car information and warnings about road works, changes to the road layout and applicable driving regulations, helping to avoid sudden braking or steering / swerving manoeuvres. This improves traffic safety and reduces the severity of accidents at road works.

This service was deployed at the test areas CTAG surroundings and city of Vigo using the ITS-G5 and/or cellular communications .

Road Works Warning (RWW)



Figure 16: TESTFEST service – RWW

4.3.3.3. Slow or Stationary Vehicle Warning (SSVW)

The Slow or Stationary Vehicle Warning (SSVW) service provides to road users information related to slow or stationary/broken down vehicles ahead which may cause obstacles in the road. The main objective is to get a more attentive driving while approaching a zone where slow or stationary/broken down vehicles are detected by providing in-car information about those vehicles, minimizing the risk of collisions/accidents (mostly rear-end) and enhancing overall road safety. This results in less incidents / injuries / fatalities amongst road users.

This service was deployed at the test area CTAG surroundings using only the cellular communications.

Slow or Stationary Vehicle Warning (SSVW)



Figure 17: TESTFEST service – SSVW

4.3.3.4. GLOSA - Time To Red/Time To Green (TTR/TTG)

The GLOSA - Time To Red/Time To Green (TTR/TTG) service provides to road users approaching and passing traffic light controlled intersections information on the current and upcoming (green/red) phase(s) and the time they are expected to start and end. The main objective is to enable road users to adapt their approaching speed based on the time left until the next phase change of the traffic light ahead. This aims at minimizing sudden stops, acceleration and deceleration for better safety and sustainability.

This service was deployed at the test areas CTAG test track and city of Vigo using the ITS-G5 and/or cellular communications.

Time To Red/Time To Green (TTR/TTG)



Figure 18: TESTFEST service – GLOSA

4.3.3.5. In Vehicle Signage (IVS)

The In-Vehicle Signage (IVS) service provides to road users information related to actual, static or dynamic (virtual) road signs via in-car systems (virtual VMS or free text). The main objective is to increase attentive driving by augmenting awareness for road signage as the information is provided directly in the vehicles where it can be displayed throughout the entire validity period, also targeting information to specific vehicle types or to individual vehicles.

This service was deployed at the test area CTAG surroundings using the ITS-G5 and/or cellular communications.

In Vehicle Signage (IVS)



Figure 19: TESTFEST service – IVS

4.3.4. Communication technology

For the provision of access to the services described above connection was established using both the ITS-G5 channels of the SISCOGA corridor and cellular communication using the CTAG GeoMessaging platform.

The SISCOGA (Sistemas Cooperativos Galicia) Smart Corridor, managed by CTAG, integrates more than 100 km on interurban roads and urban sections in collaboration with the city of Vigo. The objective of this permanent corridor is to conduct operational tests on car-to-car and car-to-infrastructure communication systems and matched the requirements for the TESTFEST.

To use the PKI security, the participants of the TESTFEST had to provide the necessary data, i.e. CanonicalID, Public Technical Key, Key Curve, etc.



Figure 20: SISCOGA corridor

The CTAG GeoMessaging platform that provides the cellular communication is deployed in a CTAG server and it consists of two main parts:

- Registration Server: Validates the device credentials to allow access to the Geoserver messages by providing a token.
- Geoserver: MQTT broker where messages are published in the corresponding channels. The client applications will subscribe to the proper channels.

The participants of the TESTFEST had to register with the Registration Server. C-Mobile members participated with their own application which had already proven to be interoperable with the CTAG Registration Server.

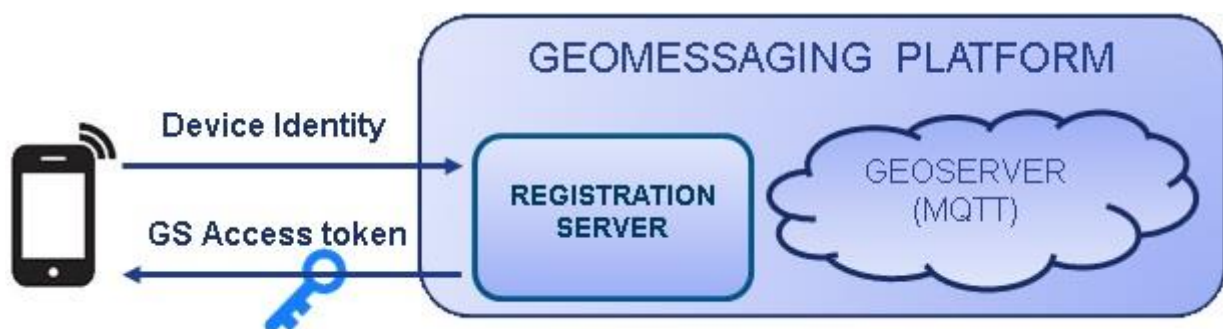


Figure 21: Geoserver registration and connection

External, i.e. non-C-Mobile participants could either install the latest version of the C-Mobile client application or use their own client application. In the latter case the registration step was omitted and they were provided with a user identity and a password to access to the Geoserver.

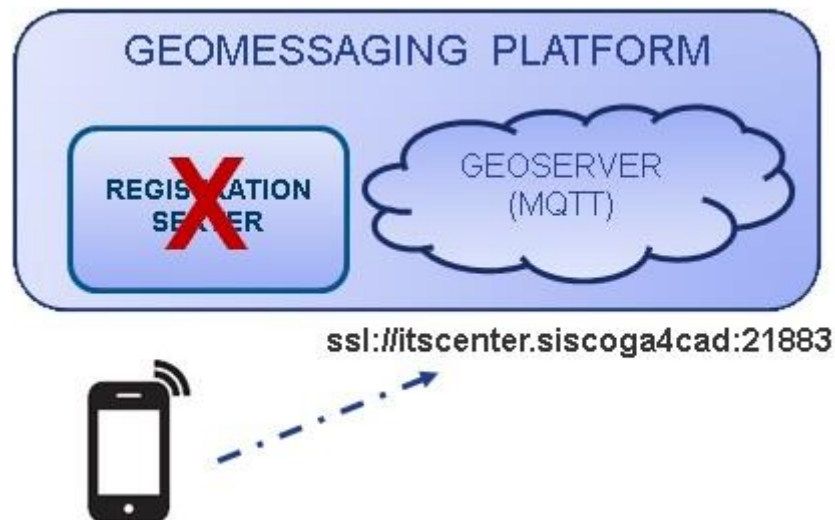


Figure 22: Direct Geoserver connection

4.4. TESTFEST execution

The TESTFEST took place from Monday, 2 December to Wednesday, 4 December 2019. Teams from all eight C-MobILE deployment sites were present with their PID and/or OBU equipment. In addition, three external companies joined the event: Alps Alpine from the Czech Republic and a TNO team (not involved in the C-MobILE project) from the Netherlands, both for active testing, and PSA from France as observer. Three further external companies had registered to the event (YOGOKO, V-tron, GMV), but had unfortunately to cancel their participation. In total about 25 participants were present at the TESTFEST event executing test runs during 5 test sessions in 8 cars. A WhatsApp group was created for speedy announcements of real traffic hazards, reminders for debriefing sessions and all other technical / non-technical information related to the TESTFEST.

The Monday and Tuesday were dedicated to testing in the testing areas at the CTAG test tracks and the interurban scenarios in the CTAG surroundings. Wednesday saw testing at the urban test area in the city of Vigo. The complete schedule is shown in the figure below.

Hour	Monday December 2 (CTAG facilities)	Tuesday December 3 (CTAG facilities)	Wednesday December 4 (City of Vigo) → (CTAG facilities)
08:30	Registration	Site open at 08:30	Site open at 08:30
09:00	Welcome, briefing, Safety instruction	Briefing Safety instruction	Test session 5
10:00	Test setup	Test session 3	
11:00	Test session 1		
12:00			Final de-briefing and wrap up
13:00	Lunch break	Lunch break	Site closure at 13:00
14:00	Test session 2	Test session 4	
15:00			
16:00			
17:00	De-briefing	De-briefing and Wednesday briefing	
18:00	Site closure at 18:00	Site closure at 18:00	

Figure 23: TESTFEST schedule

Each testing day started with a briefing session held at the CTAG premises during which the test scenarios of the particular day were presented by CTAG. Each testing day ended with a debriefing session at which the results of testing were collected and testing issues that had been experienced were reported and discussed. Technical problems, e.g. coding problems, caused by the on-site deployments were resolved by the CTAG team fast and efficiently overnight. After the final test session on Wednesday, the final debriefing acted also as wrap-up session and was used to record the opinion of all participants on the TESTFEST experience.

The photos below show a few impressions from the TESTFEST execution.



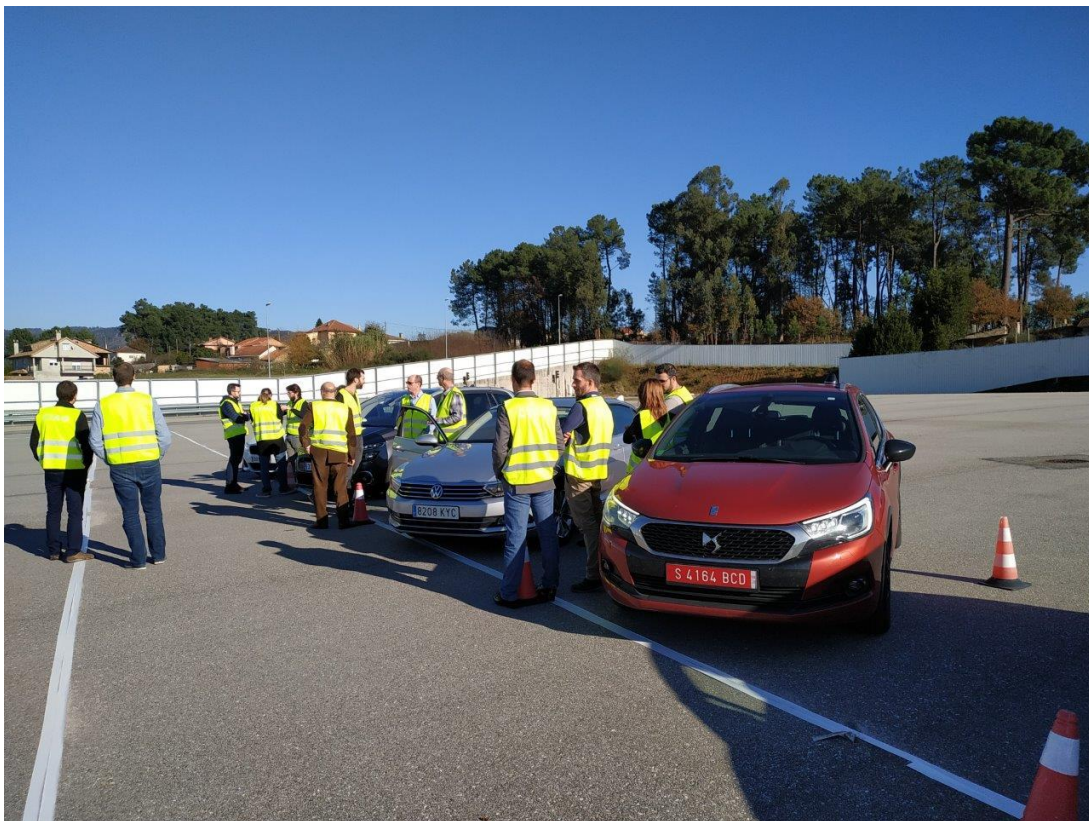


Figure 24: TESTFEST execution

4.5. TESTFEST results

4.5.1. Qualitative assessment

A qualitative assessment of the results of the test sessions took place at the debriefing sessions after each testing day. Where generally the devices of the test participants showed a good level of interoperability with the service deployments in the three test areas, still technical issues were reported. Some examples are given below:

- Some DENM, IVI messages were not received or not displayed by an OBU or PID. This meant that a device either missed a certain message completely or it did receive it but did not process and display it to the user (driver).
 - ➔ This lead to modifications in the concerned OBU/PID.
- Several coding issues in the CTAG deployment were reported by the participants, e.g.:
 - DENM messages had erroneous country code, expected string 'ES', received binary string,
 - DENM messages received without relative distance field,
 - IVI without zone heading field, which is mandatory since C-Roads profile 1.2.
 - ➔ CTAG fixed those problems in their infrastructure immediately which resolved the issues.
- Delays in cellular SPAT messages in regard to real traffic lights were experienced; a difference of up to 10 seconds between event and display of event was experienced.
 - ➔ The participant fixed its application which resolved the issue.
- GLOSA profile; the service was implemented differently in regard to the status (optional/mandatory) of message fields.
 - ➔ This issue could not be resolved at the event and was forwarded for further discussion to the Interoperability Task Force.

The individual results and comments from each test session were collected in the below table to visualise the progress in the testing per participant. The inputs were gathered from the participants at the debriefing sessions.

Team	02/12 am	02/12 pm	03/12 am	03/12 pm	04/12 am
Barcelona	Issue with token validity, --> Compatibility of application	Token problem open, works "for a while" IVI with different definition GLOSA profile different to Vigo	Post-processing of issues, profile problem still open	Token problem remains, but does not block testing GLOSA profile problem under investigation with Dynniq	No testing. GLOSA not working. General: It is not clear how devices subscribe to tiles ==> too early/late event display
Bilbao	Advice to "accident" was very short before. Used CTAG App	Use own (experimental) App Some connection problems to server	Own app now operational, all works, GLOSA not tested yet	Repeated tests, all works, GLOSA not tested	Tried GLOSA and received "plenty" of MAP/SPAT messages. No HMI to display them (no Bilbao service)
Bordeaux	No testing	Problems with MQTT connection Cellular: All messages received, DENM/IVI not in all tiles ITS-G5: 2 missing DENM Country Id is wrong! Should be "ES" is bitstring	Cellular: Some issues, may be internal problem, SPAT msgs outdated and not in line with real traffic light (~10 s delay)		
Copenhagen	No testing	GLOSA with profile problem DENM received but relative distance field missing	DENM now received with relative distance field but still not displayed on HMI GLOSA profile problem remains	Status unchanged	DENM revised version tested. Works now!
Newcastle	No testing	2016 RSU: header errors, under investigation	No testing, problems with OBU installation	Status unchanged	
North Brabant	No testing	Dynniq RSU: lost GPS synchronisation	No testing, RSU tests planned for pm	RSU set up, after debugging messages seen by OBUs	No testing
Thessaloniki	Did not see RHW or RWW	DENM received but not displayed on HMI	Cellular: Real live IVI displayed and also "pedestrian" DENM (which was not seen yesterday)	Some DENM still not visible	No testing
External participant 1	ITS-G5, pedestrian crossing msg not received, validity expired. DENM not always received, maybe problem with distance to RSU.	Cellular: Worked well IVI without zone header! Mandatory since C-Roads profile 1.2 No HelpFlash messages received through C-Mobile App CTAG: On server, but not delivered -> under investigation	ITS-G5: See old and new messages, generally better than yesterday	Cellular: Some messages arrive with delay	GLOSA worked with ITS-G5 and cellular Tried security equipped traffic lights, encountered PKI problems. Will re-test in afternoon.
External participant 2	No testing	MAP/SPAT from MQTT, some TNO App problems under investigation	ITS-G5: GLOSA, DENM, IVI all visible	ITS-G5: GLOSA testing, status ok but time indication missing. Messages ok, prob app issue.	No testing

Table 31: TESTFEST test progress per participant

4.5.2. Inputs to C-Mobile evaluation

The TESTFEST event (like the cross-deployment site verification events held in September 2019) was also used to gather trial data for the C-Mobile evaluation activities of work package WP6, namely task T6.4. Task 6.4 assesses the impact of C-ITS services in each deployment site by analysing data collected during the large-scale demonstrations. At the time when the TESTFEST took place such data was not widely available and therefore the recorded data samples were considered a valuable starting point for the evaluation trials.

During the test execution at the TESTFEST the teams from the deployment sites in Barcelona, Bordeaux, Copenhagen, Thessaloniki and Vigo recorded the C-ITS data exchanges that occurred. A Central Repository for the “TestFestVigo” project was created online to which the teams could upload data from on-board units and roadside stations. From those data samples for each session, a single experiment for analysis was defined and put through the evaluation procedures. An experiment includes the analysis of communication, applications and HMI events within a single on-board unit, as well as the interactions and communication between on-board units and roadside stations. A total of 16 evaluation experiments have been performed; the results are available on the password protected website <https://ada1.tno.nl/testfestvigo/experiments.php>.

The figure below gives an example of the DENM related results of one such experiment, the meaning of each of the shown graphs is described below.

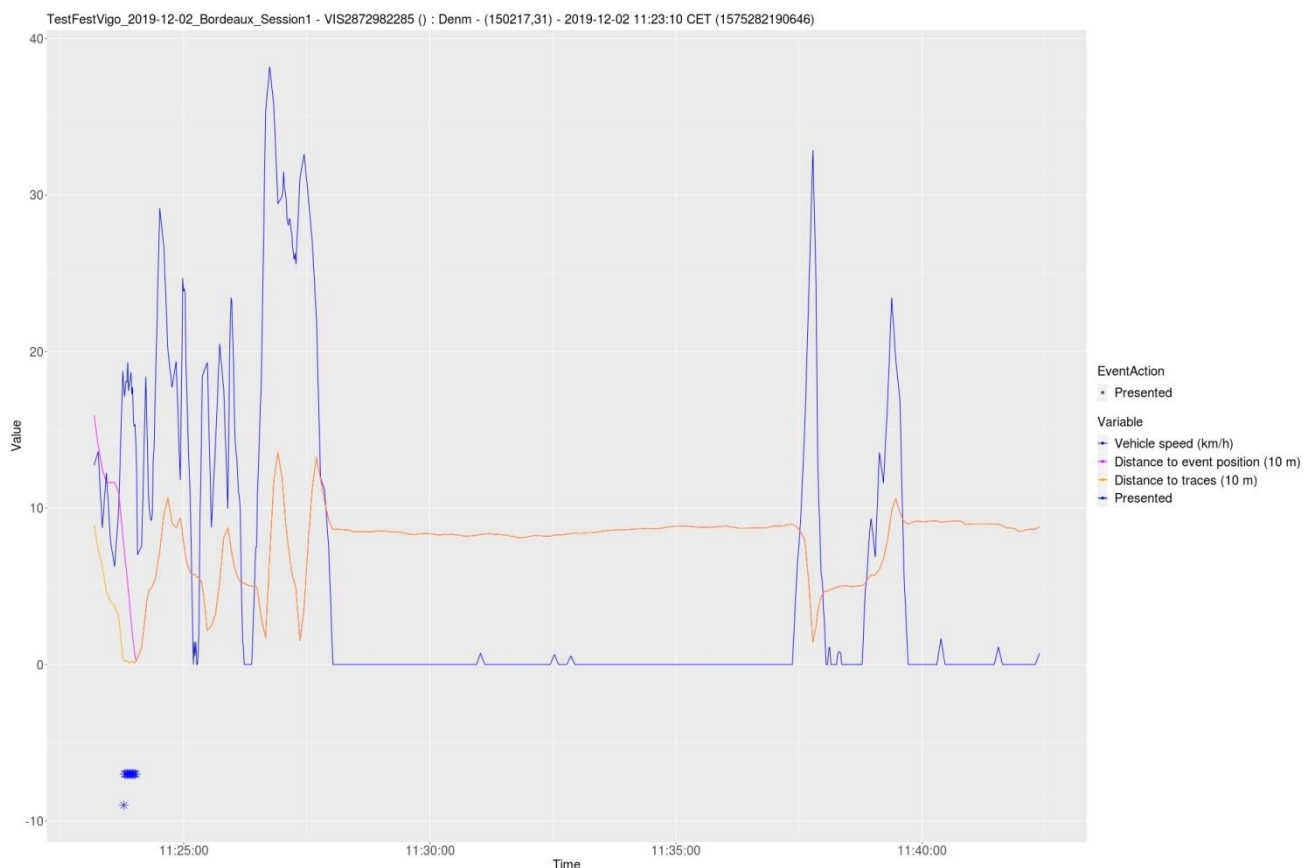


Figure 25: TESTFEST evaluation examples

- Vehicle Speed (km/h): The vehicle speed of the given ITS-S, extracted from the logging of the CAMs sent by the vehicle.
- Distance to Event Position (10 m): Distance of the position of the ITS-S to the DENM event position (scaled by 10 m), calculated from the logging of the CAMs sent by the vehicle and the logging of the DENMs sent by the RSUs.
- Distance to Traces (10 m): Distance of the position of the ITS-S to the nearest DENM trace (scaled by 10 m), calculated from the logging of the CAMs sent by the vehicle and the logging of the DENMs sent by the RSUs.
- Presented: The HMI presentation events 'presented as warning' or 'presented as information' of the given ITS-S, extracted from the logging of the DenmAction by the vehicle.

4.6. TESTFEST participant feedback

The final debriefing session was used to gather feedback from all participants on their overall impression on the event. All teams present at that session (the Bordeaux and Newcastle teams had unfortunately already left) were asked for a statement on the TESTFEST, its usefulness and the benefit they have drawn from their participation.

The C-MOBILE deployment site teams:

- Barcelona: We achieved good results on DEMN/IVI with (nearly) perfect logging. We discovered an uncertainty on how devices should subscribe to tiles to avoid too early/too late event displays. This is useful input to future discussions in the ITF.
- Bilbao: We are quite happy about the GLOSA testing as this service is not deployed in Bilbao. The TESTFEST gave us the opportunity to validate our assumptions on the service.
- Copenhagen: The TESTFEST was a good opportunity to experience and resolve issues and also to see what the other C-Mobile partners are doing.
- North Brabant: The TESTFEST allowed us to verify that the DENM messages we send for the WSP and BSD services are correctly received by the OBUs. We also had some helpful discussions on the log format that our cameras generate.
- Thessaloniki: The TESTFEST gave us an opportunity to test CERTH PID in a different environment and in live traffic conditions. The tests were partly successful for us and gave us the insights to improve our app in order to achieve the interoperability goal.

The external participants:

- TNO: It was good to see that all deployment sites have successfully tested. This proves that the C-Mobile partners have understood the topics.
- Alps Alpine: Very useful event! We could see messages that we never saw before!

To conclude, the TESTFEST was well received as a useful opportunity to test equipment and applications and also to exchange between participants on technical topics. The statement from Alps Alpine “We could see messages that we never saw before!” may sound silly on first sight. However, it perfectly summarises the benefit that can be drawn from a TESTFEST. Alps Alpine experienced messages in the real-traffic testing at the Vigo test areas that they would have never been able to simulate in their laboratory environment or in previous test events in which they participated. For example, self-referencing messages without egress points were not covered in their implementation, the receipt of such messages consequently caused errors in the application software. Alps Alpine adapted the software and thereby enhanced its quality. Such improvements in the participants’ implementations are actually the major takeaway from any TESTFEST event. A distinctive character of the C-Mobile TESTFEST has been the wide variety of test messages, scenarios and devices (incl. Geoserver) involved in the testing event, which is something not common in other test events.

4.7. TESTFEST conclusions

The C-Mobile TESTFEST is considered very successful for several reasons. Eight teams from all deployment sites representing five countries (France, Greece, Netherlands, Spain, and the United Kingdom) could validate their OBU/PIDs and also companies from the Czech Republic and the Netherlands external to the C-Mobile project could participate in the interoperability and validation activities.

Feedback from participants was very positive, both from organisational and technical perspectives, and was appreciated as very useful for testing and validating their systems in real life testing conditions. There was a positive and constructive atmosphere amongst the TESTFEST participants, increasing amount of discussions, enabling participants to improve and test their implementations. In the end, participants manage to interpret the C-ITS events being sent out in the right manner (meaning they understand the warning / advice). This proved that the concept of TESTFESTS - learning by doing - works.

5. C-MoBILE and the Standardisation Developing Organisations (SDO)

5.1. SDOs relevant to C-MoBILE

5.1.1. ETSI TC ITS



ETSI is the European Telecom Standards Institute and is commonly known to be a major contributor to global telecom standards such as GSM, LTE and DVB. ETSI is different from ISO and CEN since it is a private institution with paying members and where balloting is done by weighted votes according to membership size. ETSI's Technical Committee (TC) Intelligent Transport Systems (ITS) is responsible for the development and maintenance of standards, specifications and other deliverables to support the development and implementation of ITS services provision across the network, for transport networks, vehicles and transport users, including interface aspects and multiple modes of transport and interoperability between systems, but not including ITS application standards, radio matters, and EMC. This scope includes communication media, and associated physical layer, transport layer, network layer, security, lawful intercept and the provision of generic web services.

Most relevant to C-MoBILE are the data sets defining CAM (ETSI EN 302 637-2 [2]) and DENM (ETSI EN 302 637-3 [11]). These messages are broadcast from a vehicle and/or a roadside, and are used in a number of different applications. This work is partly based on data sets from CEN TC278 WG8, ISO TC204 WG3, WG14, and WG16 and SAE J2735. Also relevant is ETSI TS 103 301 [12] which defines facilities layer protocols and communication requirements for infrastructure services (MAPEM/SPATEM/IVIM). However, the data sets are mainly defined in the referenced CEN/ISO specifications TS 190091 (SPATEM/MAPEM) and TS 19321 [15] (IVIM).

5.1.2. CEN TC278



CEN, the European Committee for Standardisation (Comité européen de normalisation), is an association that brings together the National Standardisation Bodies of 34 European countries. CEN/TC 278 manages the preparation of standards in the field of Intelligent Transport Systems in Europe. It serves as a platform for European stakeholder to exchange knowledge, information, best practices and experiences in ITS. Most relevant to C-MoBILE is the work of WG16 on Co-operative systems, namely its work on MAPEM/SPATEM/IVIM. This WG was created on an initiative coming out of Europe to answer the European ITS Roadmap and ITS Directive and is fully joint with ISO TC204 WG18. It has two main roles: Firstly to develop new standards in the field of C-ITS, and secondly to help coordinate and foster new C-ITS thinking in the existing WGs of CEN TC278 and ISO TC204. Also the outputs of WG8 on Road Traffic Data have been considered.

5.1.3. ISO TC204



ISO, the International Organisation for Standardisation is an independent, non-governmental international organisation with a membership of 165 national standards bodies. ISO TC204 is the International ITS committee and was the second ITS standardisation body to start work on ITS after CEN TC278. TC204 was patterned on TC278, and the cooperation is regulated by the Vienna Agreement between ISO and CEN, which means that many working groups have joint meetings to ensure alignment. The C-MoBILE relevant CEN TC278 working groups from the chapter above are mirrored in ISO TC204 like this:

CEN TC278 WG16 Co-operative systems → ISO TC204 WG18 Co-operative systems

CEN TC278 WG8 Road Traffic Data → ISO TC204 WG9 Integrated Transport Information, Management and Control

The C-MoBILE project was presented at the G-ITS (Green ITS) workshop that was part of the 53rd plenary meeting of ISO TC204 which was held on 7 April 2019 at the Kennedy Space Center, Florida, USA. The G-ITS workshop is organised by the Korean Agency for Technology and Standards (KATS) which is part of the Korean delegation. It always draws an international audience that is about evenly split between delegates from Asia Pacific, Europe and the Americas of about 100 participants. The C-MoBILE presentation was well received with great interest and a lively question and answer session followed between the presenter from ERTICO and the audience. It was acknowledged that the C-MoBILE activities represent an important contribution to the international acceptance and the rollout of C-ITS services.

5.1.4. IEEE



IEEE, the Institute of Electrical and Electronic Engineers is a mainly USA based organisation, but it has several work items relevant for global ITS standardisation. For C-MobILE the IEEE 802.11p Task Group is of relevance as it has defined the basic medium-range V2V/V2I (vehicle-to-vehicle and vehicle-to-roadside) communication link dedicated to ITS. This operates on 5.9 GHz and is currently accepted in all of Europe, Northern

America, Australia and New Zealand, some central and South American countries, and also some countries in Asia and Africa are considering the use.

5.1.5. Other SDOs and groups

There are a number of other SDOs that are also active in the field of ITS standardisation, such as the SAE (Society of Automotive Engineers), IETF (Internet Engineering Task Force) and the ITU (International Telecommunications Union). Their outputs were of a lesser relevance to the deployments of C-MobILE.

Furthermore, there are numerous consortia (e.g. the Car2Car Communication Consortium) that work in the field of C-ITS deployments. National (e.g. SCOOP@F in France) and international initiatives (e.g. C-Roads) exist that are active in testing and implementing C-ITS services with the objective of cross-border harmonisation and interoperability. Several of the C-MobILE deployment sites take part in their activities, e.g. Bordeaux in SCOOP@F, Vigo as part of C-Roads Spain, Helmond in InterCor, which helped to benefit from existing standardisation efforts and to reuse well established national and international standard profiles.

5.2. Recommendations to SDOs

From the results and solutions documented in the previous chapters, some specific recommendations to SDOs can be formulated:

- Found issues due to lack of **backward compatibility** with ETSI security standards (ETSI TS 103 097 v1.2.1 versus v1.3.1) and DENM standards (ETSI EN 302 637-3 v1.2.1 versus v1.3.1).
For a deployment project that inherits and enhances the C-ITS equipment currently installed, any backward incompatibility leads to a difficult situation concerning the purchase of new equipment (hardware and software) and the maintenance/updating of the already deployed one. Some of the existing equipment is likely to be not compatible with new one (e.g. due to lack of required hardware modules, such as Hardware Security Modules required only from standard v1.3.1 onwards). From this situation, most of the decisions affected by this lack of backward compatibility go towards not using any of the standards features (e.g. security) or work only with outdated equipment (unsecure), which goes against any SDO goal.
 - According to current specifications, a Certificate Authority (CA) compliant with the EU Trust Models used to issue certificates for message signing should do it according to ETSI TS 103 097 v1.3.1. As this currently only allows signing on the Geonetworking layer, ongoing work in ETSI should allow signing on different layers (e.g. facilities layer) to make the use of this security framework more attractive to adopt where Geonetworking functionality is not needed.
- **Message profiles:** Despite the fact that several projects (e.g. C-MobILE, various national C-Roads projects, NordicWay, TalkingTraffic, etc.) make good efforts to interpret the standards and to profile them for specific use cases and services, still different requirements, situations, countries and parties apply for each of them. This leads to profiles that are very close to each other but still not interoperable. There are two possible solutions to this problem:
 - Force the projects to collaborate towards defining a broad profile valid for everyone in all situations.
 - Invite the SDO to work on some profiles valid for generic situations, which can serve as starting point for the different actors implementing them.

For both cases, it is very important to define as many “mandatory” parameters as possible, especially those in the headers or those carrying generic information (e.g. “region” in the MAP standard) because a simple “mandatory” versus “optional” conflict between two profiles makes them not interoperable.

- The objective should be to minimise this effect by bringing back aspects from the profile to the standards to lower the load on the profiles and increase the legal value in the standards.

One of the most difficult standards to use in an interoperable way is the MAPEM, even with an extensive profile there are many complex infrastructure situations that can be encoded in various ways. In the C-MobILE project the Dutch Topology Guidelines were used to provide more insight in how intersections can be described. Interoperability would be improved if such guidelines would be created and shared at European level.

A process should be set up to bridge the gap between standards for message sets and the profiles and guidelines for applying the messages in specific use cases, scenarios and situations. This opens the door for alternative and non-interoperable solutions in various projects, EU member states and local profiles. A process can be set up to collect and harmonise profiles from the initial pilots onwards as a lessons learnt and reference for future deployments. Over time, such a process could gradually evolve into a pan-European profile. Having such a harmonised set of reference profiles centralised,

e.g. at an SDO or C-Roads, greatly simplifies the harmonisation in comparison to the widely dispersed ecosystem we have currently.

- The C-MoBiLE partners have collaborated to create a common way to exchange messages following the ETSI standards via the mobile data network and the Internet. Special attention has been given to create a generic and efficient location dependent filtering, and to a common access method that allows clients to roam across different countries without the need for their home service provider to collect data from all countries in Europe. Via a so called **registration service** each client can be connected to a local service provider that has a roaming arrangement with the home service provider. The used mechanism includes a secure identity of the client, allowing roaming payments between the home service provider and the local service provider. This setup might be of interest to SDOs to standardise communication via the mobile data network.
- C-MoBiLE implemented parking efficiency services for Motorway Parking availability and Urban Parking Availability. Those services use the **Point Of Interest (POI)** profile for the C-ITS message exchange. For the construction of the messages, C-MoBiLE follows the specifications of the "Common technical specifications for use cases SCOOP, InterCor, C-Roads - F1 Information on parking lots, location, availability and services" document that was elaborated and approved by COCSIC partners on 06/02/2019. This POI message structure definition is inspired by ETSI TS 101 556-1 [15] "Electric Vehicle Charging Spot Notification Specification" [32], but it is currently not included in that specification. The French Ministry has started a request for the extension of this standard at ETSI ITS to include the proposed extension.
- The tiling of large maps is used to simplify their use and still maintain the proportions, i.e. the maps are divided into a series of map sheets at various scales. From a digital point of view, a tile map is displayed in a browser by joining image files or individually requested data. The process consists of dividing the images at each zoom level into a set of map tiles, which are placed following a logical order understandable by an application. The creation of map tiles depends on a number of properties (shape and size of the tiles, numbering of zoom levels, subdivision scheme of a tile, etc.). The C-MoBiLE GeoMessaging server is implemented through an MQTT broker. The publication strategy is following the requirements defined in the C-MoBiLE deliverable D5.3 [6]. For DENM, CAM, IVI and MAPEM messages the topic structure is "basepath/type/quadtree/", and for SPATEM "basepath/spat/ID". To ensure that the applications connected to the server can adapt the subscription zoom level to the scenario, the messages are published at maximum zoom level 18. This ensures that applications subscribed to a lower zoom level can still also receive the messages. C-MoBiLE recommends finding consensus about **geo-dependent dissemination and zoom level(s)** in which the data/events are published, otherwise those might be missed by subscribers (typically end-user apps).
- Strong **cooperation between SDOs and industry** is essential to assure that content required by standards can be sent, received and interpreted by real implementations. This should happen not only in terms of quantity (i.e. fields expected to be filled), but also in terms of data quality for such data elements especially when dealing with references for position and time. This cooperation becomes key in services where such aspects are critical to achieve reliability and interoperability.
 - Practical examples: Time synchronisation between different systems; accurate positioning for dynamic elements when using 'conventional' devices (especially for V2V services).
- In the current scenario, where C-ITS penetration is still increasing, the different communication technologies used seem to be able to meet the expected requirements. However, in medium- and long-term scenarios the presence of information and communication technology may increase, and better adapted technologies may be available to meet specific communication needs of services and applications. Standards not linked to the choice of communication technology should remain **agnostic** (i.e. flexible), expecting any communication technology.

The C-MoBiLE deliverable D5.4 [5] on verification of largescale C-ITS interoperability reports an overview of the risks and gaps that were identified during the cross-deployment tests. The test cases were formulated in terms of the functionality and performance expected of providers and consumers of the interfaces. Test cases are independent of services; i.e. should apply to every service using the interface. The cross-deployment tests identified gaps in the specifications for which system developers have opted for differences in the implementations. All system developers have indicated mitigation plans and time lines in D5.4 [5] to resolve and verify the non-compliances and adapt their systems to the adapted specifications before the TESTFEST held in December 2019. The identified gaps in the specifications, and proposal for adaptations, are addressed by the Interoperability Task Force in the frame of work reported in the present deliverable.

5.3. Twinning activities with the US Department of Transportation (US DOT)

The US ITS Architecture Program publishes and maintains the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT, www.arc-it.net), which serves as an architecture reference for both "traditional" infrastructure ITS and Cooperative ITS (supporting connected and automated vehicles) in the United States of America. In addition to the architecture reference, the program also makes available companion software tools that allow users to customise ARC-IT for their own needs, all at no cost to users. The ARC-IT architecture reference and companion software tools support Infrastructure Owner Operators' (IOO) development of regional and project-level architectures customised to meet their needs.

The primary goal of this twinning cooperation was to facilitate application of ARC-IT and its tools to ITS deployment projects in other regions, and to use lessons learned from this work to evolve ARC-IT and associated toolsets for USA and international users' benefit. An additional goal was to identify potential additional services to be added to the ARC-IT reference via cooperation with C-MoBILE. It was expected that cooperating with C-MoBILE on common ITS system architecture development needs would reduce work requirements for all participants while providing greater access to expertise, resulting in improved work products at potentially reduced cost to each participant.

In addition to these initial goals, the twinning partners were exploring additional mutually beneficial collaboration, including cooperative toolset development where ARC-IT tools might be modified to support Europe-specific architecture references.

Two in-person meetings were held in 2019 along with extensive remote cooperation. The first occurred in parallel with the Transportation Research Board (TRB) meetings in Washington DC, in January 2019; this meeting included Iteris and US DOT representatives and one member of the C-MoBILE project team from the Hellenistic Institute of Transport at the Centre for Research & Technology Hellas (CERTH-HIT). This meeting was used to help prepare the agenda for a working meeting to be held one month later.

The second in-person working meeting was held in Brussels, in April of 2019. Participants were Iteris and US DOT, and also six C-MoBILE participants (including IDIADA, ERTICO, CERTH and others). The focus of this meeting was on developing a work product that the two efforts could share. The collective team agreed that the 'C-ITS Framework', a late project deliverable of the C-MoBILE project, could provide the vehicle for linkage between C-MoBILE project results and ARC-IT content. The group sketched out what the linkages might look like, and brainstormed over user scenarios. At the conclusion of the meeting, actions were taken:

- Iteris and ERTICO: To develop user scenarios,
- ERTICO, together with IDIADA: To transform those user scenarios into workable user stories they could work toward,
- Iteris to review the resulting web work product and define linkages between the C-ITS Framework and ARC-IT and to update ARC-IT with those linkages and ERTICO to update the C-ITS Framework.

Subsequent teleconferences were held between the principal involved engineers; additional user scenarios were developed and shared.

C-MoBILE specifically observed the work of the CVRIA (Connected Vehicle Implementation Architecture) USA Team, led by the ITS Joint Program Office, comprised of the National ITS Architecture Team (led by Iteris), the Standards Program Technical Support Services Team and the Policy Team (ITS JPO Policy Program and the Volpe National Transportation Systems Center). CVRIA is being developed as the basis for identifying the key interfaces across the connected vehicle environment, supporting this way further analysis for the identification and prioritisation of standards' development activities. A full description of the CVRIA is found in the C-MoBILE deliverables D3.1 [2], D3.2 [3] and D3.3 [4].

6. Recommendations for the future rollout of interoperable C-ITS services

6.1. Blocking factors

A number of factors that may potentially delay or block the rollout of C-ITS services within Europe have been identified. Those factors are listed below and should be considered in any rollout process to achieve fully interoperable (including cross-border) deployments.

- Data availability, accessibility and homogeneity (from traffic managers, road operators, mobility platforms/databases, etc.): If data is not robust and of good quality, the later use (C-ITS services, traffic management strategies etc.) will not perform as expected.
- Data aggregation: Data may come from different sources. Treating them (analysing, formatting, filtering etc.) is a key step to guarantee solid, updated information.
- Interfaces between services and users: Interactions between entities such as messaging servers and end-user apps must be standardised to ensure interoperability, thus opening the market to different vendors and purposes.
- Message standards: (C-ITS) messages must follow the current standards, but that is not enough. Because of messages can be built in many different ways (and still follow the standards), they may be not fully understood by end-user devices (or other entities). Defining common (machine readable) message profiles is crucial to ensure full interoperability.
- Geographical dissemination: Messages and other information that is relevant for specific areas may be provided in different ways, which may lead to delivery or machine interpretation issues, among others, resulting on the loss of data. The way such information is published on the HMI of a OBU/PID is also something to be addressed.
- National policies may differ from one region or country to another. This means that different regional standards (including message profiles) may be not compatible EU-wide. Homogenisation and harmonisation actions should be carried out to find the best approach towards full EU standardisation and interoperability.
- C-ITS and smart mobility technologies are not yet widely deployed in Europe. Accelerating processes such as dedicated funding programs, informative / dissemination actions, etc. should be planned EU-wide in the upcoming years to ease the C-ITS services uptake across cities and regions.

6.2. A practical approach to roll out and interoperability of C-ITS Services

After determining the standards and profiles to be used, interoperability between parties should follow automatically. In practice, this is almost never the case. There are various reasons for this effect, from differences in interpretation by the developers to ambiguities in the standards or profiles themselves. Even if the data is exchanged exactly as designed, providing the data or using the data to perform real life tasks might be challenging.

To find the issues and to finally reach interoperability developers from the involved parties must work together, following the stream of data and events to find the cause. Sometimes such cooperation organises itself, but it would be good to acknowledge the need for this interaction, and possibly to organise it explicitly. Good examples are the so called TESTFEST events organised by ERTICO and the Plugtests™ events organised by ETSI, where developers from a large number of parties come together to test their implementations against each other, and to discuss, and solve, the issues they find. Regular wrap-up moments are organised to share the findings with all parties, and even to discuss ways to improve the standards. The TESTFEST organised by ERTICO together with CTAG within the C-MobILE project served the same purpose and was considered by the participants as a useful event and an important stepping stone towards the interoperability between the deployment sites.

The following key points list more general considerations regarding successful C-ITS rollout exercises:

- At the start of a C-ITS deployment project, or even better before the start, it is recommended to define a clear vision statement for what the deployment is looking to achieve at a strategic level that defines the overall direction and sets the context for more specific aims and objectives. In this context it is recommended to consider relationships, commitments and/or interaction with other (European and neighbouring countries) programs and initiatives.
- It is important that the aims and objectives are clearly defined, and that they are achievable and measurable, where possible, so that it can be determined if/when goals and benefits have been

realised. Doing so, will also allow relating requirements to the project objectives, which helps avoiding imposing requirements that are not critical and impossible to meet.

- There are a lot of geographical, technical, cost and policy considerations to be taken into account when selecting an appropriate deployment site. It is therefore advisable to always perform site visits to assess all of the above aspects.
- Consider which communication technologies you wish to deploy early in the planning as this largely determines the equipment requirements. Consider a cellular (network-based) communication versus a direct (localised) communication (like ITS-G5) or a combination of both.
- In terms of deployment site operation and maintenance, it is essential to ensure continuous and transversal monitoring of project stages especially for deployment and working, with clearly identified roles and responsibilities.
- Particular attention must be paid to interactions and interventions of external stakeholders (users, drivers, partners) during tests and validations.
- Evaluation is central to achieving the goals of any C-ITS deployment project. It is therefore crucial to develop an evaluation plan early in the pilot planning phase to get it aligned with the objectives of the deployment. Automation can much facilitate the data collection and analyses of the extensive data sets.
- In order to deploy C-ITS services in a cost-efficient manner, take into consideration the use of current and planned projects/ contracts for (life cycle) upgrades of infrastructure, as well as to make use of market prototypes and concepts which can still be further developed based on your deployment site's needs and requirements.

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Annex A - Overview of applicable standards

A1.1 Introduction

This annex lists the different standards which are applied in the domain of Cooperative Intelligent Transport Systems. The structure of the catalogue is set-up according to the C-ITS reference architecture proposed by the C-MobILE project. Where possible a link to the services deployed by the C-MobILE project is made. Additional to this catalogue an annex specific extended bibliography is added listing the documents which are used as a basis for this catalogue.

A1.2 The C-ITS Reference architecture

As the basis for this annex the C-MobILE deliverables D3.2 [1] and D3.3 [2] were used as a guideline. The framework of the C-ITS Reference architecture is used as a classifier for the different standards used. Each of the standards is documented in its own paragraph and ordered according to the OSI layered model shown by D3.3 [2] and D3.2 [1]. For each of the standards a link is given to the component or components it corresponds in D3.2 [1]. Remark that some of the standards listed are not mentioned in these deliverables but for since these standards are used in the ITS domain they are included in the list.

A1.3 Standards Catalogue

The table below gives the communication viewpoint and lists the relevant communication standards and protocols.

Standard	Description	Standards Body	Ref.	Component(s)
Bluetooth 5.0	Bluetooth	Bluetooth SIG	[3]	Vehicle/Sensors/Road side Unit ¹
Bluetooth Low Energy	Bluetooth	Bluetooth SIG	[4]	Vehicle/Sensors/Road side unit
EN 300 400	DAB - Digital Audio Broadcasting	ETSI	[5]	Vehicle
CEN/TS 16157	DATEX II	CEN	[6]	TMC Backoffice
ETSI EN 302 637-3 V1.2.2	DENM - Decentralized Environmental Notification messages	ETSI	[7]	Vehicle/Roadside Unit
J1699-2	OBD-II, EOBD	SAE	[8]	Vehicle
ETSI EN 302 637-2	CAM - Cooperative Awareness Message	ETSI	[9]	V2X
IEEE802.11p	Wireless Access in Vehicular environments	IEEE	[9]	V2V -V2X
IEEE 802.15.4	Zigbee	IEEE	[10]	In-Vehicle
ISO 10681-1	FlexRay Part 1	ISO/TC 22/SC 31	[11]	In-Vehicle
ISO-10682-2	FlexRay Part 2	ISO/TC 22/SC 31	[11]	In-Vehicle
ISO-11898-1	CAN Part 1	ISO/TC 22/SC 31	[12]	In-Vehicle
ISO 11898-2	CAN Part 2	ISO/TC 22/SC 31	[13]	In-Vehicle
ISO 11898-3	CAN Part 3	ISO/TC 22/SC 31	[12]	In-Vehicle
ETSI TS 102 894-2 CEN ISO/TS 19091	SPATEM	ETSI/CEN	[13]	Facilities layer
SAE J2735, TS19091	MAPEM	SAE/ISO	[13] [14]	Facilities layer – Road and Lane Topology (RLT) service.
SAE J2735 DSRC	TOPO	SAE derived from DSRC	[15]	Roadside Unit/Vehicle
ISO/IEC 14443	RFID	ISO	[16]	VRU
ETSI ITS G5	See IEEE802.11p	ETSI	[17]	V2V - V2X
IVERA	IVERA v4.1.1	IVERA	[18]	Roadside Unit
LTE (4G)	LTE 4G Long Term	3GPP ²	[19]	Personal Information Device

¹ Core standards

² ARIB, CCSA, ETSI, ATIS, TTA and TTC

Standard	Description	Standards Body	Ref.	Component(s)
	Evolution			(PID)
UMTS (3G)	UMTS 3G Universal Mobile Telecommunications System	3GPP	[20]	PID
TS 102 941 V1.3.1	ITS Security and Trust	ETSI	[21]	Vehicle/RSU
GPS	Global Positioning System	US Government	[22]	Vehicle/PID
Galileo	Galileo	ESA	[23]	Vehicle/PID
Glonass	ГЛОБАЛЬНАЯ НАВИГАЦИОННАЯ СПУТНИКОВАЯ СИСТЕМА (Global Navigation Satellite System)	Russian Government	[24]	Vehicle/PID
Beidou	北斗卫星导航系统Běidǒu Wèixīng Dǎoháng Xìtǒng	Chinese Government	[25]	Vehicle/PID
RFC793	TCP	IETF/DARPA	[26]	Vehicle/PID/RSU/TMC/Service Provider/Backoffice
RFC791	IP	IETF/DARPA	[27]	Vehicle/PID/RSU/TMC/Service Provider/Backoffice
RFC768	UDP	IETF/DARPA	[28]	Vehicle/PID/RSU/TMC/Service Provider/Backoffice
ETSI EN 302 895	LDM location dynamic map	ETSI	[29]	Repository for facilities and applications
RFC 791	IPv4	IETF	[30]	Vehicle/PID/RSU/TMC/Service Provider/Backoffice
RFC2460	IPv6	IETF	[31]	Vehicle/PID/RSU/TMC/Service Provider/Backoffice
IEEE802.11p	DSRC	IEEE	[9]	Vehicle/RSU
5G-V2X	(5G) C-V2X Cellular V2X	3GPP/5GAA	[32]	Vehicle/RSU
ISO 21806-1	MOST – Media Oriented Systems Transport	ISO/MOST Cooperation	[33]	Vehicle
IEC 61851-3 DIN EN 50604-1 IEC DIN 62196-4	EnergyBus	EnergyBus.org	[34]	Vehicle ³
ETSI TS 123 060	GPRS – General Packet Radio Service	ETSI/3GPP	[35]	Vehicle/PID/RSU/TMC/Service Provider/Backoffice
TMC	TMC – Traffic Message Channel ⁴	TISA		Vehicle/Backoffice
TPEG2	TPEG	TISA	[36]	Vehicle/Backoffice
SOAP V1.2	SOAP/XML – Simple Object Access Protocol	W3C	[37]	RSU/Backoffice/PID
RFC7540	HTTP – Hypertext Transfer Protocol	IETF	[38]	Vehicle/PID/RSU/TMC/Service Provider/Backoffice
AMQP 1.0	AMQP – Advanced Message Queueing Protocol	OASIS	[39]	Vehicle/PID/RSU/TMC/Service Provider/Backoffice
XML 1.0	XML – Extensible Markup Language	W3C	[40]	Vehicle/PID/RSU/TMC/Service Provider/Backoffice
ECMA-404	JSON – Java Script Object Notation	Json.org	[41]	Vehicle/PID/RSU/TMC/Service Provider/Backoffice
IEEE 802.11x	Wifi	IEEE	[42]	Vehicle/PID/RSU
ETSI TS 102 894-2 CEN ISO/TS 1909	SREM	ETSI	[13]	Facilities layer - Traffic Light Control service (TLC)
ETSI TS 102 894-2 CEN ISO/TS 1909	SSEM	ETSI	[13]	Facilities layer (TLC Service)
TS 102 894-2	IVIM	ETSI	[13]	Facilities layer -Infrastructure to

³ Light Electric Vehicles (LEV)⁴ Over RDS (Radio Data System)

Standard	Description	Standards Body	Ref.	Component(s)
CEN ISO/TS 19321				Vehicle information service (IVI)
ETSI TS 103 301 V1.3.1	RTCMEM	ETSI	[13]	Facilities layer - GNSS Positioning Correction (GPC) service

Table 32: Communication standards and protocols

A1.3 Bibliography to annex 1

The below references refer to the standards catalogue in annex A1.2. More references to the main body of this deliverable are found in the References section after chapter 6.

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